

# Internet

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# Recap: Subnet and Gateway

## DNS request

dstmac 34:36:3b:d2:8a:89

dstip 8.8.8.8

payload What is the IP address  
of www.baidu.com?



34:36:3b:d2:8a:10

192.168.1.9

Subnet: 255.255.255.0

Default gateway: 192.168.1.1



34:36:3b:d2:8a:89

192.168.1.1

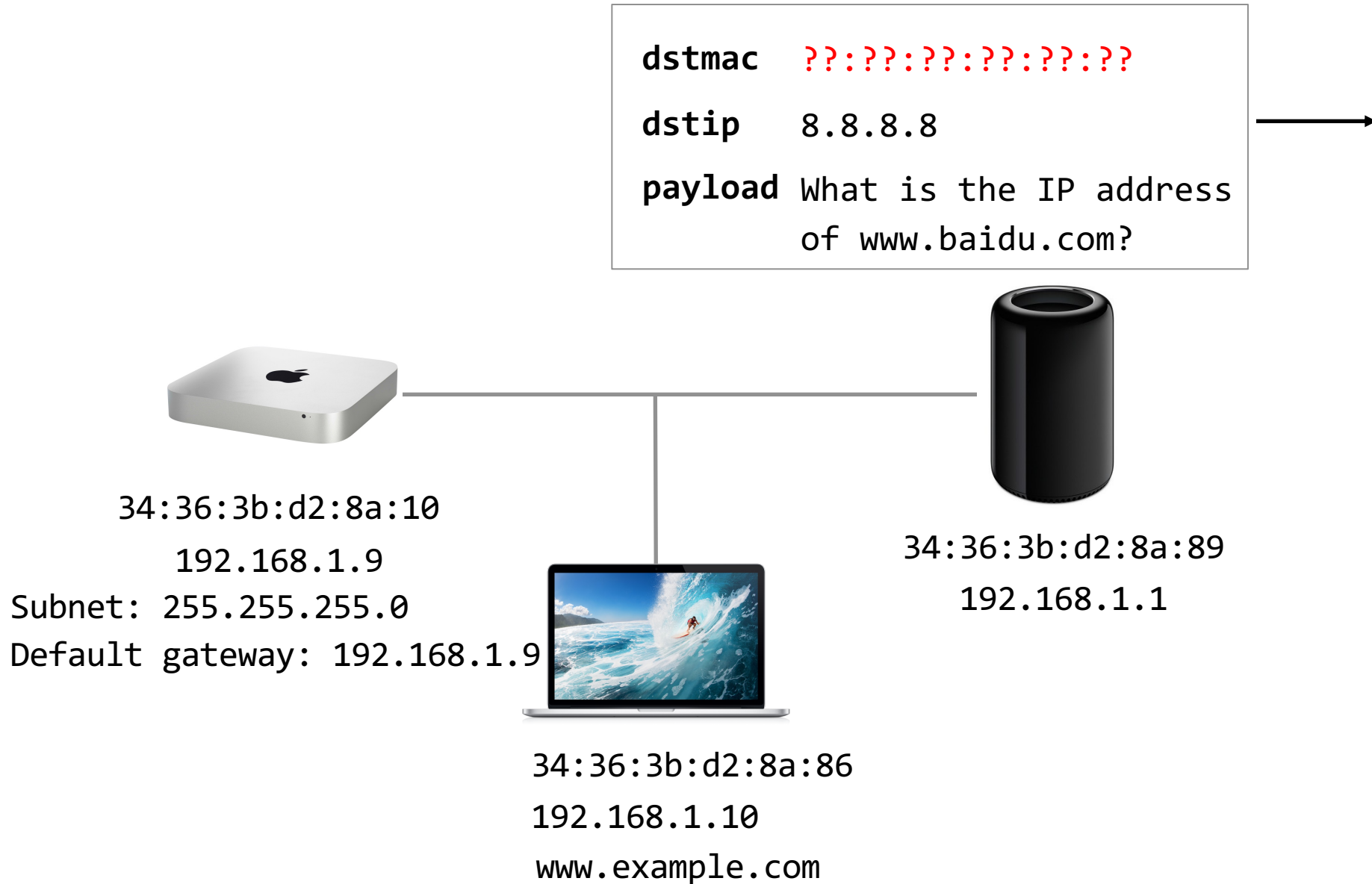


34:36:3b:d2:8a:86

192.168.1.10

www.example.com

# Time to Reach Internet



# Internet

# What is “Internet”

- World Wide Web?

- Locating information through URLs  
([www.example.com](http://www.example.com))
- Invented in 1989



- All computers/mobile devices connected?

- Network
- Why “inter”?

# What is “Internet”

“The Internet (or internet) is the global system of **interconnected computer networks** that uses the Internet protocol suite (TCP/IP) to communicate between networks and devices. ”

