An Open Platform to Teach How the Internet Practically Works

Thomas Holterbach &
Tobias Bühler

SIGCOMM Best of CCR

12th August 2020

Joint work with Tino Rellstab,
and Laurent Vanbever

ETH zürich

How do we traditionally teach how the Internet works?

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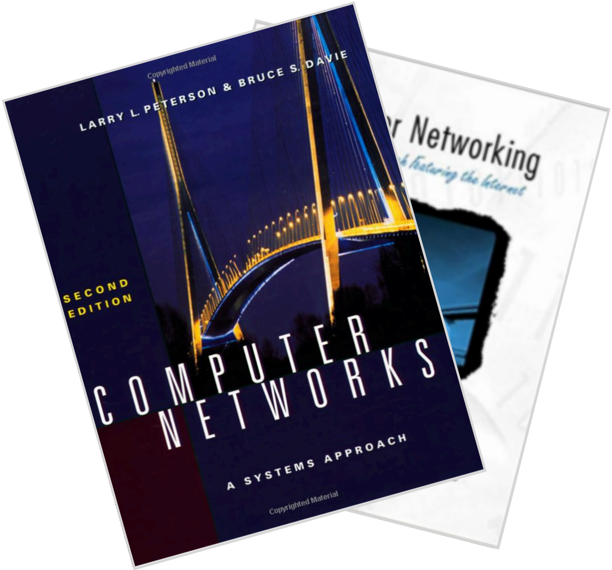
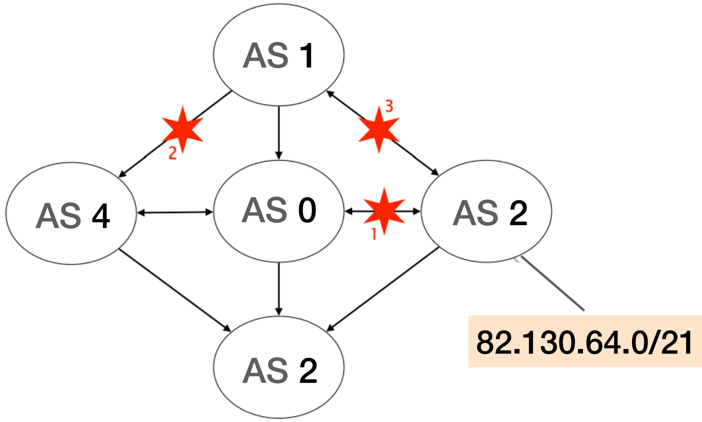
theory



exercises



Which messages are exchanged?

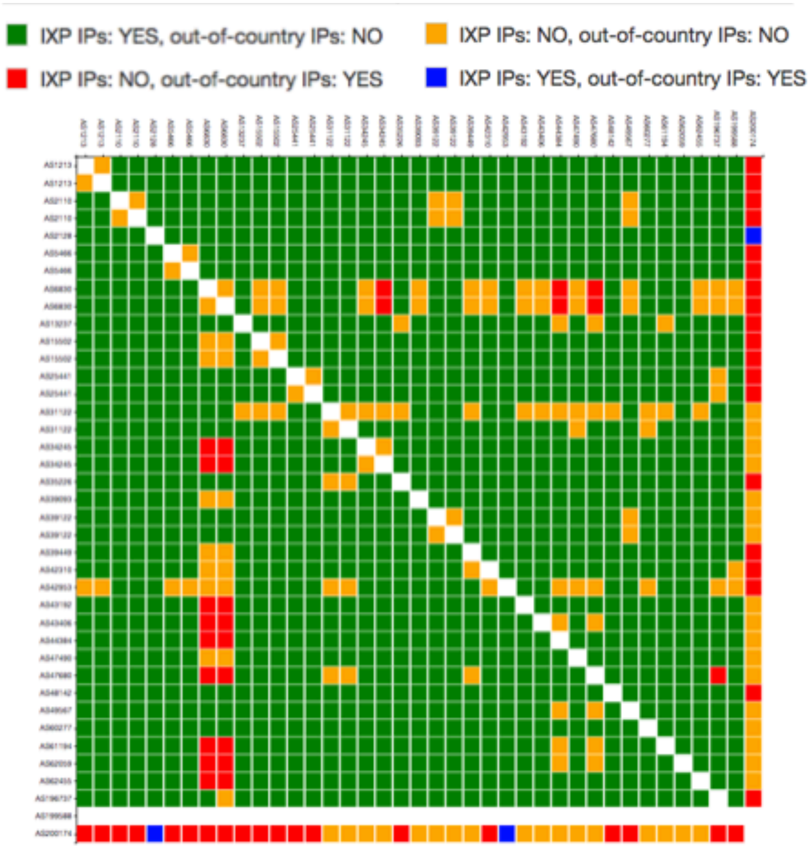
labs

These concepts are not sufficient to understand how the Internet *practically* works

In practice, there are peering agreements with stringent SLAs

Network operators talking during NANOG'76

In practice, there are thousands of ASes and connectivity must be monitored network-wide



IXP Country Jedi
Emile Aben

In practice, debugging can be tricky

```
Anybody else is experiencing packet loss since last Tuesday across the AT&T network in the L.A. area?

I'm seeing it coming from both Zayo and HE


 8. ae2.cs1.lga5.us.zip.zayo.com

 9. ae18.ter1.lga5.us.zip.zayo.com

10. 192.205.36.105

11. cr1.n54ny.ip.att.net

12. cgcil22crs.ip.att.net

13. cgcil21crs.ip.att.net

14. dvmco22crs.ip.att.net

15. slkut21crs.ip.att.net

16. la2ca21crs.ip.att.net

17. gar20.la2ca.ip.att.net
```

NANOG mailing list
December 9, 2019

At ETH Zurich, we let the students operate their own mini-Internet, altogether, like if they were the network operators

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ETH students working on the mini-Internet

Outline

1. The mini-Internet mimics the real one and is entirely virtual

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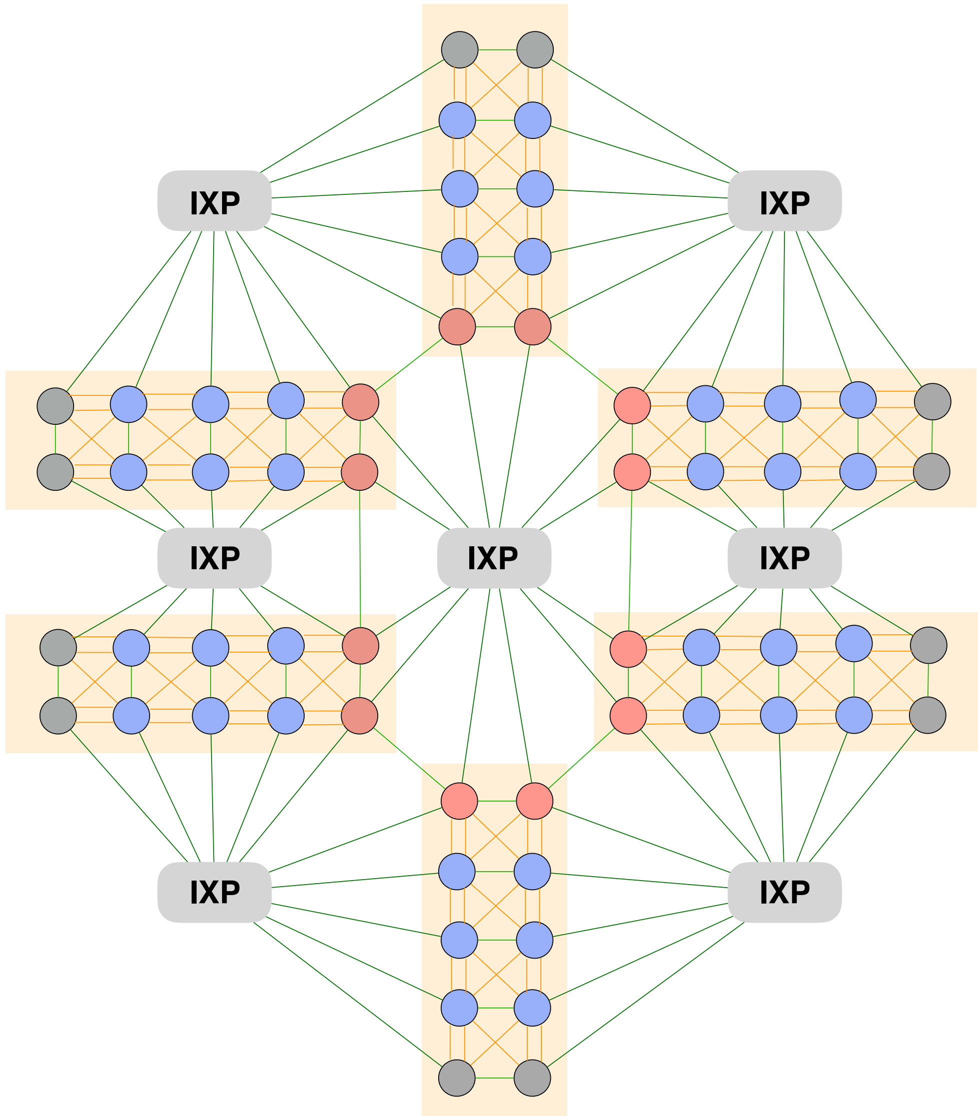
The AS-level topology we use in our mini-Internet



