Communication Networks

Spring 2021

Laurent Vanbever

nsg.ee.ethz.ch

ETH Zürich (D-ITET)

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Materials inspired from Scott Shenker and Jennifer Rexford

Last Monday on

Communication Networks

DNS

Web

google.ch ↔ 172.217.16.131

http://www.google.ch

(the beginning)

Internet has one **global system** for

- addressing hosts IP

  by design

- naming hosts DNS

  by "accident", an afterthought

To scale,
DNS adopt three intertwined hierarchies

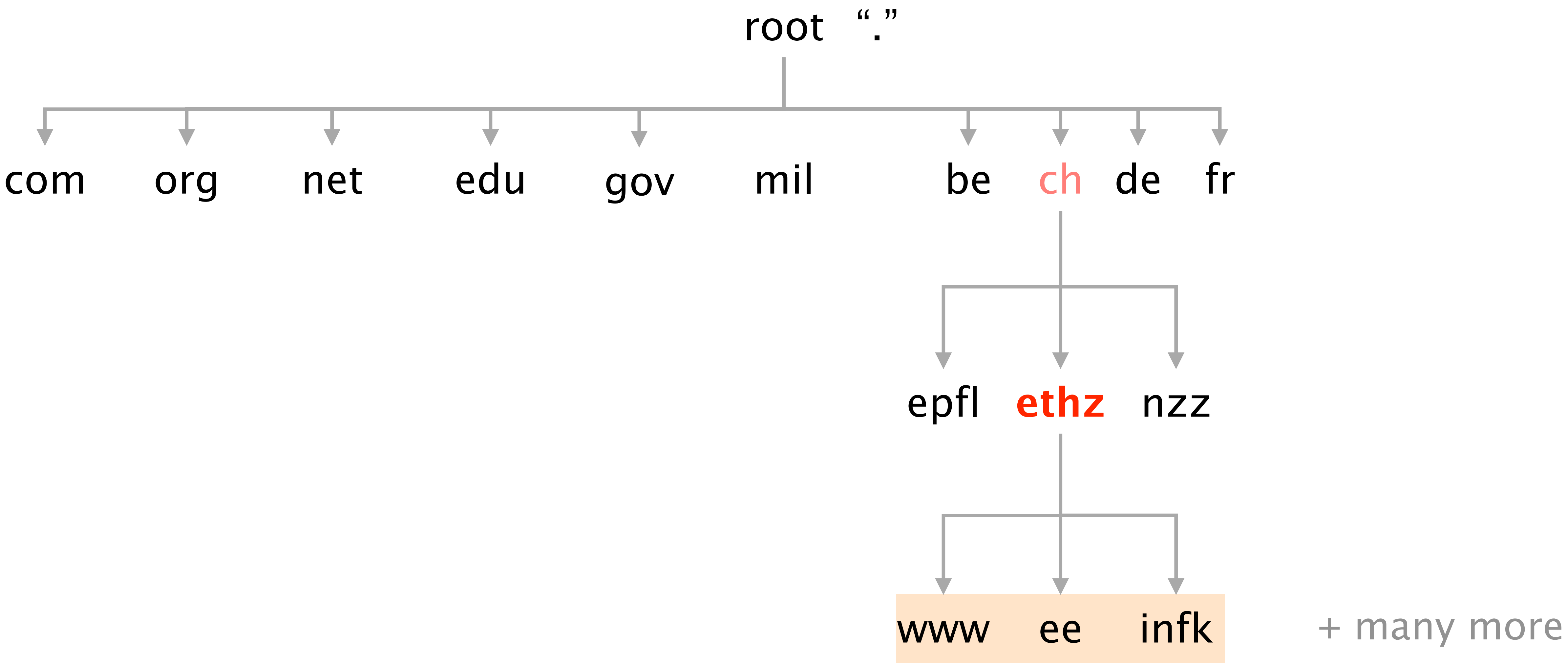
naming structure	hierarchy of addresses https://www.ee.ethz.ch/de/departement/
management	hierarchy of authority over names
infrastructure	hierarchy of DNS servers

naming structure

hierarchy of addresses

https://www.ee.ethz.ch/de/departement/

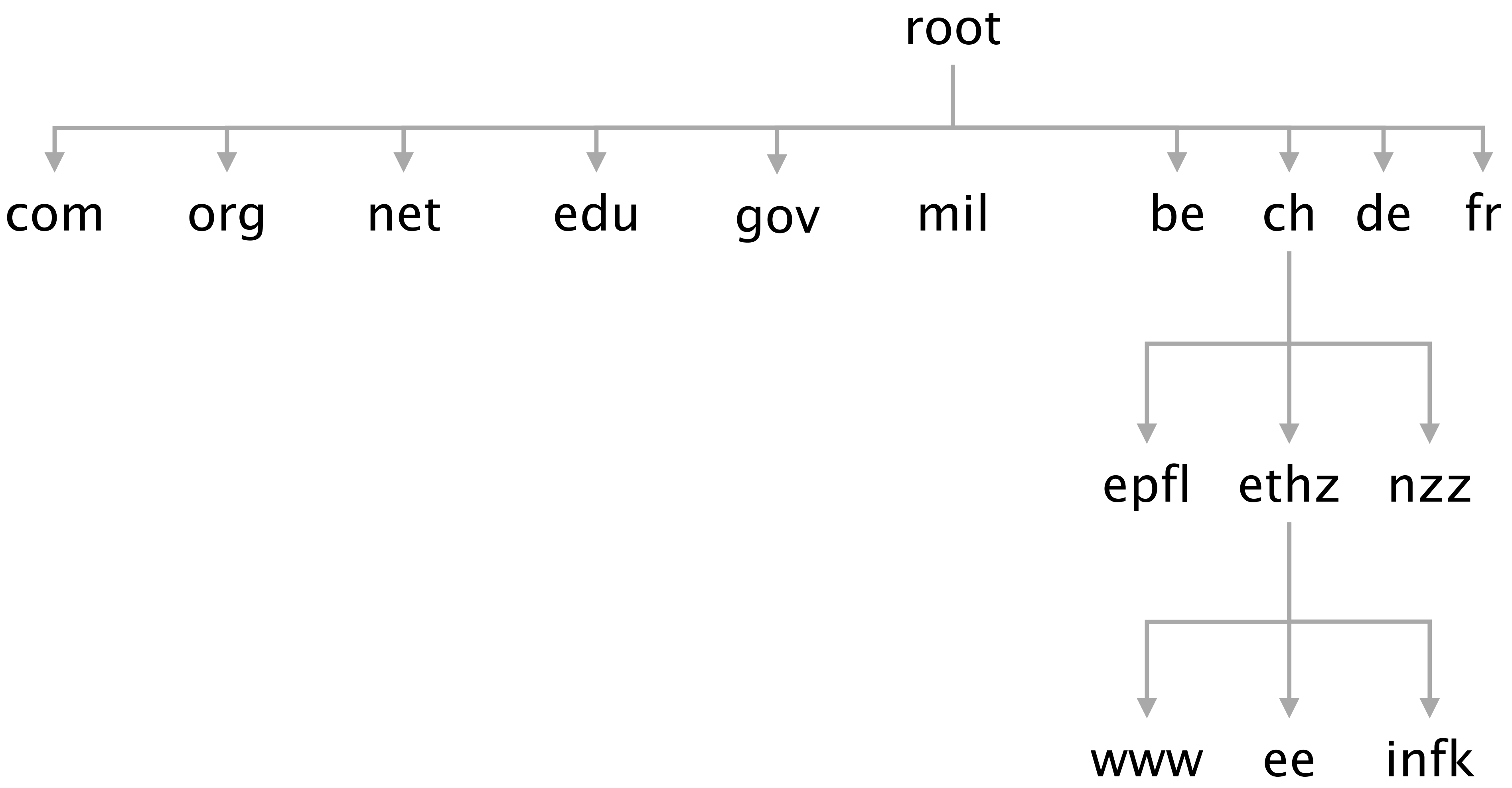
A name, *e.g.* ee.ethz.ch, represents a leaf-to-root path in the hierarchy

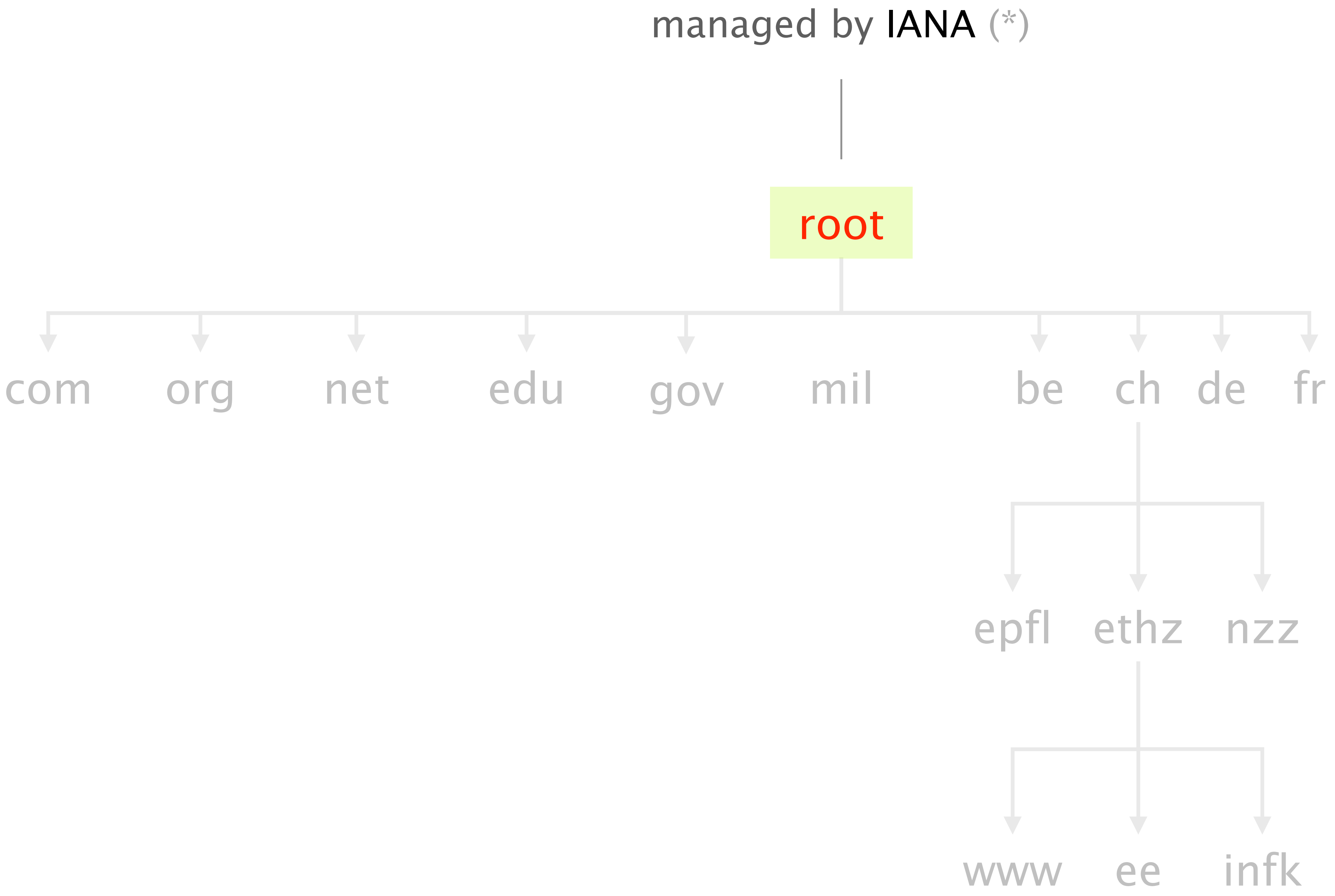


management

hierarchy of authority
over names

The DNS system is hierarchically administered





managed by IANA (*)

root

com
org
net
edu
gov
mil
be
ch
de
fr

epfl
ethz
nzz

www
ee
infk

(*) see http://www.iana.org/domains/root/db infrastructure

hierarchy of DNS servers

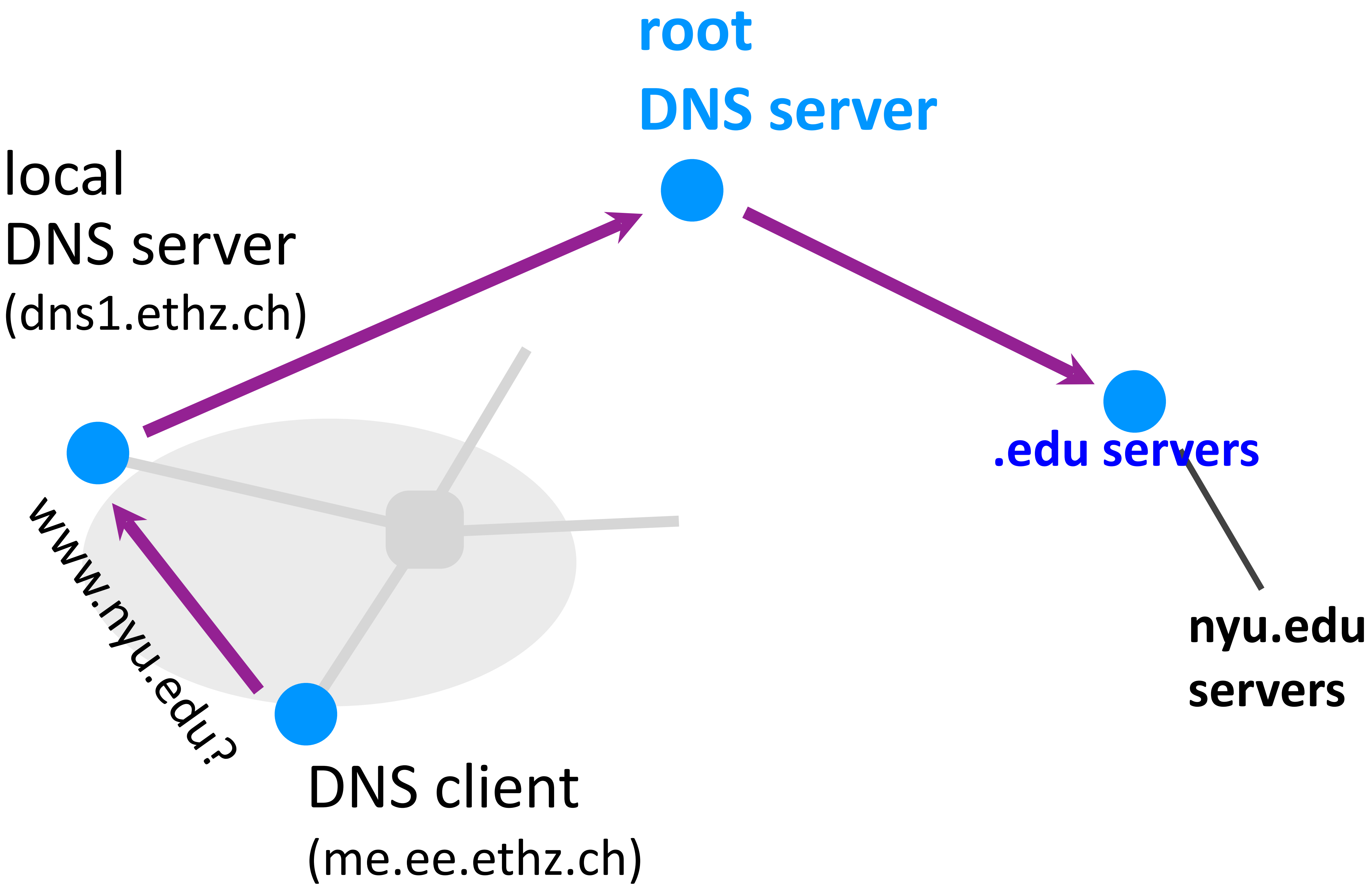
13 root servers (managed professionally) serve as root

a. root-servers.net	VeriSign, Inc.
b. root-servers.net	University of Southern California
c. root-servers.net	Cogent Communications
d. root-servers.net	University of Maryland
e. root-servers.net	NASA
f. root-servers.net	Internet Systems Consortium
g. root-servers.net	US Department of Defense
h. root-servers.net	US Army
i. root-servers.net	Netnod
j. root-servers.net	VeriSign, Inc.
k. root-servers.net	RIPE NCC
l. root-servers.net	ICANN
m. root-servers.net	WIDE Project

A DNS server stores Resource Records composed of a (name, value, type, TTL)

Records	Name	Value
A	hostname	IP address
NS	domain	DNS server name
MX	domain	Mail server name
CNAME	alias	canonical name
PTR	IP address	corresponding hostname

