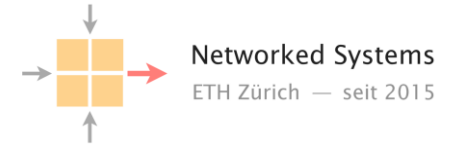


Connectivity Fäscht 2026



Grab a piece of paper and write your AS name on it!

Try to sit together with regards to your area in the mini-internet

Lukas Röllin
roellinl@ethz.ch

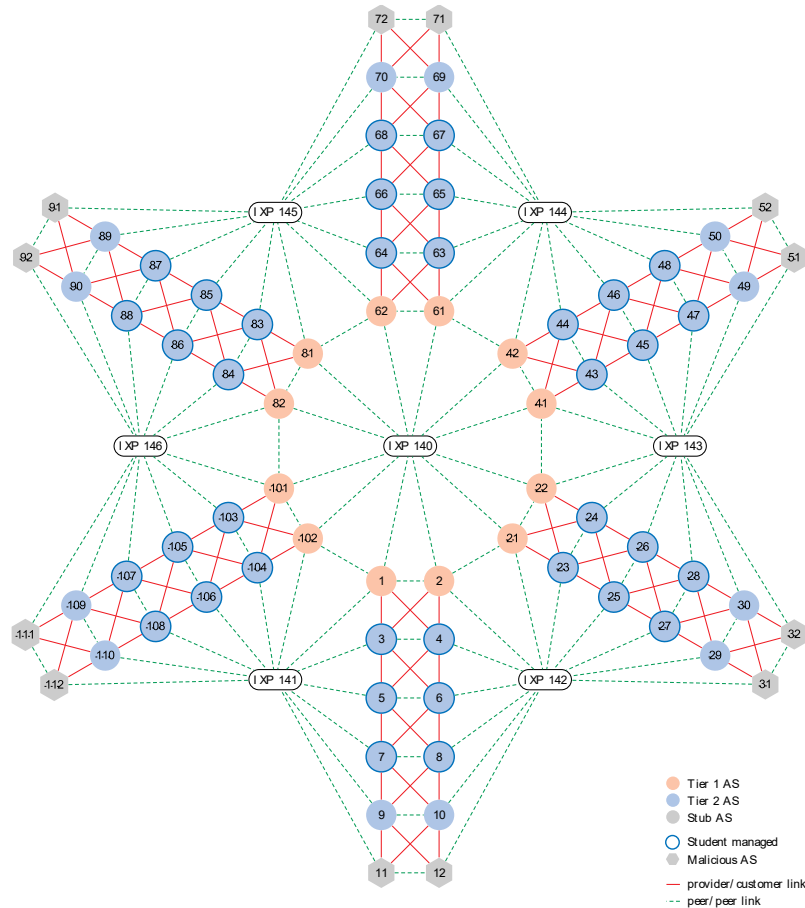
Slides inspired by
Alexander Dietmüller

Please Sign up for a Discussion Slot (oral part of the project)

You can sign up by using the following link:

https://docs.google.com/spreadsheets/d/1ZLmFonBnD5F3TjY_-6l5my3uhW39Fp70PBvBekGnrCE/edit?gid=0#gid=0

Goals for today



- Connectivity across ASes
- Learn how to debug common problems, especially with BGP
- Have fun and connect with other people from the class

What you should have done already

Group x manages AS x with IP prefix x.0.0.0/8

Host network and subnets for router y:

```
Host: x.(100 + y).0.1/24
Router: x.(100 + y).0.2/24
```

Loopback interface for router y:

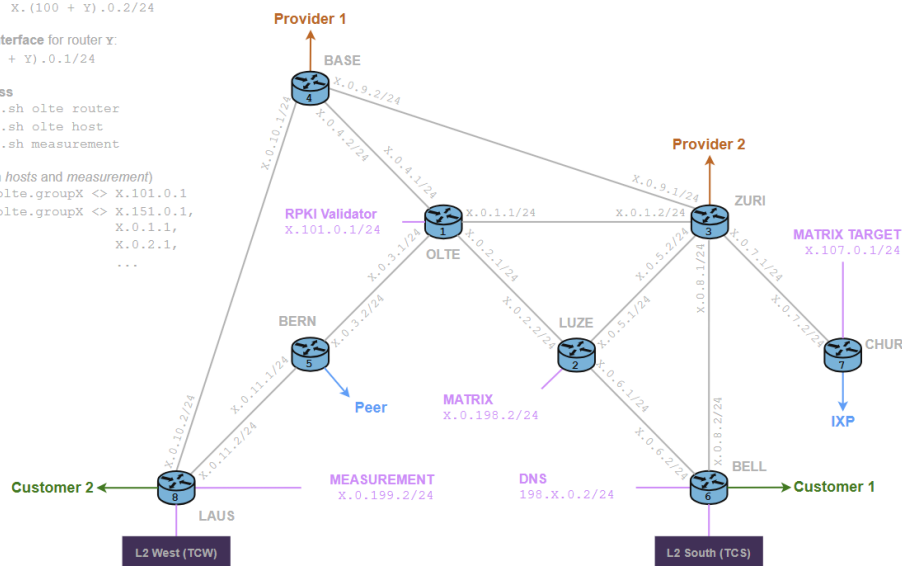
```
x.(150 + y).0.1/24
```

Device access

```
./goto.sh olte router
./goto.sh olte host
./goto.sh measurement
```

DNS (only on hosts and measurement)

```
host.olte.groupX <> X.101.0.1
olte.groupX <> X.151.0.1,
X.0.1.1,
X.0.2.1,
...
```

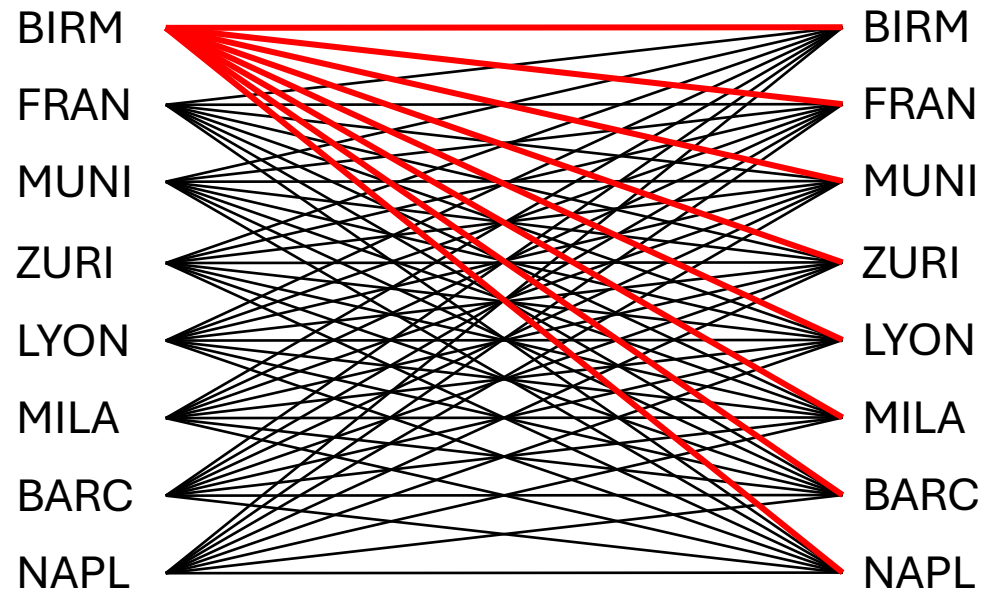


- Connectivity inside your own AS
 - Question 1.2: Routers need IP addresses and OSPF needs to be configured
 - **Test: ping between your routers and hosts**
- Setup full iBGP mesh
 - Question 2.1: All routers need iBGP sessions with each other -> full mesh
 - **Test: show ip bgp summary**