Tier1 AS

Transit AS

Stub AS

Customer-provider link

Peer-2-peer link

We build internal topologies
with the technologies used in practice

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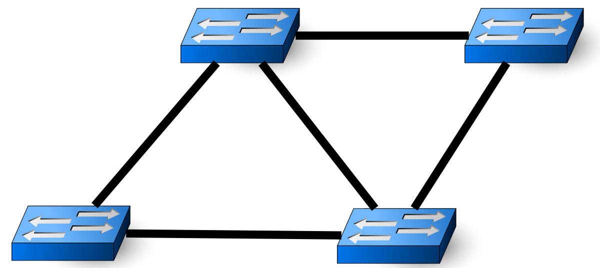
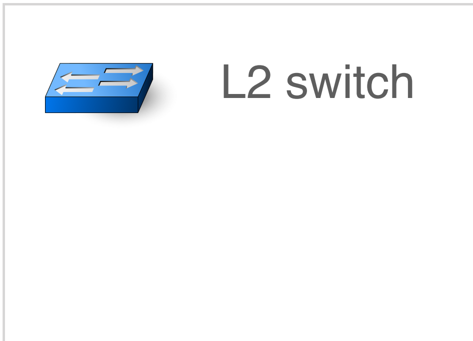
with the technologies used in practice





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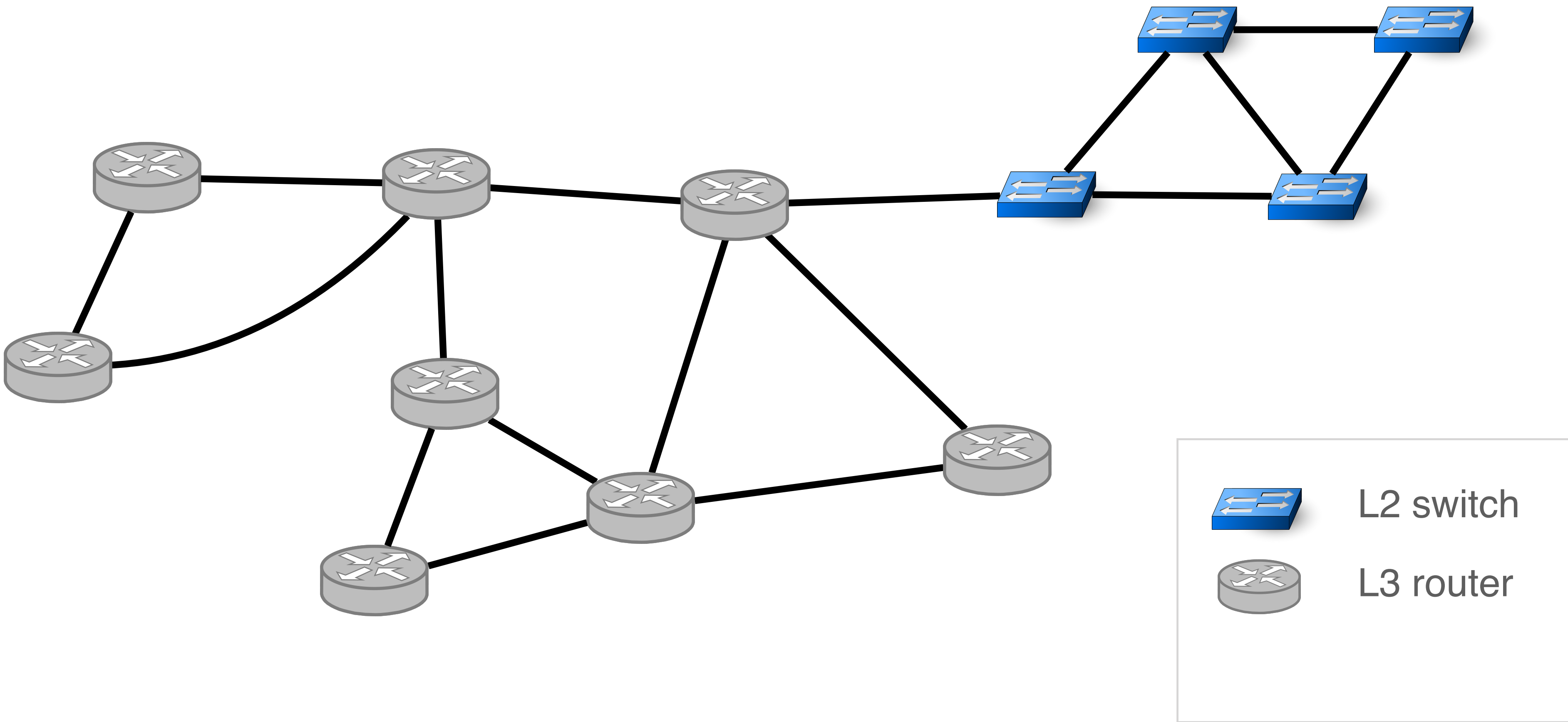

