Communication Networks

Spring 2020

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Last Monday on

Communication Networks

E-mail

IPv6

MX, SMTP, POP, IMAP

the (very) beginning

E-mail

IPv6

MX, SMTP, POP, IMAP

We studied e-mail from three different perspectives

Content	Infrastructure/ Transmission	Retrieval
Format: Header/Content Encoding: MIME	SMTP: Simple Mail Transfer Protocol Infrastructure mail servers	POP: Post Office Protocol IMAP:Internet Message Access Protocol

Content

Infrastructure/
Transmission

Retrieval

Format: Header/Content

Encoding: MIME

A header, in 7-bit U.S. ASCII text

Header

From: Laurent Vanbever <lvanbever@ethz.ch>

To: Tobias Buehler <buehlert@ethz.ch>

Subject: [comm-net] Exam questions

A body, also in 7-bit U.S. ASCII text

From: Laurent Vanbever <lvanbever@ethz.ch>

To: Tobias Buehler <buehlert@ethz.ch>

Subject: [comm-net] Exam questions

Body

Hi Tobias,

Here are some interesting questions...

Best,
Laurent

Email relies on 7-bit U.S. ASCII…

How do you send non-English text? Binary files?

Solution

Multipurpose Internet Mail Extensions

commonly known as MIME, standardized in RFC 822

MIME defines

- additional headers for the email body
- a set of content types and subtypes
- base64 to encode binary data in ASCII

MIME relies on Base64 as binary-to-text encoding scheme

Relies on 64 characters out of the 128 ASCII characters

the most common *and* printable ones, i.e. A-Z, a-z, 0-9, +, /

Divides the bytes to be encoded into sequences of 3 bytes

each group of 3 bytes is then encoded using 4 characters

Uses padding if the last sequence is partially filled

i.e. if the |sequence| to be encoded is not a multiple of 3

Content

Infrastructure/
Transmission

Retrieval

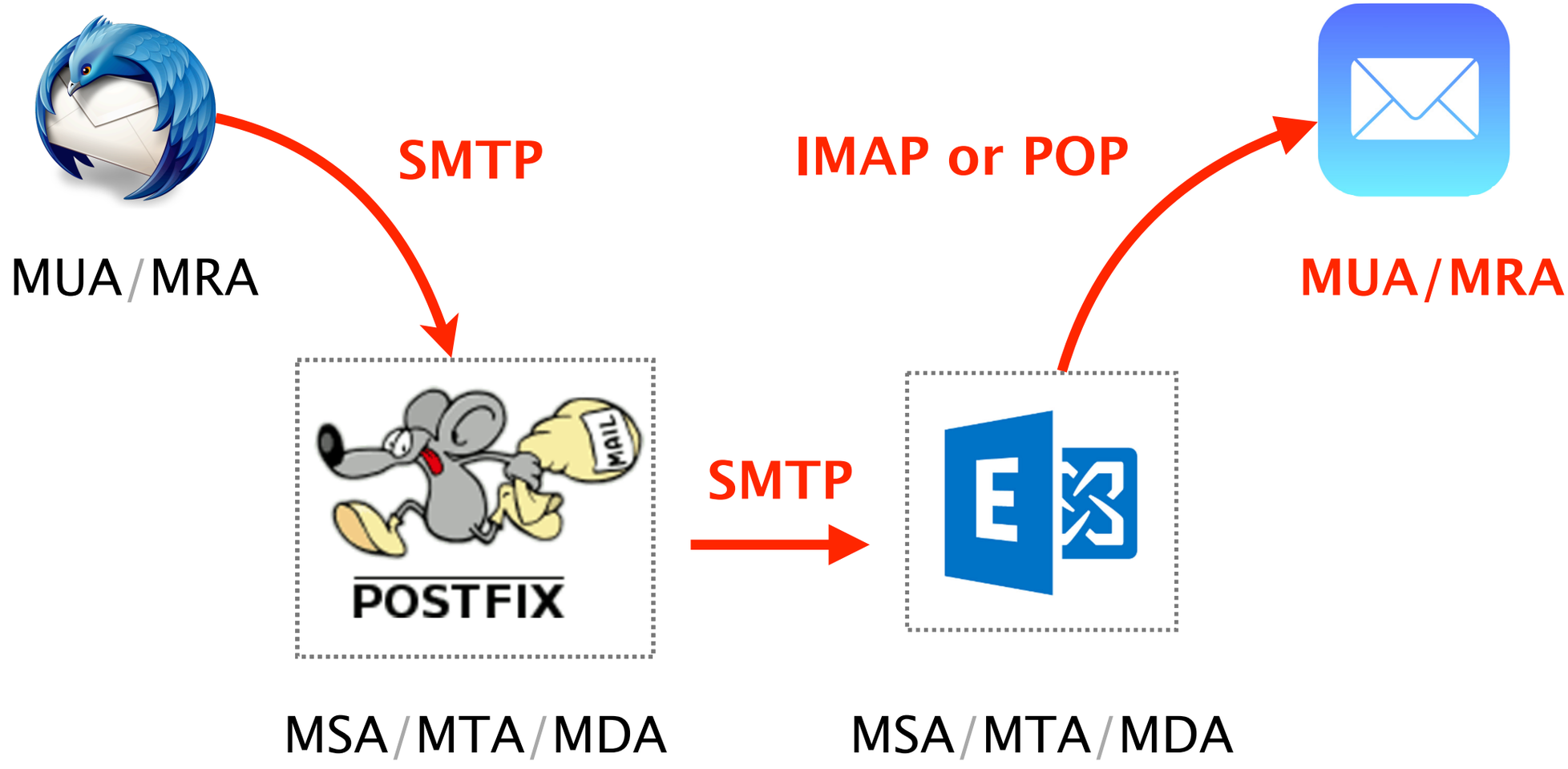
SMTP: Simple Mail
Transfer Protocol

Infrastructure
mail servers

We can divide the e-mail infrastructure into five functions

Mail	User	Agent	Use to read/write emails (mail client)
Mail	Submission	Agent	Process email and forward to local MTA
Mail	Transmission	Agent	Queues, receives, sends mail to other MTAs
Mail	Delivery	Agent	Deliver email to user mailbox
Mail	Retrieval	Agent	Fetches email from user mailbox

MSA/MTA/MDA and MRA/MUA are often packaged together leading to simpler workflows



Simple Mail Transfer Protocol (SMTP) is the current standard for transmitting e-mails

SMTP is a text-based, client-server protocol

client sends the e-mail, server receives it

SMTP uses reliable data transfer

built on top of TCP (port 25 and 465 for SSL/TLS)

SMTP is a push-based protocol

sender pushes the file to the receiving server

E-mails typically go through at least 2 SMTP servers, but often way more

Separate SMTP servers for separate functions

SPAM filtering, virus scanning, data leak prevention, etc.

Separate SMTP servers that redirect messages

e.g. from lvanbever@tik.ee.ethz.ch to lvanbever@ethz.ch

Separate SMTP servers to handle mailing-list

mail is delivered to the list server and then expanded

As with most of the key Internet protocols, security is an afterthought

SMTP Headers

MAIL FROM: no checks are done to verify that the sending MTA is authorized to send e-mails on behalf of that address

Email content (DATA)

From: no checks are done to verify that the sending system is authorized to send e-mail on behalf of that address

Reply-to: ditto

In short, *none* of the addresses in an email are typically reliable

Content

Infrastructure/
Transmission

Retrieval

POP: Post Office Protocol

IMAP: Internet Message
Access Protocol

POP is a simple protocol which was designed to support users with intermittent network connectivity

POP enables e-mail users to

- retrieve e-mails locally — when connected
- view/manipulate e-mails — when disconnected

and that's pretty much it…

Unlike POP, Internet Message Access Protocol (IMAP) was designed with multiple clients in mind

Support multiple mailboxes and searches on the server

client can create, rename, move mailboxes & search on server

Access to individual MIME parts and partial fetch

client can download only the text content of an e-mail

Support multiple clients connected to one mailbox

server keep state about each message (e.g. read, replied to)

Today on

Communication Networks

IPv6

Course recap

the end

So… **What?!**

IPv6

Course recap

the end

(see last week's slides)