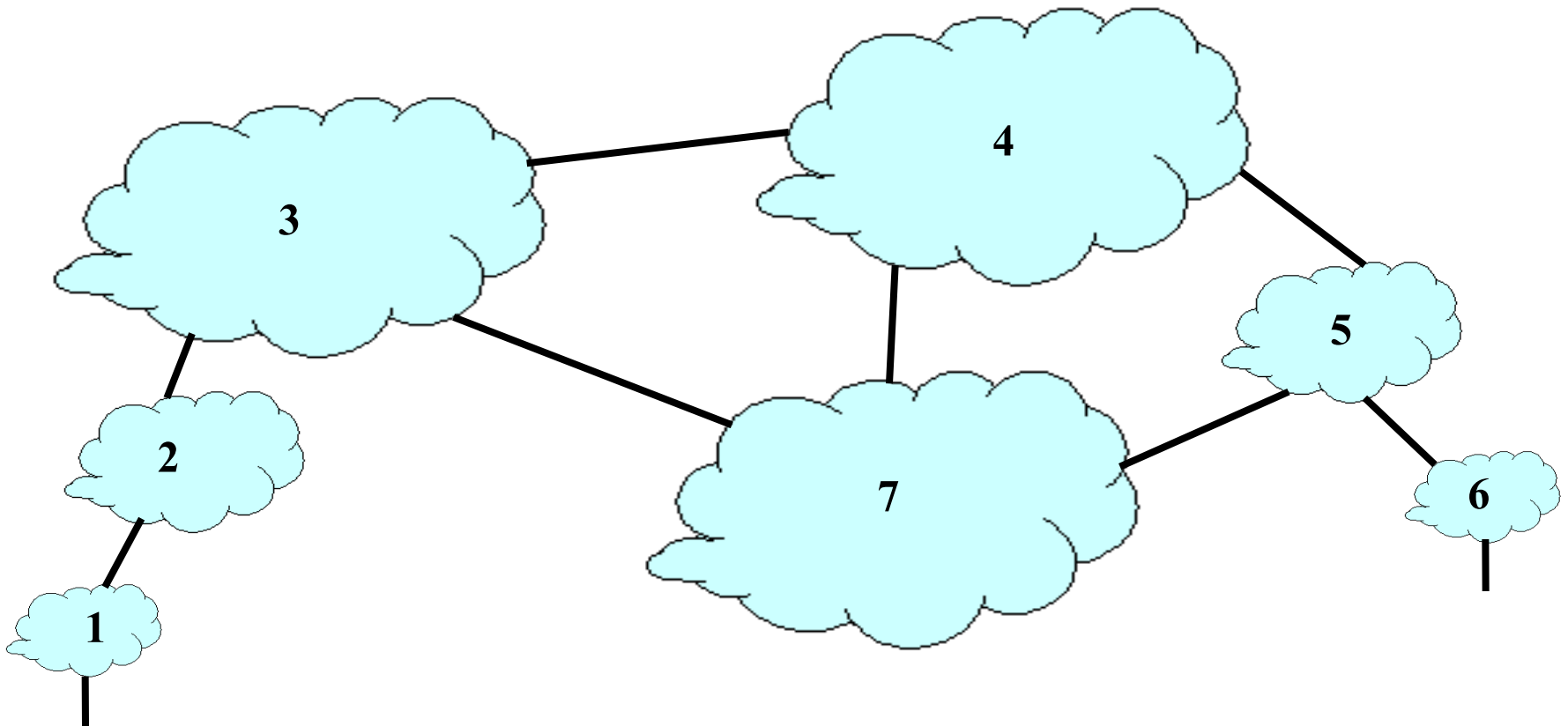
- Wikipedia

# What is “Internet”

- Internet is “a network of networks”
  - Campus networks (XJTU, Tsinghua, ...)
  - Enterprise networks (Google, Tencent, ...)
  - Internet service providers (China Mobile, China Unicom, ...)
  - ...
- Each network is owned and managed by some organization, and connected together

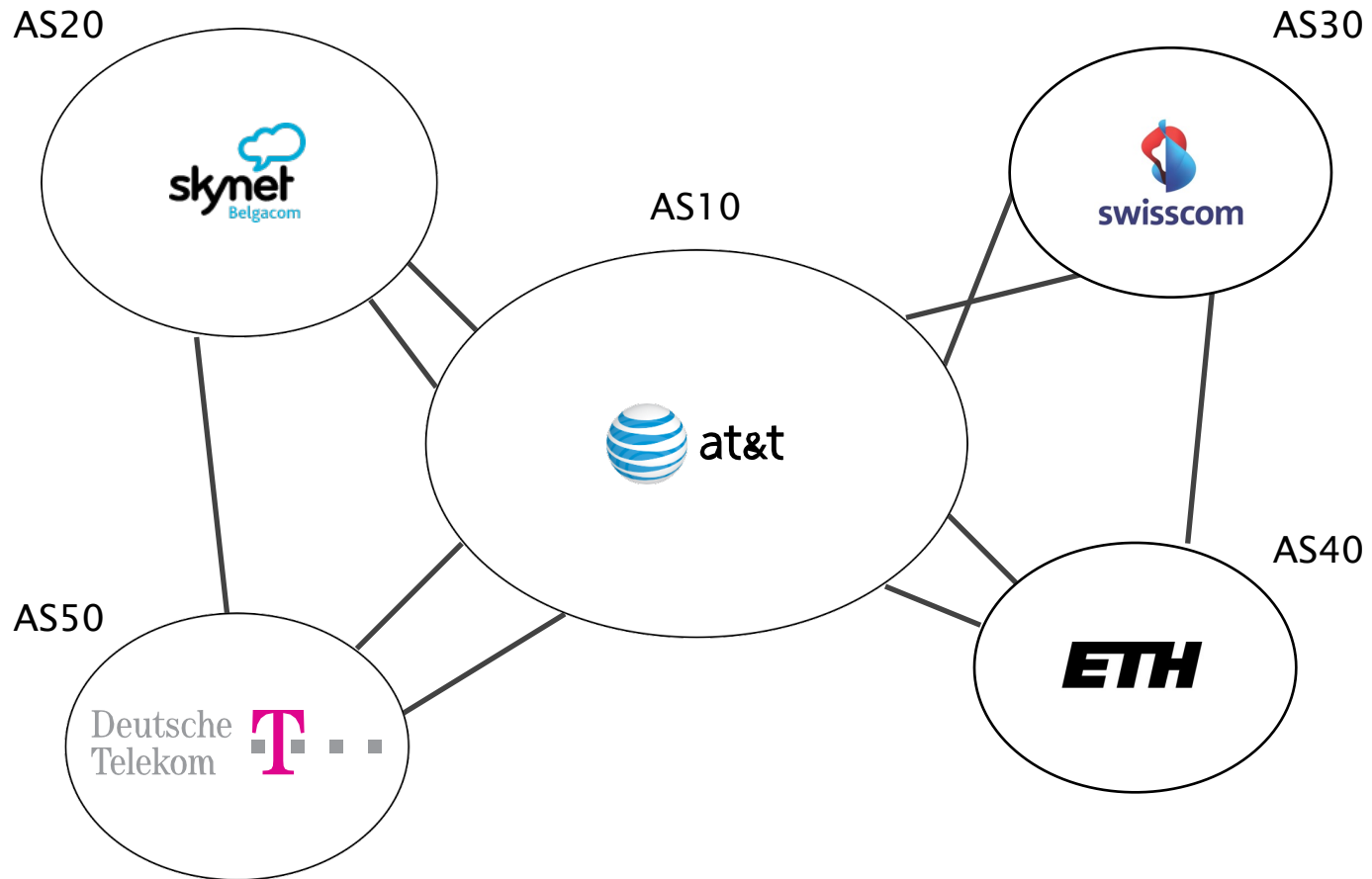
# Autonomous Systems

- Internet is divided into **Autonomous Systems**
  - Node: Autonomous System (AS)
  - Edge: Two ASes connect to each other