DNS resolution can either be recursive or iterative



root
DNS server

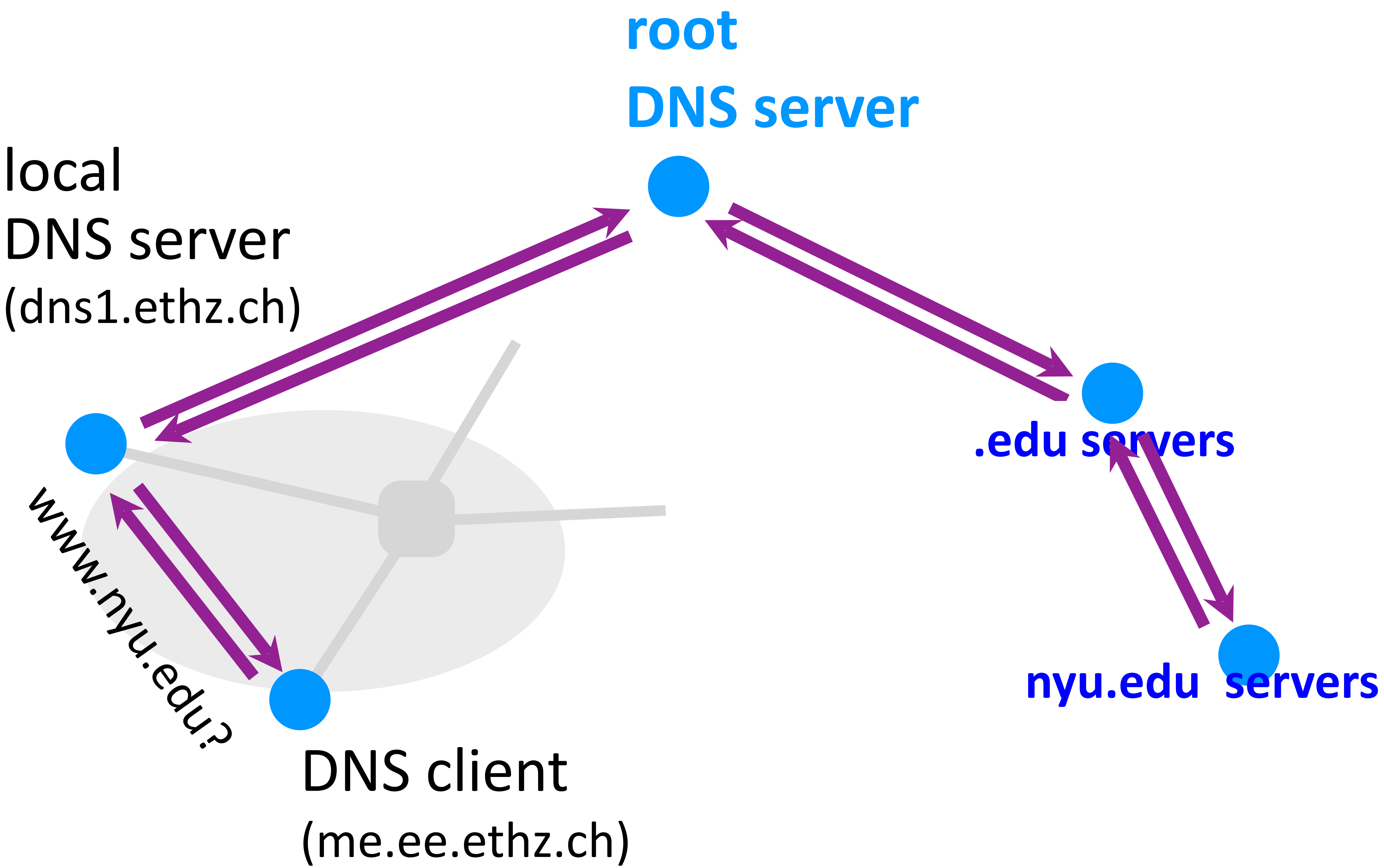
local
DNS server
(dns1.ethz.ch)

.edu servers

nyu.edu
servers

www.nyu.edu?

DNS client
(me.ee.ethz.ch)



root
DNS server

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(dns1.ethz.ch)

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www.nyu.edu?

DNS client
(me.ee.ethz.ch)

Today on

Communication Networks

Web

http://www.google.ch

(the end)

Email

MX, SMTP, POP, IMAP

Web

Email

http://www.google.ch

(the end)

Web

Email

MX, SMTP, POP, IMAP

We'll study e-mail from three different perspectives

Content

Format: Header/Content

Encoding: MIME

Infrastructure/ Transmission

SMTP: Simple Mail Transfer Protocol

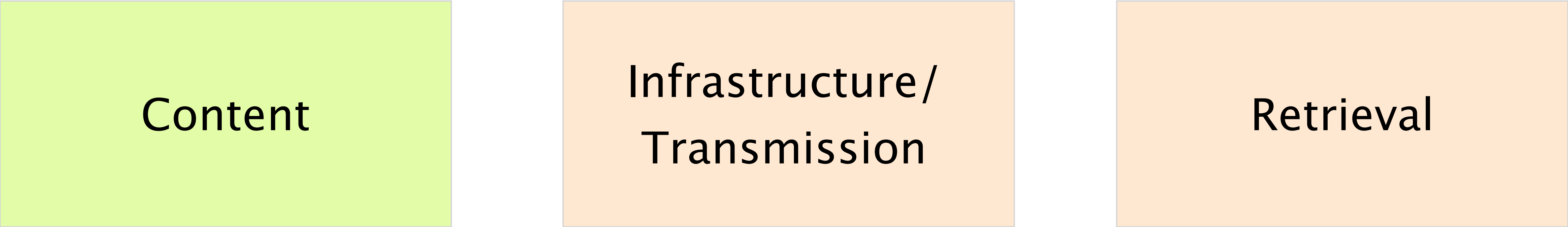
Infrastructure

mail servers

Retrieval

POP: Post Office Protocol

IMAP:Internet Message Access Protocol



Content

Infrastructure/ Transmission

Retrieval

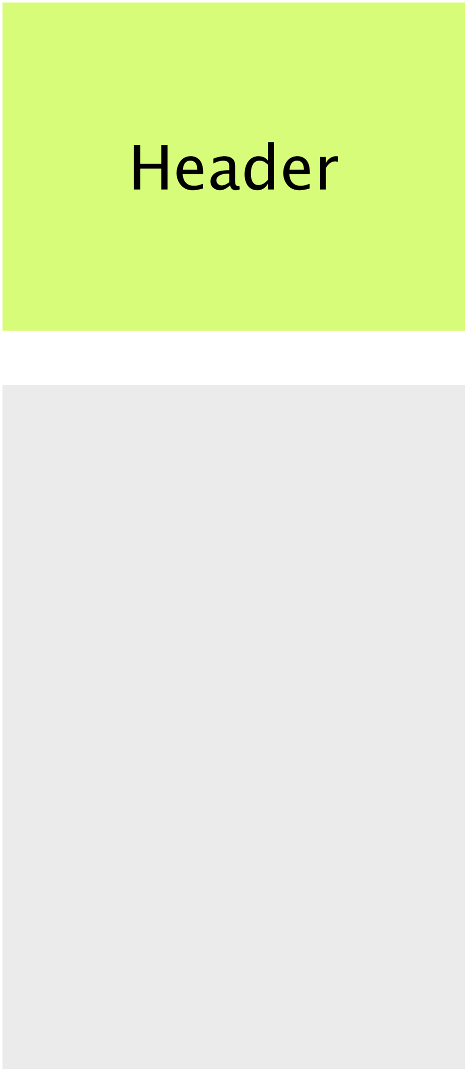
Format: Header/Content

Encoding: MIME

An e-mail is composed of two parts

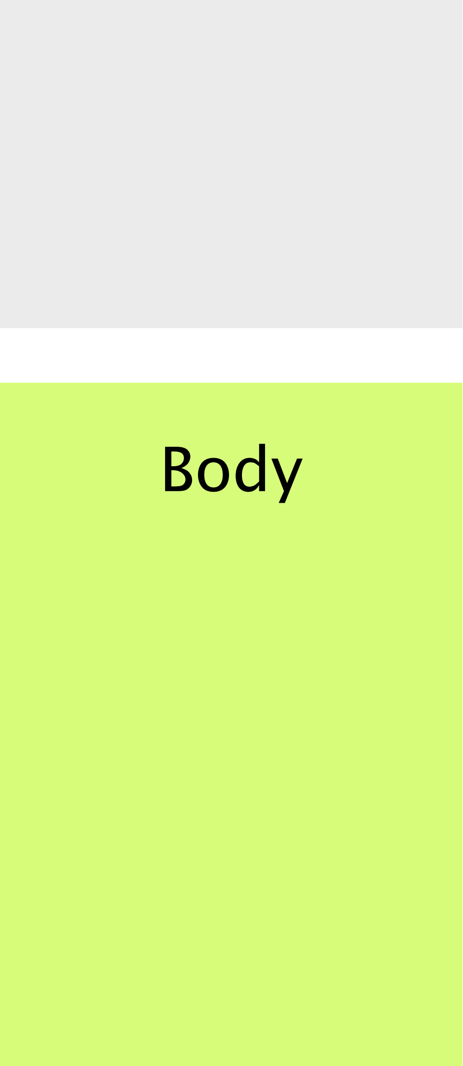
E-mail

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



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

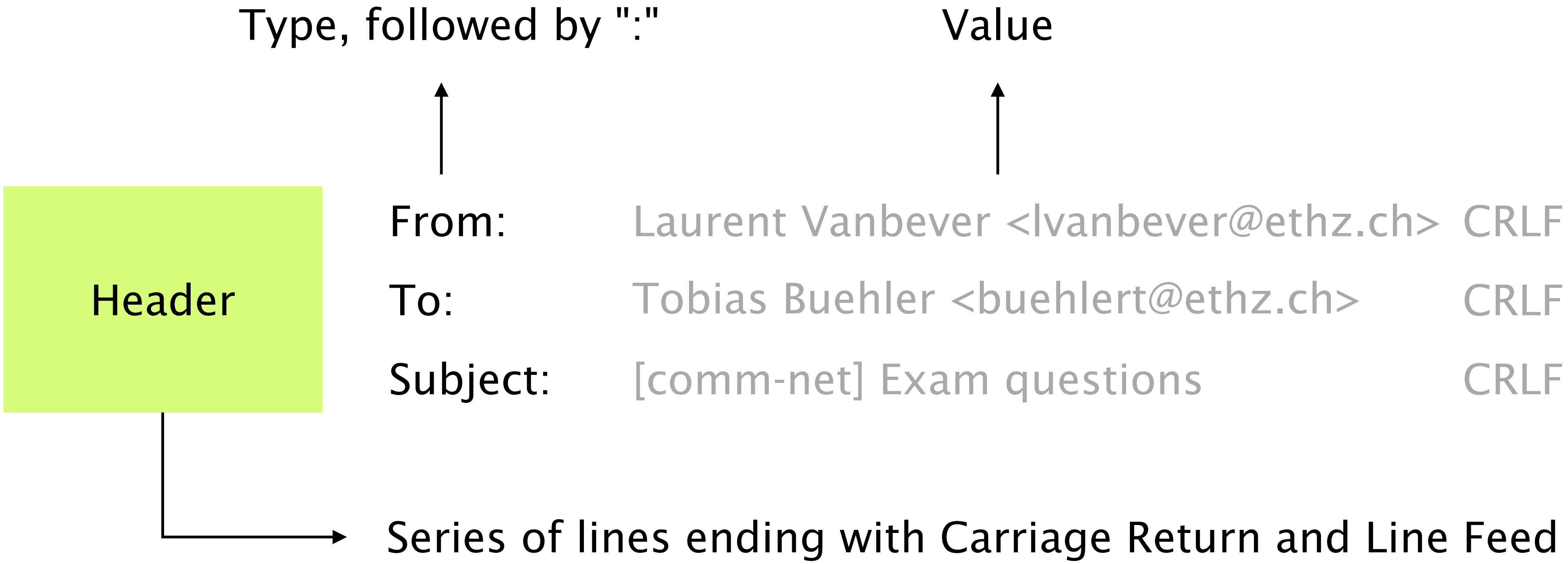


From: Laurent Vanbever <lvanbever@ethz.ch>
To: Tobias Buehler <buehlert@ethz.ch>
Subject: [comm-net] Exam questions

Hi Tobias,

Here are some interesting questions…

Best,
Laurent



Type, followed by ":"

Value

Header

From: Laurent Vanbever <lvanbever@ethz.ch> CRLF

To: Tobias Buehler <buehlert@ethz.ch> CRLF

Subject: [comm-net] Exam questions CRLF

Series of lines ending with Carriage Return and Line Feed

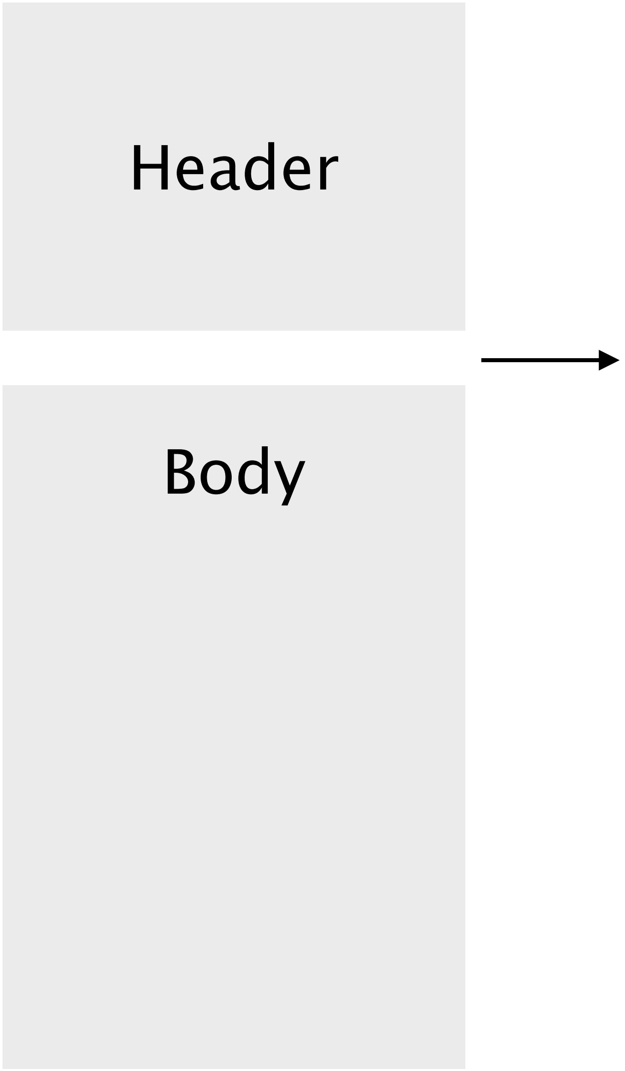
Body

Series of lines with no structure/meaning

Hi Tobias,

Here are some interesting questions…

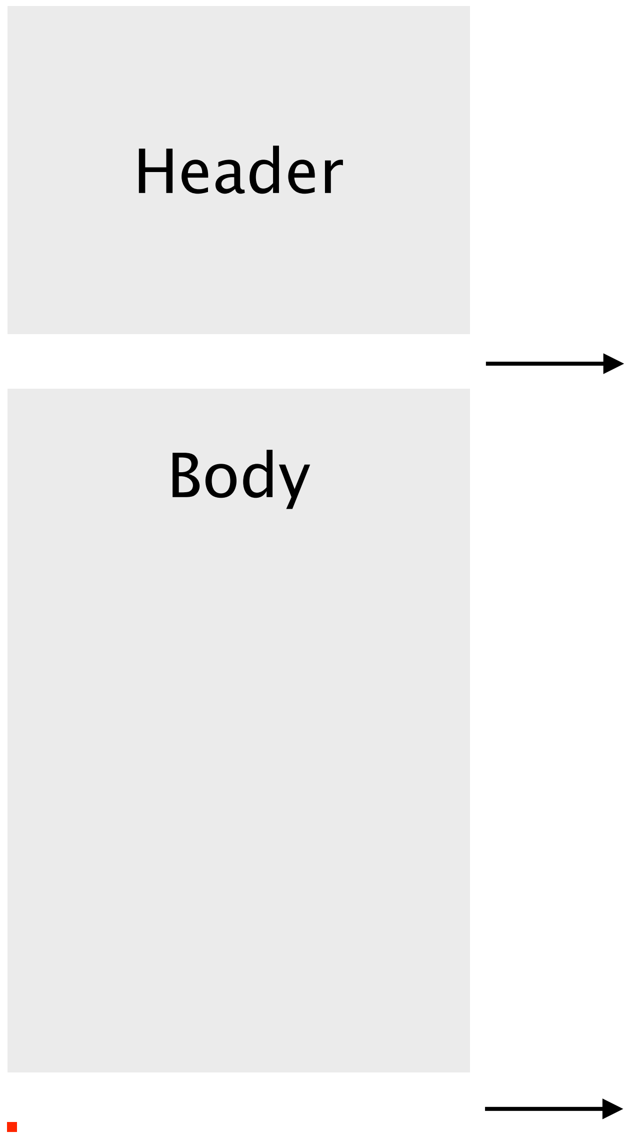
Best,
Laurent



Header

Body

A blank line separates the header from the body



Header

Body

.