You need a total of 56 iBGP sessions

from **each** router

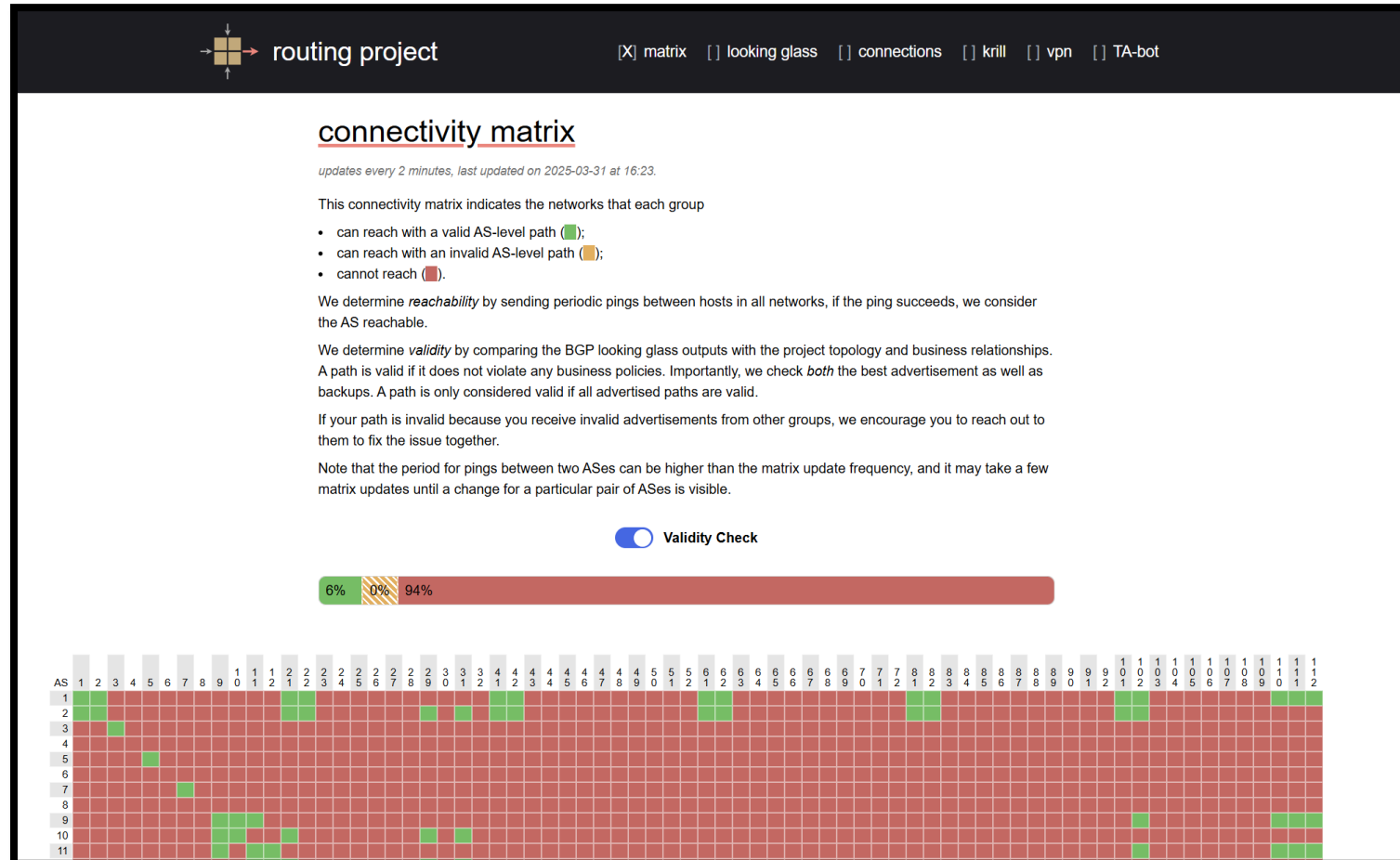
To **each other** router



Today

- You will connect your own networks with your neighbors' networks to form the mini-internet
- **Internet** -> **inter**connected **net**works

duvel.ethz.ch/matrix will show the current mini-Internet connectivity



RED
Not reachable

YELLOW
Reachable but not following
business relationships

GREEN
Reachable using a «valid» path

What you will be doing today

The screenshot shows a web interface for 'routing project'. At the top, there are navigation links: 'matrix', 'looking glass', 'connections' (which is active), 'krill', 'vpn', and 'TA-bot'. The main heading is 'AS connections'. Below the heading is a descriptive paragraph: 'This list shows all inter-AS connections. For each connection, it shows both involved ASes, the edge-routers at which their networks are connected, as well as their business relationship. Initially, the interfaces are not yet configured. When setting them up, use the IP addresses provided below.' There is a 'reset filter' button. The connections are displayed in two columns, each with a dropdown menu set to 'any AS'. Each connection card includes an icon representing the relationship (PEER, PROVIDER, or CUSTOMER), the ASes involved, and the IP addresses of the edge-routers.

Relationship	AS 1	AS 2	IP 1	IP 2
PEER	AS 1 / ZURI	AS 2 / ZURI	179.1.2.1/24	179.1.2.2/24
PROVIDER	AS 1 / ZURI	AS 3 / BIRM	179.1.3.1/24	179.1.3.3/24
PROVIDER	AS 1 / ZURI	AS 4 / BIRM	179.1.4.1/24	179.1.4.4/24
PEER	AS 1 / ZURI	AS 140 / IXP	180.140.0.1/24	180.140.0.140/24
PEER	AS 1 / ZURI	AS 141 / IXP	180.141.0.1/24	180.141.0.141/24
PROVIDER	AS 2 / ZURI	AS 3 / FRAN	179.2.3.2/24	179.2.3.3/24

- Have a look at duvel.ethz.ch/as-connections and enter your AS number in the filer
- This webpage will show you the business relations as well as the subnets to use

What you will be doing today

The screenshot shows a web interface for a 'routing project'. At the top, there are navigation links: 'matrix', 'looking glass', 'connections' (which is active), 'krill', 'vpn', and 'TA-bot'. The main heading is 'AS connections'. Below this, a paragraph explains that the list shows inter-AS connections with details on ASes, edge-routers, and business relationships. A 'reset filter' button is present. The connections are displayed in two columns under the heading 'any AS'. Each connection is represented by a card with an icon, a relationship type (PEER, PROVIDER, CUSTOMER), AS names, and IP addresses.