IPv6

Course recap

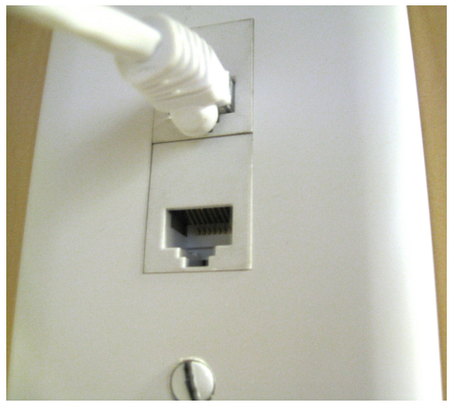
So… **What?!**

Communication Networks

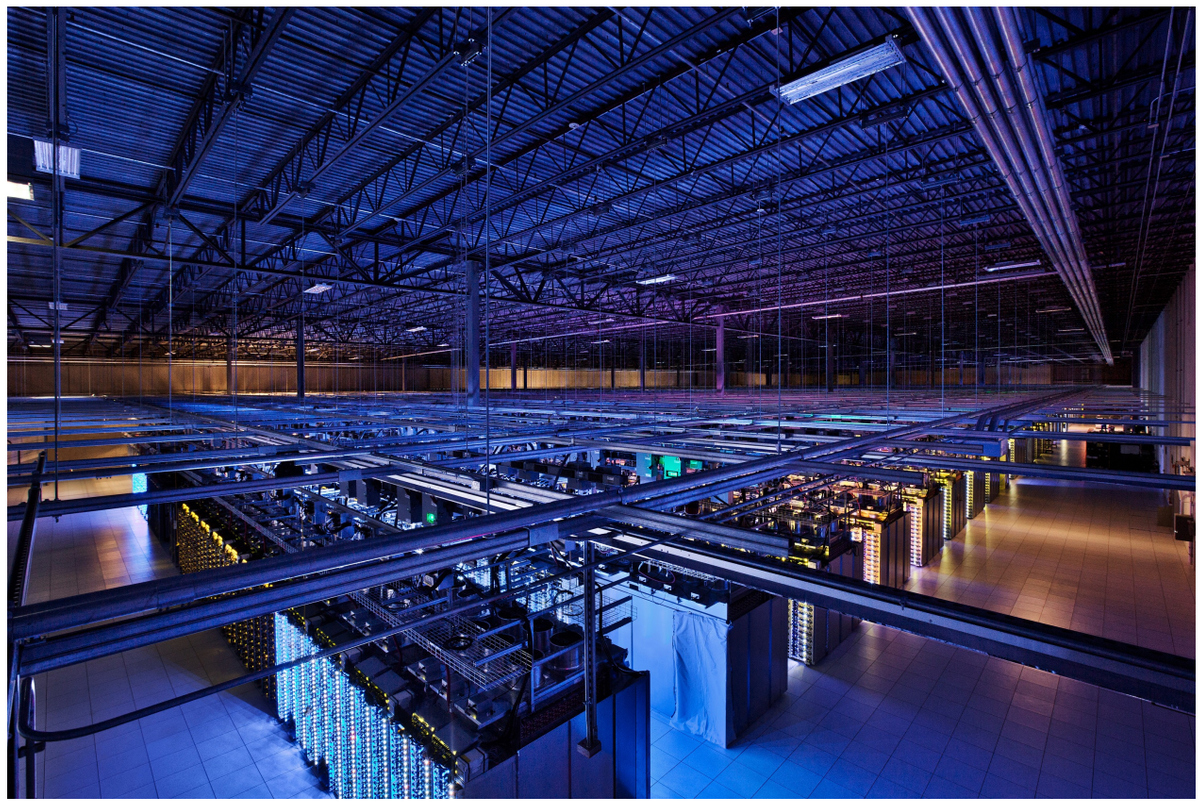
So what?!

Knowledge

Understand how the Internet works and why



from your
network plug...



...to Google's data-center

List any

technologies, principles, applications...

used after typing in:

> www.google.ch

and pressing enter in your browser

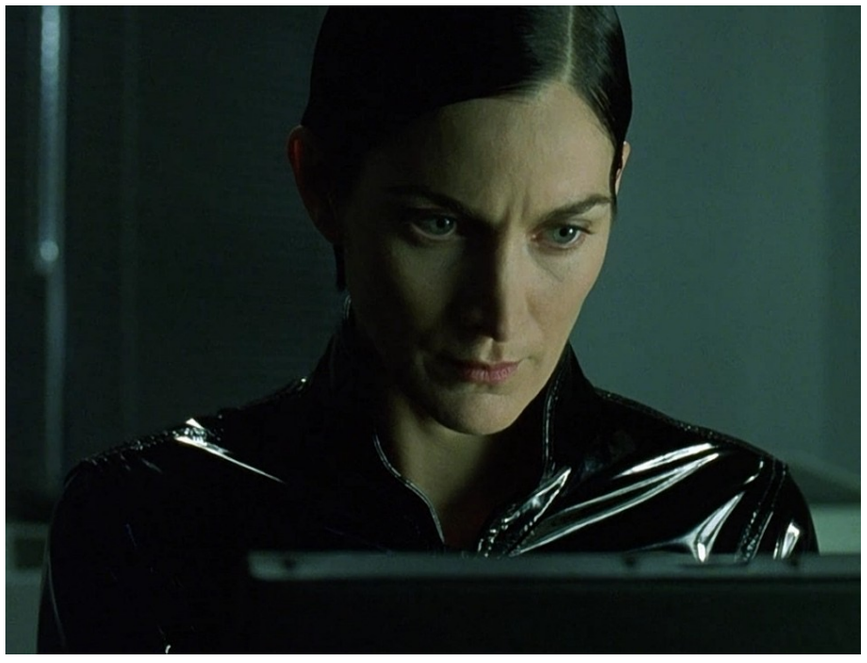
Insight

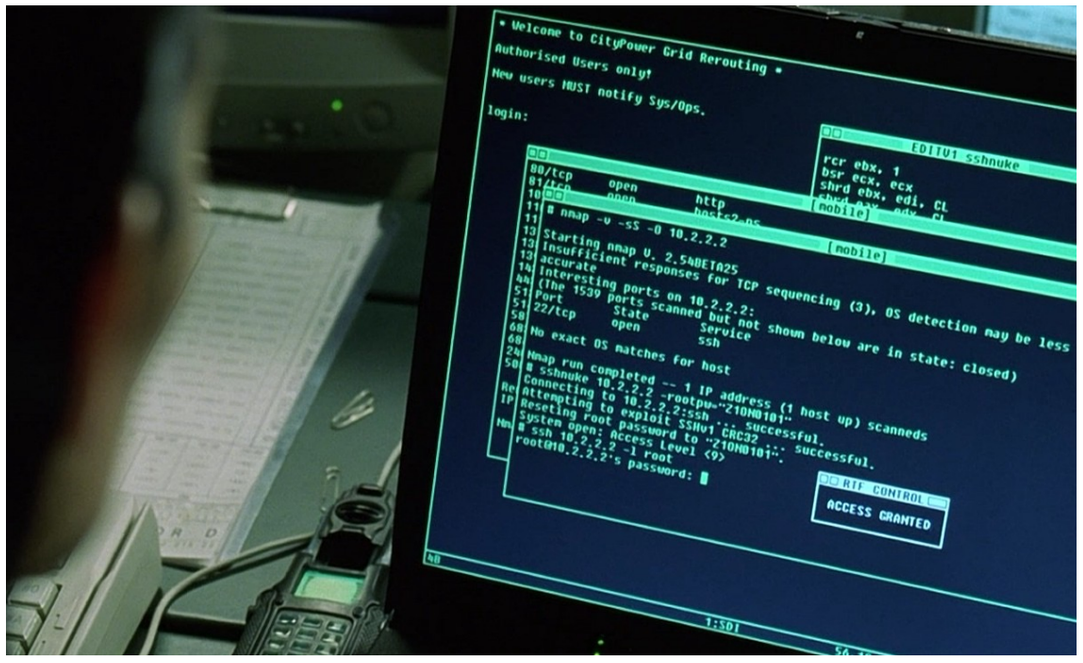
Key concepts and problems in Networking

Naming Layering Routing Reliability Sharing

Skill

Build, operate and configure networks

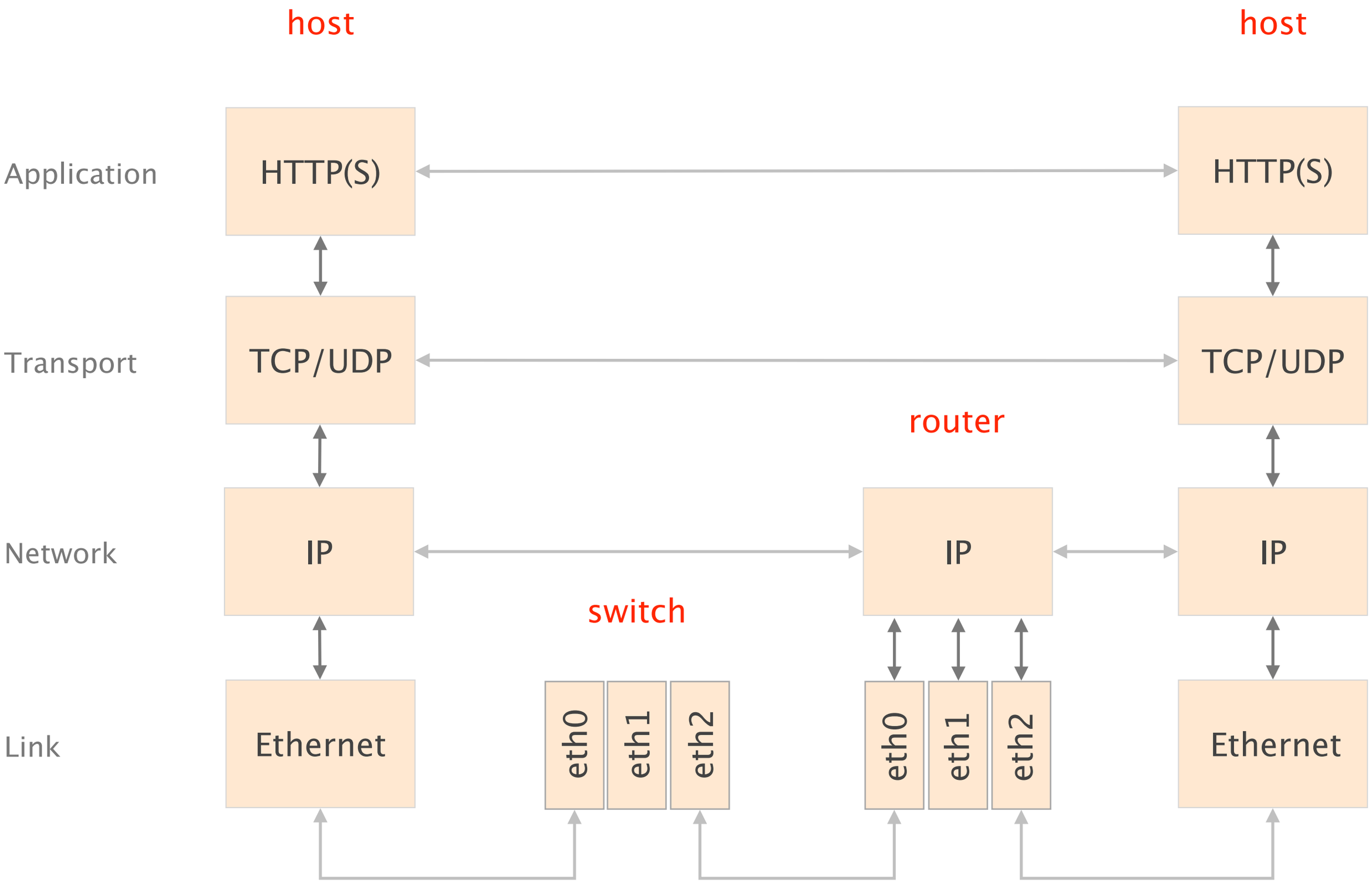




Trinity using a port scanner (nmap) in Matrix Reloaded™

The Internet is organized as layers, providing a set of services

	layer	service provided
L5	Application	network access
L4	Transport	end-to-end delivery (reliable or not)
L3	Network	global best-effort delivery
L2	Link	local best-effort delivery
L1	Physical	physical transfer of bits


host
host
Application
HTTP(S)
HTTP(S)
Transport
TCP/UDP
TCP/UDP
router
Network
IP
IP
IP
switch
Link
Ethernet
eth0
eth1
eth2
eth0
eth1
eth2
Ethernet