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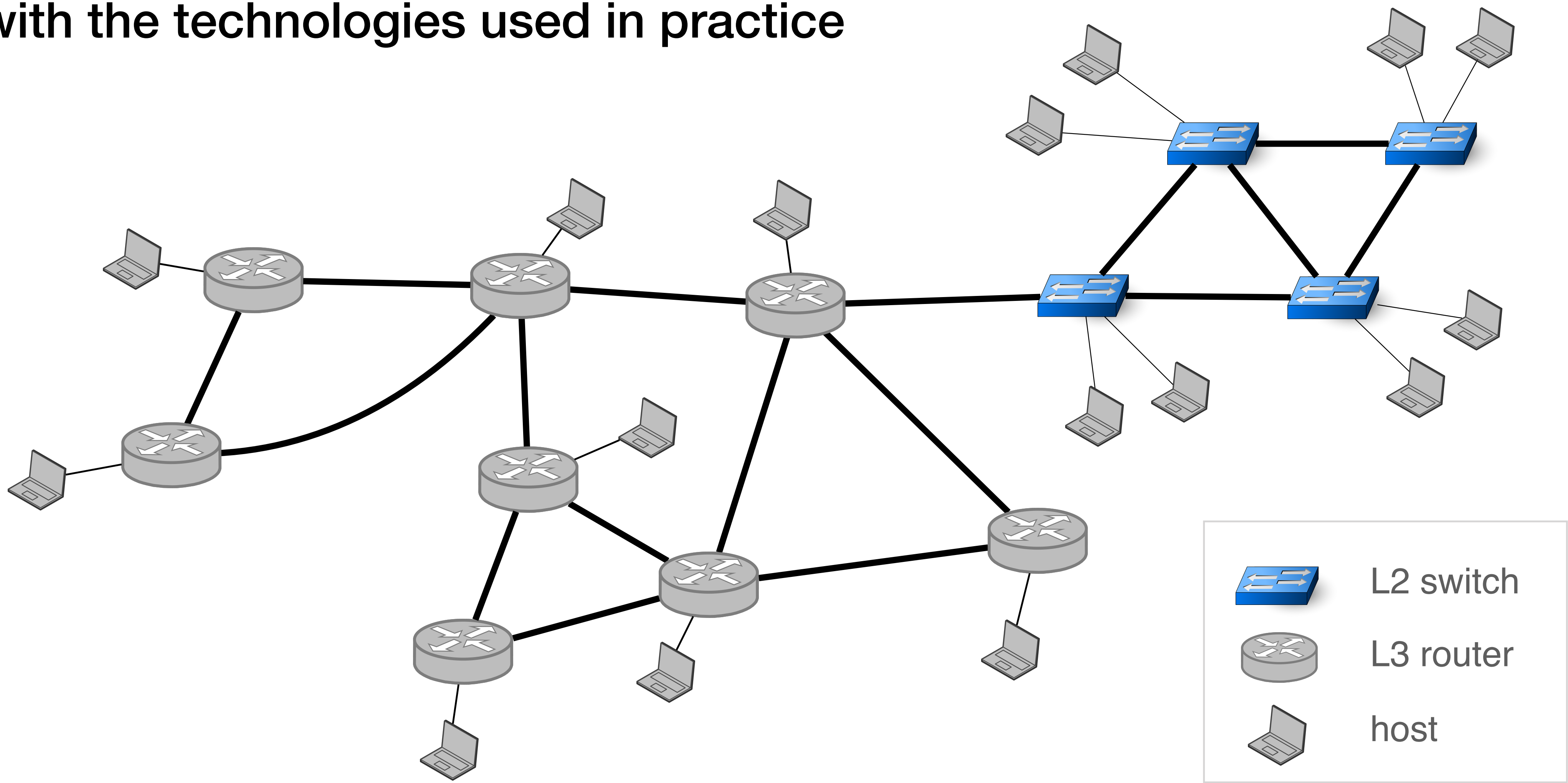
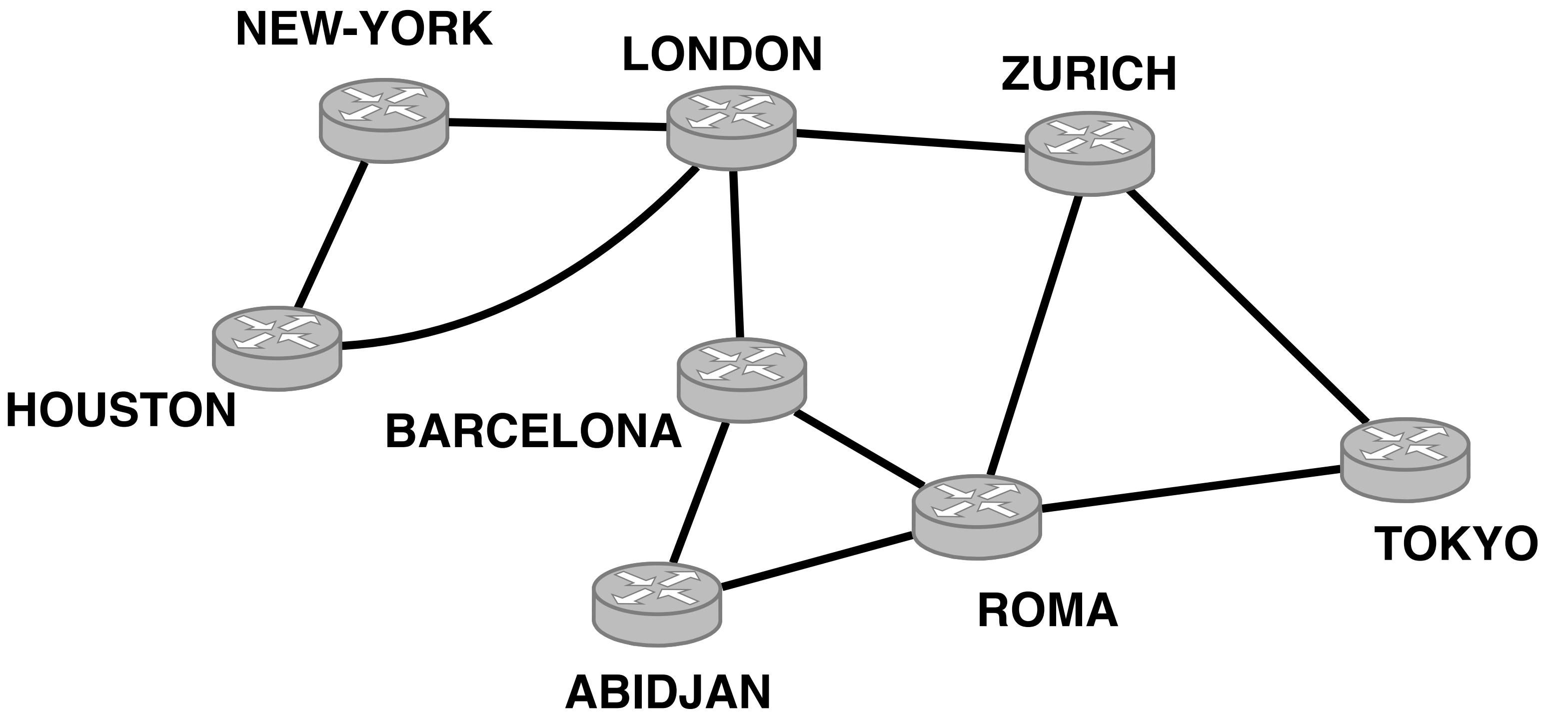


We build realistic internal topologies
that require students to solve real problems



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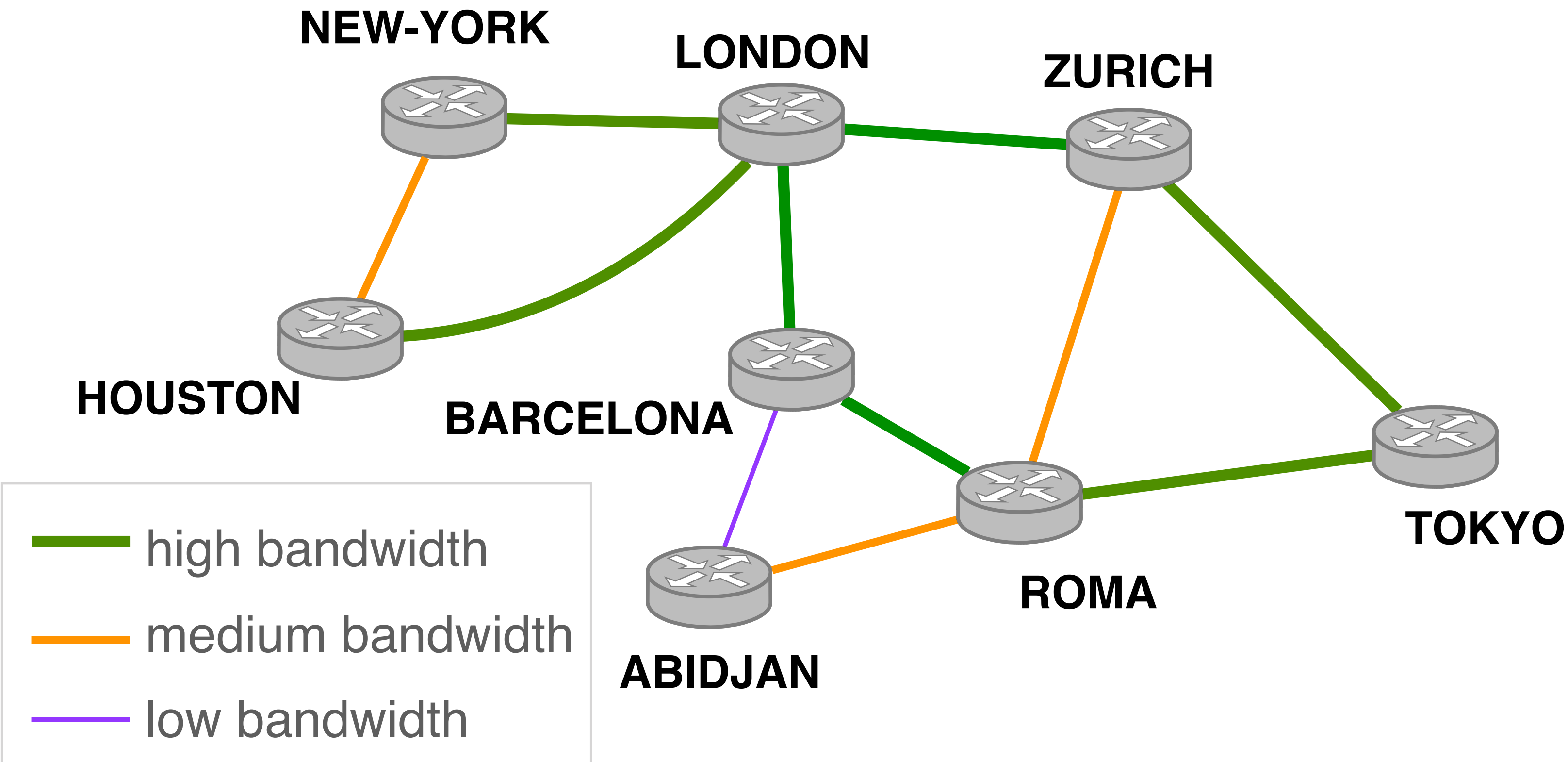