A blank line separates the header from the body

A dot (".") on a new line ends the body

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 defines

- additional headers for the email body

  MIME-Version: the version of MIME being used

  Content-Type: the type of data contained in the message

  Content-Transfer-Encoding: how the data is encoded

MIME defines

- additional headers for the email body
- a set of content types and subtypes

  e.g. image with subtypes gif or jpeg

  text with subtypes plain, html, and rich text

  application with subtypes postscript or msword

  multipart with subtypes mixed or alternative

The two most common types/subtypes for MIME are: *multipart/mixed* and *multipart/alternative*

Content-Type	indicates that the message contains
multipart/mixed	multiple independent parts e.g. plain text *and* a binary file
multipart/alternative	multiple representation of the same content e.g. plain text *and* HTML

What kind of delimiter do we use?

multipart/mixed

multiple independent parts

multipart/alternative

multiple representation of the same content

Content-Type contains a parameter that specifies a string delimiter (chosen randomly by the client)

ensuring that the delimiter
does *not* appear in the email itself

```
From: Laurent Vanbever <lvanbever@ethz.ch>
To: Tobias Buehler <buehlert@ethz.ch>
Subject: [comm-net] Final exam
MIME-Version: 1.0
Content-Type: multipart/related;
boundary="_004_cc163051808f425a9b67b778666b785eeeethzch_";
   type="multipart/alternative"

--_004_cc163051808f425a9b67b778666b785eeeethzch_
Content-Type: multipart/alternative;
   boundary="_000_cc163051808f425a9b67b778666b785eeeethzch_"

--_000_cc163051808f425a9b67b778666b785eeeethzch_
Content-Type: text/plain; charset=us-ascii
Content-Transfer-Encoding: 7bit

Let's start the exam with ...

--_000_cc163051808f425a9b67b778666b785eeeethzch_
Content-Type: text/html; charset="utf-8"
Content-Transfer-Encoding: base64

PGh0bWwgeG1sbnM6dj0idX ...
```

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, +, /

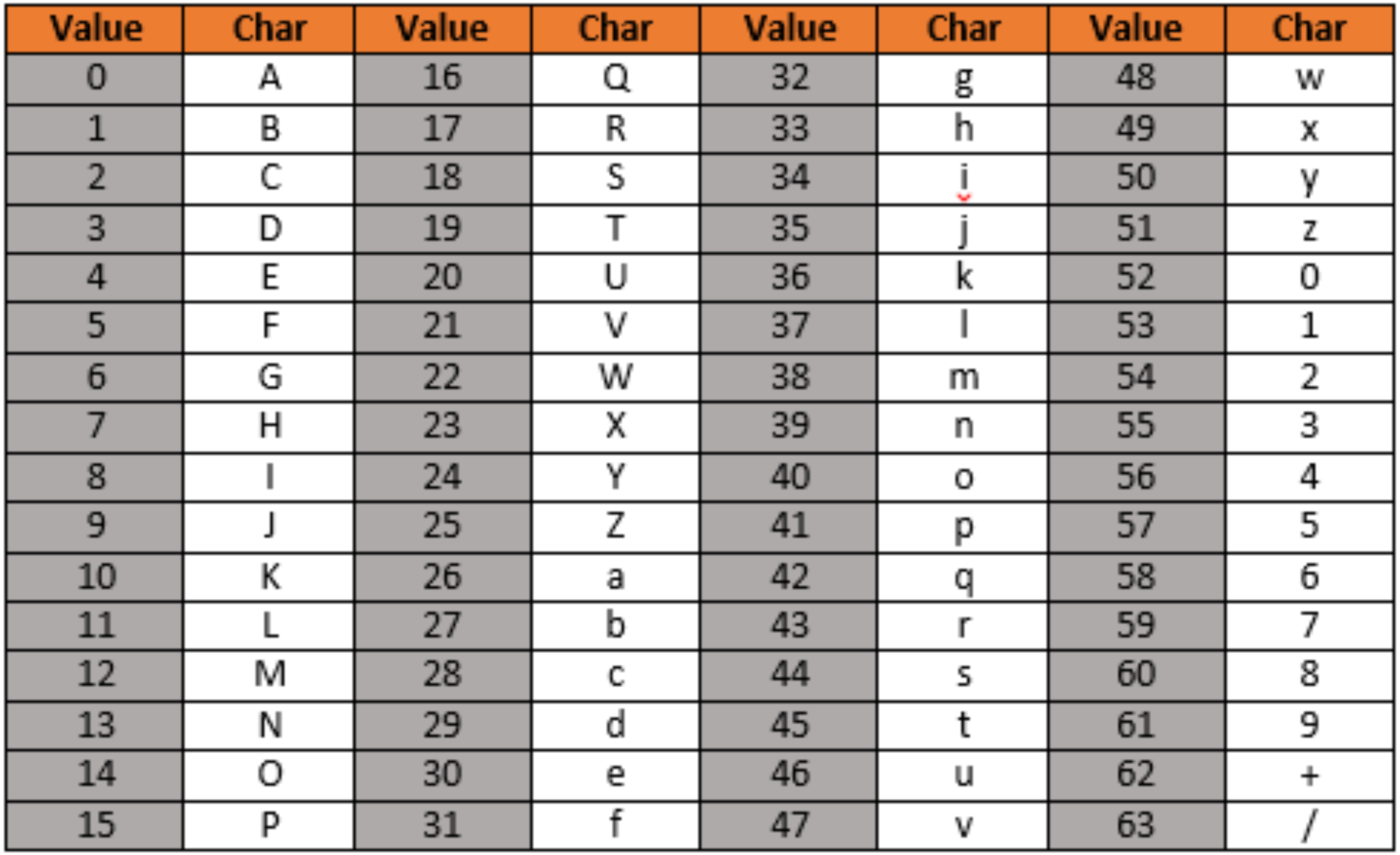
Divides the bytes to be encoded into sequences of 3 bytes

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

Binary input	0x14fb9c03d97e
8-bits	00010100 11111011 10011100 00000011 11011001 01111110
6-bits	000101 001111 101110 011100 000000 111101 100101 111110
Decimal	5 15 46 28 0 61 37 62
base64	F P u c A 9 l +

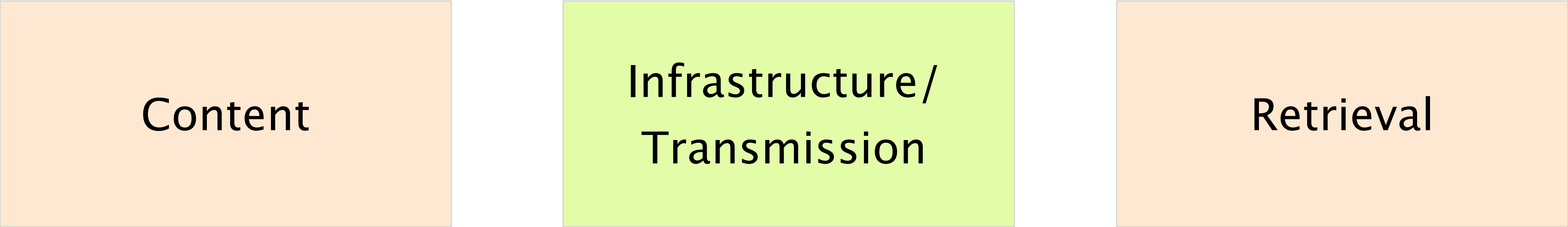


Value	Char	Value	Char	Value	Char	Value	Char
0	A	16	Q	32	g	48	w
1	B	17	R	33	h	49	x
2	C	18	S	34	i	50	y
3	D	19	T	35	j	51	z
4	E	20	U	36	k	52	0
5	F	21	V	37	l	53	1
6	G	22	W	38	m	54	2
7	H	23	X	39	n	55	3
8	I	24	Y	40	o	56	4
9	J	25	Z	41	p	57	5
10	K	26	a	42	q	58	6
11	L	27	b	43	r	59	7
12	M	28	c	44	s	60	8
13	N	29	d	45	t	61	9
14	O	30	e	46	u	62	+
15	P	31	f	47	v	63	/

If the length of the input is not a multiple of three, Base64 uses "=" as padding character

Binary input	0x14
8-bits	00010100
6-bits	000101 000000
Decimal	5 0
base64	F A = =

```
From: Laurent Vanbever <lvanbever@ethz.ch>
To: Tobias Buehler <buehlert@ethz.ch>
Subject: [comm-net] Final exam
MIME-Version: 1.0
Content-Transfer-Encoding: base64
Content-Type: multipart/mixed;
        boundary="123boundary"

This is a multipart message in MIME format.

--123boundary
Content-Type: text/plain

Hi Tobias, Please find the exam enclosed. Laurent

--123boundary
Content-Type: application/pdf;
Content-Disposition: attachment;
        filename="exam_2020.pdf"

base64 encoded data .....
.........................
......base64 encoded data
```



Content

Infrastructure/ Transmission

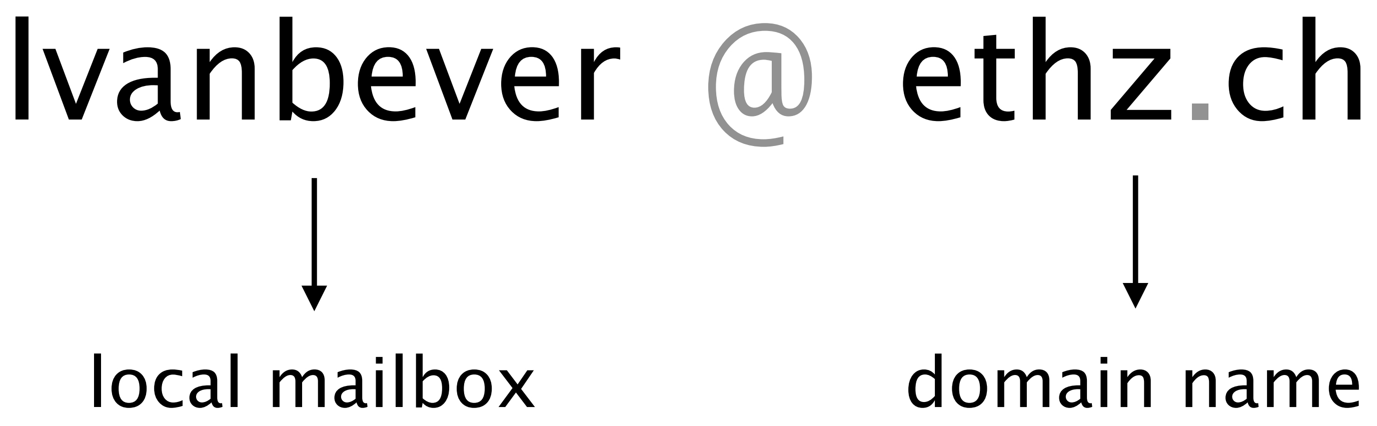
Retrieval

SMTP: Simple Mail Transfer Protocol

Infrastructure

mail servers

An e-mail address is composed of two parts identifying the local mailbox and the domain



lvanbever @ ethz.ch

local mailbox

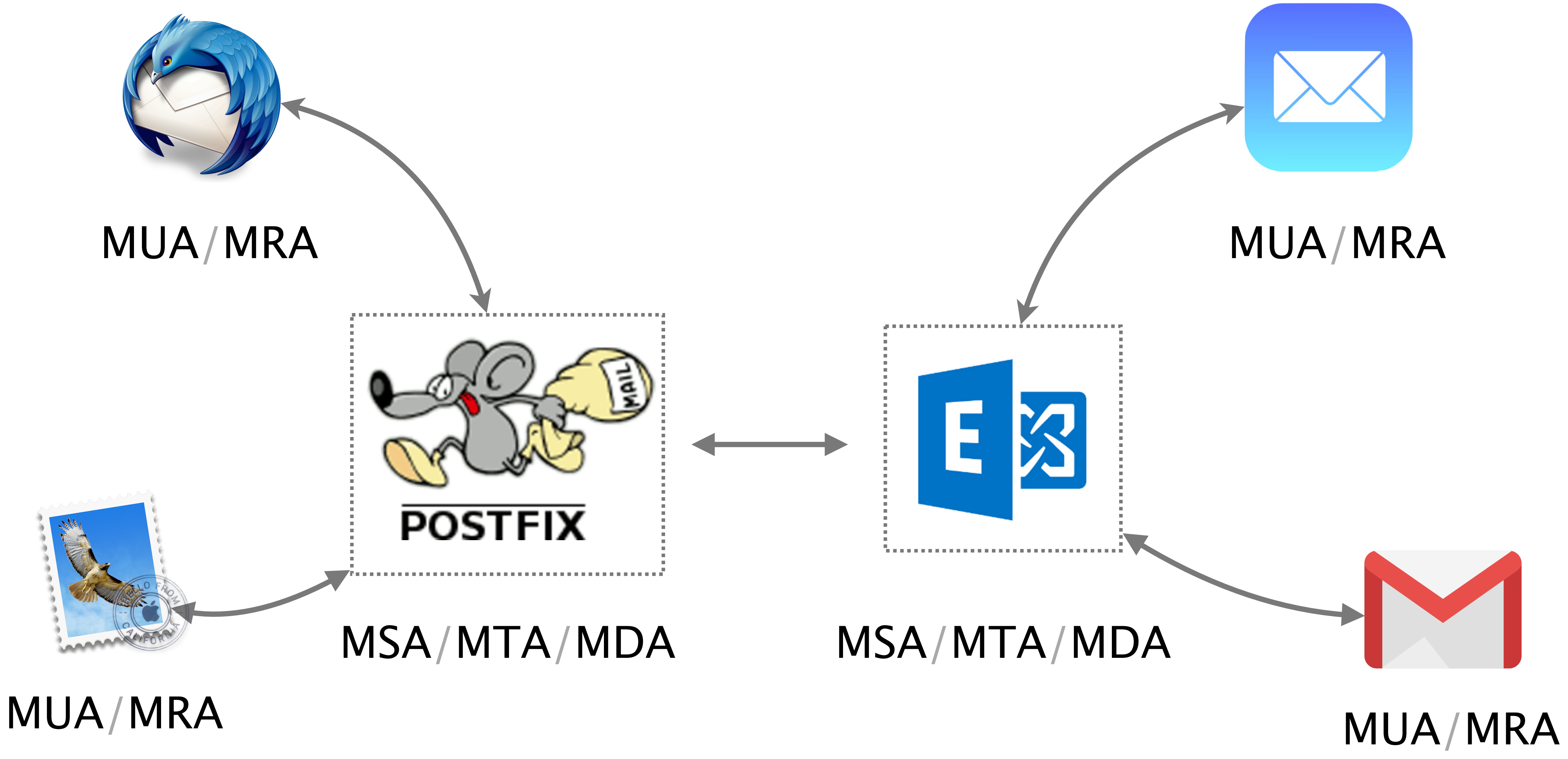
domain name

actual mail server is identified using
a DNS query asking for MX records

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



MUA/MRA

MUA/MRA

MSA/MTA/MDA

MSA/MTA/MDA

MUA/MRA

MUA/MRA

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)