Relationship	AS 1	AS 2
PEER	AS 1 / ZURI 179.1.2.1/24	AS 2 / ZURI 179.1.2.2/24
PROVIDER	AS 1 / ZURI 179.1.3.1/24	CUSTOMER AS 3 / BIRM 179.1.3.3/24
PROVIDER	AS 1 / ZURI 179.1.4.1/24	CUSTOMER AS 4 / BIRM 179.1.4.4/24
PEER	AS 1 / ZURI 180.140.0.1/24	PEER AS 140 / IXP 180.140.0.140/24
PEER	AS 1 / ZURI 180.141.0.1/24	PEER AS 141 / IXP 180.141.0.141/24
PROVIDER	AS 2 / ZURI 179.2.3.2/24	CUSTOMER AS 3 / FRAN 179.2.3.3/24

- **You will need to find the students that manage a neighboring AS**
 - Discuss which IP address each of you will use within the subnet provided such that you can establish a session
- For TA-managed ASes, use the provided IP address

What you will be doing today

routing project

matrix looking glass connections krill vpn TA-bot

AS connections

This list shows all inter-AS connections. For each connection, it shows both involved ASes, the edge-routers at which their networks are connected, as well as their business relationship. Initially, the interfaces are not yet configured. When setting them up, use the IP addresses provided below.

reset filter

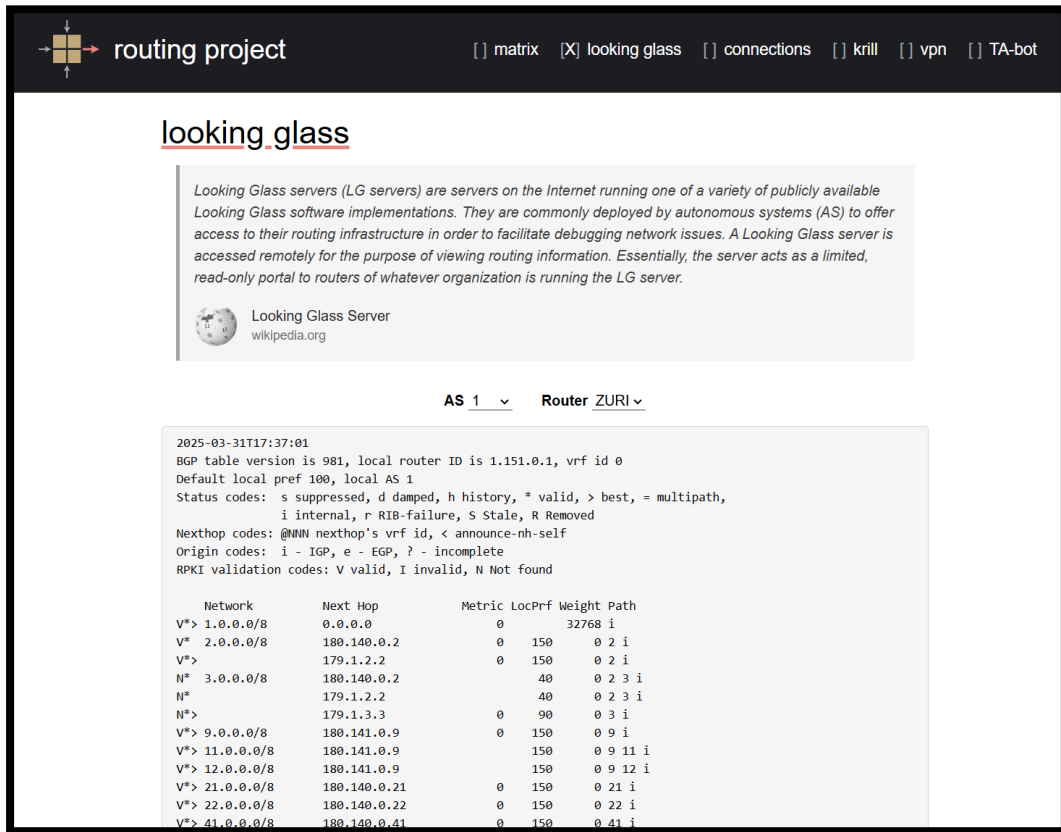
any AS		any AS
PEER AS 1 / ZURI 179.1.2.1/24	<>	PEER AS 2 / ZURI 179.1.2.2/24
PROVIDER AS 1 / ZURI 179.1.3.1/24	<>	CUSTOMER AS 3 / BIRM 179.1.3.3/24
PROVIDER AS 1 / ZURI 179.1.4.1/24	<>	CUSTOMER AS 4 / BIRM 179.1.4.4/24
PEER AS 1 / ZURI 180.140.0.1/24	<>	PEER AS 140 / IXP 180.140.0.140/24
PEER AS 1 / ZURI 180.141.0.1/24	<>	PEER AS 141 / IXP 180.141.0.141/24
PROVIDER AS 2 / ZURI 179.2.3.2/24	<>	CUSTOMER AS 3 / FRAN 179.2.3.3/24