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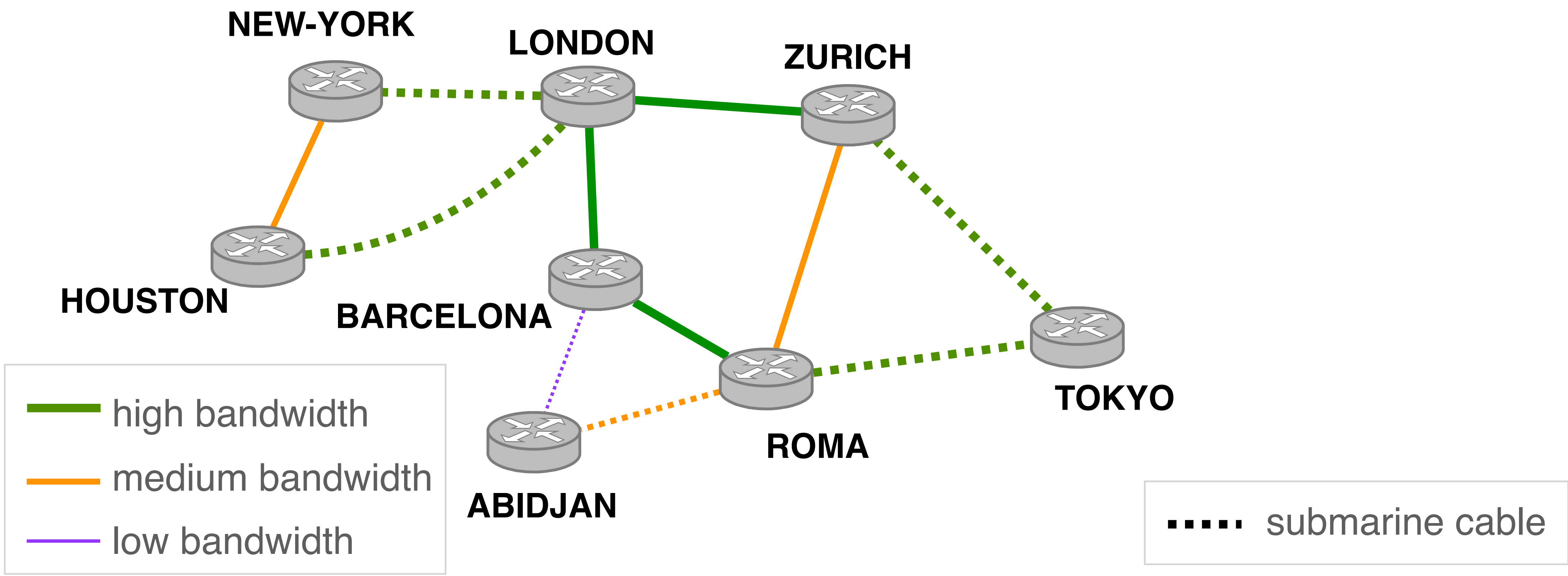

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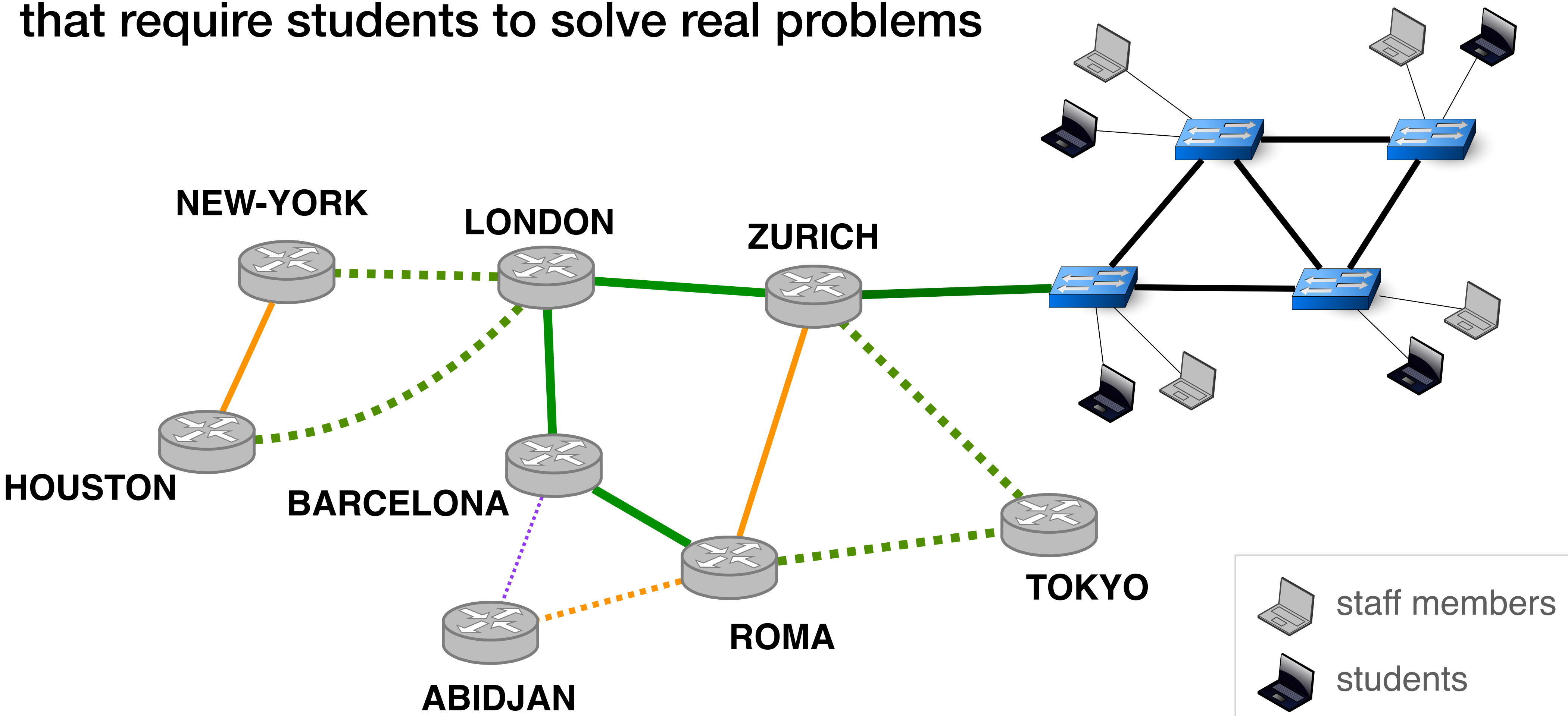