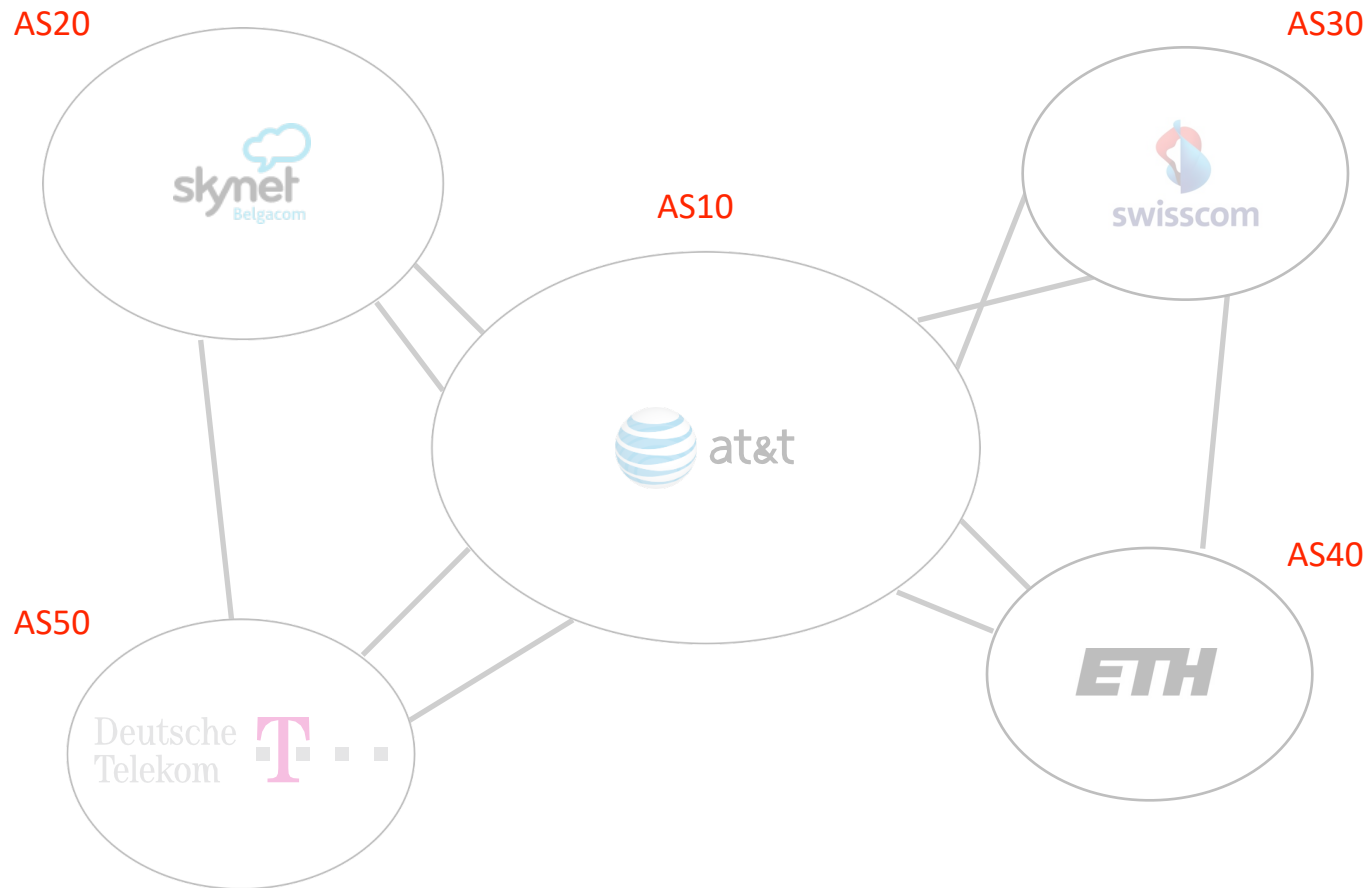




# Example



# Example



# Autonomous System Numbers

**AS Numbers are 16 bit values.**

**Currently just over 20,000 in use.**

- **Level 3: 1**
- **MIT: 3**
- **Harvard: 11**
- **Yale: 29**
- **AT&T: 7018, 6341, 5074, ...**
- **CERNET (China Education and Research Network): 4538, 4789, 4839, 3840, ...**

Check it yourself at <https://www.ultratools.com/tools/asnInfo>

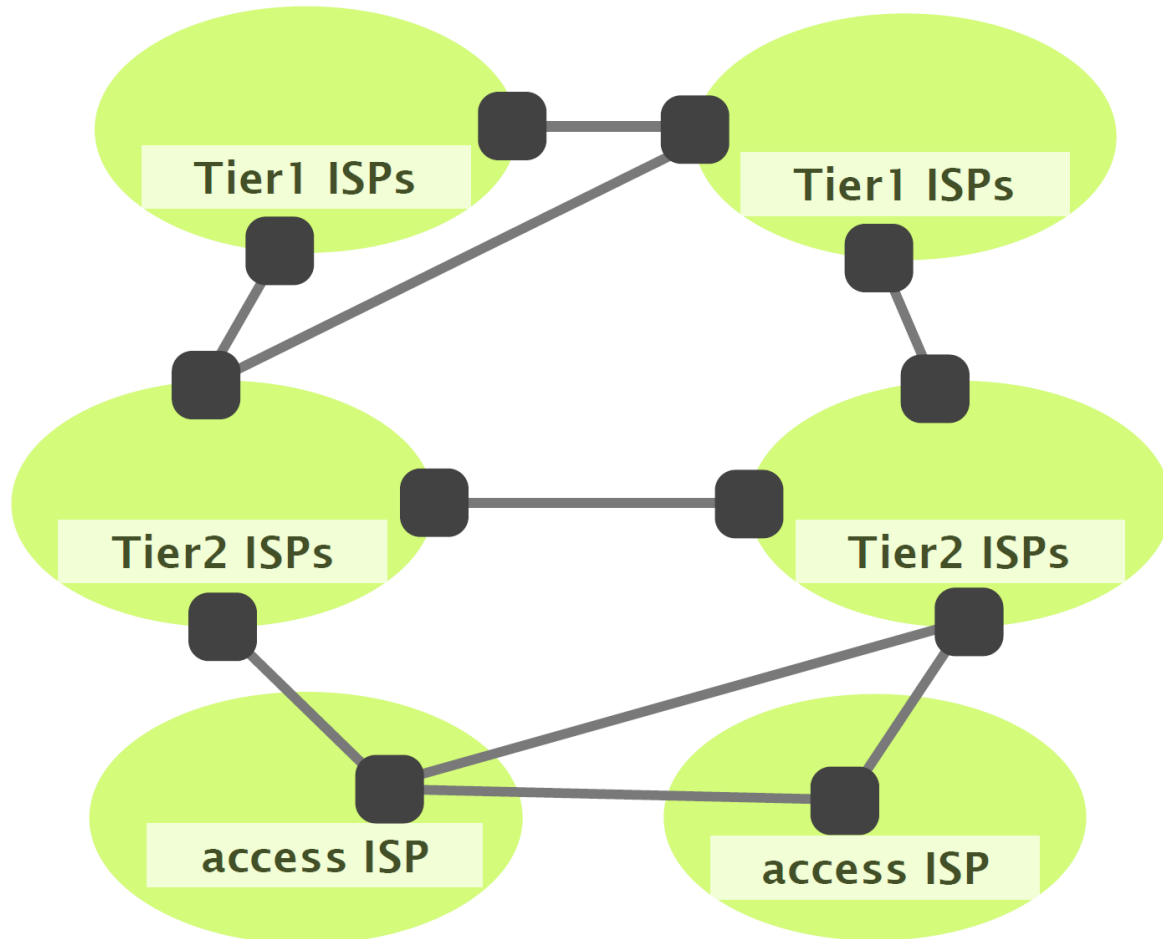
# Internet Service Provider (ISP)