- If your neighbors aren't here reach out to them on the routing project matrix channel later
- If this doesn't work let us know

There are several useful tools for debugging BGP

- **show ip bgp summary**
BGP neighbors and session status
- **show ip bgp**
Routes learned with BGP with the AS path
- **show ip bgp neighbor x.x.x.x routes**
Routes received from x.x.x.x
- **show ip bgp neighbor x.x.x.x advertised-routes**
Routes advertised to x.x.x.x

Debug output from other ASes



The screenshot shows the 'looking_glass' web interface. At the top, there's a navigation bar with 'routing project' and several menu items: 'matrix', 'looking glass' (selected), 'connections', 'krill', 'vpn', and 'TA-bot'. Below the navigation bar, the page title is 'looking_glass'. A descriptive paragraph explains that Looking Glass servers are used for debugging network issues. Below this is a 'Looking Glass Server' logo with the text 'wikipedia.org'. The main content area shows the selected AS 'AS 1' and Router 'ZURI'. The BGP table version is 981, and the local router ID is 1.151.0.1. The output shows the BGP table for the local router, including status codes, next-hop codes, and origin codes. A table of BGP entries is displayed below, showing network, next hop, metric, local preference, weight, and path.

```
2025-03-31T17:37:01
BGP table version is 981, local router ID is 1.151.0.1, vrf id 0
Default local pref 100, local AS 1
Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,
              i internal, r RIB-failure, S Stale, R Removed
Nexthop codes: @NNN nexthop's vrf id, < announce-nh-self
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

  Network      Next Hop      Metric LocPrf Weight Path
V*> 1.0.0.0/8  0.0.0.0        0       32768 i
V*  2.0.0.0/8  180.140.0.2    0       150   0 2 i
V*> 179.1.2.2  179.1.2.2      0       150   0 2 i
N*  3.0.0.0/8  180.140.0.2    40      150   0 2 3 i
N*  179.1.2.2  179.1.2.2      40      150   0 2 3 i
N*> 179.1.3.3  179.1.3.3      0        90   0 3 i
V*> 9.0.0.0/8  180.141.0.9    0       150   0 9 i
V*> 11.0.0.0/8 180.141.0.9    150      150   0 9 11 i
V*> 12.0.0.0/8 180.141.0.9    150      150   0 9 12 i
V*> 21.0.0.0/8 180.140.0.21   0       150   0 21 i
V*> 22.0.0.0/8 180.140.0.22   0       150   0 22 i
V*> 41.0.0.0/8 180.140.0.41   0       150   0 41 i
```

- Look at duvel.ethz.ch/looking-glass
- Shows the output of *show ip bgp* for a given AS and router
- Can help you understand how other ASes reach you
- Police Analyzer to help with some common policy mistakes

