

## Communication Networks

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Exercises week 1 and 2 - Introduction

### Traceroute

#### Decipher a Packet Route

The traceroute (or `tracert` on Windows) command<sup>a</sup> is a useful tool to observe the route of packets towards a network host. You will learn the underlying functionality of traceroute in a later lecture. Below, you find a traceroute output from ETHZ towards the New York University ([www.nyu.edu](http://www.nyu.edu)).

<sup>a</sup><https://linux.die.net/man/8/traceroute>

```
> traceroute www.nyu.edu
traceroute to web.gslb.nyu.edu (128.122.119.202), 64 hops max, 52 byte packets
 1  82.130.102.1                (82.130.102.1)    0.849 ms  0.616 ms  0.820 ms
 2  rou-ref-rz-bb-ref-rz-etx    (10.10.0.41)     0.741 ms  0.671 ms  0.643 ms
 3  rou-fw-rz-ee-tik            (10.1.11.129)    0.892 ms  0.836 ms  5.057 ms
 4  rou-fw-rz-gw-rz             (192.33.92.170)  1.040 ms  0.852 ms  0.892 ms
 5  swiez2                       (192.33.92.11)   0.982 ms  1.032 ms  0.974 ms
 6  swizh1-100ge-0-1-0-0.switch.ch (130.59.38.110)  0.913 ms  0.884 ms  0.959 ms
 7  swice1-100ge-0-3-0-0.switch.ch (130.59.36.93)   5.796 ms  6.485 ms  4.591 ms
 8  switch.mx1.gen.ch.geant.net  (62.40.124.21)   4.213 ms  4.173 ms  4.203 ms
 9  ae4.mx1.par.fr.geant.net     (62.40.98.152)   11.508 ms 13.460 ms 11.560 ms
10  et-3-1-0.102.rtsw.newy32aoo.net.internet2.edu (198.71.45.236)  85.752 ms 82.767 ms 82.455 ms
11  nyc-9208-12-newy.nysernet.net (199.109.5.1)    82.457 ms 82.548 ms 82.434 ms
12  199.109.5.6                  (199.109.5.6)    82.609 ms 82.624 ms 82.684 ms
13  dmzgwa-ntp-extgwa.net.nyu.edu (128.122.254.65)  83.006 ms 83.225 ms 83.279 ms
14  nyugwa-ntp-dmzgwa.net.nyu.edu (128.122.254.88)  82.815 ms 82.789 ms 82.701 ms
15  wsqdcgwa-v1902.net.nyu.edu   (128.122.1.38)   83.156 ms 83.194 ms 82.933 ms
16  * * *
```

Formatted traceroute output from ETHZ towards [www.nyu.edu](http://www.nyu.edu) (New York University). The columns from left to right are: network hop number, IP/domain name (if resolvable), actual IP address, three individual measurements for the round trip time.

Look at the route the packet takes. Can you identify different ASes? At which point does it leave ETHZ?

Compare hop 9 and 10. Can you explain the time difference?

Execute the same traceroute command from your personal computer. Do you observe the same route? What did change? (Over the ETH WLAN you will see strange output due to NAT<sup>a</sup>.)

Assuming you could execute the reverse traceroute command from the New York University towards [www.tik.ethz.ch](http://www.tik.ethz.ch), would you expect the same route just in reverse order?

<sup>a</sup><http://lostintransit.se/2013/05/29/nat-translation-what-happened-to-my-traceroute/>

# Internet Structure

## Layer Model

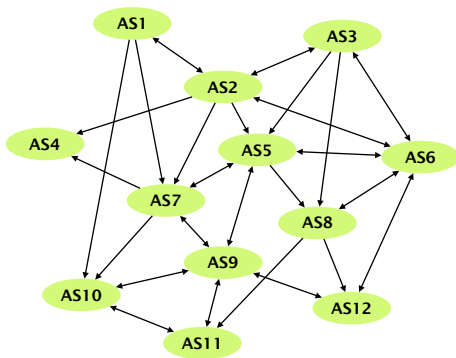
Internet protocol stack	OSI reference model
Application	Application
	Presentation
	Session
Transport	Transport
Network	Network
Link	Link
Physical	Physical

Internet communication layers: Internet protocol stack and the OSI reference model.