We started with the fundamentals of

routing and reliable transport

	Application	network access
L4	Transport	end-to-end delivery (reliable or not)
L3	Network	global best-effort delivery
	Link	local best-effort delivery
	Physical	physical transfer of bits

We saw three ways to compute valid routing state

	Intuition	Example
#1	Use tree-like topologies	Spanning-tree
#2	Rely on a global network view	Link-State SDN
#3	Rely on distributed computation	Distance-Vector BGP

We saw how to design a reliable transport protocol

and you implemented one yourself

goals

correctness	ensure data is delivered, in order, and untouched
timeliness	minimize time until data is transferred
efficiency	optimal use of bandwidth
fairness	play well with other concurrent communications

In each case, we explored the rationale behind each protocol and why they came to be

Why did the protocols end up looking like this?

minimum set of features required

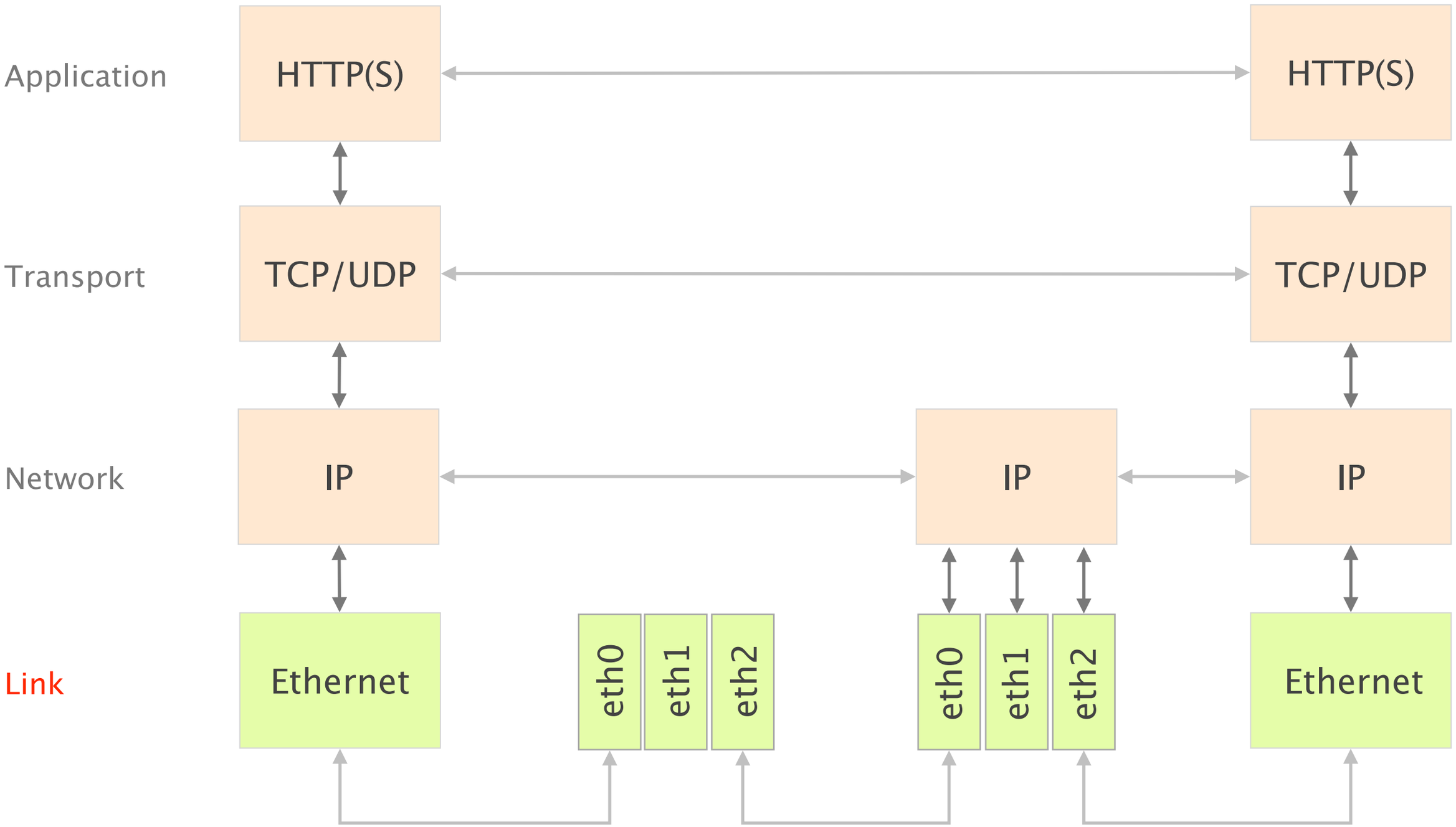
What tradeoffs do they achieve?

efficiency, cost,…

When is one design more adapted than another?

packet switching *vs* circuit switching, DV *vs* LS,…

We then climbed up the layers, starting from layer 2



Communication Networks

Part 2: The Link Layer

#1 What is a link?

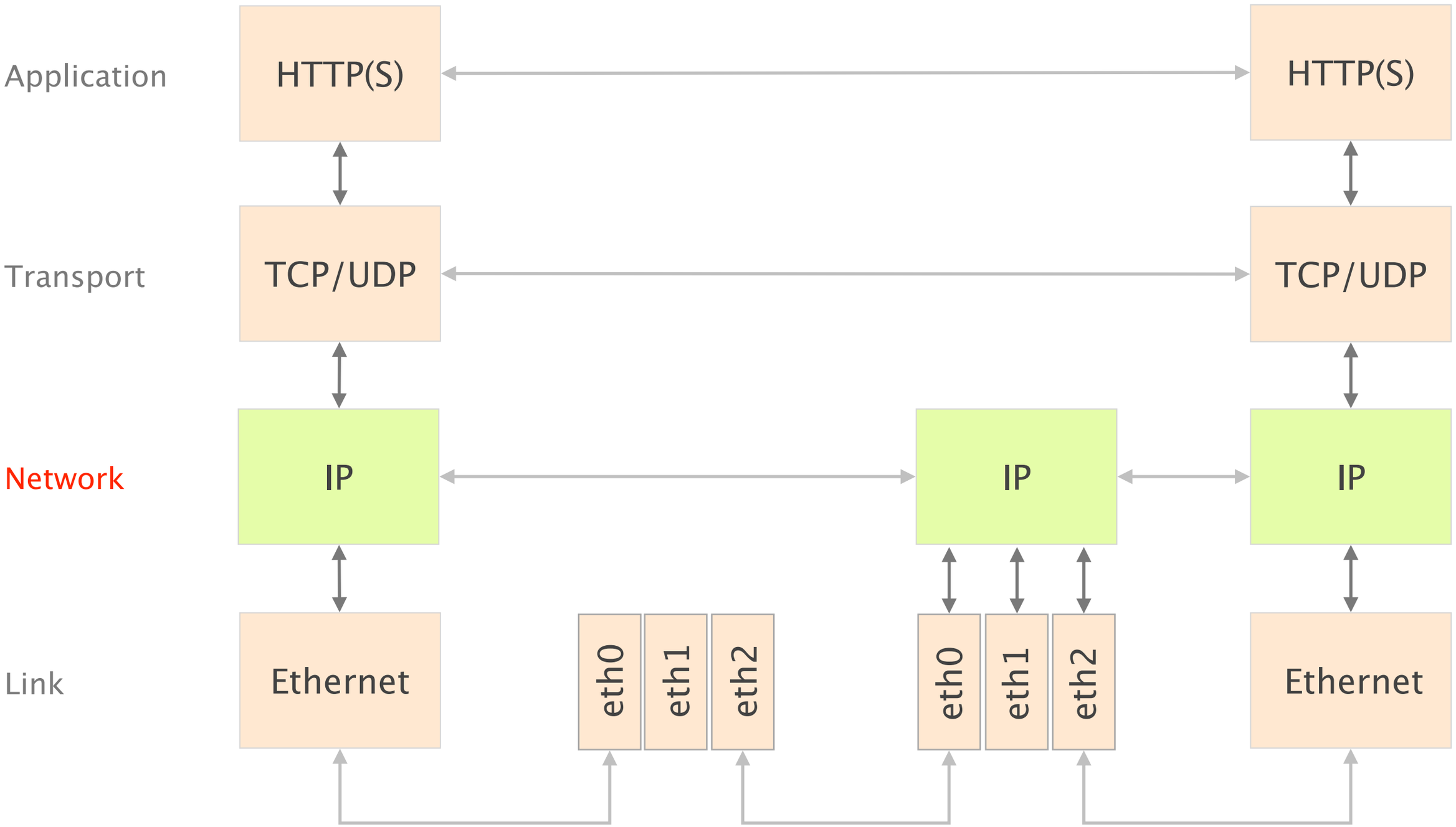
#2 How do we identify link adapters?

#3 How do we share a network medium?