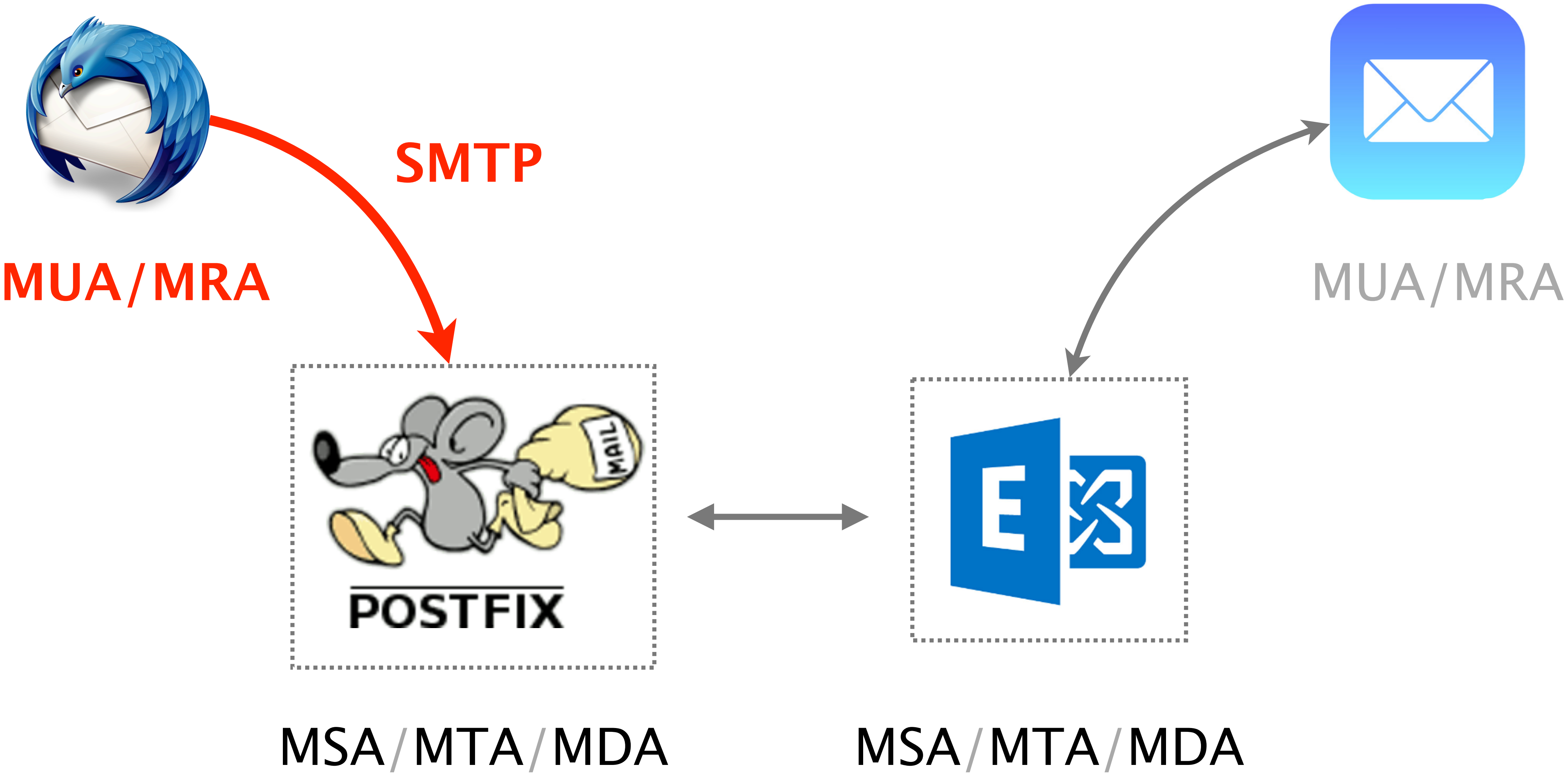
SMTP is a push-based protocol

sender pushes the file to the receiving server

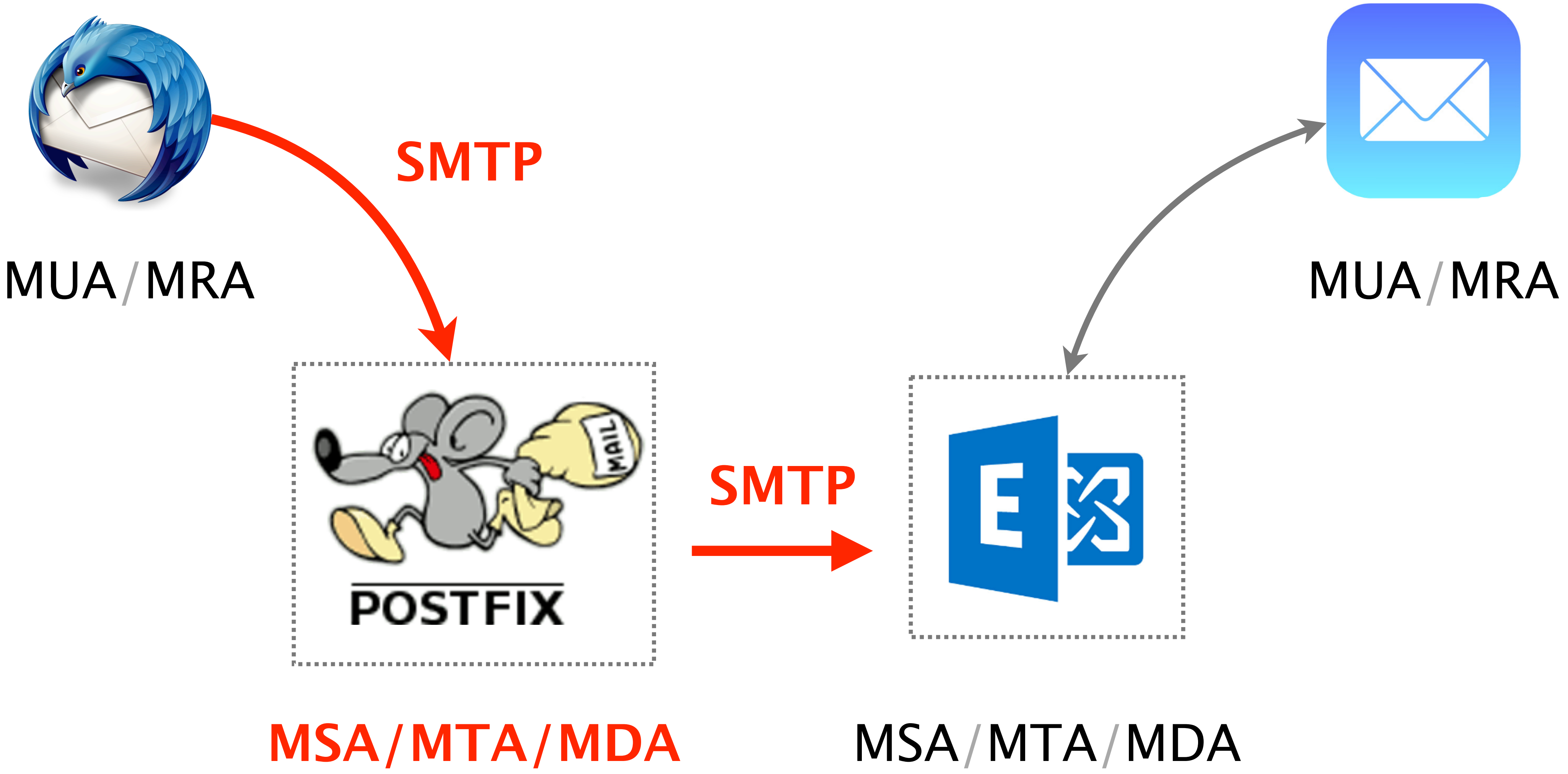
	SMTP 3 digit response code			comment
Status	2XX	success	220	Service ready
			250	Requested mail action completed
	3XX	input needed	354	Start mail input
	4XX	transient error	421	Service not available
			450	Mailbox unavailable
			452	Insufficient space
	5XX	permanent error	500	Syntax error
			502	Unknown command
			503	Bad sequence

```
server —— 220 hamburger.edu
          EHLO crepes.fr
          250  Hello crepes.fr, pleased to meet you
client —— MAIL FROM: <alice@crepes.fr>
          250 alice@crepes.fr... Sender ok
          RCPT TO: <bob@hamburger.edu>
          250 bob@hamburger.edu ... Recipient ok
          DATA
          354 Enter mail, end with "." on a line by
          itself
          Do you like ketchup?
          How about pickles?
          .
          250 Message accepted for delivery
          QUIT
          221 hamburger.edu closing connection
```

The sender MUA uses SMTP to transmit the e-mail to a local MTA (e.g. mail.ethz.ch, gmail.com, hotmail.com)



The local MTA then looks up the MTA of the recipient domain (DNS MX) and transmits the e-mail further



SMTP

MUA/MRA

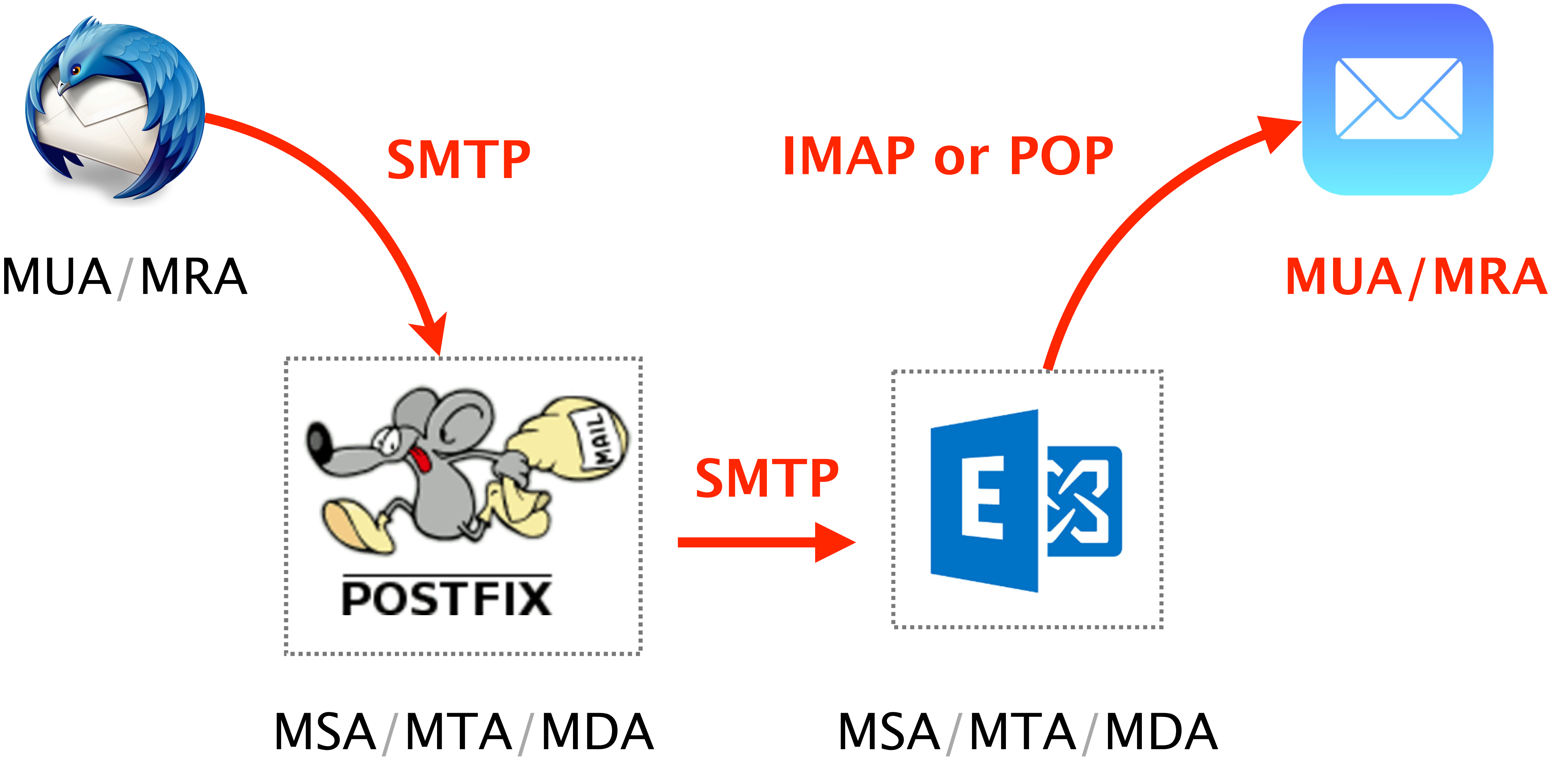
MUA/MRA

SMTP

MSA/MTA/MDA

MSA/MTA/MDA

Once the e-mail is stored at the recipient domain, IMAP or POP is used to retrieve it by the recipient MUA



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

sending and receiving sides

Each SMTP server/MTA hop adds its identity to
the e-mail header by prepending a "Received" entry

```
8   Received: from edge20.ethz.ch (82.130.99.26) by CAS10.d.ethz.ch
     (172.31.38.210) with Microsoft SMTP Server (TLS) id 14.3.361.1; Fri, 23 Feb
     2018 01:48:56 +0100
7   Received: from phil4.ethz.ch (129.132.183.133) by edge20.ethz.ch
     (82.130.99.26) with Microsoft SMTP Server id 14.3.361.1; Fri, 23 Feb 2018
     01:48:57 +0100
6   Received: from outprodmail02.cc.columbia.edu ([128.59.72.51])   by phil4.ethz.ch
     with esmtps (TLSv1:AES256-SHA:256)     (Exim 4.69)    (envelope-from
     <ethan@ee.columbia.edu>)      id 1ep1Xg-0002s3-FH  for lvanbever@ethz.ch; Fri, 23
     Feb 2018 01:48:55 +0100
5   Received: from hazelnut (hazelnut.cc.columbia.edu [128.59.213.250])  by
     outprodmail02.cc.columbia.edu (8.14.4/8.14.4) with ESMTP id w1N0iAu4026008
         for <lvanbever@ethz.ch>; Thu, 22 Feb 2018 19:48:51 -0500
4   Received: from hazelnut (localhost.localdomain [127.0.0.1])   by hazelnut
     (Postfix) with ESMTP id 421126D      for <lvanbever@ethz.ch>; Thu, 22 Feb 2018
     19:48:52 -0500 (EST)
3   Received: from sendprodmail01.cc.columbia.edu (sendprodmail01.cc.columbia.edu
     [128.59.72.13])    by hazelnut (Postfix) with ESMTP id 211526D    for
     <lvanbever@ethz.ch>; Thu, 22 Feb 2018 19:48:52 -0500 (EST)
2   Received: from mail-pl0-f43.google.com (mail-pl0-f43.google.com
     [209.85.160.43])  (user=ebk2141 mech=PLAIN bits=0)  by
     sendprodmail01.cc.columbia.edu (8.14.4/8.14.4) with ESMTP id w1N0mnlx052337
         (version=TLSv1/SSLv3 cipher=AES128-GCM-SHA256 bits=128 verify=NOT)      for
     <lvanbever@ethz.ch>; Thu, 22 Feb 2018 19:48:50 -0500
1   Received: by mail-pl0-f43.google.com with SMTP id u13so3927207plq.1       for
     <lvanbever@ethz.ch>; Thu, 22 Feb 2018 16:48:50 -0800 (PST)
```

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

Try it out yourself!

SMTP-MTA

```
telnet server_name 25
```

plaintext (!),
hard to find

SMTP-MSA

```
openssl s_client -starttls smtp
   -connect mail.ethz.ch:587
   -crlf -ign_eof (*)
```

rely on TLS
encryption

authentication
required

```
perl -MMIME::Base64 -e 'print encode_base64("username");'
perl -MMIME::Base64 -e 'print encode_base64("password");'
```

(*) https://www.ndchost.com/wiki/mail/test-smtp-auth-telnet

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

And, as usual, multiple countermeasures have been proposed with various level of deployment success

Example*

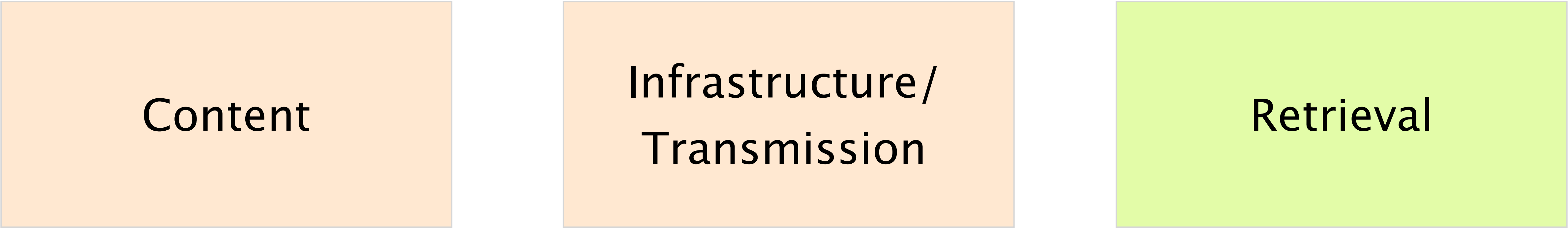
Sender Policy Framework (SPF)

Enables a domain to explicitly authorize
a set of hosts that are allowed to send emails
using their domain names in "MAIL FROM".