Communication over the Internet can be decomposed into independent layers. In the lecture, we have discussed the Internet protocol stack which contains 5 layers. Another often used model is the OSI (Open Systems Interconnection) model with 7 layers. Find the best matching layer for the following operations/devices. You can use the already known 5-layer model. **Hint:** Some of the operations could be implemented in different layers.

- Bit-to-bit transmission between two devices.
- Encryption of a message.
- A switch in a network.
- Routing path search.
- Adding a sequence number to each packet.
- A router in a network.
- A middlebox in a network performing deep packet inspection (DPI) to find malware in Web traffic.

## Internet Organization



A network of multiple autonomous systems (AS).

The network on the left consists of multiple autonomous systems (AS). Single-headed arrows point from providers to their customers. Double-headed arrows represent peer connections.

- For each AS, identify if it is a Tier-1, Tier-2 or Tier-3 ISP network or an IXP.
- AS7 has two different providers (AS1 and AS2). How is this type of interconnection called? What are the advantages of multiple different providers for AS7? Can you see any disadvantages?

## Internet Communication

The figure on the left shows a (simplified version of a) packet that was recorded at your machine's network interface using Wireshark<sup>a</sup>.

64:a0:e7:42:2e:c2			
78:4f:43:6c:b7:e2			
4	5	2	657
1622		2	0
64	6		63144
10.2.120.16			
82.130.102.210			
51236		80	
3710236014			
866143669			
4	0	00000110000	4117
4370		0	
GET / HTTP/1.1\r\n           Host: comm-net.ethz.ch\r\n           Connection: keep-alive\r\n           Cache-Control: max-age=0\r\n           Upgrade-Insecure-Requests: 1\r\n           User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_12_3) ...			
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,...			
Accept-Encoding: gzip, deflate, sdch\r\n           Accept-Language: de-DE,de;q=0.8,en-US;q=0.6,en;q=0.4\r\n           ...			

Packet consisting of data in four layers (link, network, transport and application layer).

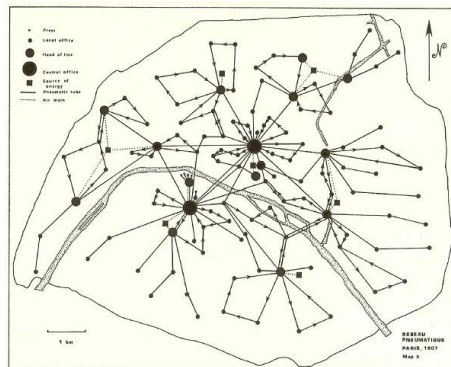
- What kind of activity does this packet belong to?
- From the lecture, you know that a packet is composed of data in different layers. The fields in the left-hand figure are already grouped to four blocks representing the link, network, transport and application layer. Do you know which protocol is used in each of the four layers? *Hint: You may want to have a look at the list of protocols on Wikipedia<sup>b</sup>.*
- After being sent out at your machine's network interface, the packet will traverse a switch which will forward it based on the destination address. On which layer does the switch operate and which is the destination address it will look at?
- After leaving your local network, the packet will traverse a router. On which layer does the router operate and which is the destination address it will look at?

<sup>a</sup><https://www.wireshark.org/>

<sup>b</sup>[https://en.wikipedia.org/wiki/Internet\\_protocol\\_suite](https://en.wikipedia.org/wiki/Internet_protocol_suite)

# Bandwidth and Delay

## Network Characterization



The pneumatic tube network of Paris in 1907.

Calculate and compare the bandwidth and the delay for different communication methods.

- a) Pigeon post: Pigeons can be used as messengers. They are trained to transport messages from one location to another. Assuming you want to send a USB flash drive with 16 GB<sup>a</sup> from Zürich to a friend in Paris (500 km) (only in one direction). Calculate the bandwidth and the delay for one pigeon carrying the USB drive and traveling at an average speed of 80 km/h.
- b) Pneumatic tube: These systems were introduced in the late 19th century to transport small, urgent items within buildings or even within cities. The capsules travel at an average speed of 8 meters per second. Assuming you send an external hard drive with 2 TB<sup>b</sup> of storage through a tube from ETZ to the main building (distance 400 m), calculate the bandwidth and delay.
- c) AWS Snowmobile: Amazon uses a truck to move data from its customers to their data center. The truck houses a container which can store 100 PB<sup>c</sup> of data.<sup>d</sup> Assuming the truck is transporting data from New York to an AWS data center in San Francisco (distance 4700 km) at an average speed of 100 km per hour, calculate the bandwidth and the delay.