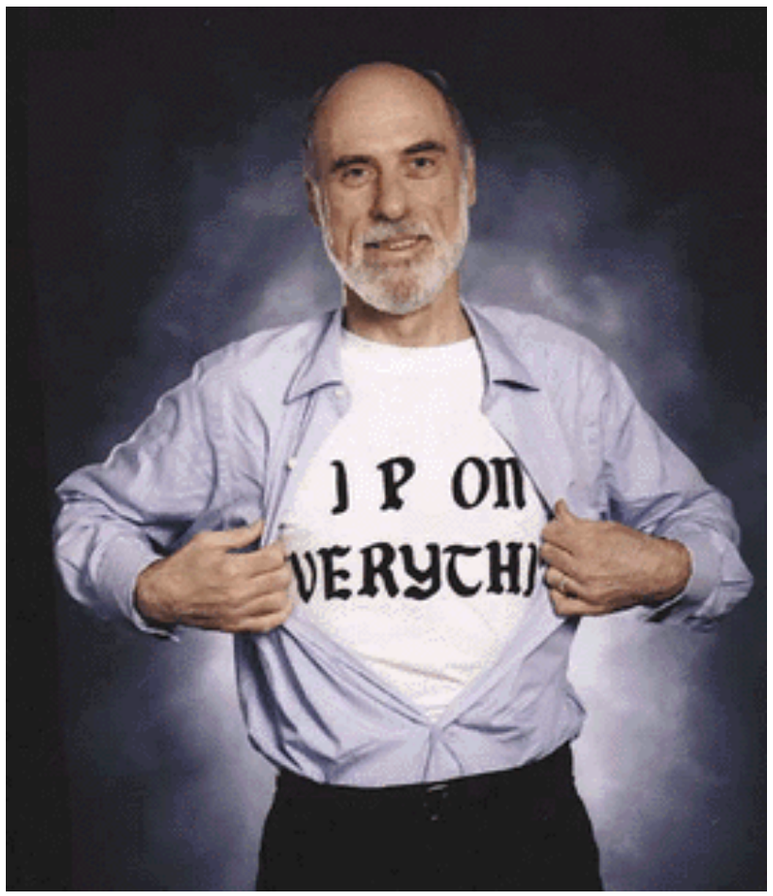
#4 What is Ethernet?

#5 How do we interconnect segments at the link layer?

We then spent multiple weeks on layer 3



Internet Protocol and Forwarding



source: Boardwatch Magazine

1 **IP addresses**
use, structure, allocation

2 **IP forwarding**
longest prefix match rule

3 **IP header**
IPv4 and IPv6, wire format

We also talked about **IPv6**

Internet routing

from here to there, and back

1 Intra-domain routing

Link-state protocols

Distance-vector protocols

2 Inter-domain routing

Path-vector protocols

Internet routing comes into two flavors:

intra- and *inter-domain* routing

inter-domain routing

Find paths between networks

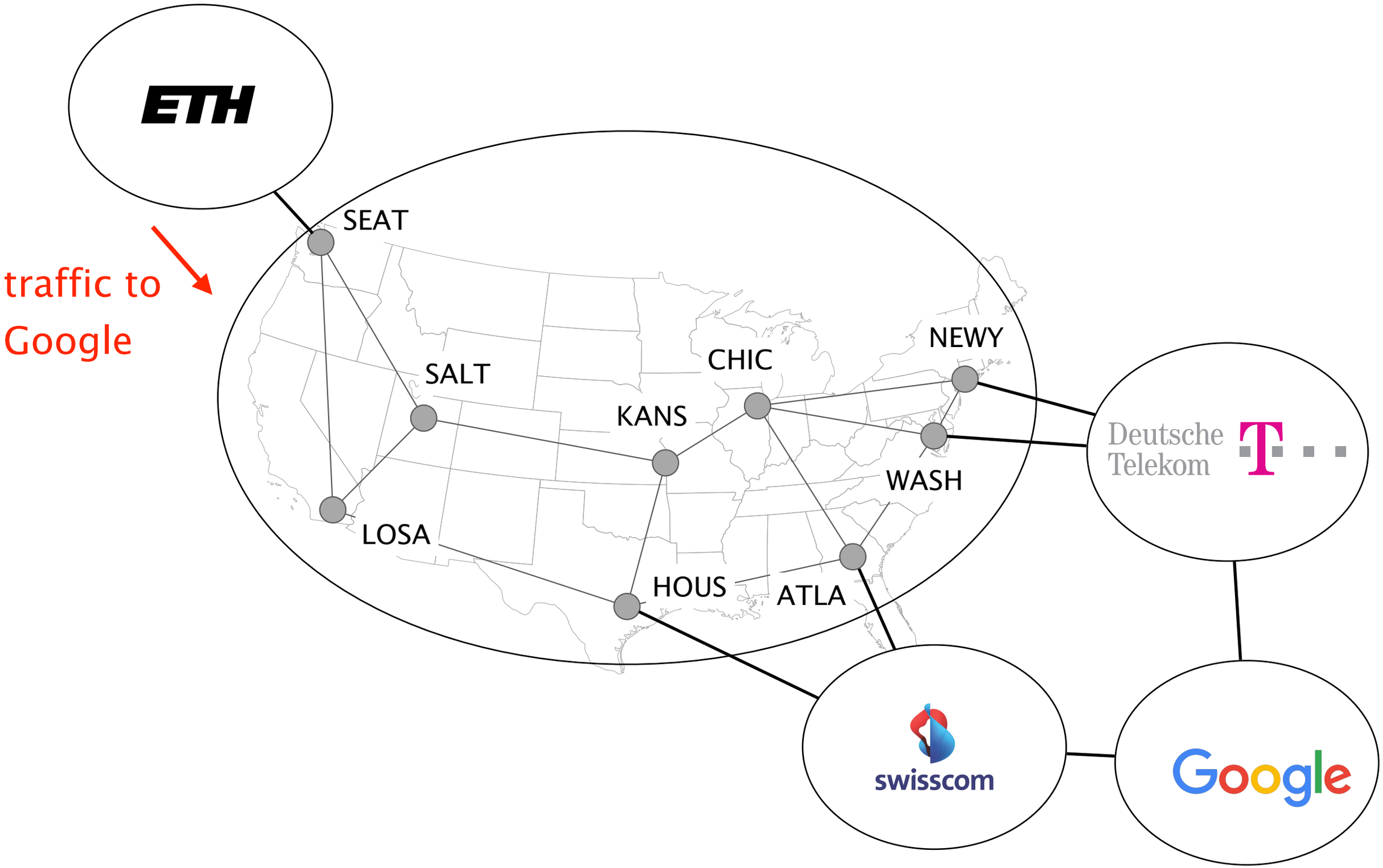
intra-domain routing

Find paths within a network

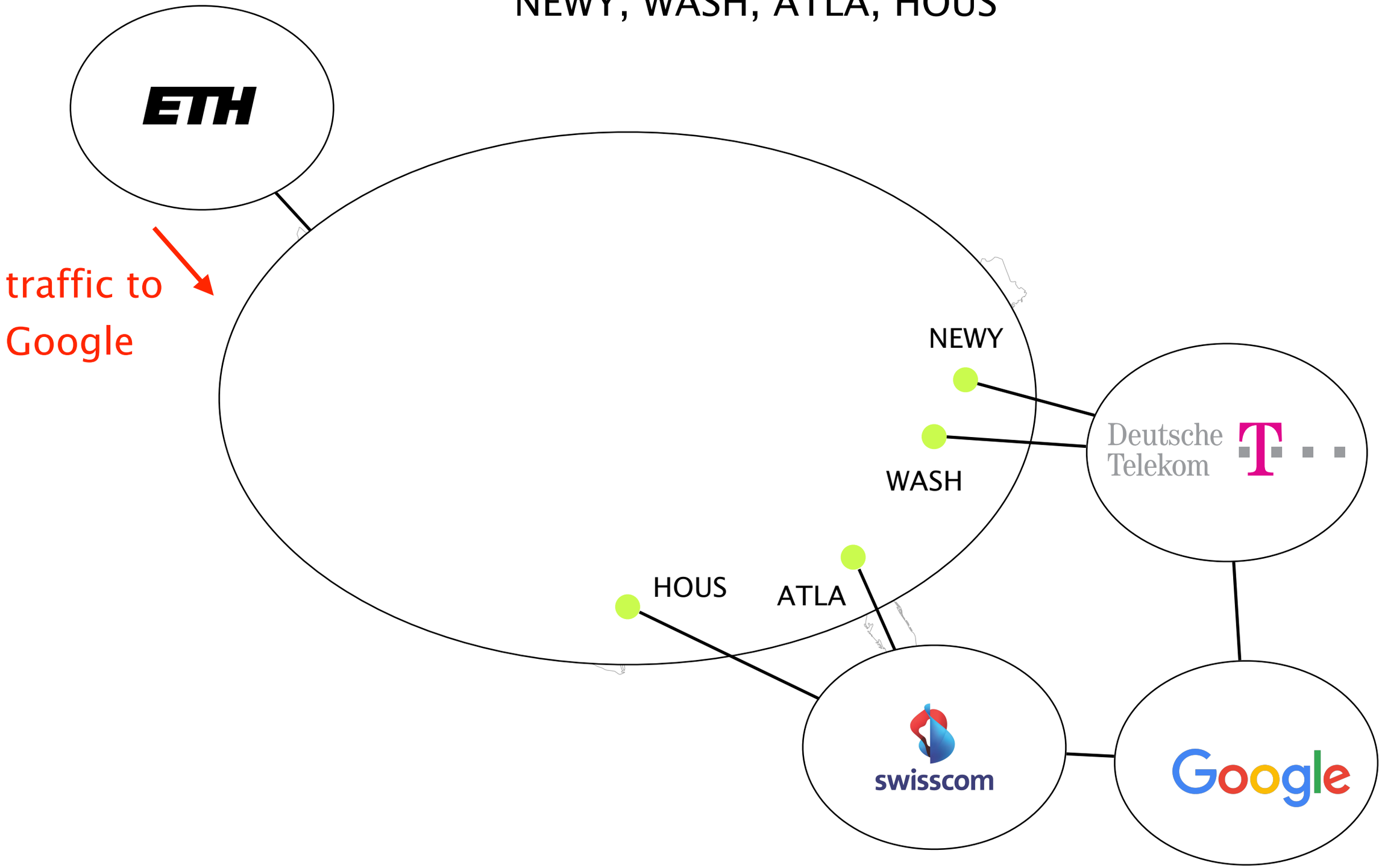
inter-domain routing

intra-domain routing

Find paths between networks


ETH
traffic to Google
SEAT
SALT
CHIC
NEWY
KANS
WASH
LOSA
HOUS
ATLA
Deutsche Telekom
swisscom
Google