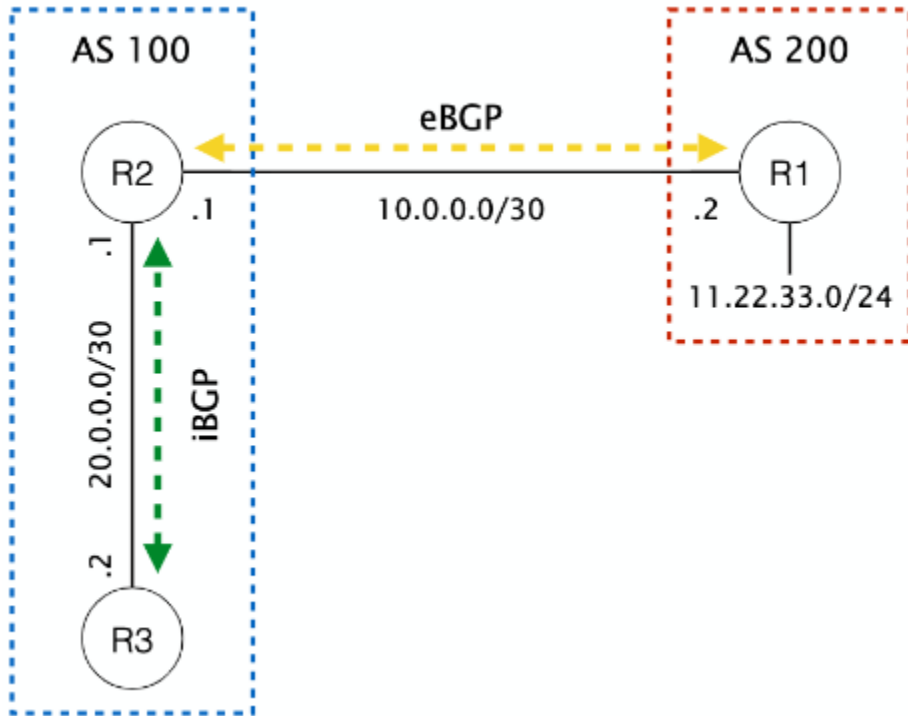
Common mistakes

- iBGP & update-source
- eBGP & next-hop-self
- Business relationship

iBGP sessions should use the loopback interface

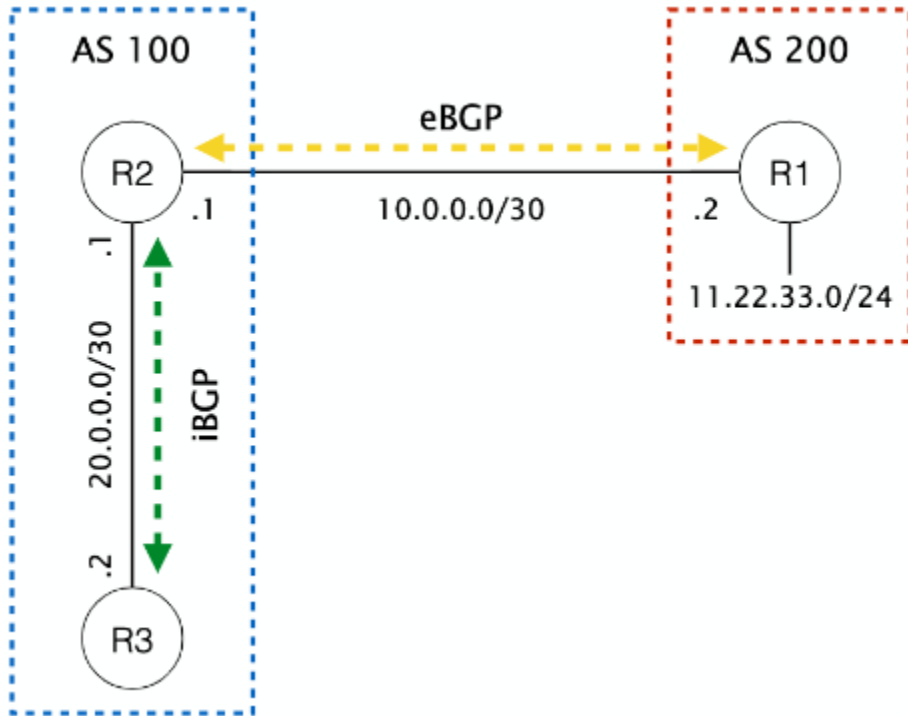
- Each router is available over multiple paths, if one link fails the iBGP session should still work
- For that reason use the loopback interface which is reachable as long as the router still has one link that works
- When configuring the iBGP session, use:
neighbor X.X.X.X update-source lo
- The loopback address should only be reachable internally

border routers must use next-hop-self for their iBGP sessions



- R1 announces prefix for AS 200 to R2:
You can reach AS 200 with next hop 10.0.0.2
- R2 propagates the announcement to R3 via iBGP
- **Problem: R3 does not know how to reach 10.0.0.2 only R2 does**

border routers must use next-hop-self for their iBGP sessions



- **Solution:** When configuring the iBGP session on R2, use:
neighbor x.x.x.x next-hop-self
- **Result:** R2 send the following to R3:
«You can reach AS 200 with next hop <loopback address of R2>»

BGP business relationships

- You might have heard about local-pref which can be used to prioritize certain announcements
- But why would you prefer one advertisement over another?