How? using a DNS TXT resource record

look for "v=spf1" in the results of "dig TXT google.com"

* if you are interested, also check out Sender ID, DKIM, and DMARC



Content

Infrastructure/ Transmission

Retrieval

POP: Post Office Protocol

IMAP: Internet Message Access Protocol

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…

Example

POP server

client

```
+OK POP3 server ready
user bob
+OK
pass hungry
+OK user successfully logged on

list
1 498
2 912
.
retr 1
<message 1 contents>
.
dele 1
retr 2
<message 1 contents>
.
dele 2
quit
+OK POP3 server signing off
```

Authorization phase

Clients declares username
password

Server answers +OK/-ERR

```
+OK POP3 server ready
user bob
+OK
pass hungry
+OK user successfully logged on

list
1 498
2 912
.
retr 1
<message 1 contents>
.
dele 1
retr 2
<message 1 contents>
.
dele 2
quit
+OK POP3 server signing off
```

Transaction phase

`list`	get message numbers
`retr`	retrieve message X
`dele`	delete message X
`quit`	exit session

```
+OK POP3 server ready
user bob
+OK
pass hungry
+OK user successfully logged on

list
1 498
2 912
.
retr 1
<message 1 contents>
.
dele 1
retr 2
<message 1 contents>
.
dele 2
quit
+OK POP3 server signing off
```

POP is heavily limited. Among others, it does not go well with multiple clients or always-on connectivity

Cannot deal with multiple mailboxes

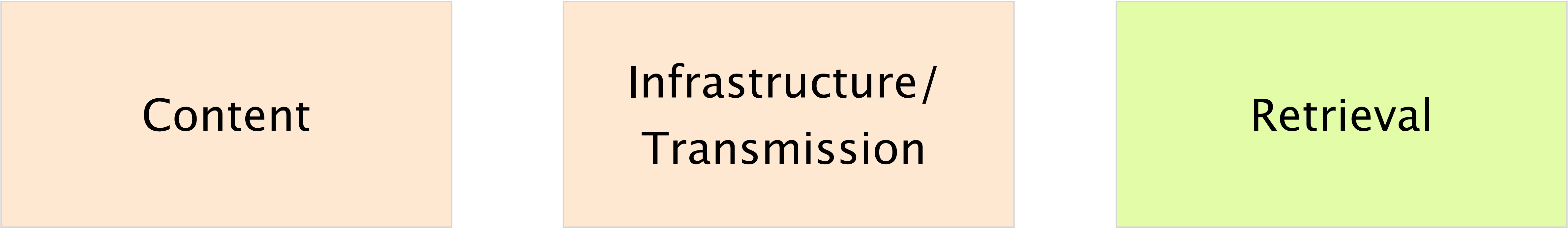
designed to put incoming emails in one folder

Not designed to keep messages on the server

designed to download messages to the client

Poor handling of multiple-client access

while many (most?) users have now multiple devices



Content

Infrastructure/
Transmission

Retrieval

POP: Post Office Protocol

IMAP: Internet Message
Access Protocol

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)

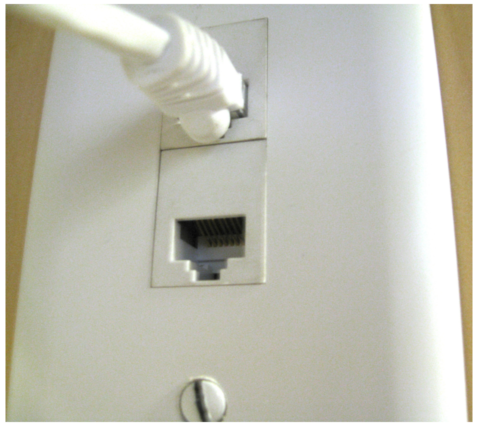
Communication Networks

So what?!

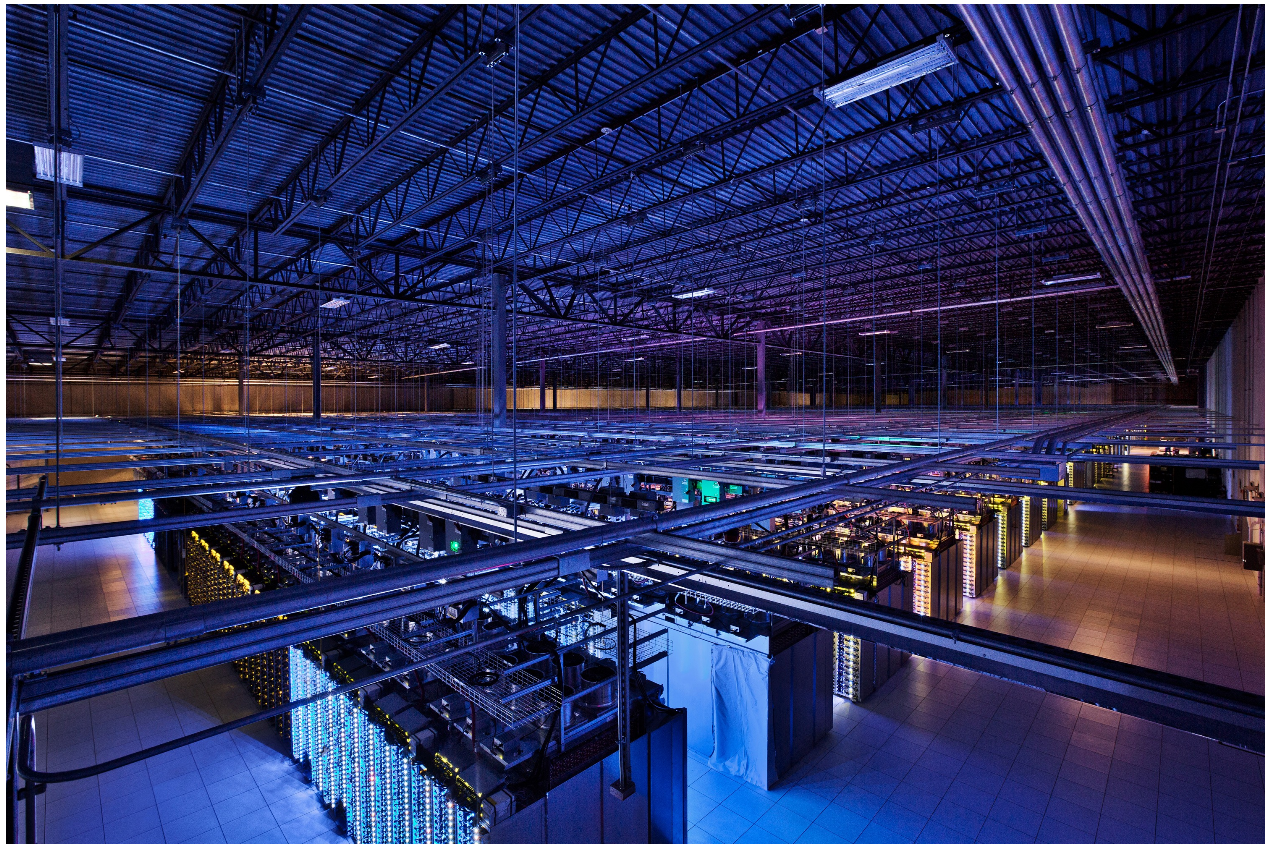
Google | google.com/datacenters

Knowledge

Understand how the Internet works and why



from your
network plug…



…to the largest data-centers out there

List any

technologies, principles, applications…

used after typing in:

> www.google.ch

and pressing enter in your browser

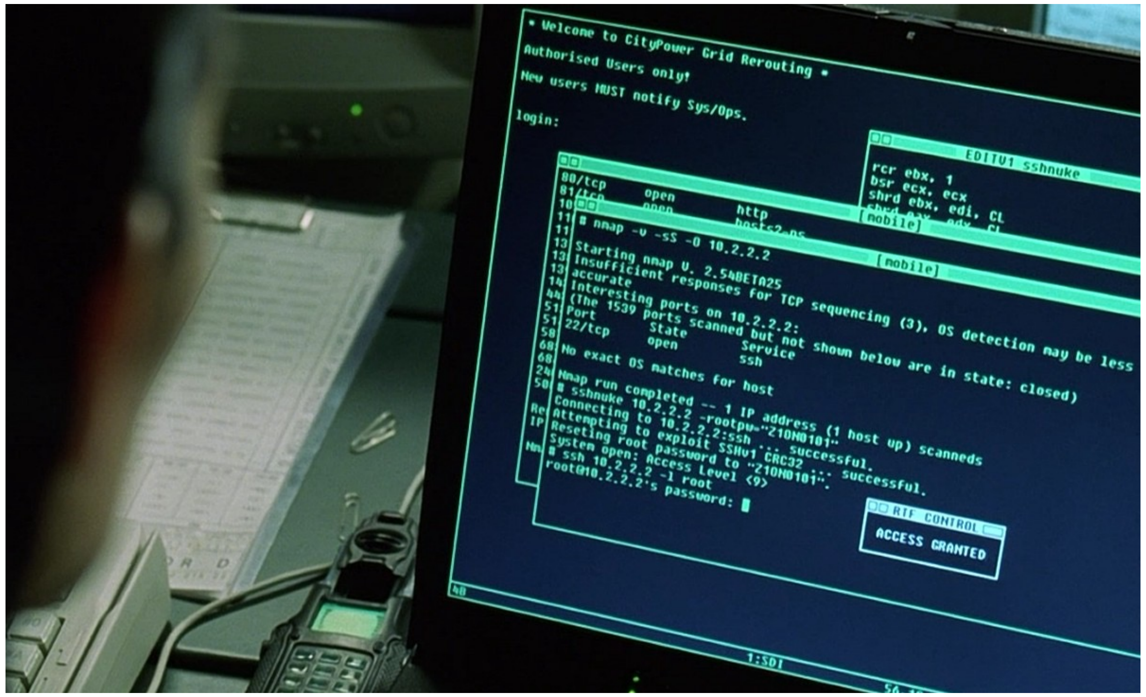
Insight

Key concepts and problems in Networking

Naming Layering Routing Reliability Sharing

Skill

Build, operate and configure networks



```
* Welcome to CityPower Grid Rerouting *
Authorised Users only!
New users MUST notify Sys/Ops.

login:
```

```
80/tcp
81/tcp     open          http
```

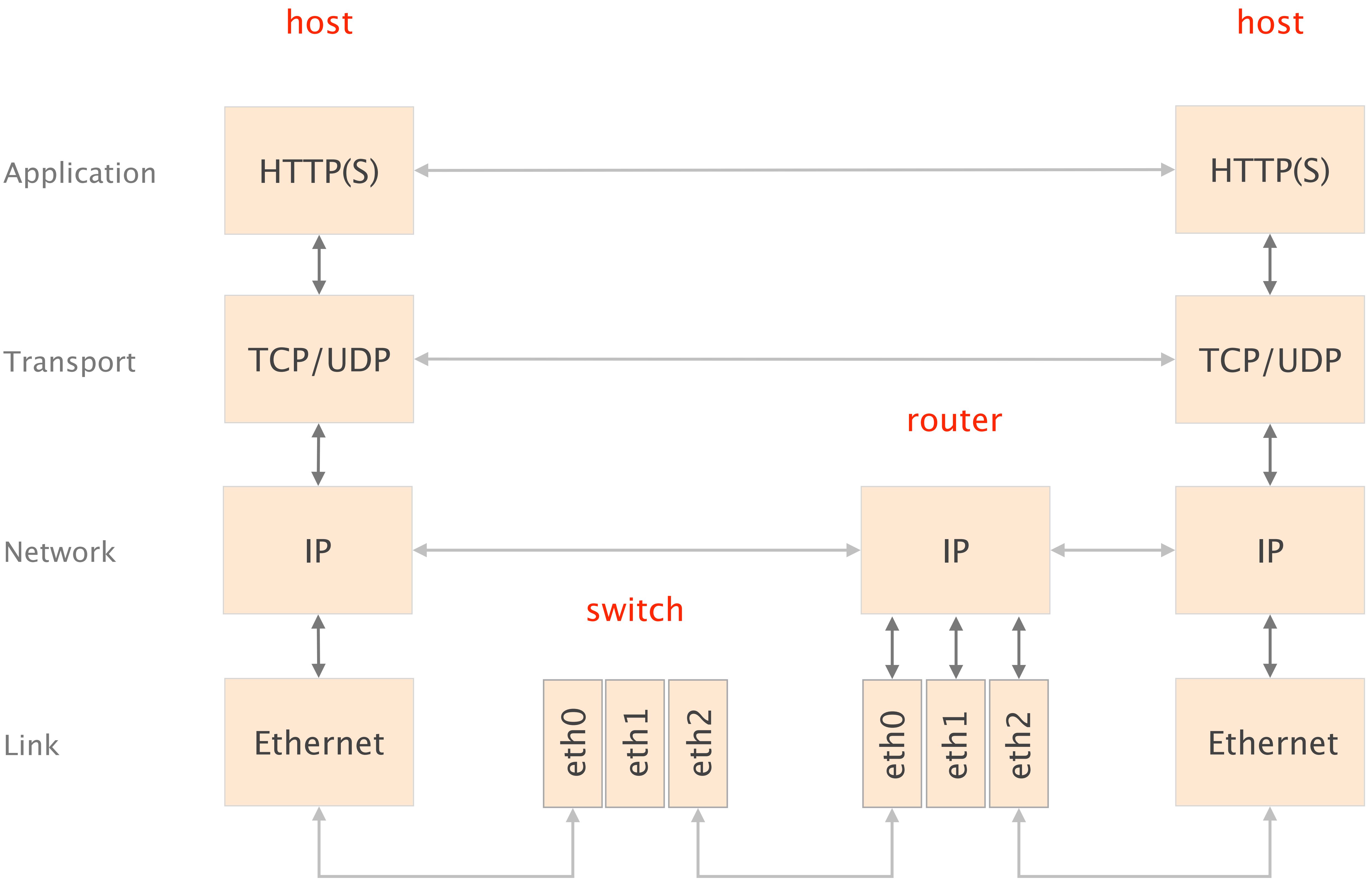
```
# nmap -v -sS -O 10.2.2.2
Starting nmap V. 2.54BETA25
Insufficient responses for TCP sequencing (3), OS detection may be less
accurate
Interesting ports on 10.2.2.2:
(The 1539 ports scanned but not shown below are in state: closed)
Port       State       Service
22/tcp     open        ssh
No exact OS matches for host
Nmap run completed -- 1 IP address (1 host up) scanneds
# sshnuke 10.2.2.2 -rootpw="Z1ON0101"
Connecting to 10.2.2.2:ssh ... successful.
Attempting to exploit SSHv1 CRC32 ... successful.
Reseting root password to "Z1ON0101".
System open: Access Level <9>
# ssh 10.2.2.2 -l root
root@10.2.2.2's password:
```

```
EDITV1 sshnuke
rcr ebx, 1
bsr ecx, ecx
shrd ebx, edi, CL
```

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

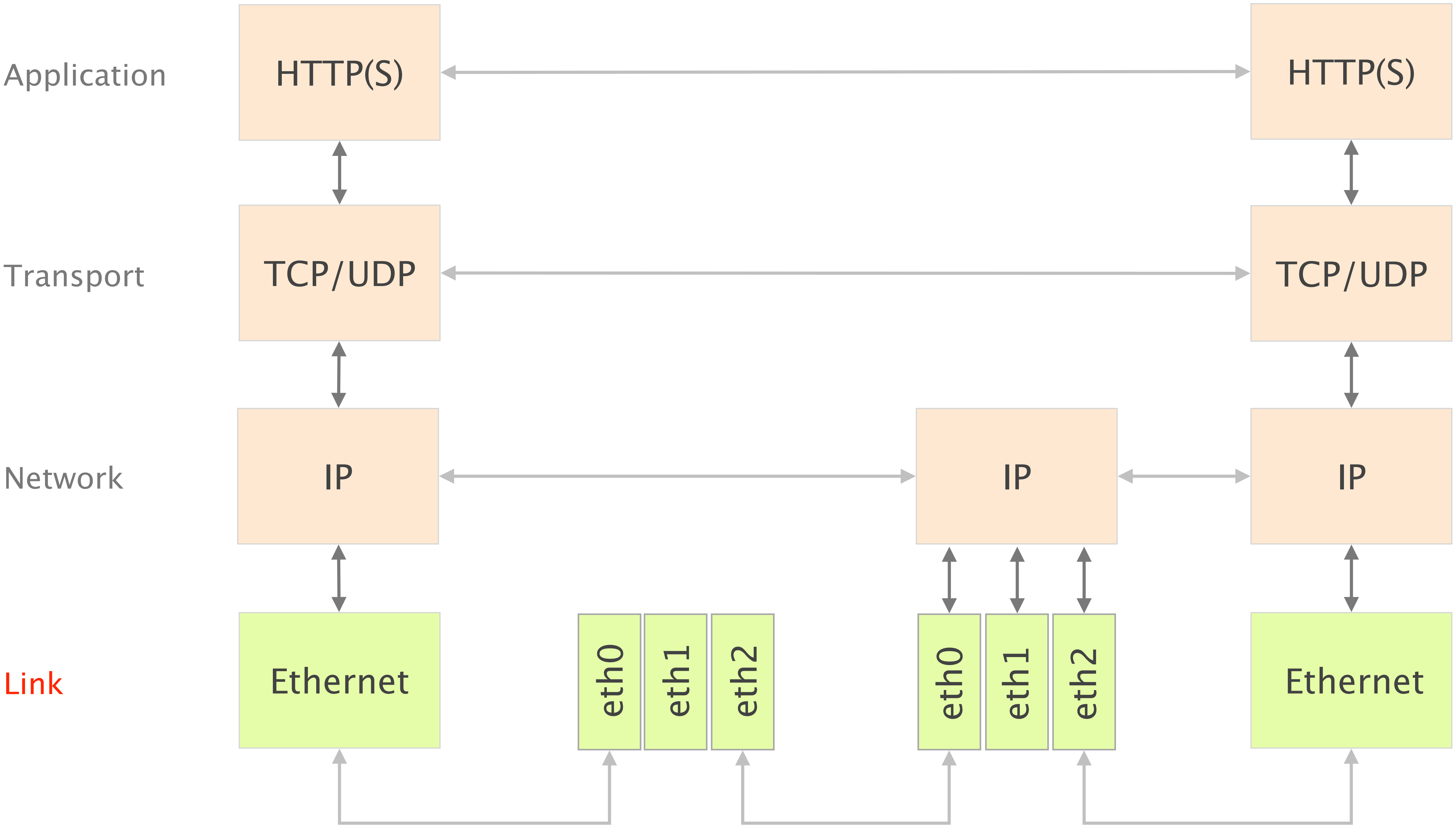
What tradeoffs do they achieve?