Google can be reached via
NEWY, WASH, ATLA, HOUS

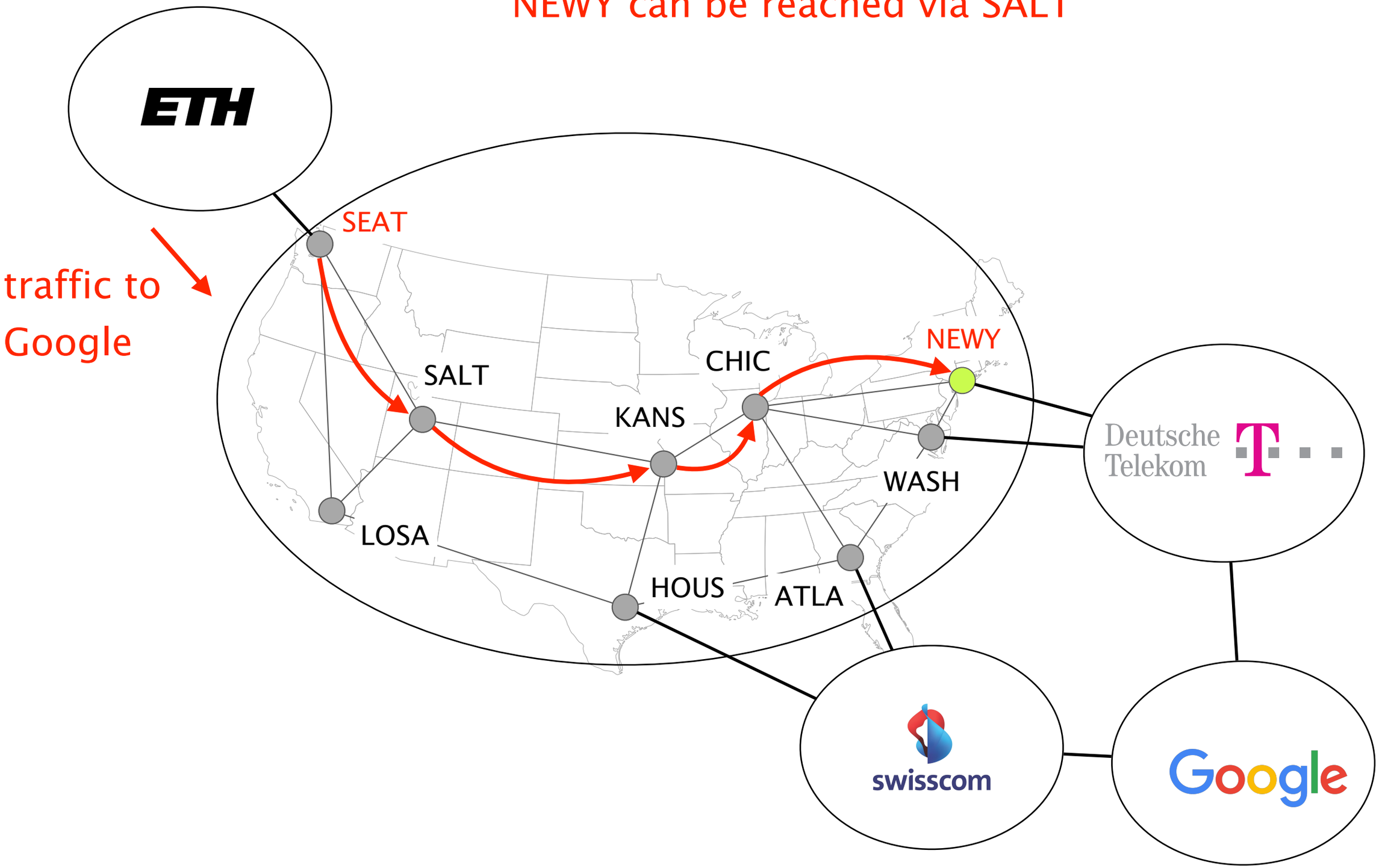


inter-domain routing

intra-domain routing

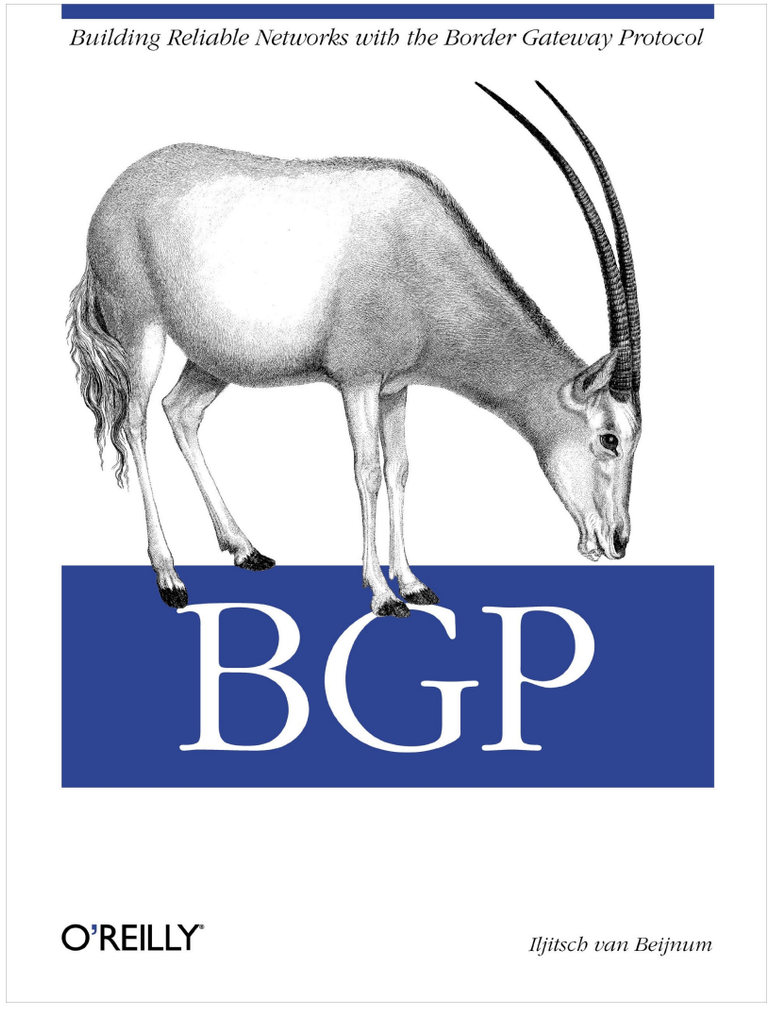
Find paths within a network

NEWY can be reached via SALT



Border Gateway Protocol

policies and more



1 **BGP Policies**

Follow the money

2 **Protocol**

How does it work?

3 **Problems**

security, performance, …

Business relationships conditions

route selection

For a destination *p*, prefer routes coming from

- customers over
- peers over
- providers

route type

Business relationships conditions

route exportation

		send to		
		customer	peer	provider
	customer			
from	peer			
	provider			

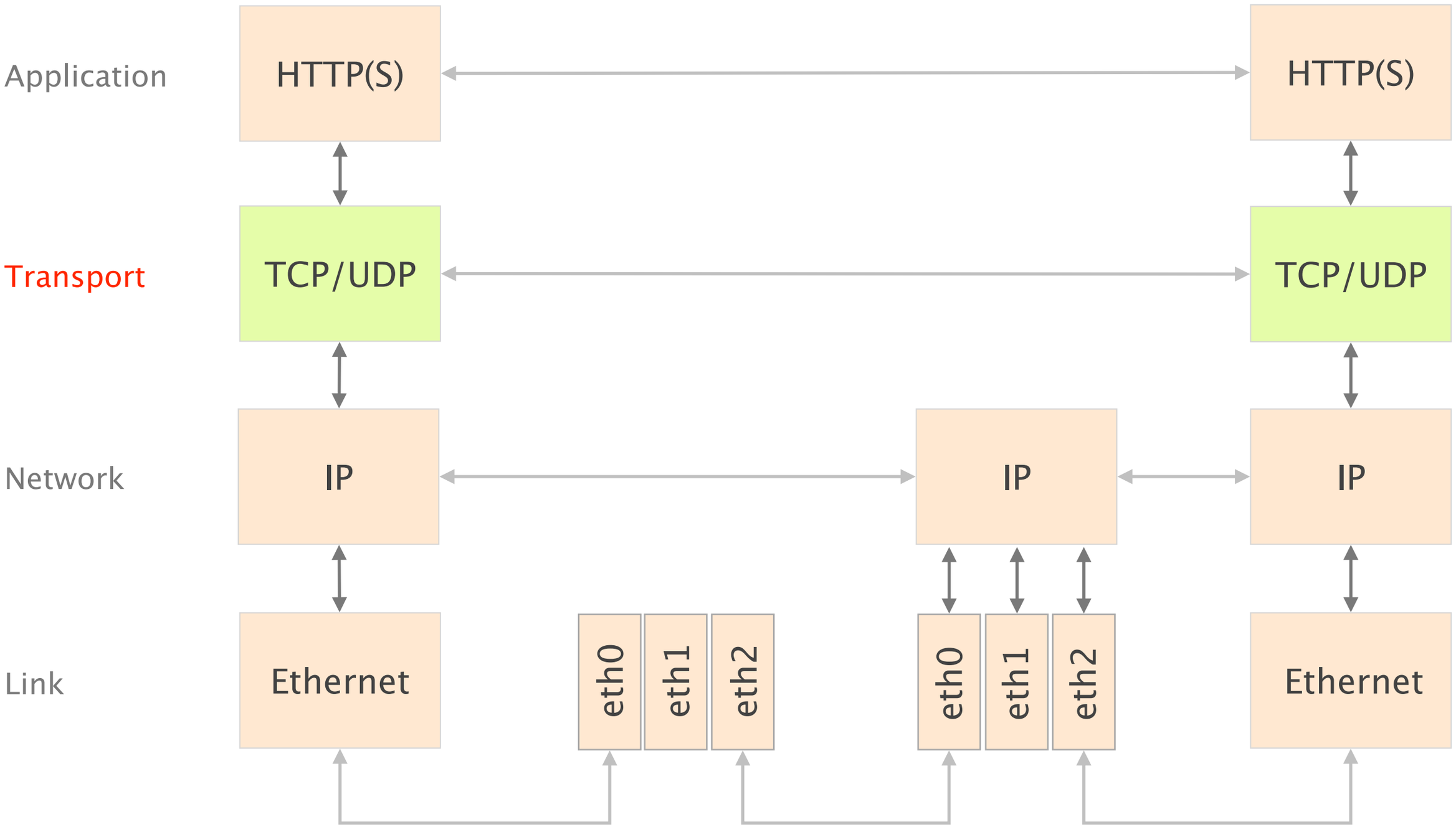
Routes coming from customers
are propagated to everyone else