- An **Internet service provider (ISP)** is an organization that provides services for connecting to the Internet



- An ISP can have multiple ASes
  - China telecom: 4812, 4813, 4815, 4816, ...

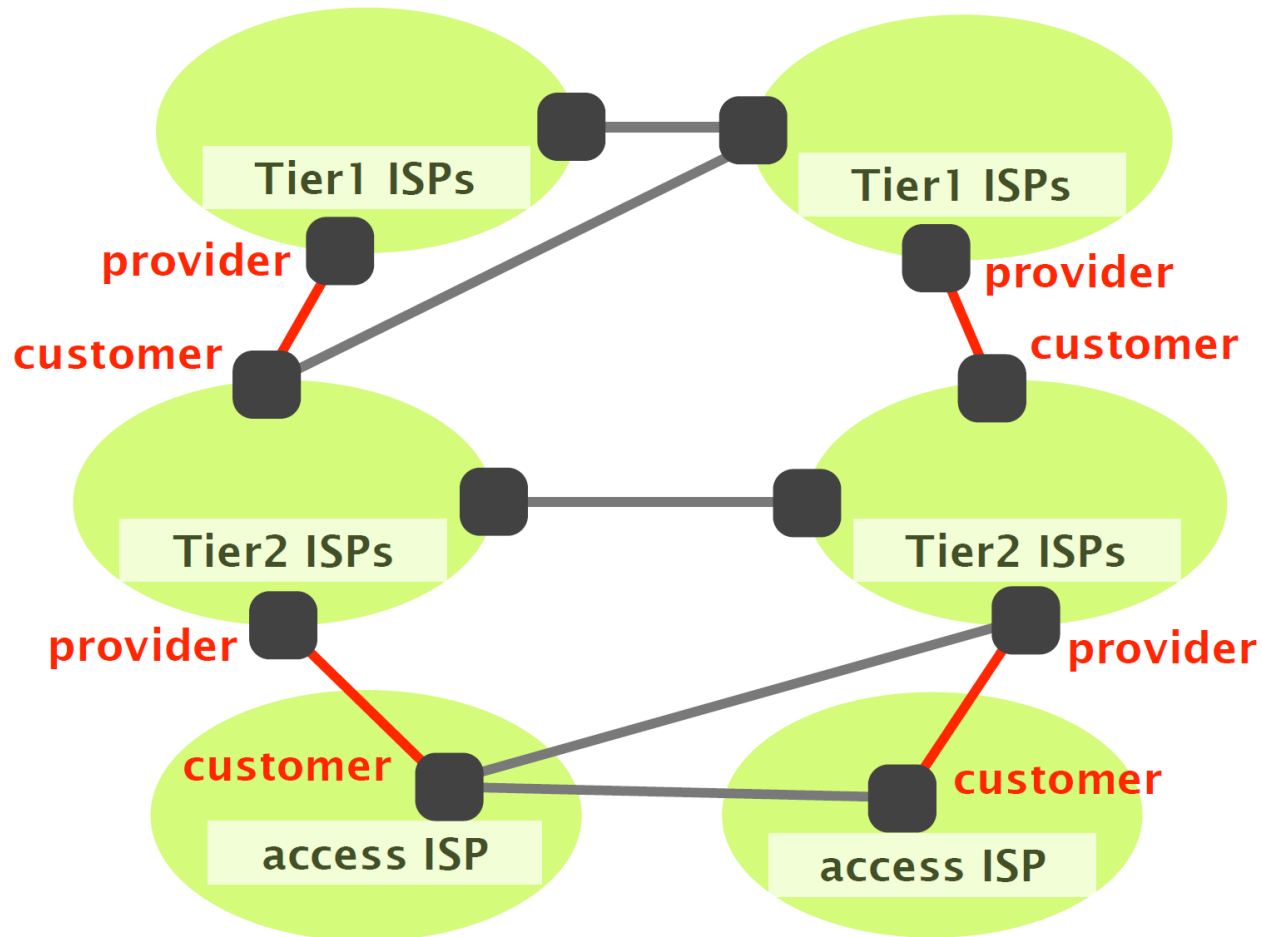
# Tiers of ISPs



# Business Relationships

- **Neighboring ASes have business contracts**
  - How much traffic to carry
  - Which destinations to reach
  - How much money to pay
- **Common business relationships**
  - Customer-provider:
  - Peer-peer: Princeton is a peer of Patriot Media, AT&T is a peer of Sprint