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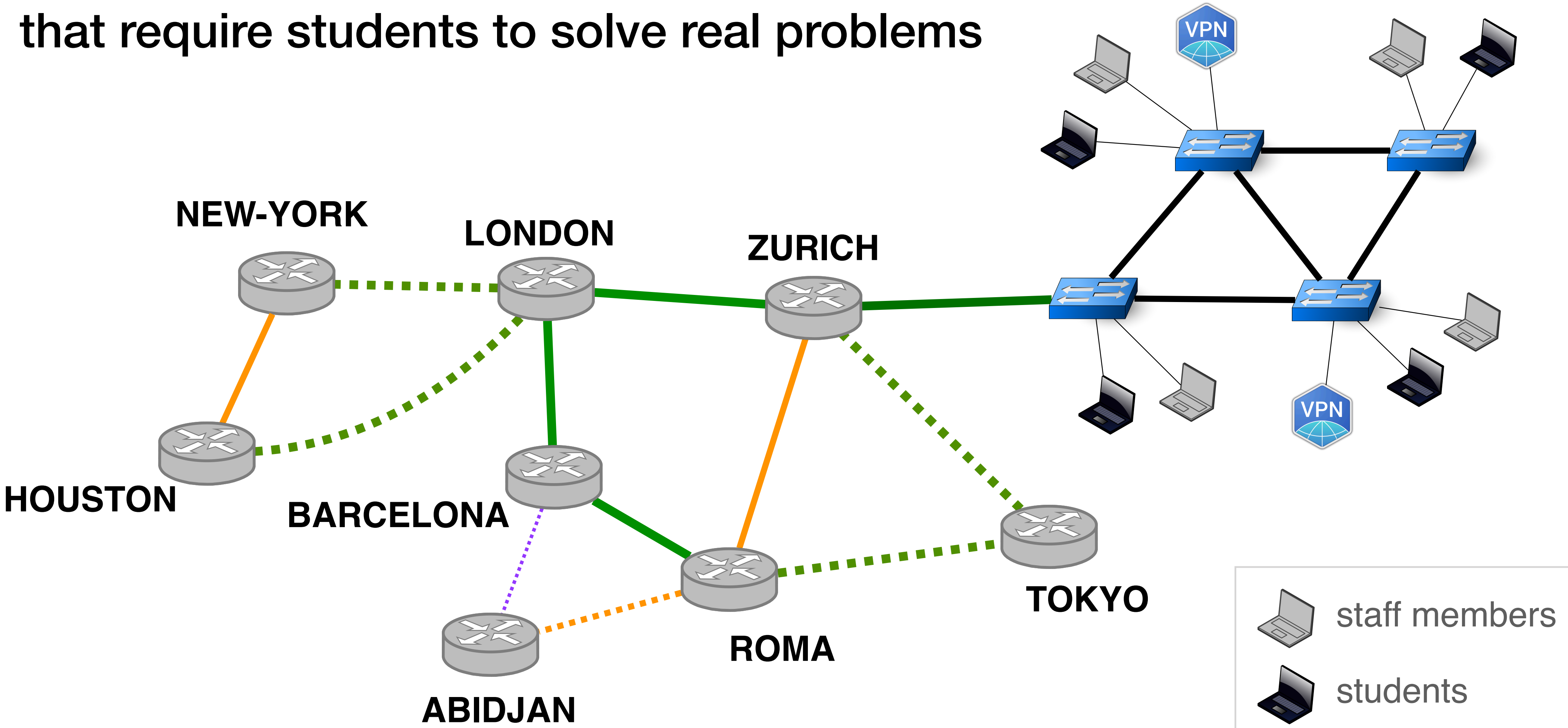

The mini-Internet runs in a single server

Each component (router, switch and host)
runs in its own docker container

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With connect the containers following the topology using virtual links

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With connect the containers following the topology using virtual links

We use the state of the art software suite for the routers and switches

Outline

1. The mini-Internet mimics the real one and is entirely virtual

2. The mini-Internet turns the students into network operators

3. The mini-Internet provides students with tools to ease operations

We give one transit AS and one IP prefix to each group of students

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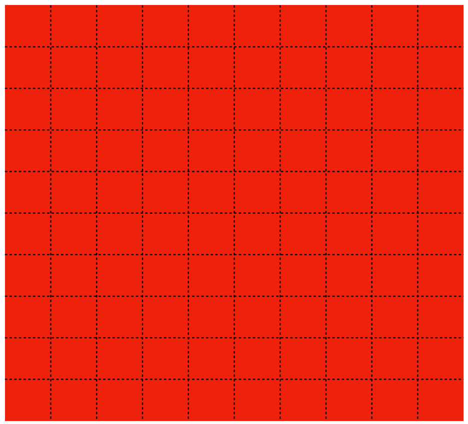
At the beginning



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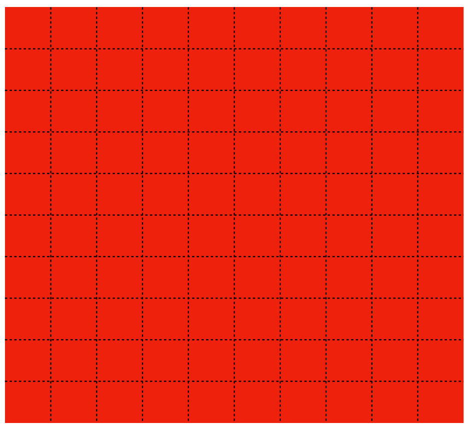

Goal: enabling Internet-wide connectivity

Students have to enable internal connectivity and perform traffic engineering

In the L2 network

e.g., custom spanning tree and VLANs

In the L3 network

e.g., load-balancing

We organise a Hackathon where students gather to configure BGP sessions

mini-Internet Hackathon, April 19, 2018

Besides enabling BGP sessions,
students have to implement routing policies

Following business agreements
e.g., local-preference and exportation rules

Following preferences
e.g., one provider is preferred

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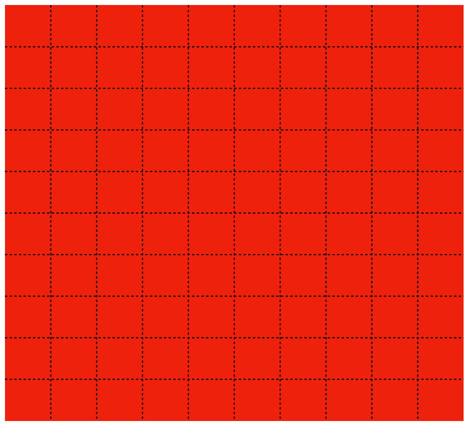
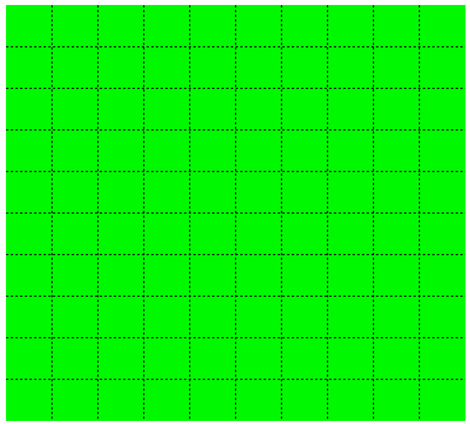


This year, at the end of the project
the mini-Internet was fully connected



Device access

Students access a so call proxy container

From there they can access every device with a single command:
`./goto.sh <device_name> <device_type>`