		send to		
		customer	peer	provider
from	customer	✓	✓	✓
	peer			
	provider			

Routes coming from peers and providers are only propagated to customers

		send to		
		customer	peer	provider
	customer	✓	✓	✓
from	peer	✓	-	-
	provider	✓	-	-

4 = 3+1


Application
Transport
Network
Link
HTTP(S)
HTTP(S)
TCP/UDP
TCP/UDP
IP
IP
IP
Ethernet
Ethernet
eth0
eth1
eth2
eth0
eth1
eth2

We looked at the requirements and implementation of transport protocols (UDP/TCP)

Data delivering, to the *correct* application

- IP just points towards next protocol
- *Transport needs to demultiplex incoming data (ports)*

Files or bytestreams abstractions for the applications

- Network deals with packets
- *Transport layer needs to translate between them*

Reliable transfer (if needed)

Not overloading the receiver

Not overloading the network

We then looked at Congestion Control
and how it solves three fundamental problems

#1	bandwidth estimation	How to adjust the bandwidth of a single flow to the bottleneck bandwidth? could be 1 Mbps or 1 Gbps…
#2	bandwidth adaptation	How to adjust the bandwidth of a single flow to variation of the bottleneck bandwidth?
#3	fairness	How to share bandwidth “fairly" among flows, without overloading the network

… by combining two key mechanisms

detecting congestion

reacting to congestion

We then looked at
what's running on top of all this …

DNS

Web

google.ch ⟷ 172.217.16.131

http://www.google.ch

We then looked at
what's running on top of all this …

Video Streaming

HTTP-based

E-mail

MX, SMTP, POP, IMAP

Your final grade

Exam

70%

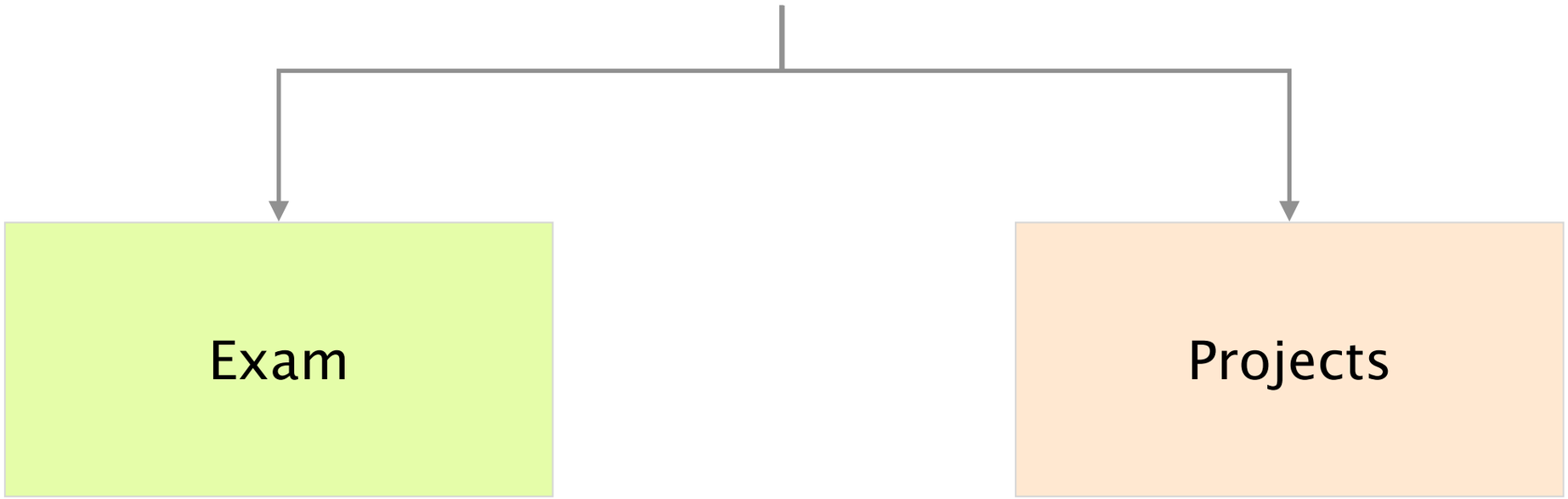
written, open book

Projects

30%

- 20% routing
- 10% transport

Your final grade



70%

written, open book

30%

20% routing

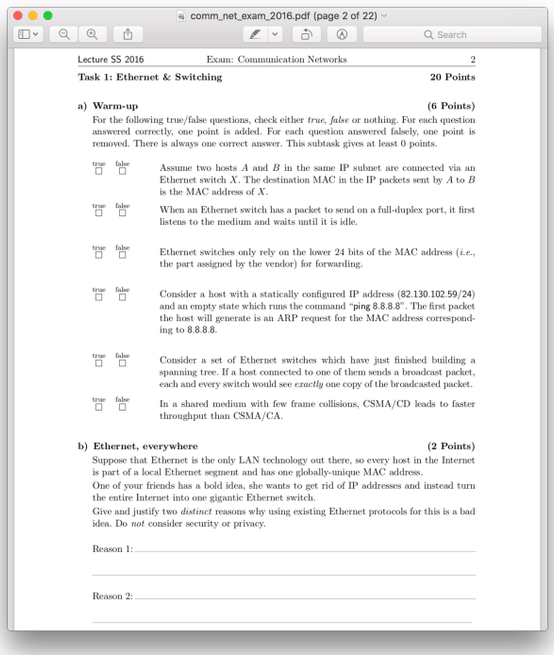
10% transport

The exam will be open book, most of the questions will be open-ended, with some multiple choices

verify your understanding of the material

Make sure you can do *all* the exercises, especially the ones in previous exams

Millesime 2016


comm_net_exam_2016.pdf (page 2 of 22)

Lecture SS 2016 Exam: Communication Networks 2

Task 1: Ethernet & Switching **20 Points**

a) Warm-up **(6 Points)**

For the following true/false questions, check either *true*, *false* or nothing. For each question answered correctly, one point is added. For each question answered falsely, one point is removed. There is always one correct answer. This subtask gives at least 0 points.

true ☐ false ☐ Assume two hosts A and B in the same IP subnet are connected via an Ethernet switch X. The destination MAC in the IP packets sent by A to B is the MAC address of X.

true ☐ false ☐ When an Ethernet switch has a packet to send on a full-duplex port, it first listens to the medium and waits until it is idle.

true ☐ false ☐ Ethernet switches only rely on the lower 24 bits of the MAC address (*i.e.*, the part assigned by the vendor) for forwarding.

true ☐ false ☐ Consider a host with a statically configured IP address (82.130.102.59/24) and an empty state which runs the command "ping 8.8.8.8". The first packet the host will generate is an ARP request for the MAC address corresponding to 8.8.8.8.

true ☐ false ☐ Consider a set of Ethernet switches which have just finished building a spanning tree. If a host connected to one of them sends a broadcast packet, each and every switch would see *exactly* one copy of the broadcasted packet.

true ☐ false ☐ In a shared medium with few frame collisions, CSMA/CD leads to faster throughput than CSMA/CA.

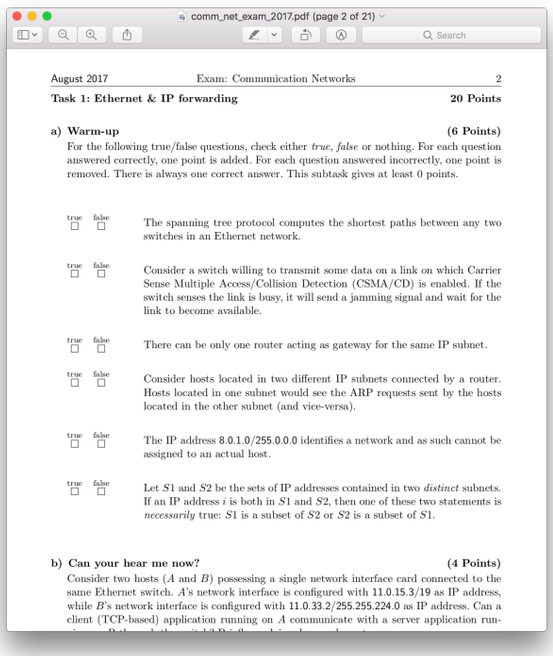
b) Ethernet, everywhere **(2 Points)**

Suppose that Ethernet is the only LAN technology out there, so every host in the Internet is part of a local Ethernet segment and has one globally-unique MAC address.
One of your friends has a bold idea, she wants to get rid of IP addresses and instead turn the entire Internet into one gigantic Ethernet switch.
Give and justify two *distinct* reasons why using existing Ethernet protocols for this is a bad idea. Do *not* consider security or privacy.