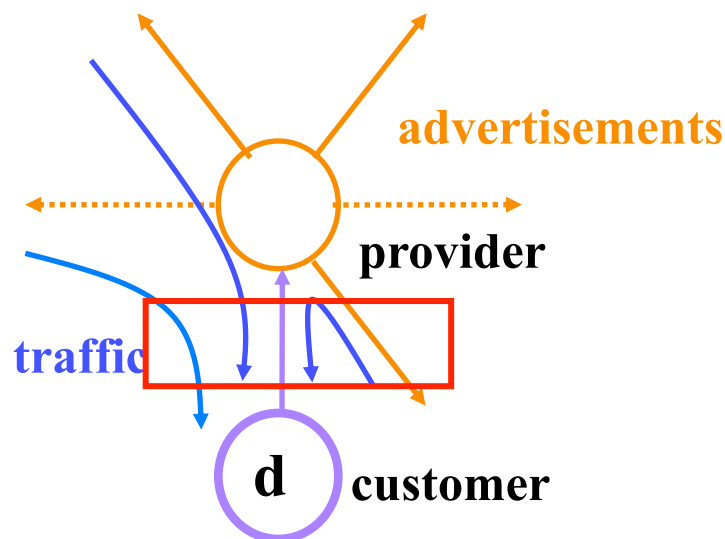
# Customer-Provider Relationship



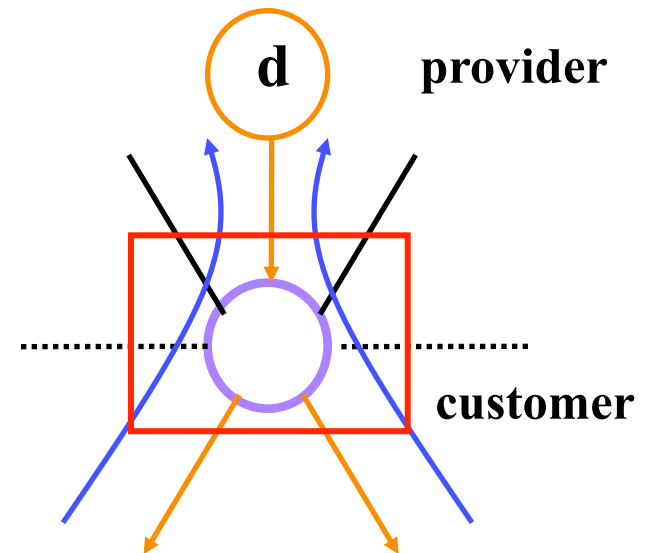
# Customer-Provider Relationship

- Customer needs to be reachable from everyone
  - Provider tells all neighbors how to reach the customer
- Customer does not want to provide transit service
  - Customer does not let its providers route through it

## Traffic to the customer

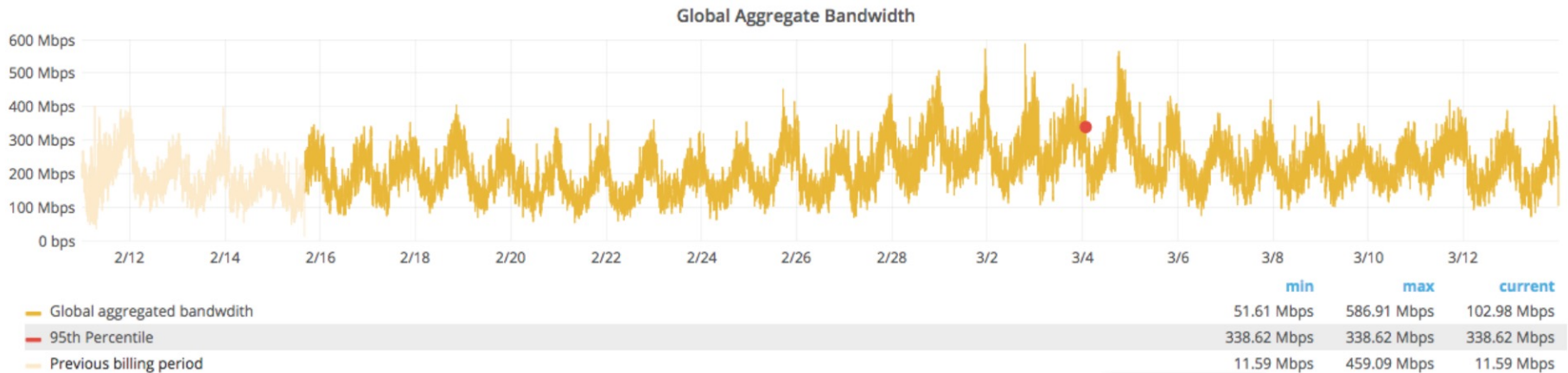


## Traffic from the customer





# How to bill?

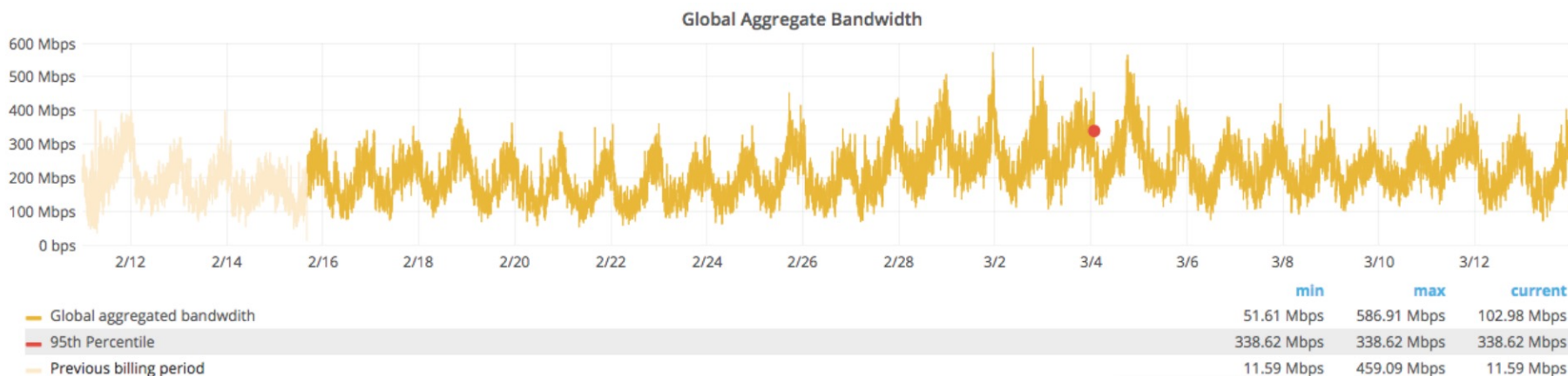


- Burstable billing method: bill based on peak bandwidth use
- Most ISPs use a five-minute sampling and 95% usage when calculating usage.