To access a router called NEWY:
`./goto.sh NEWY router`

Let's perform a traceroute from a host

```
root@NEWY_host:~# traceroute 16.103.0.1
traceroute to 16.103.0.1 (16.103.0.1), 30 hops max, 60 byte packets
 1  NEWY-host.group6 (6.105.0.2)  0.427 ms  0.107 ms  0.030 ms
 2  180.82.0.13 (180.82.0.13)  8.505 ms  7.949 ms  7.898 ms
 3  ATLA-NEWY.group13 (13.0.11.2)  7.829 ms  7.714 ms  7.660 ms
 4  ZURI-LOND.group16 (16.0.2.1)  12.675 ms  12.620 ms ZURI-PARI.group16 (16.0.1.1)  12.560 ms
 5  PARI-NEWY.group16 (16.0.5.1)  12.234 ms  12.066 ms  11.990 ms
 6  host-PARI.group16 (16.103.0.1)  12.053 ms  9.375 ms  9.281 ms
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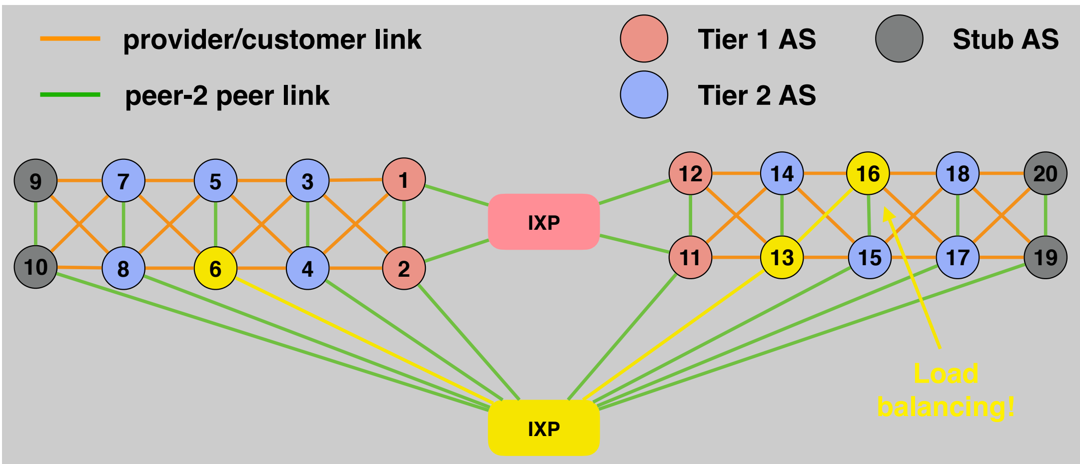

Even a single traceroute command can reveal a lot of important events

Students can confirm their forwarding policies
as well as the correct usage of IXPs

They observe load-balancing
which at first often looks confusing in the traceroute output

We often observe that students will start to contact other groups/ASes
for example if they observe a mistake in their policies

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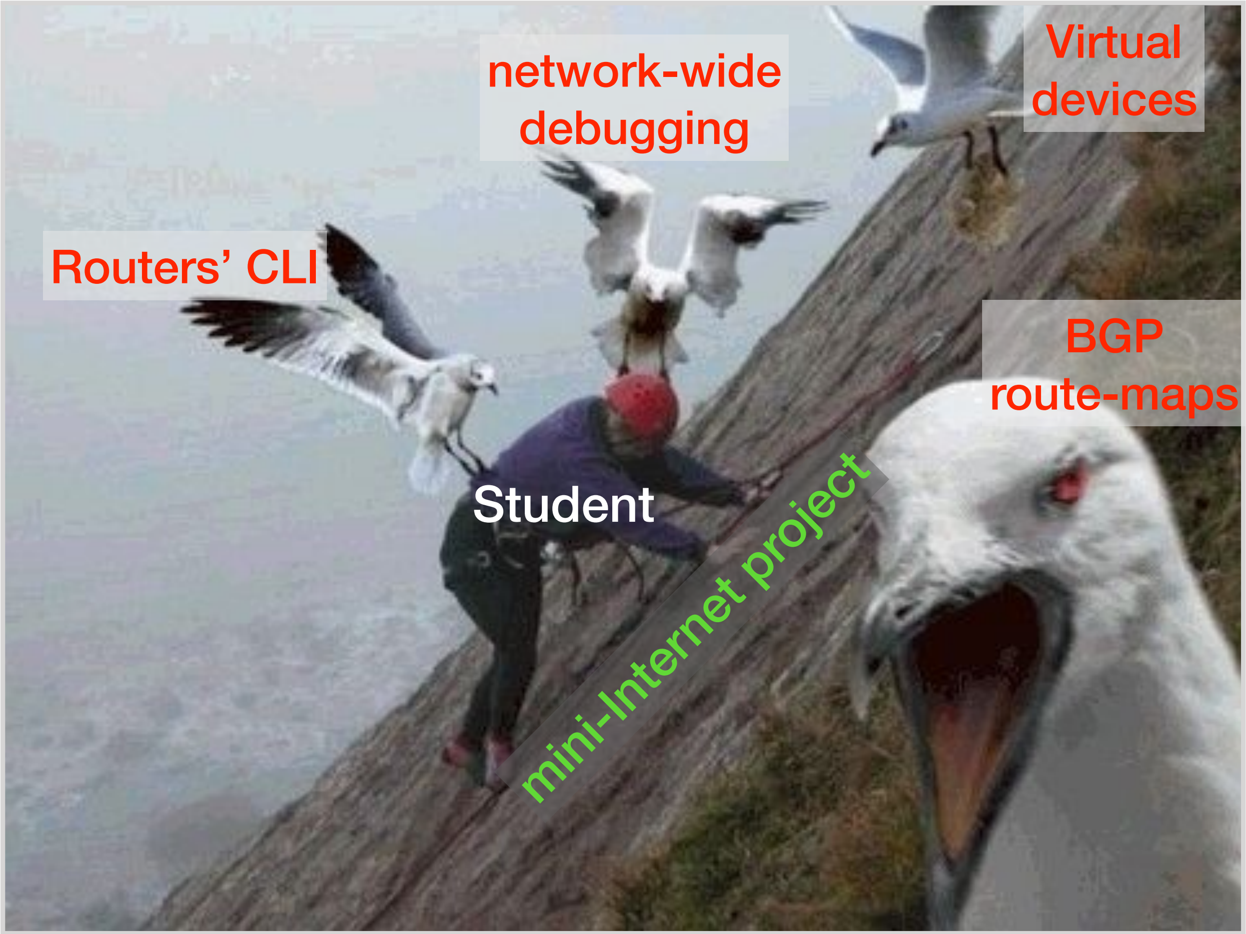
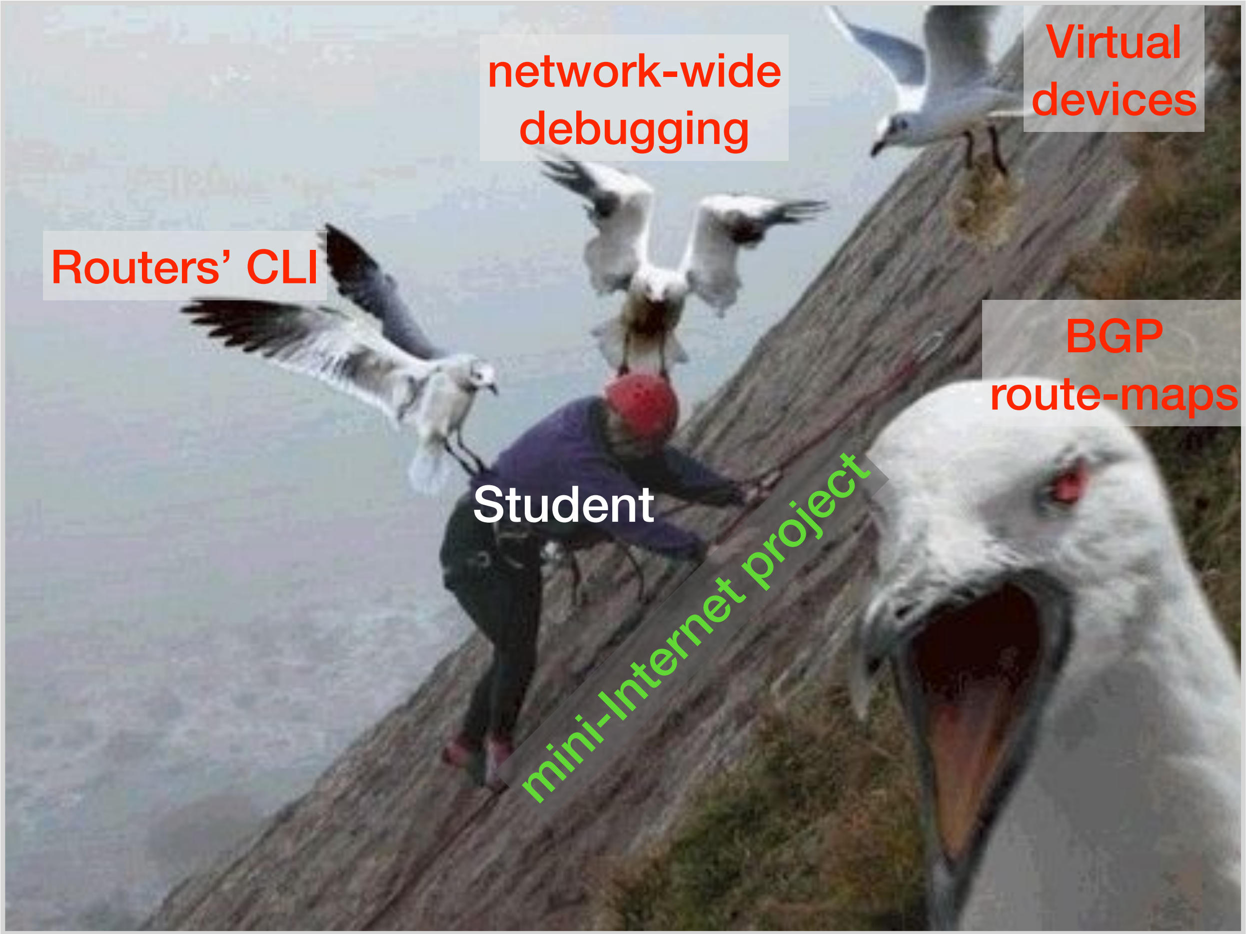
Operating the mini-Internet is challenging and sometimes painful



Operating the mini-Internet is challenging and sometimes painful
Fortunately, there are tools to help



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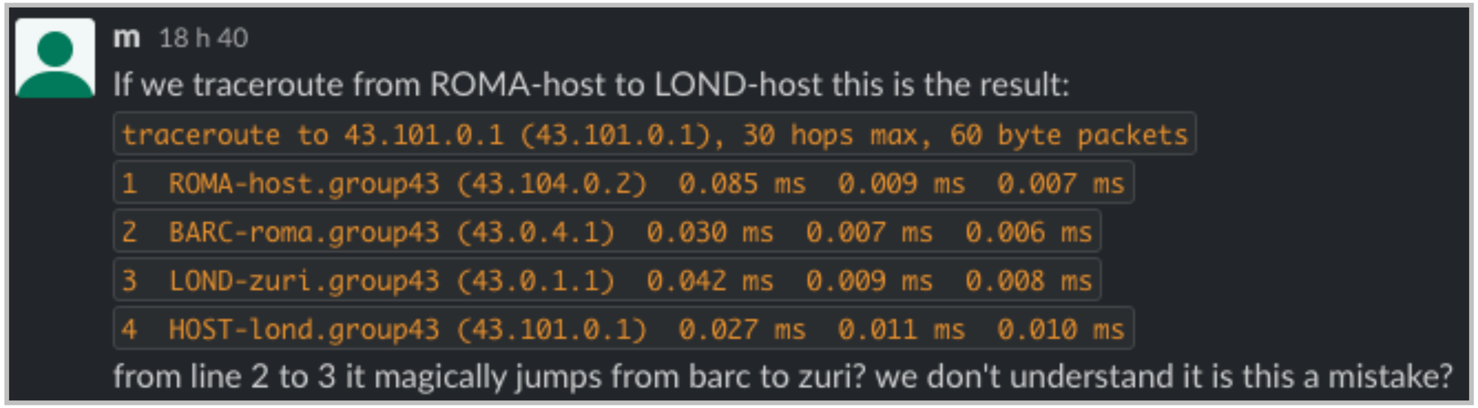