Reason 1: _____

Reason 2: _____

Millesime 2017


comm_net_exam_2017.pdf (page 2 of 21)

August 2017 Exam: Communication Networks 2

Task 1: Ethernet & IP forwarding **20 Points**

a) Warm-up **(6 Points)**

For the following true/false questions, check either *true*, *false* or nothing. For each question answered correctly, one point is added. For each question answered incorrectly, one point is removed. There is always one correct answer. This subtask gives at least 0 points.

true ☐ false ☐ The spanning tree protocol computes the shortest paths between any two switches in an Ethernet network.

true ☐ false ☐ Consider a switch willing to transmit some data on a link on which Carrier Sense Multiple Access/Collision Detection (CSMA/CD) is enabled. If the switch senses the link is busy, it will send a jamming signal and wait for the link to become available.

true ☐ false ☐ There can be only one router acting as gateway for the same IP subnet.

true ☐ false ☐ Consider hosts located in two different IP subnets connected by a router. Hosts located in one subnet would see the ARP requests sent by the hosts located in the other subnet (and vice-versa).

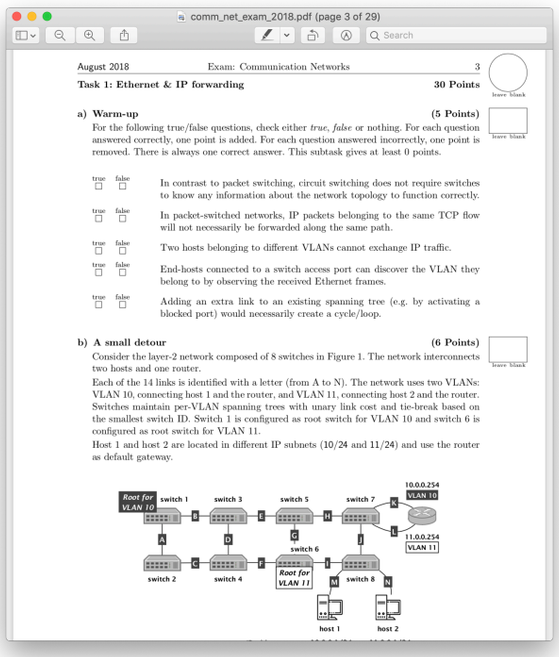
true ☐ false ☐ The IP address 8.0.1.0/255.0.0.0 identifies a network and as such cannot be assigned to an actual host.

true ☐ false ☐ Let $S1$ and $S2$ be the sets of IP addresses contained in two *distinct* subnets. If an IP address i is both in $S1$ and $S2$, then one of these two statements is *necessarily* true: $S1$ is a subset of $S2$ or $S2$ is a subset of $S1$.

b) Can your hear me now? **(4 Points)**

Consider two hosts (A and B) possessing a single network interface card connected to the same Ethernet switch. A's network interface is configured with 11.0.15.3/19 as IP address, while B's network interface is configured with 11.0.33.2/255.255.224.0 as IP address. Can a client (TCP-based) application running on A communicate with a server application run-

Millesime 2018


comm_net_exam_2018.pdf (page 3 of 29)

August 2018 Exam: Communication Networks 3

Task 1: Ethernet & IP forwarding **30 Points**

leave blank

a) Warm-up **(5 Points)**

leave blank

For the following true/false questions, check either *true*, *false* or nothing. For each question answered correctly, one point is added. For each question answered incorrectly, one point is removed. There is always one correct answer. This subtask gives at least 0 points.

true ☐ false ☐ In contrast to packet switching, circuit switching does not require switches to know any information about the network topology to function correctly.

true ☐ false ☐ In packet-switched networks, IP packets belonging to the same TCP flow will not necessarily be forwarded along the same path.

true ☐ false ☐ Two hosts belonging to different VLANs cannot exchange IP traffic.

true ☐ false ☐ End-hosts connected to a switch access port can discover the VLAN they belong to by observing the received Ethernet frames.

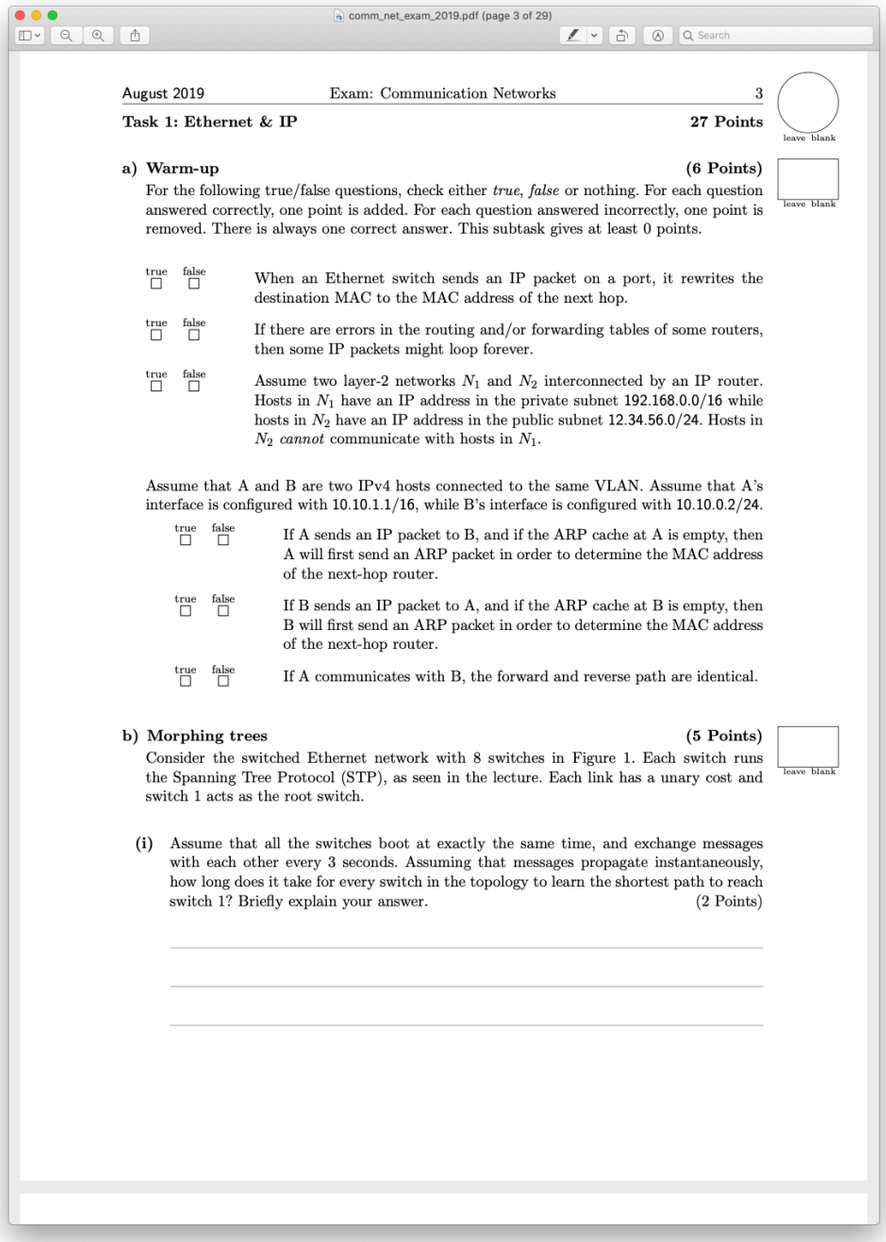
true ☐ false ☐ Adding an extra link to an existing spanning tree (e.g. by activating a blocked port) would necessarily create a cycle/loop.

b) A small detour **(6 Points)**

leave blank

Consider the layer-2 network composed of 8 switches in Figure 1. The network interconnects two hosts and one router.
Each of the 14 links is identified with a letter (from A to N). The network uses two VLANs: VLAN 10, connecting host 1 and the router, and VLAN 11, connecting host 2 and the router. Switches maintain per-VLAN spanning trees with unary link cost and tie-break based on the smallest switch ID. Switch 1 is configured as root switch for VLAN 10 and switch 6 is configured as root switch for VLAN 11.
Host 1 and host 2 are located in different IP subnets (10/24 and 11/24) and use the router as default gateway.

Millesime 2019


comm_net_exam_2019.pdf (page 3 of 29)

August 2019 Exam: Communication Networks 3

Task 1: Ethernet & IP **27 Points**

leave blank

a) Warm-up **(6 Points)**

leave blank

For the following true/false questions, check either *true*, *false* or nothing. For each question answered correctly, one point is added. For each question answered incorrectly, one point is removed. There is always one correct answer. This subtask gives at least 0 points.

true ☐ false ☐ When an Ethernet switch sends an IP packet on a port, it rewrites the destination MAC to the MAC address of the next hop.

true ☐ false ☐ If there are errors in the routing and/or forwarding tables of some routers, then some IP packets might loop forever.

true ☐ false ☐ Assume two layer-2 networks N_1 and N_2 interconnected by an IP router. Hosts in N_1 have an IP address in the private subnet 192.168.0.0/16 while hosts in N_2 have an IP address in the public subnet 12.34.56.0/24. Hosts in N_2 *cannot* communicate with hosts in N_1.