[https://en.wikipedia.org/wiki/Burstable\\_billing](https://en.wikipedia.org/wiki/Burstable_billing)

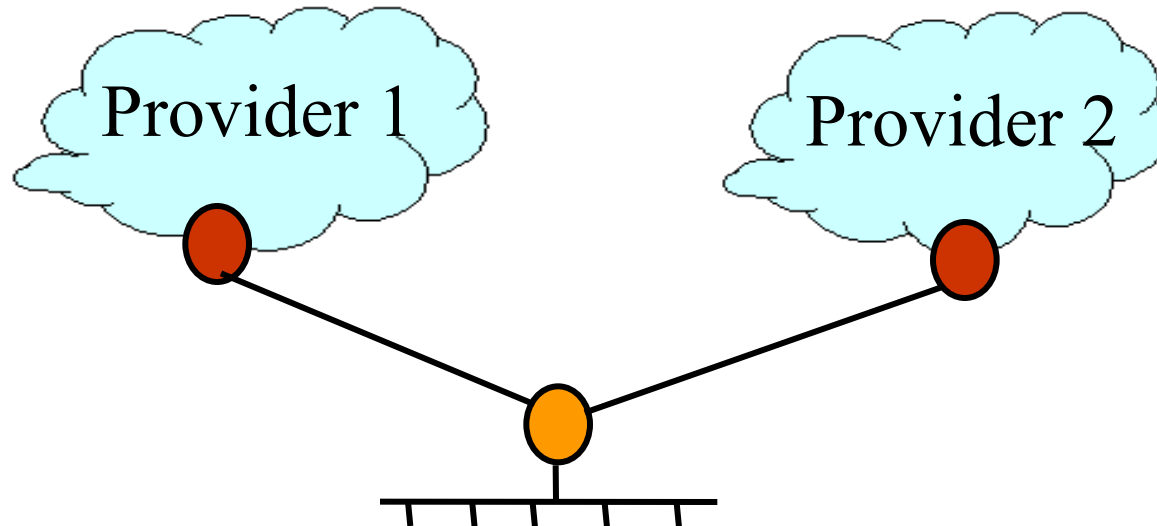
# The 95<sup>th</sup>-percentile billing model

1. Bandwidth is measured and recorded in a log file. In most cases, this is done every 5 minutes
2. At the end of the month, the samples are sorted from highest to lowest, and the top 5% of data is thrown away
3. The next highest measurement becomes the *billable use* for the entire month



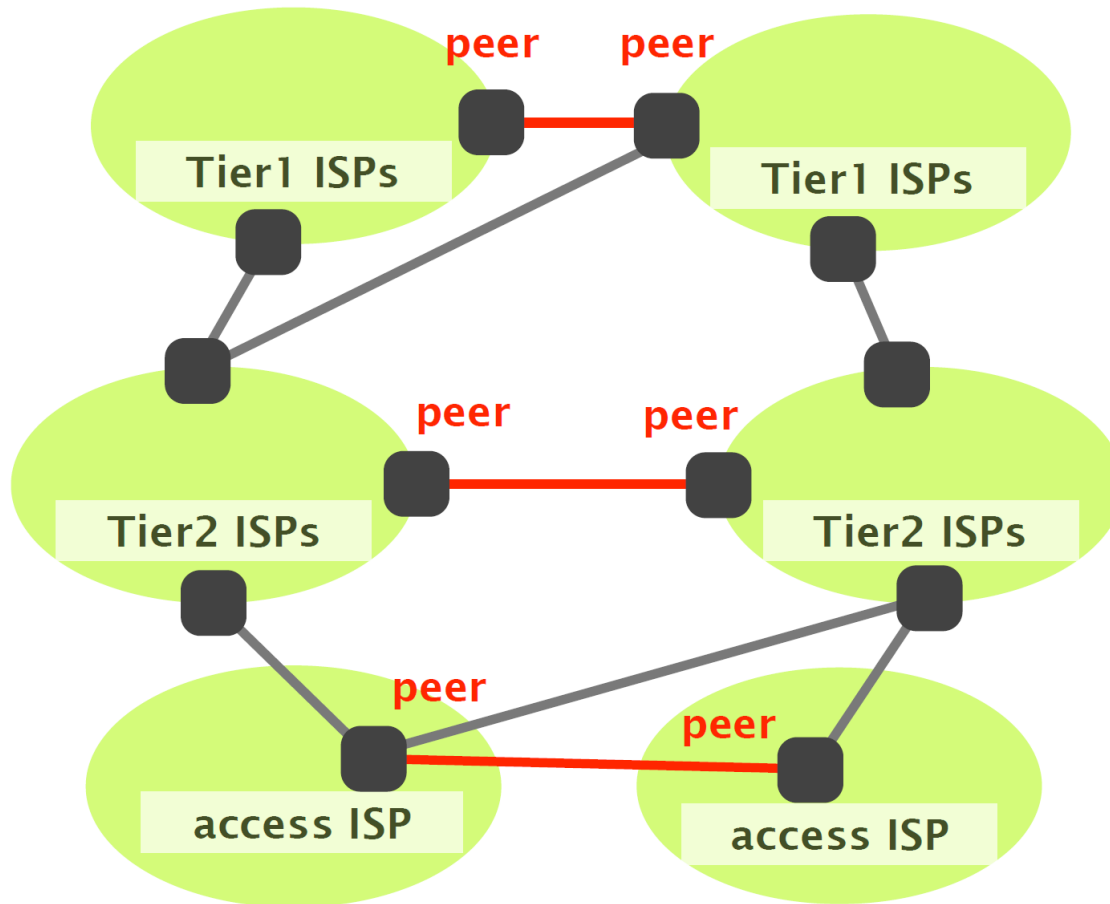
# Multi-Homing: Two or More Providers

- Motivations for multi-homing
  - Higher reliability, survive single ISP failure
  - Better performance by selecting better path
  - Financial leverage through competition
  - Gaming the 95<sup>th</sup>-percentile billing model