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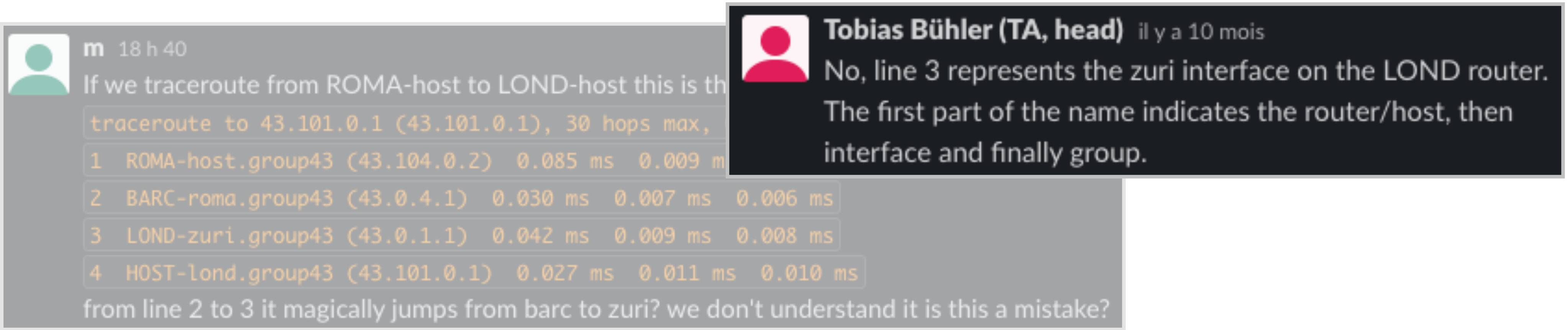

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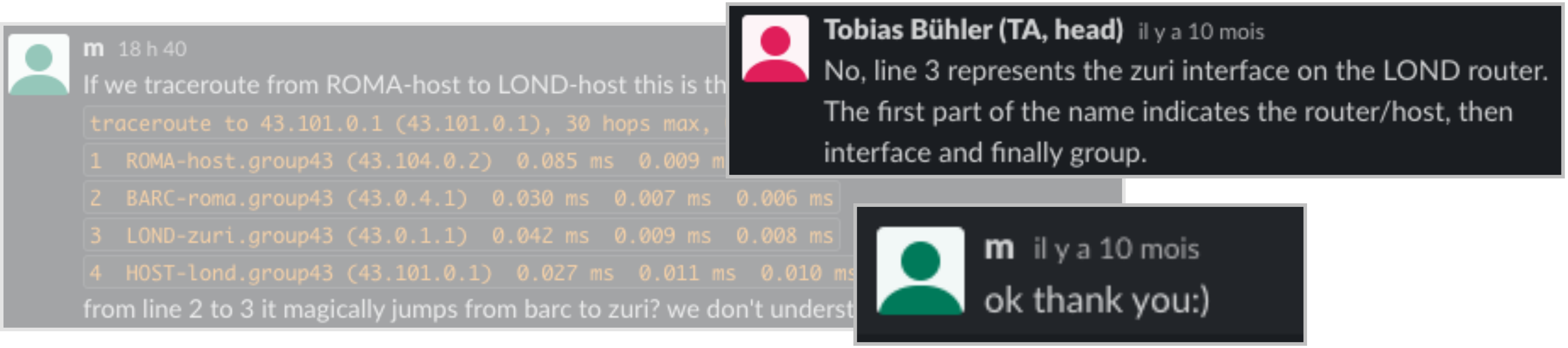

Monitoring and debugging a network is tricky

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We provide monitoring and debugging tools

Looking glass: the routing table of every router is available on a web interface

Active probing: the students can run ping and traceroute between any pair of ASes to test connectivity

DNS: the students can use domain names instead of IP addresses

Students are not familiar with routers and switches’ CLI

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We provide a documentation tailored for the mini-Internet

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Networked Systems
ETH Zürich — seit 2015

Spring 2018 Prof. L. Vanbever/ T. Bühler, R. Birkner, T. Holterbach, R. Meier

Communication Networks

Project 1: Build your own Internet

Deadline: May 3 2018 at 11.59pm

In this document, we first introduce in §1 a set of commands you may need to configure an Open vSwitch. We then show in §2 how to configure a Quagga router.

1 Configuring Open vSwitch

Open vSwitch[1] [1] is one of the most popular software switches. It can typically be used in virtual environnements, for instance to connect two virtual machines. When an Open vSwitch is running, a set of commands are available to check its state and configure it. To print a brief overview of the switch state and its parameters, you can use the following command:

```
> ovs-vsctl show
```

This command also tells you the VLANs each port belongs to. One port has the name of the switch and has the type *internal*. This is a local port used by the host to communicate with the switch. You do **not** need to use this port. To get more precise information about the status of the ports, you can use the following command:

```
> ovs-ofctl show NAME
```

Students do not progress at the same speed

Students do not progress at the same speed

We ensure minimal connectivity

We provide redundancy in the AS-level topology

Each transit AS has two providers and two customers

We pre-configure Tier1 and Stub ASes as well as IXPs

Enough for the students to answer most of the questions

Students must configure many virtual devices

Students must configure many virtual devices

We provide tools to facilitate the remote access to the virtual devices

Two commands are enough to access a router

```
laptop> ssh -p 2001 root@server
g1-proxy> ./goto.sh ZURI router
```

How to run your own mini-Internet?

1. Pull from our GitHub page
   github.com/nsg-ethz/mini_internet_project
2. Follow the documentation
3. Define your topologies
4. Run it on your server

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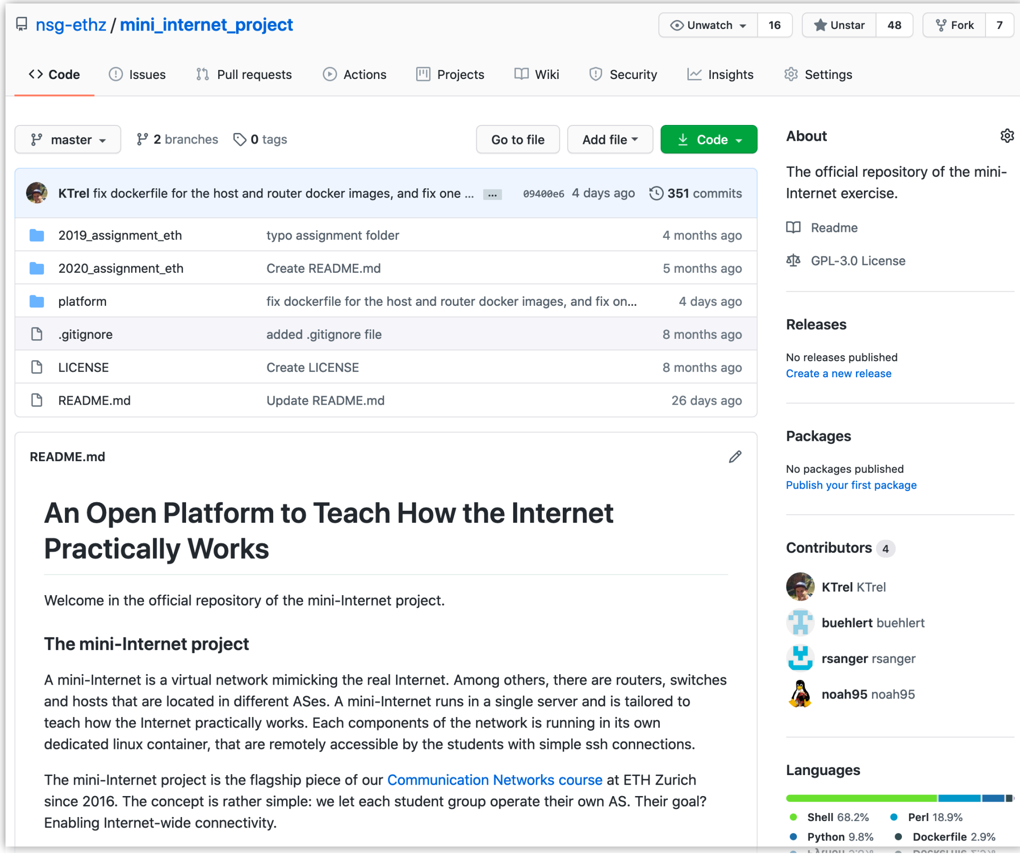

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Prerequisite

To build the mini-Internet, you need to install the following software on the server which hosts the mini-Internet.

Install the Docker Engine

To run all the different components in the mini-Internet (hosts, switches, routers, ...) we use Docker containers.

Follow this installation guide to install docker. In the directory `docker_images` you can find all the Dockerfile and docker-start files used to build the containers. In case you want to add some functionalities into some of the docker containers, you can update these files and build you own docker images:

```
docker build --tag=your_tag your_dir/
```

Then, you have to manually update the scripts in the `setup` directory and run your custom docker images instead of the ones we provide by default.

Install Open vSwitch

We use the Open vSwitch framework in two ways: (i) to build the L2 component of the mini-Internet and (ii) to connect Docker containers together.

```
sudo apt-get install openvswitch-switch
```

For further information, see the installation guide.

Install OpenVPN

Finally, we also need Open VPN which allows the students to connect their own devices to the mini-Internet.

```
sudo apt-get install openvpn
```

Install OpenSSL

Make sure to use OpenSSL 1.1.1 (2018-Sep-11). If you want to use the latest OpenSSL version, then you need to use DH keys of size 2048 (see here), but that will increase the startup time.

Build the mini-Internet

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For example the internal links in:
config/internal_links_config.txt

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ZURI     PARI     100000     100
ZURI     LOND     100000     1000
...
```

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For example the internal links in:
config/internal_links_config.txt

```
ZURI    PARI    100000    100
ZURI    LOND    100000    1000
...
```

Or external connectivity in:
config/external_links_config.txt

```
1 ZURI Peer     2 ZURI Peer     100000 1000 3.0.1.0/24
1 ZURI Provider 3 BOST Customer 100000 1000 9.0.3.0/24
...
```

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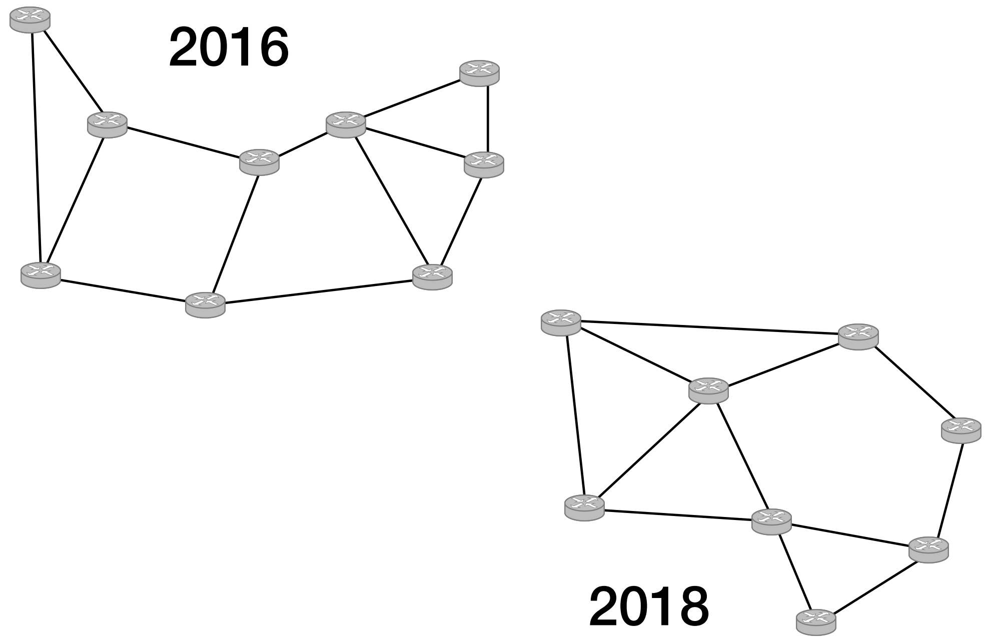
… or use a predefined one:



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Execute a single command:

```
sudo ./startup.sh
```

Wait until your mini-Internet is completely built (varies with topology size)

Enjoy!

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