Assume that A and B are two IPv4 hosts connected to the same VLAN. Assume that A's interface is configured with 10.10.1.1/16, while B's interface is configured with 10.10.0.2/24.

true ☐ false ☐ If A sends an IP packet to B, and if the ARP cache at A is empty, then A will first send an ARP packet in order to determine the MAC address of the next-hop router.

true ☐ false ☐ If B sends an IP packet to A, and if the ARP cache at B is empty, then B will first send an ARP packet in order to determine the MAC address of the next-hop router.

true ☐ false ☐ If A communicates with B, the forward and reverse path are identical.

b) Morphing trees **(5 Points)**

leave blank

Consider the switched Ethernet network with 8 switches in Figure 1. Each switch runs the Spanning Tree Protocol (STP), as seen in the lecture. Each link has a unary cost and switch 1 acts as the root switch.

(i) Assume that all the switches boot at exactly the same time, and exchange messages with each other every 3 seconds. Assuming that messages propagate instantaneously, how long does it take for every switch in the topology to learn the shortest path to reach switch 1? Briefly explain your answer. (2 Points)

https://comm-net.ethz.ch/#tab-exam

Don't forget the assignments,

they matter

No programming question no Python at the exam

but we could ask you to describe a procedure in English

What would you change in your solution to achieve *X*?

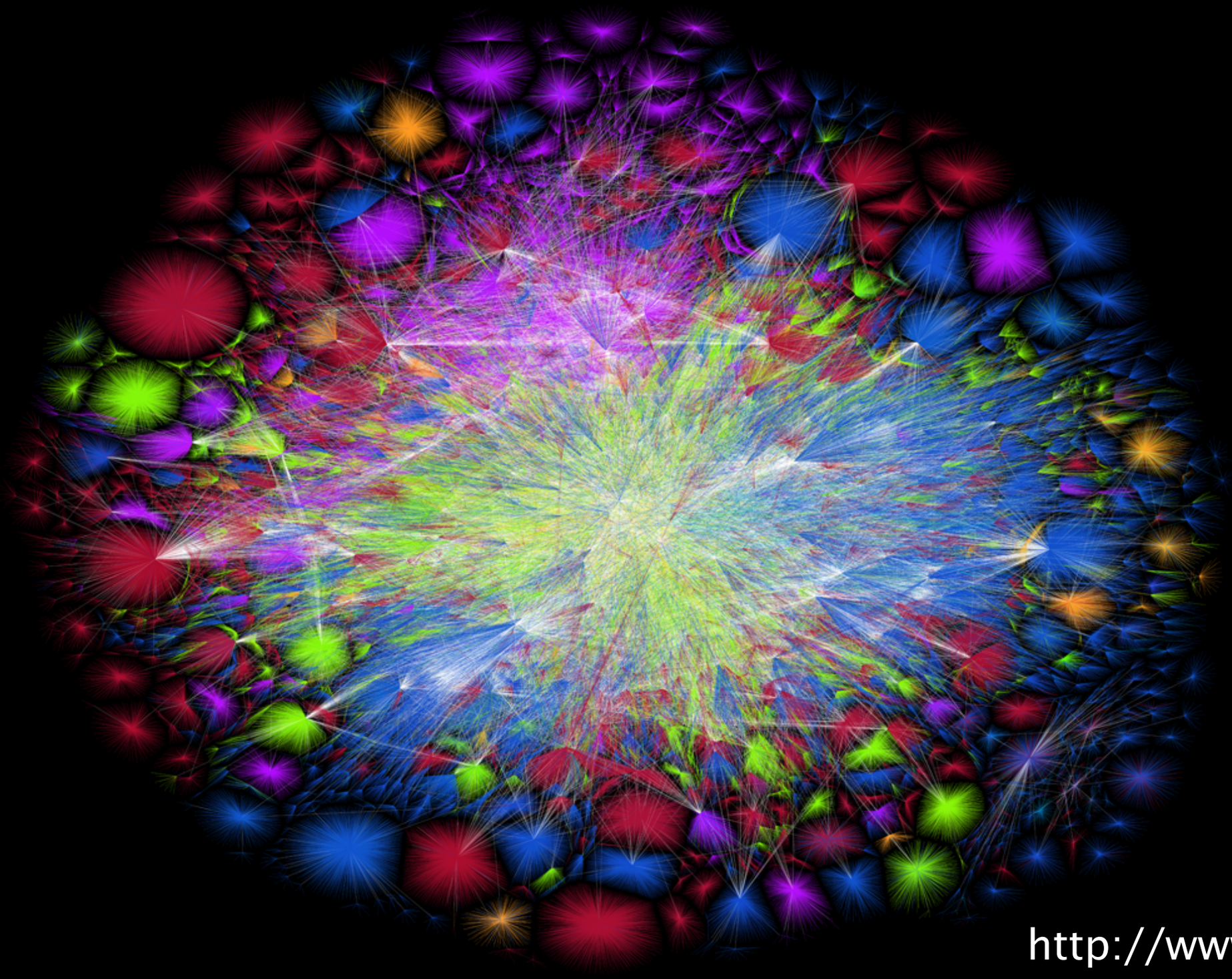
No configuration question no Quagga at the exam

but we could ask you to describe a configuration in English

How would you enforce policy *X*?

We'll organize another remote Q&A session closer to the exam (details to follow)

Now you (better) understand this!



http://www.opte.org

Communication Networks

What's next?

Master-level lecture, every Fall semester

Advanced Topics in Communication Networks

Topics

(not exhaustive)

Tunneling

Hierarchical routing

Traffic Engineering

Virtual Private Networks

Quality of Service/Scheduling

IP Multicast

Fast Convergence

Network virtualization

Network programmability

Network measurements

+ labs & a project

if you liked the routing project, you will like this lecture as well

https://adv-net.ethz.ch/

Master-level lecture, every semester (with D-INFK)

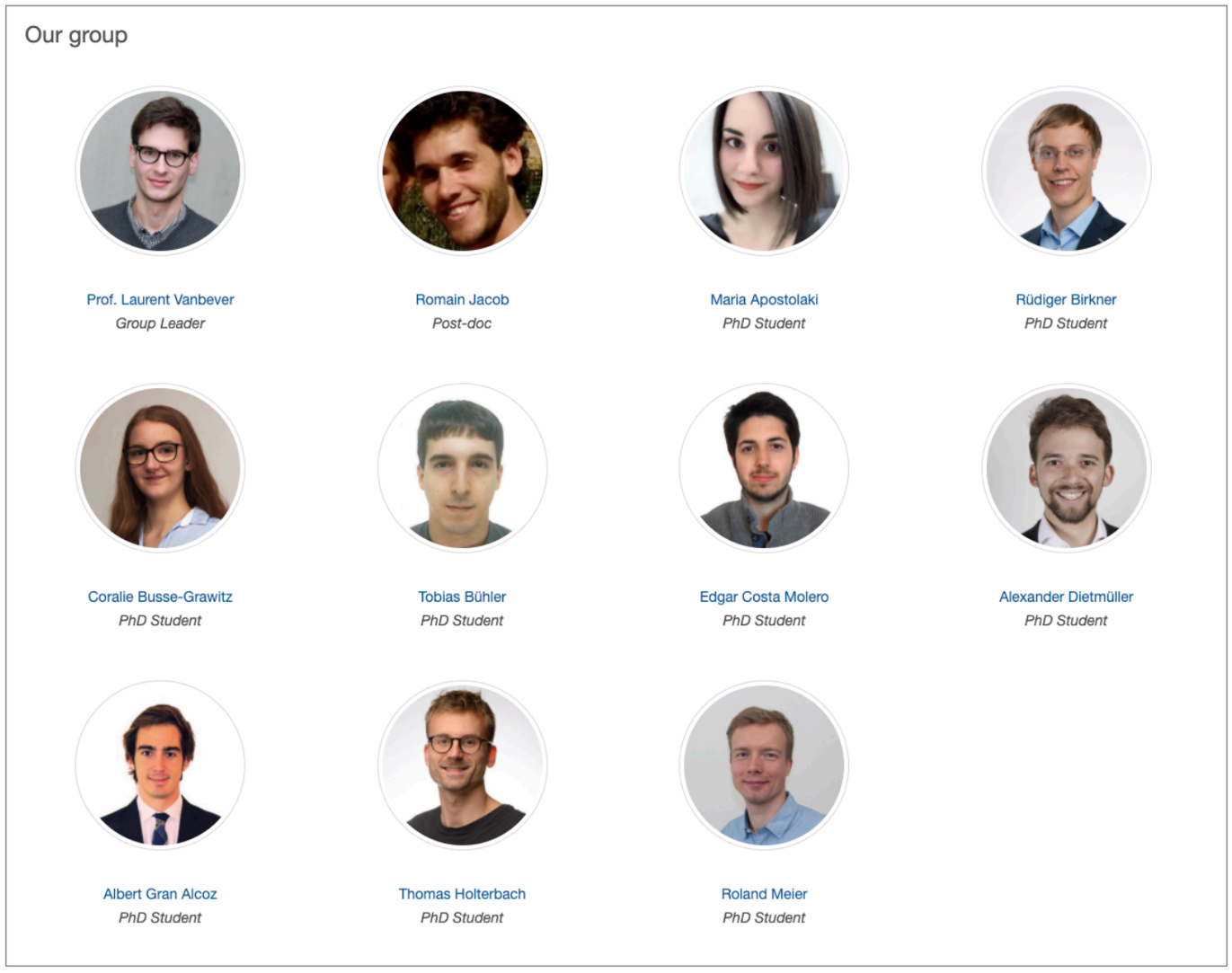
Seminar in Communication Networks

- Understand recent research result
- Read, present, and critique research papers
- Identify new research opportunities

https://nsg.ee.ethz.ch/courses/

Consider doing one of your theses with our group!

bachelor, semester or master



https://nsg.ee.ethz.ch/theses/

That's all Folks!

Enjoy a **well-deserved** break!

Communication Networks

Spring 2020

Laurent Vanbever

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