# Peer-Peer Relationship

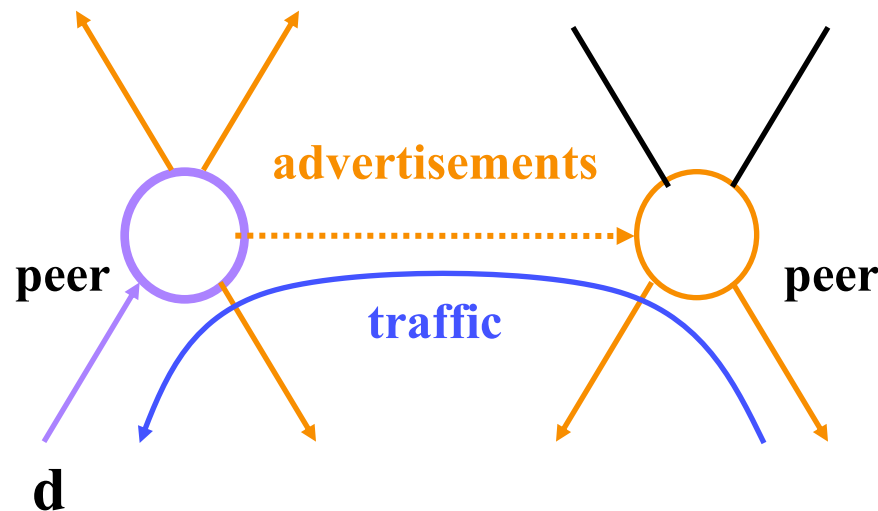
- Some networks have an incentive to connect directly, to reduce their bill with their own provider



# Peer-Peer Relationship

- Peers exchange traffic between customers
  - AS exports only customer routes to a peer
  - AS exports a peer's routes only to its customers
  - Often the relationship is settlement-free (i.e., no \$\$\$)

## Traffic to/from the peer and its customers

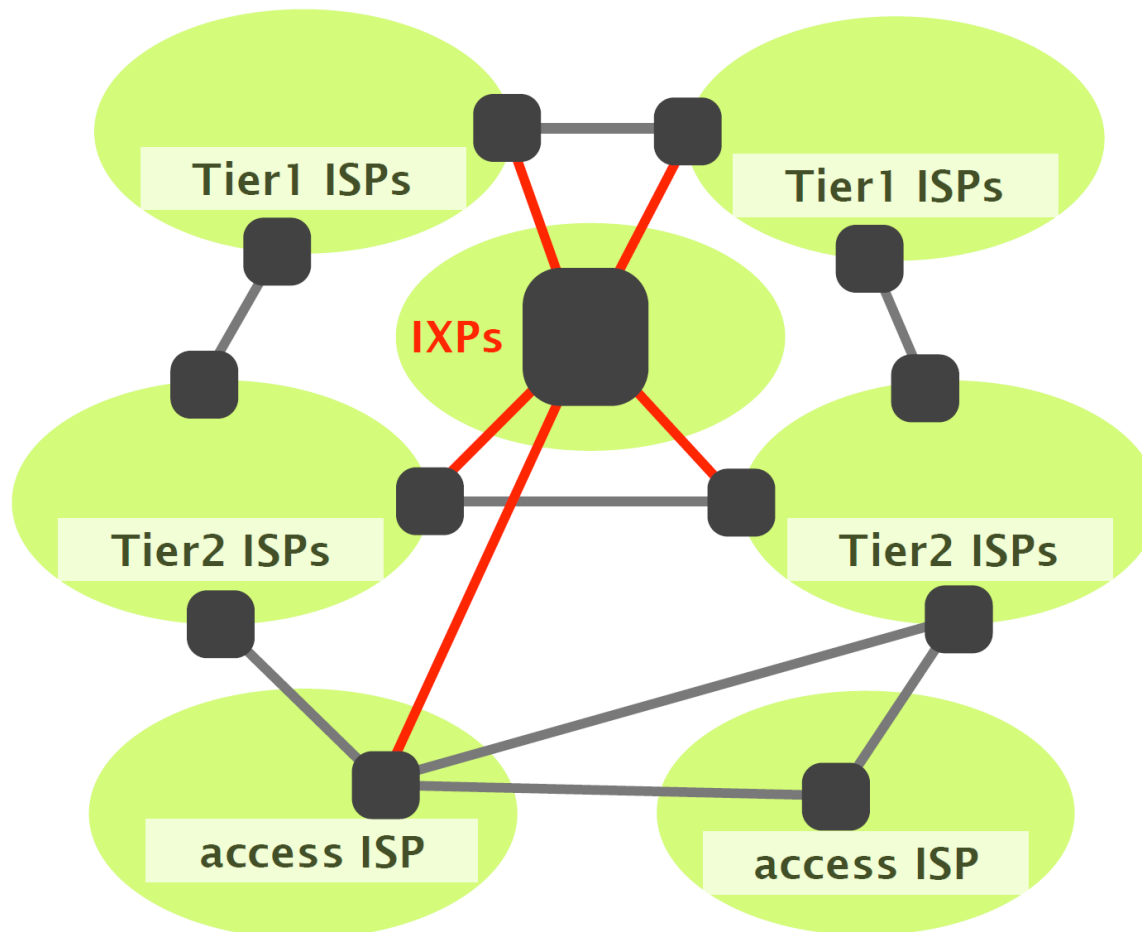


# How to connect ASes?

- Interconnecting each network to its neighbors one-by-one is not cost effective
  - Physical costs of provisioning or renting physical links
  - Bandwidth costs a lot of links are not necessarily fully utilized
  - Human costs to manage each connection individually