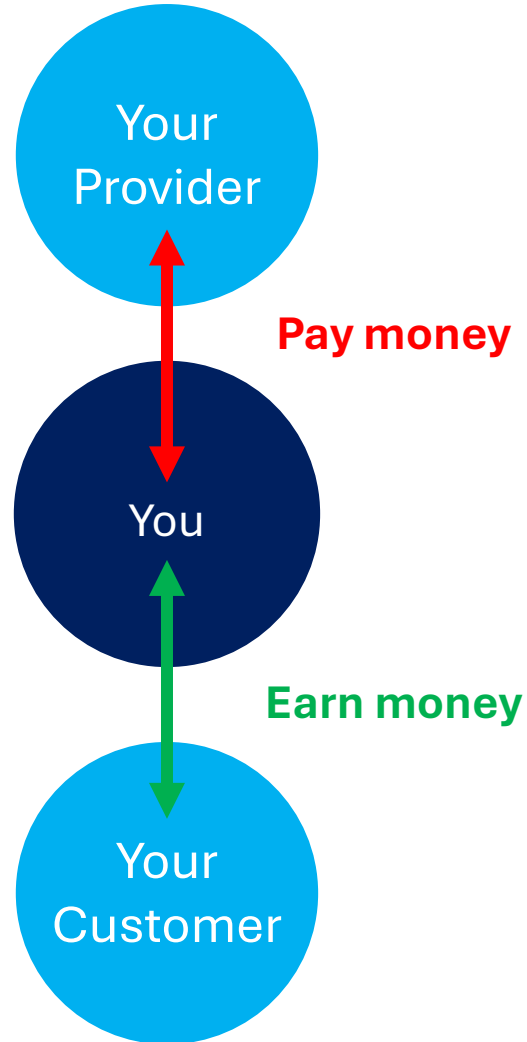
BGP business relationships

- Of course it is **money**



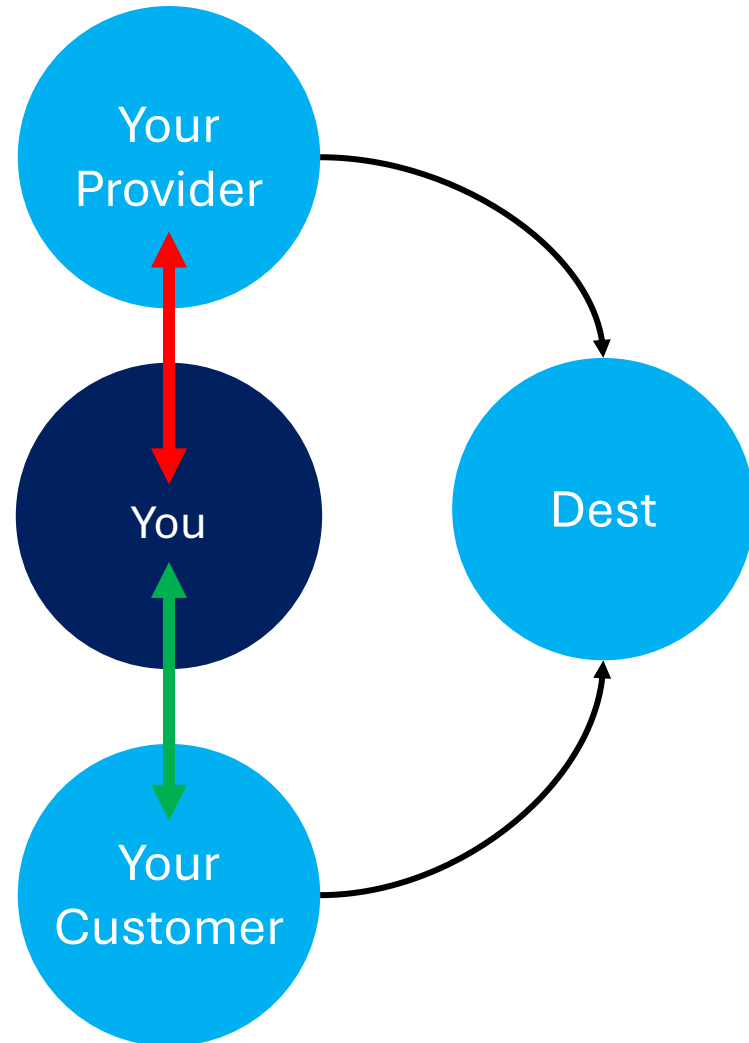
- More details in the lecture

BGP business relationships



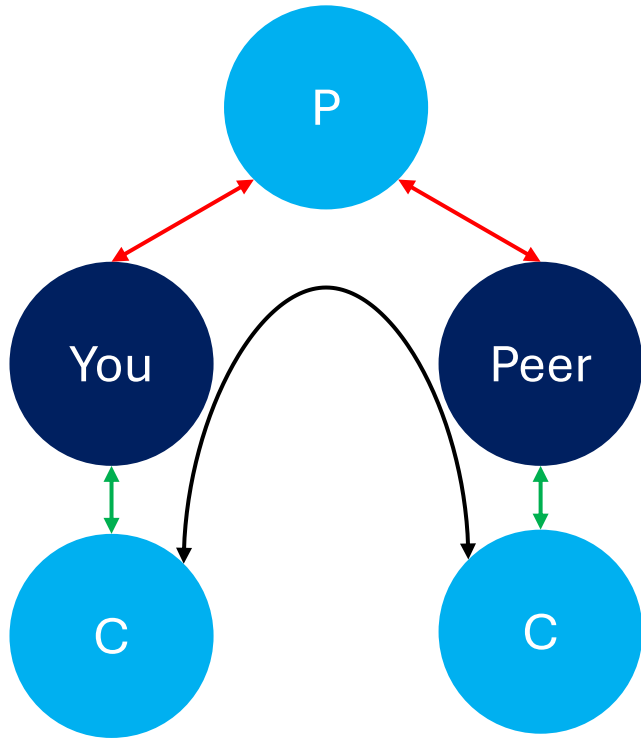
- In the real world you pay your provider for access
- Similarly your customers will pay you for access
- So if at all possible you want to send your traffic to your customer not to your provider, because that generates you money
- How?
Filtering advertisements and using local-pref

BGP business relationships

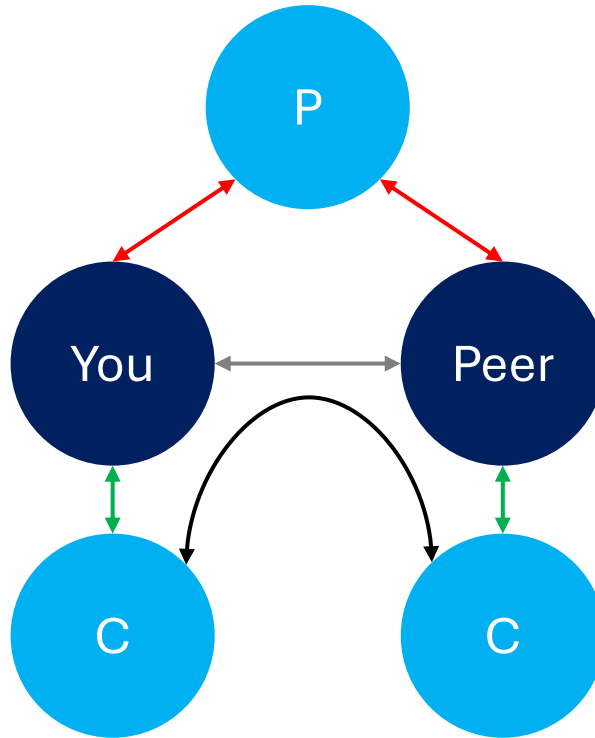


- Destination is reachable both through your provider as well as your customer
- Prefer the one that goes over your customer

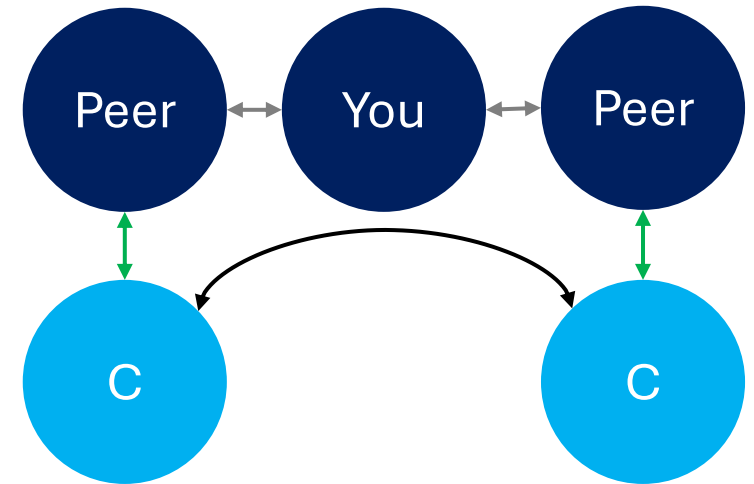
Peers exchange traffic for free out of common interest.



No Peering: You get paid by your customer but you also have to pay your provider



Good Peering: Your customer still pays, but you don't have to pay your provider



Bad Peering: You need to do work but don't get paid by anyone

How to enforce those rules

- **Outgoing traffic is determined by which incoming advertisements you select (route-map in)**

If you deny an advertisement, you cannot use that path.

For multiple paths, use local-pref to select the best.

- **Incoming traffic is determined by which selected advertisements you send out (route-map out)**

If you deny, others cannot use this path via your AS.

Remember that only the selected advertisements are considered.

Cheat sheet

import	local-pref
customer	high
peer	medium
provider	low

		<i>send to</i>		
	export	customer	peer	provider
<i>from</i>	customer	✓	✓	✓
	peer	✓	✗	✗
	provider	✓	✗	✗