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?

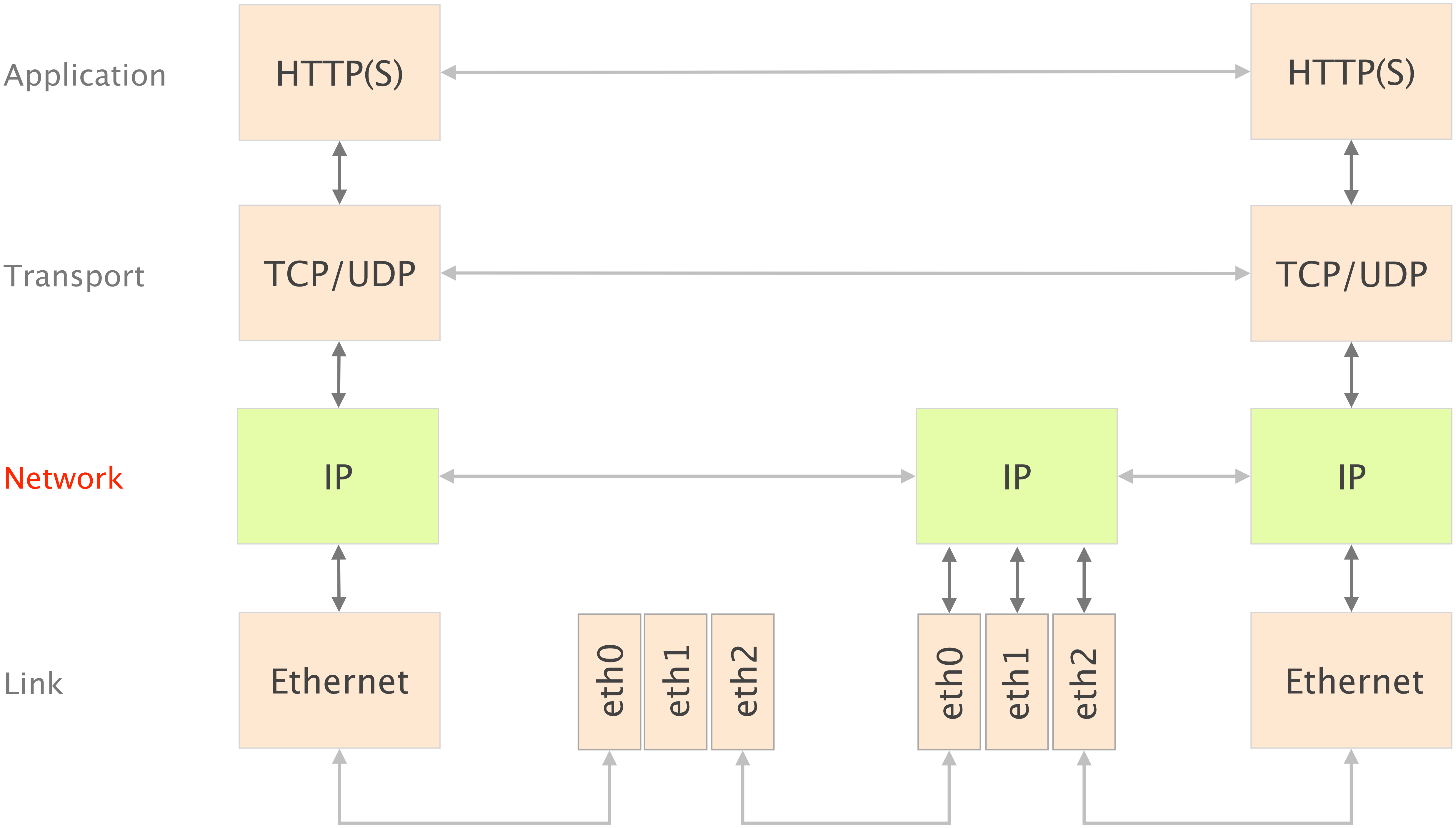
#2 How do we identify link adapters?

#3 How do we share a network medium?

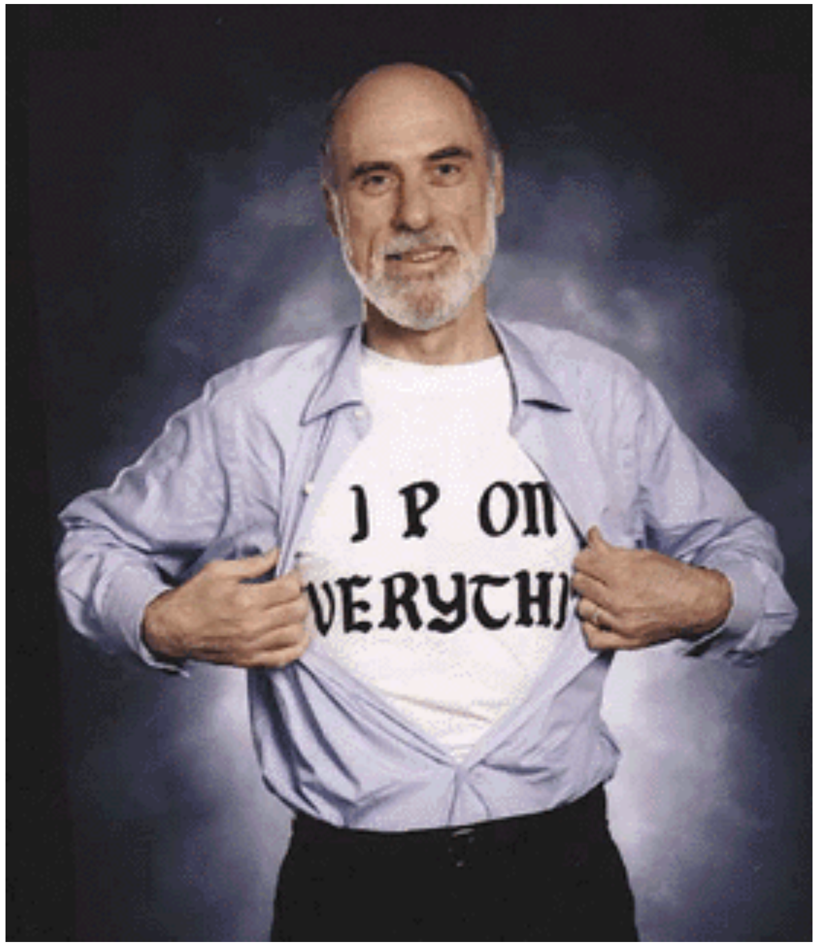
#4 What is Ethernet?