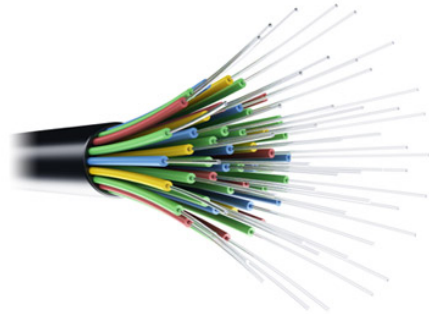
<sup>a</sup>1 GB = 10<sup>9</sup> bytes

<sup>b</sup>1 TB = 10<sup>12</sup> bytes

<sup>c</sup>1 PB = 10<sup>15</sup> bytes

<sup>d</sup><https://techcrunch.com/2016/11/30/amazon-will-truck-your-massive-piles-of-data-to-the-cloud-with-an-18-wheeler/>

## Types of Delay



Optical fiber cable.

When accessing a website your data has to travel from your computer through different networks to the server on which the website resides and back.

- a) You want to access the website of the University of Sydney ([www.sydney.edu.au](http://www.sydney.edu.au)). How long does it take for a data packet to travel to the server and back (straight-line distance Zürich-Sydney 16'600 km) assuming your data packet travels at the speed of light ( $3 \times 10^8$  m/s)?
- b) Measure the time it actually takes for a packet to travel to the server and back by issuing a `ping www.sydney.edu.au` in a terminal<sup>a</sup>. If you don't have a computer available you can use our measurement:  
PING sydney.edu.au (129.78.5.8):  
time=328.942ms  
The calculated and measured times are not even close. Why do we observe such a difference?

<sup>a</sup><https://linux.die.net/man/8/ping>

## Application Requirements



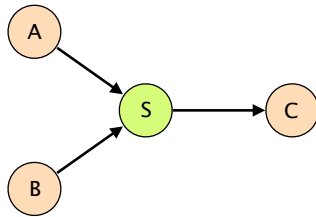
Different Internet applications.

Different applications pose different requirements to the network that need to be fulfilled for a good user experience. For each of the following applications, list their requirements in terms of bandwidth and delay (low, medium, high, not important) and explain your choices.

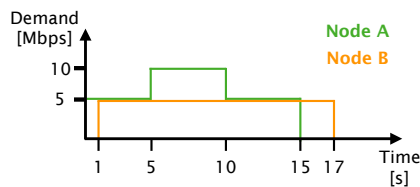
- a) Skype audio call
- b) Skype HD video call
- c) Youtube video
- d) Data download from cloud storage

# Sharing

## Packet vs. Circuit Switching



Network with a shared link.



Demand distributions for node A and B.

Consider the network on the left. A and B are sending data towards C over a switch S and a shared link. All the links in the network have a bandwidth of 10 Mbps and you can assume that the propagation and switch processing time are negligible. For circuit switching, assume that circuit establishment and tear-down each take 50 ms. For packet switching, you can assume that switch S already knows how to reach C.

- a) How long does it take if node A is sending a 50 Mbit file to C using packet switching? B sends nothing.
- b) How long does it take if node B is sending a 50 Mbit file to C using circuit switching? A sends nothing.

Assume now that A and B are using packet switching and are each sending a 50 Mbit file to C at the same time.

- c) What will happen if the switch has no buffer?
- d) How large has the buffer to be (in Mbit) such that both senders can successfully transmit their files to C?
- e) For obvious reasons, switch buffers cannot be of unlimited size. How is it possible to successfully send data over the Internet even if some packets are dropped due to full buffers?

Finally, assume that A and B have to send data with a demand according to the diagram on the left.

- f) How long does it take to send all data if A and B use circuit switching (reserving for the peak demand)?
- g) How long does it take to send all data if A and B use packet switching (you can assume an unlimited buffer size on S)?