#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

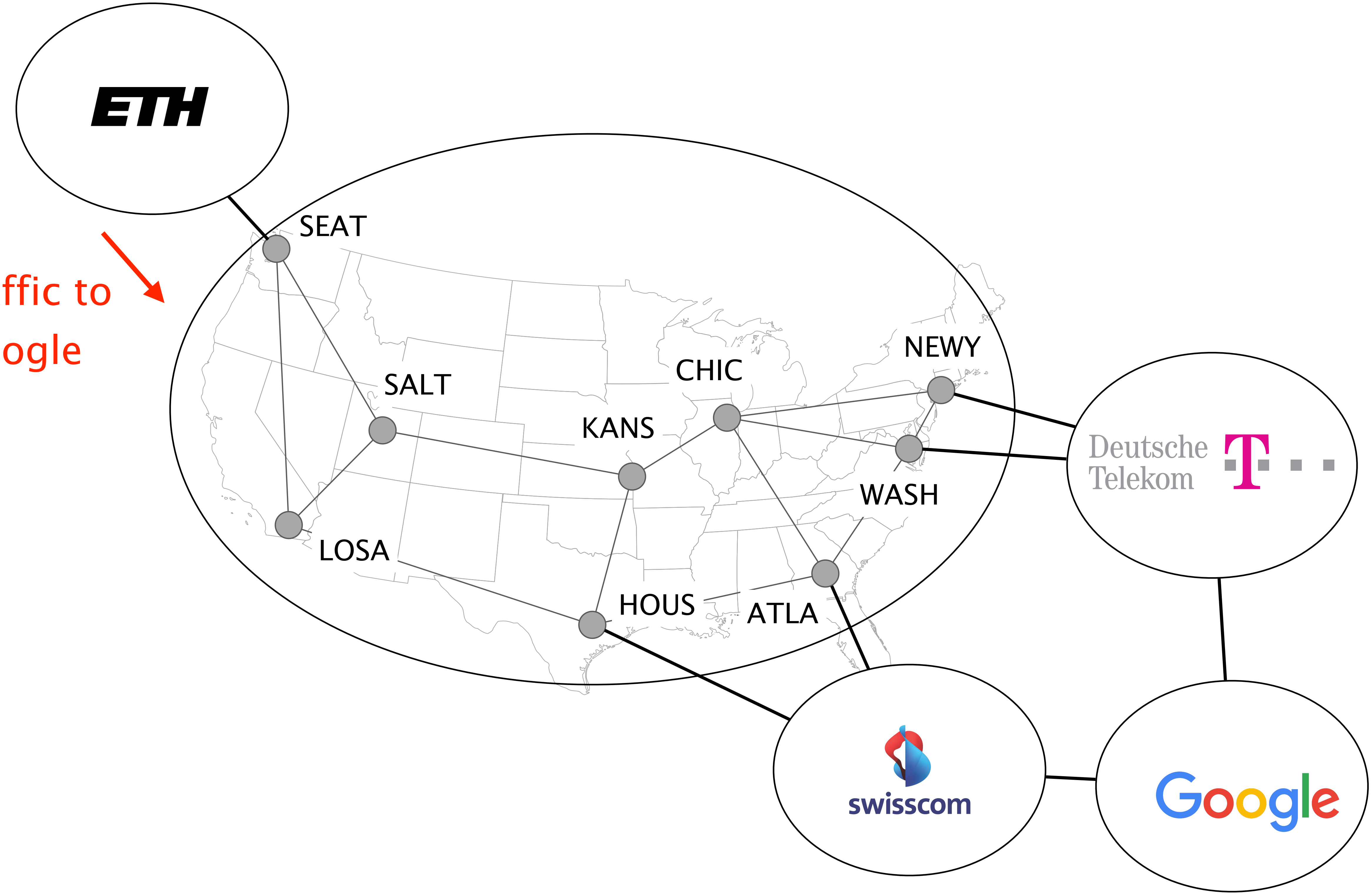
intra-domain routing

Find paths within a network

inter-domain
routing

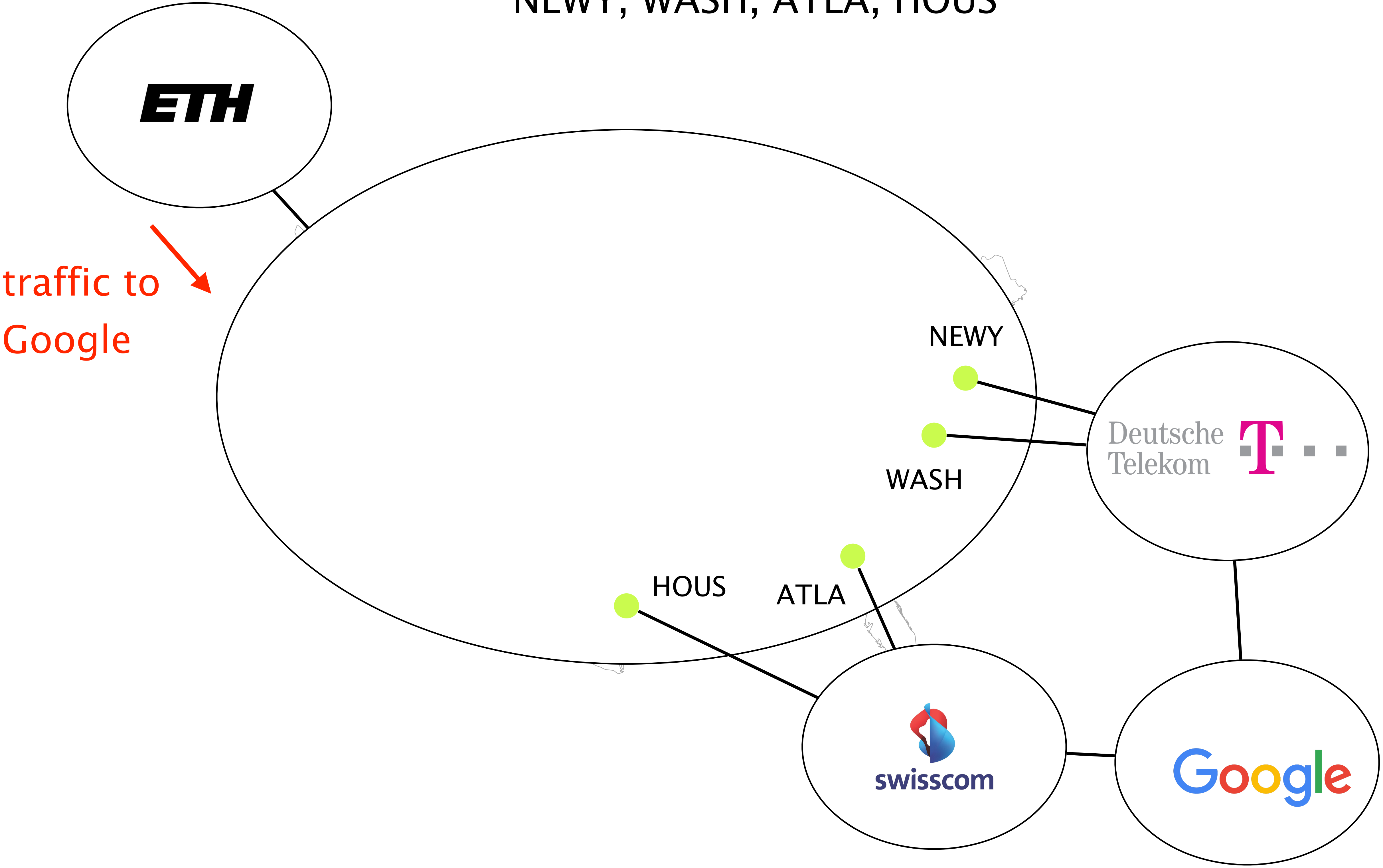
intra-domain
routing

Find paths between networks



traffic to Google

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



traffic to Google

ETH

NEWY

WASH

HOUS

ATLA

Deutsche Telekom

swisscom

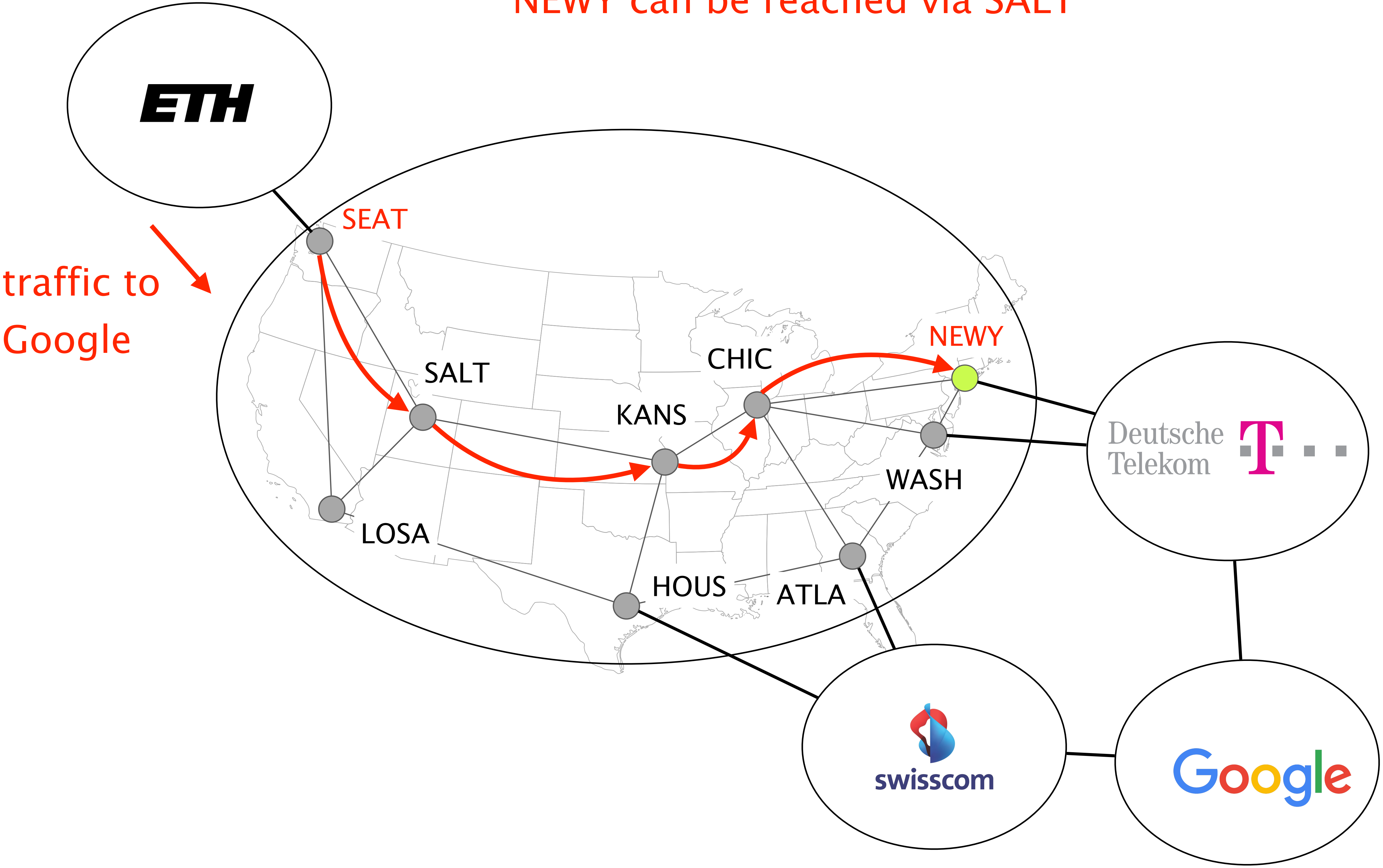
Google

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?

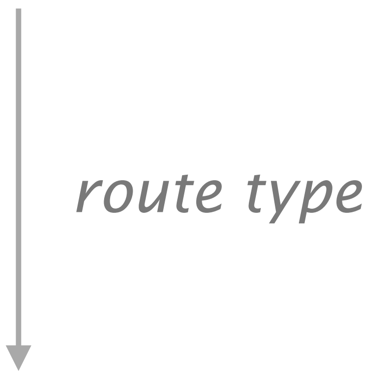
3 Problems

security, performance, …

Business relationships conditions
route selection

For a destination *p*, prefer routes coming from

- customers over
- peers over
- providers



Business relationships conditions

route exportation

		send to		
		customer	peer	provider
from	customer			
	peer			
	provider			

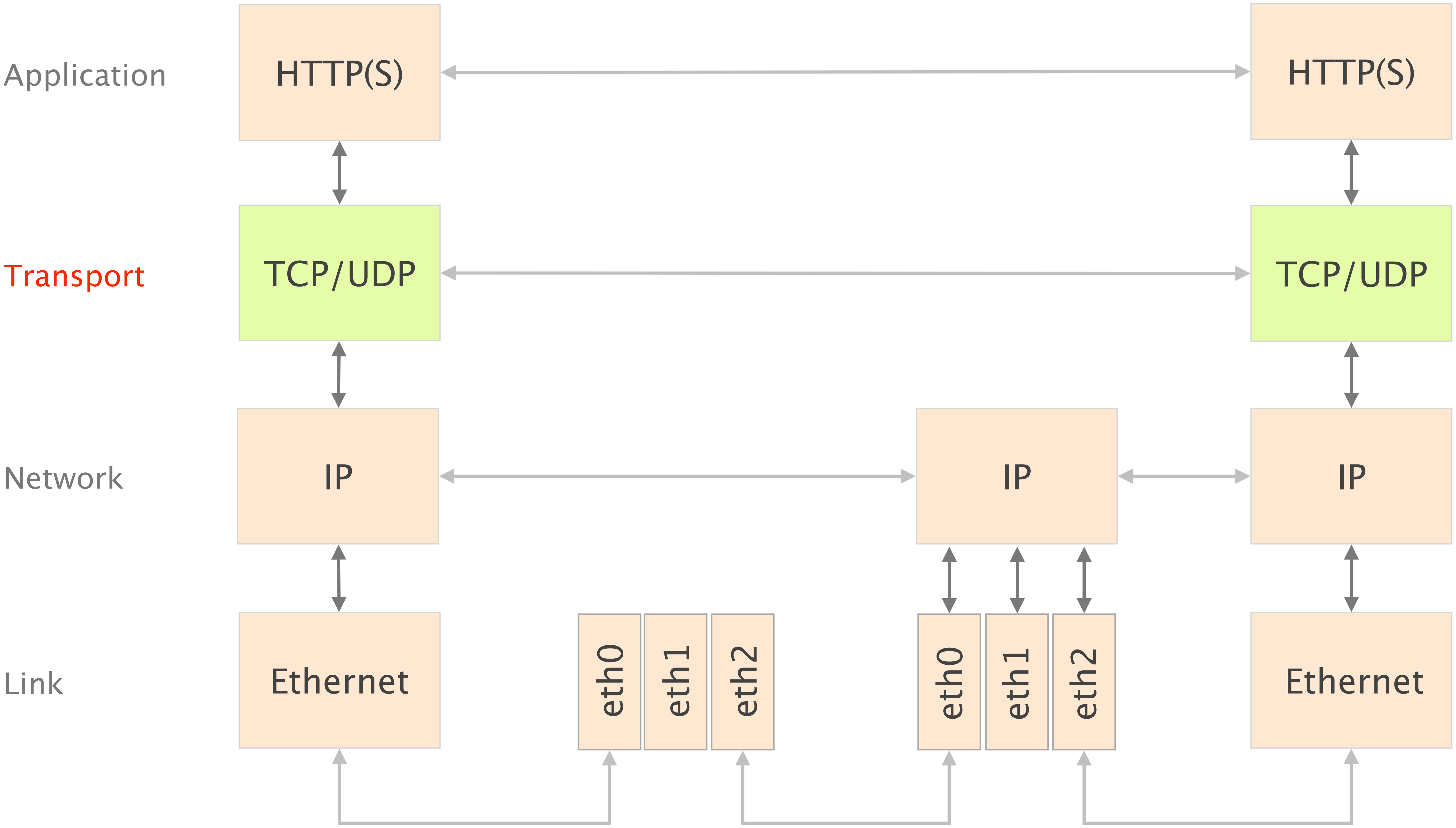
Routes coming from customers are propagated to everyone else

		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
eth0
eth1
eth2
eth0
eth1
eth2
Ethernet

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

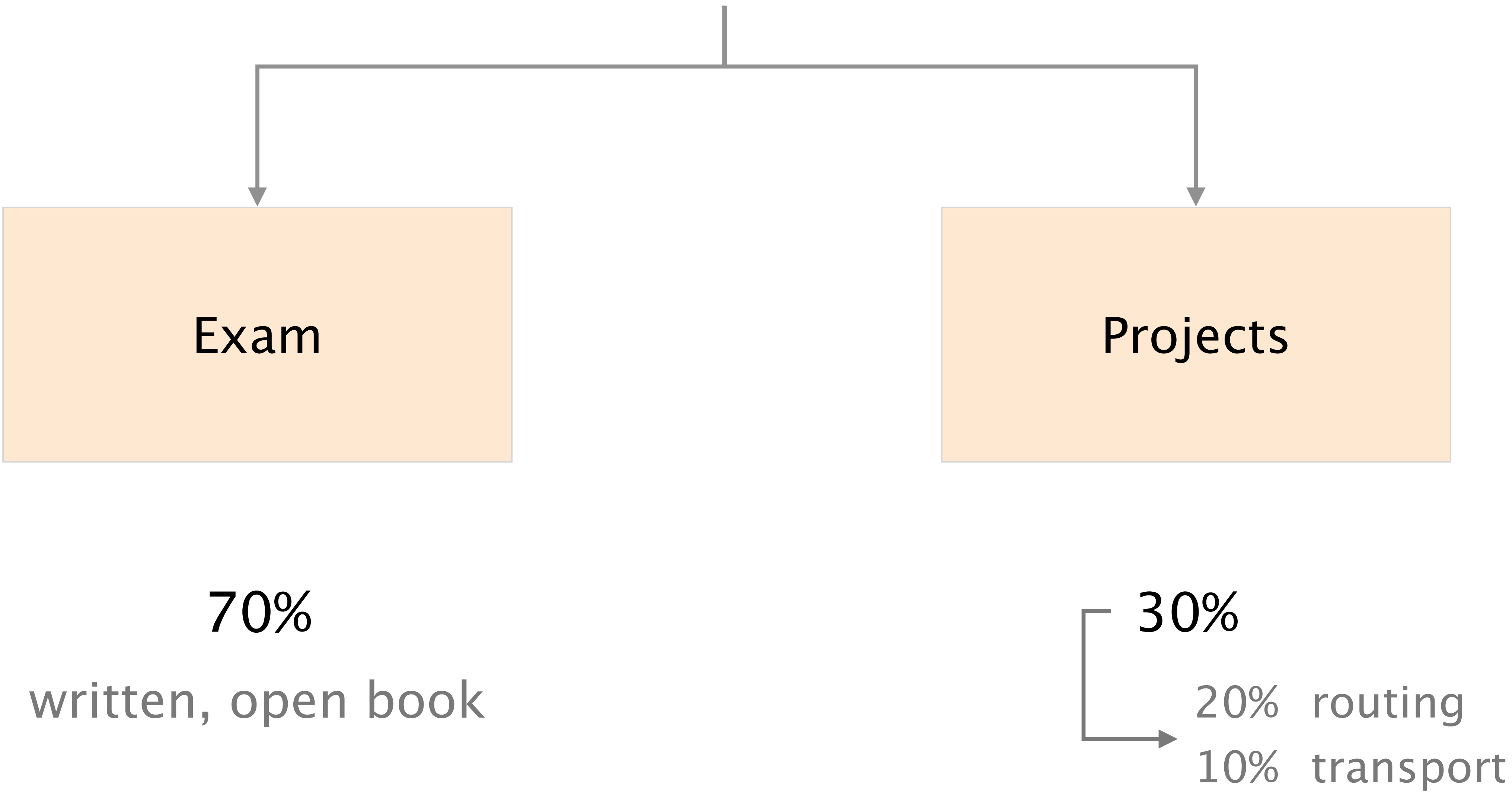
We then looked at
what’s running on top of all this …

DNS

Web

E-mail

Your final grade



Exam

70%

written, open book

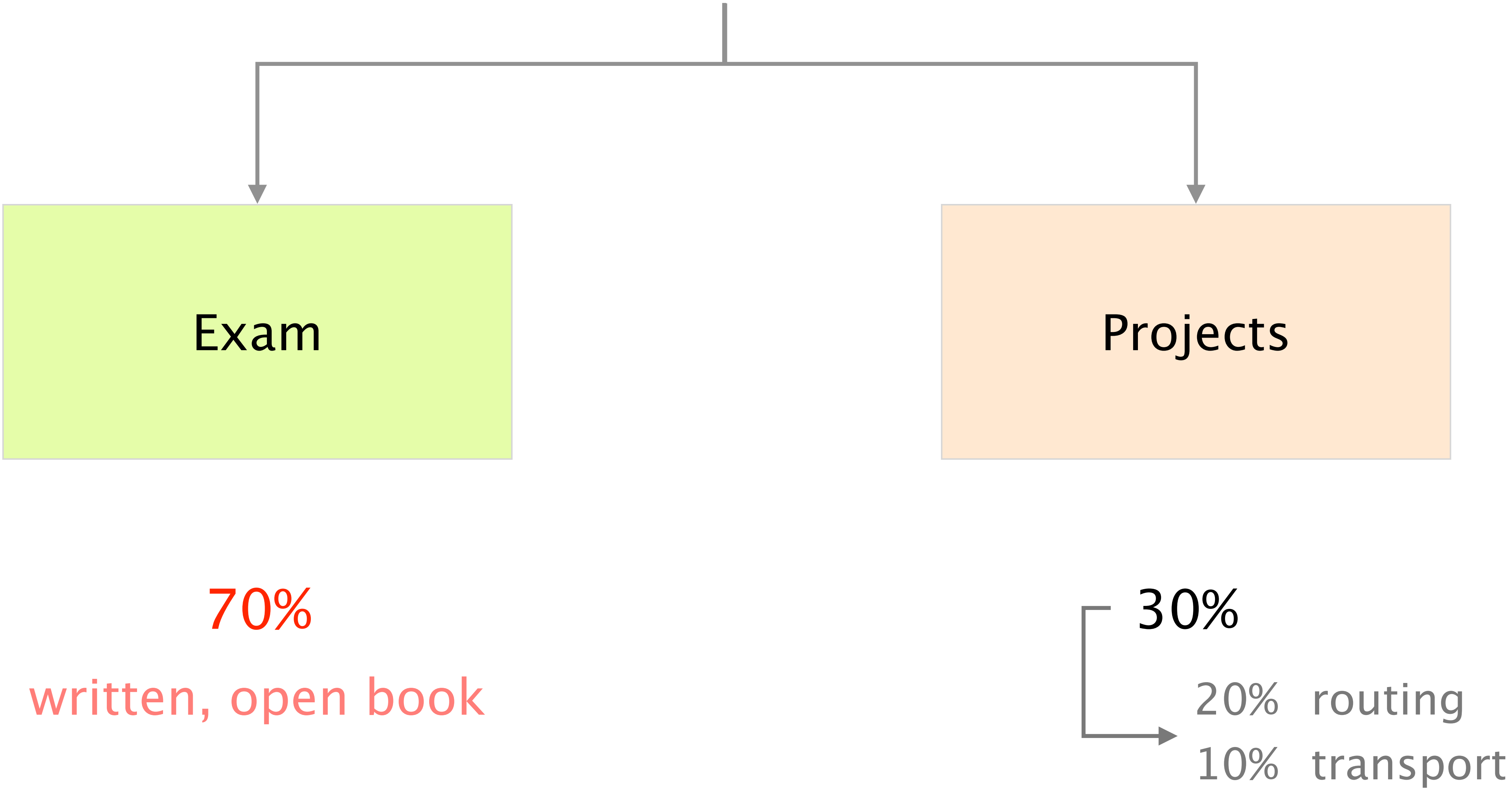
Projects

30%

20% routing

10% transport

Your final grade



Exam

Projects

70%

written, open book

30%

20% routing

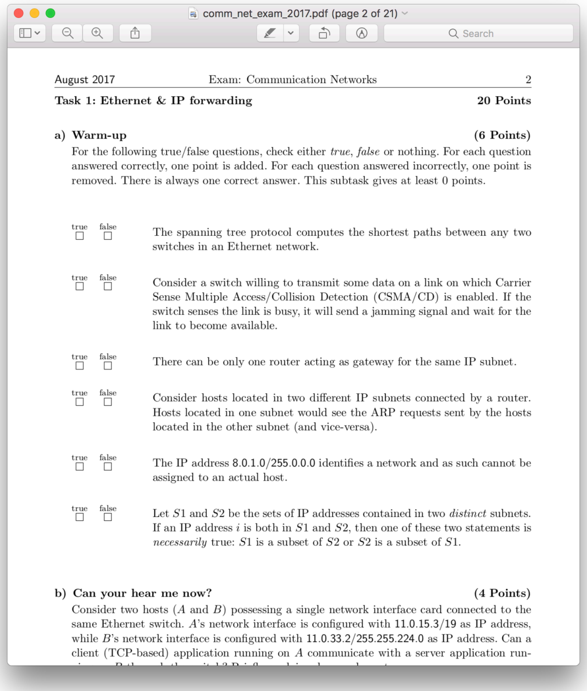
10% transport

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 2017



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).

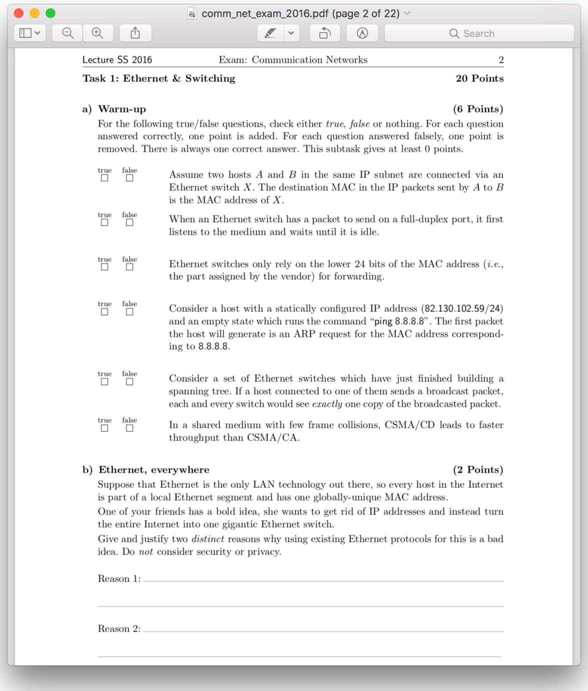
true □ false □ The IP address 8.0.1.0/255.0.0.0 identifies a network and as such cannot be assigned to an actual host.

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 2016



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.

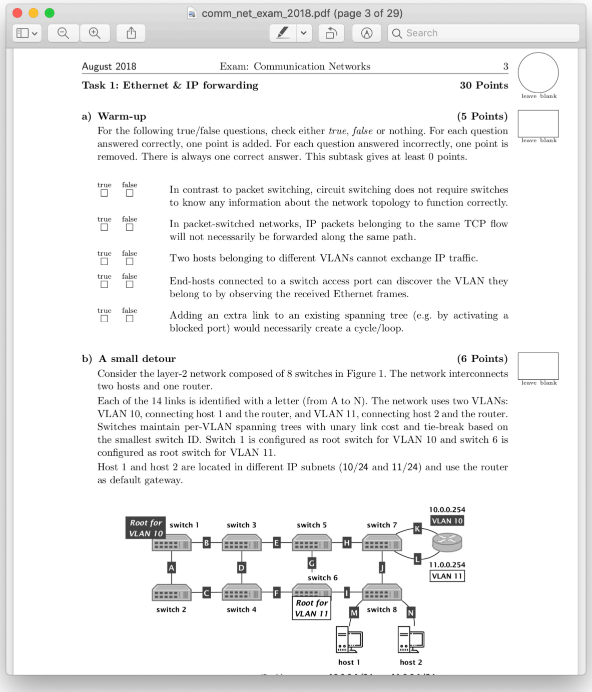
One of your friends has a bold idea, she wants to get rid of IP addresses and instead turn the entire Internet into one gigantic Ethernet switch.

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 2018



August 2018 Exam: Communication Networks 3

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

a) Warm-up **(5 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 □ 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.

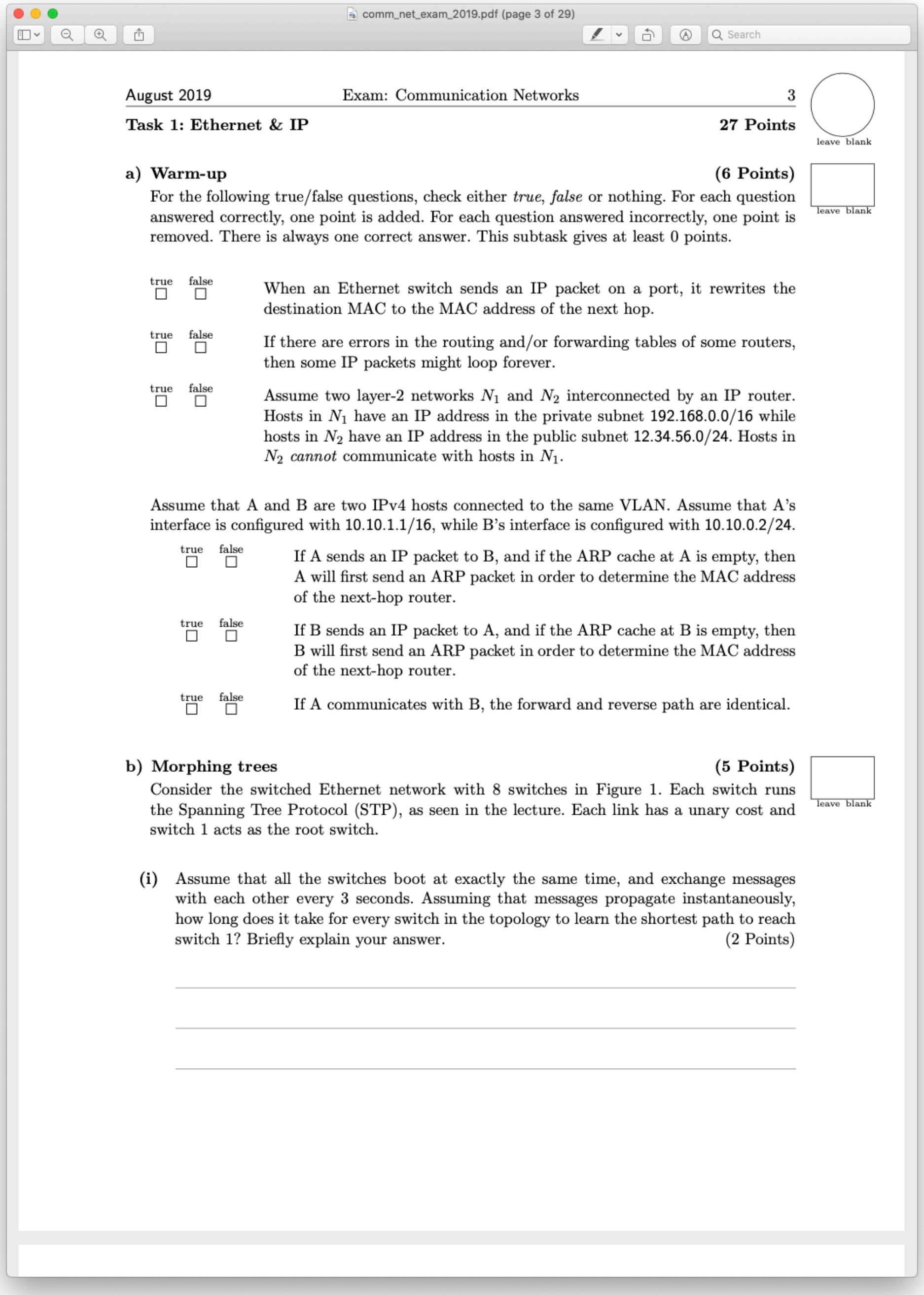
b) A small detour **(6 Points)**

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



August 2019 Exam: Communication Networks 3

Task 1: Ethernet & IP **27 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 □ 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)**

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*?

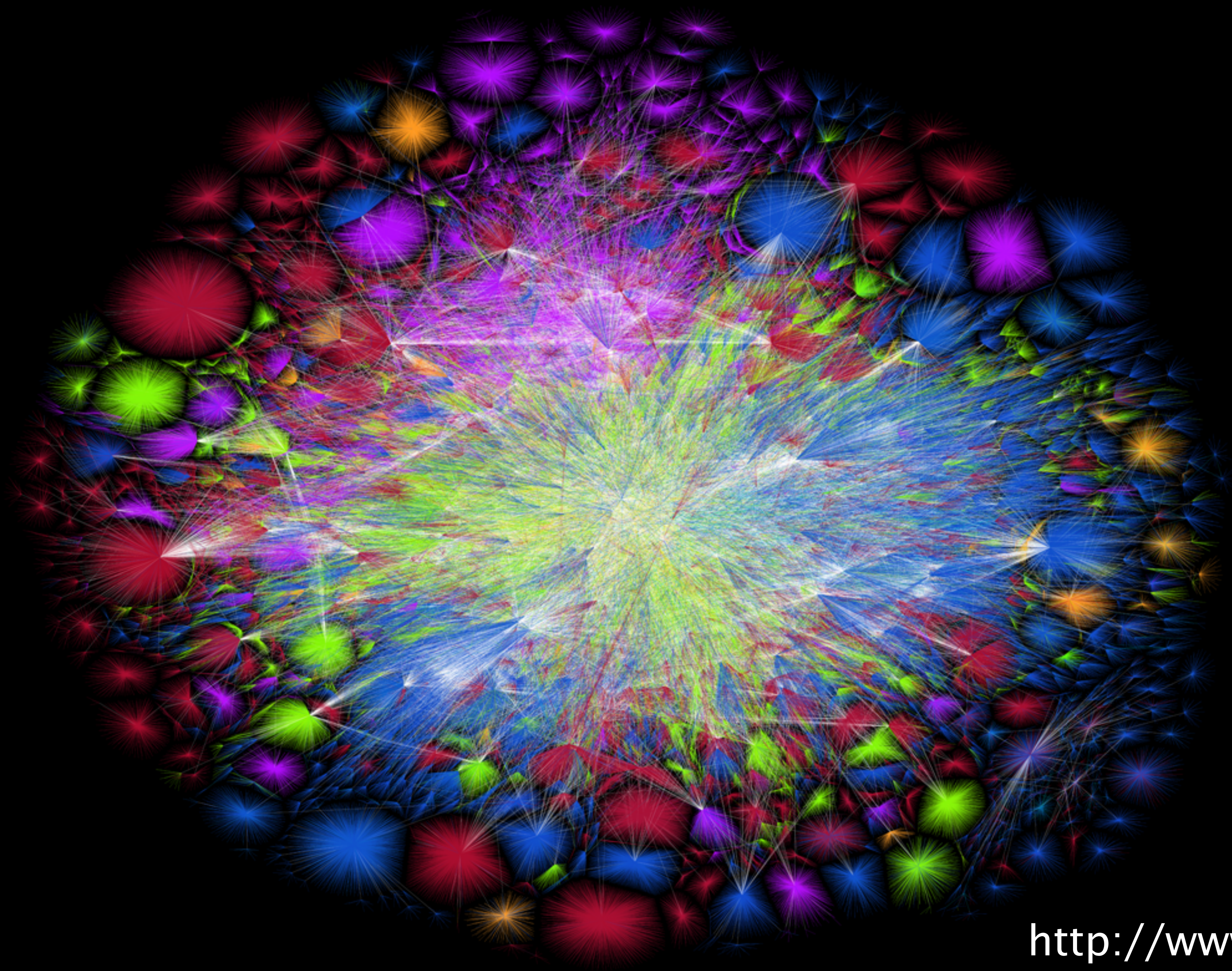
No configuration question — no Quagga at the exam

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?

Google | google.com/datacenters

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/

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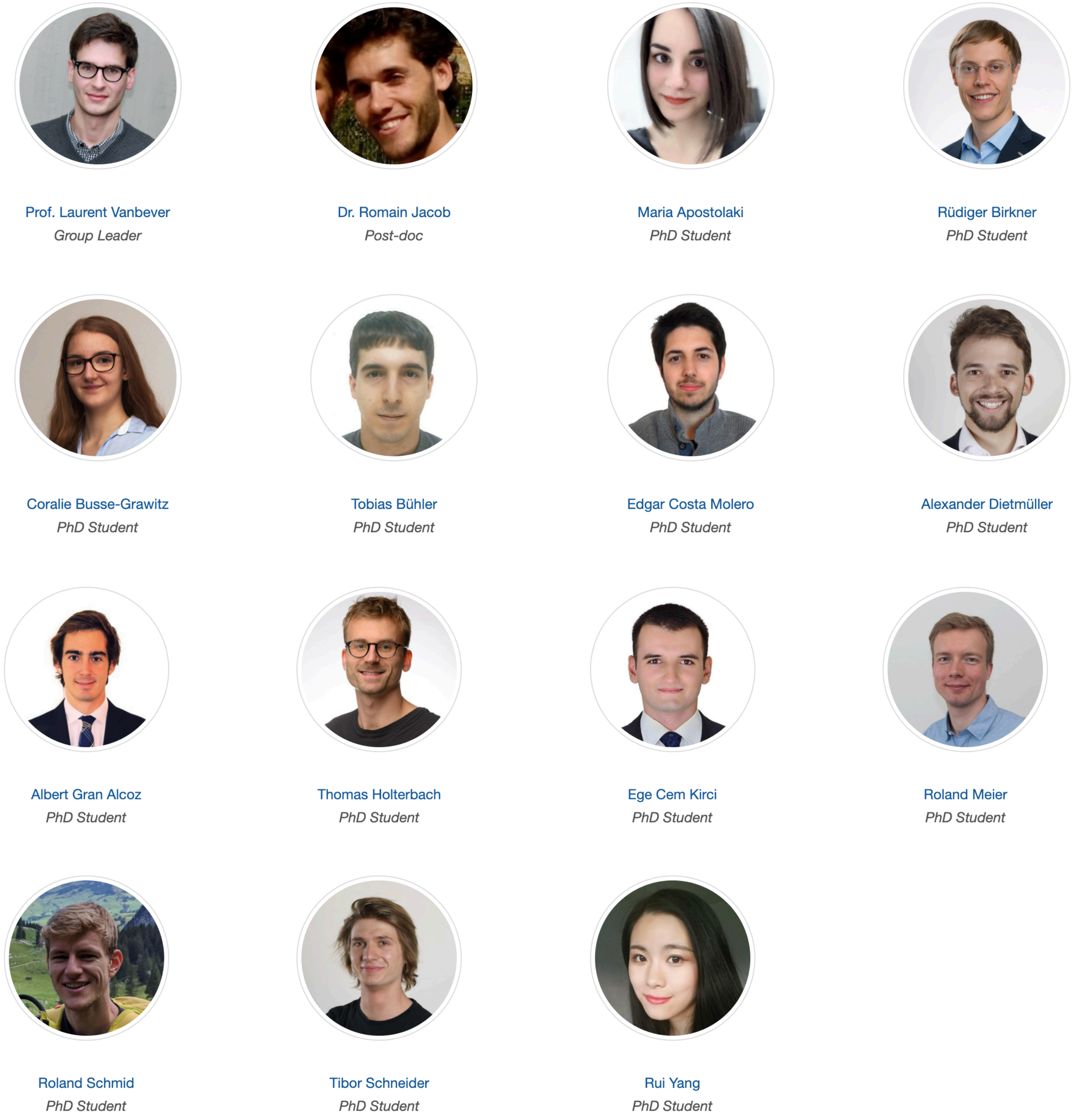
bachelor, semester or master



Prof. Laurent Vanbever
Group Leader

Dr. Romain Jacob
Post-doc

Maria Apostolaki
PhD Student

Rüdiger Birkner
PhD Student

Coralie Busse-Grawitz
PhD Student

Tobias Bühler
PhD Student

Edgar Costa Molero
PhD Student

Alexander Dietmüller
PhD Student

Albert Gran Alcoz
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Ege Cem Kirci
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Roland Meier
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Roland Schmid
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That's all Folks!

Enjoy a ***well-deserved*** break!

Communication Networks

Spring 2021

Laurent Vanbever

nsg.ee.ethz.ch

ETH Zürich (D-ITET)

May 31 2021