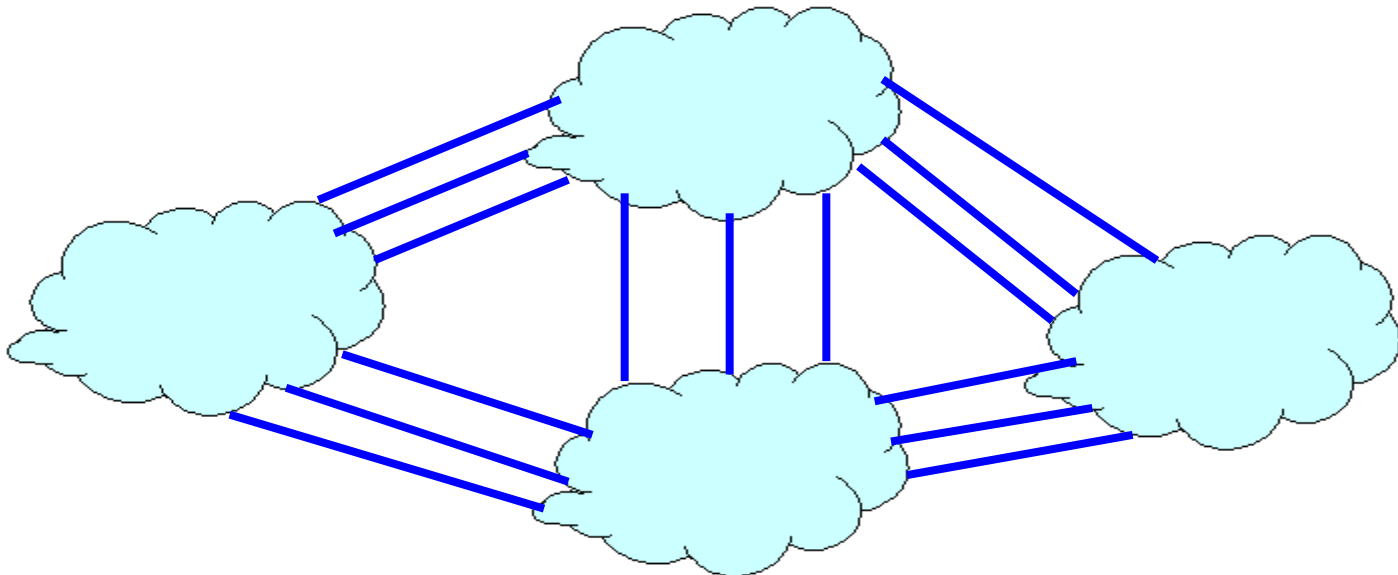
# Internet eXchange Points (IXPs)

- Many networks connect in one location



# Tier-1 Providers

- **Tier-1 provider**
  - Has no upstream provider of its own
  - Typically has a national or international backbone
  - Level 3, Verizon, Sprint, AT&T, Orange, Tata...
- **Top of the Internet hierarchy of 12-20 ASes**
  - Full peer-peer connections between tier-1 providers





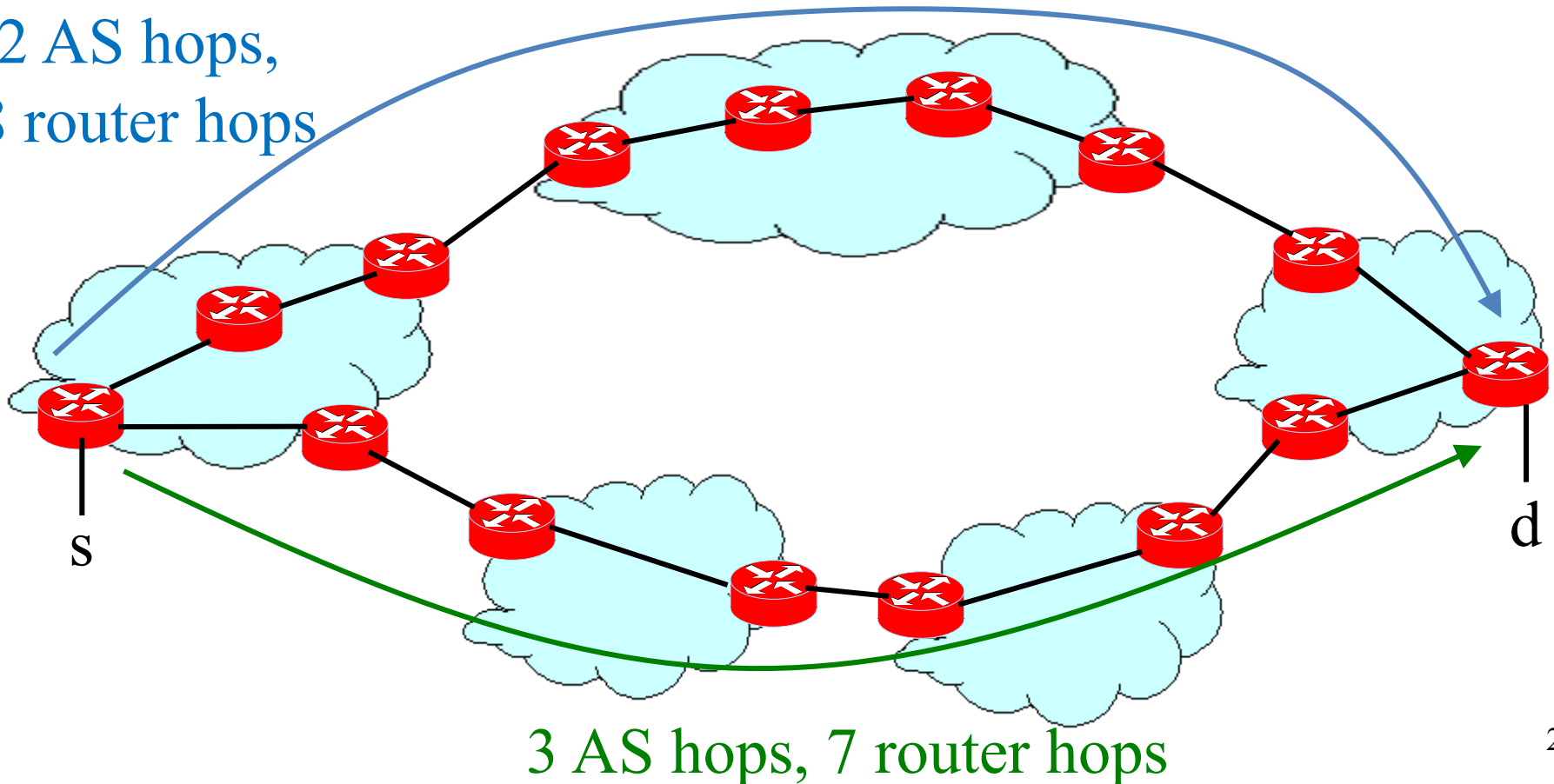
# Other ASes

- Tier-2 providers
  - Provide transit service to downstream customers
  - ... but, need at least one provider of their own
  - Typically have national or regional scope
- Stub ASes
  - Do not provide transit service to others
  - Connect to one or more upstream providers
  - Includes vast majority (e.g., 85-90%) of the ASes

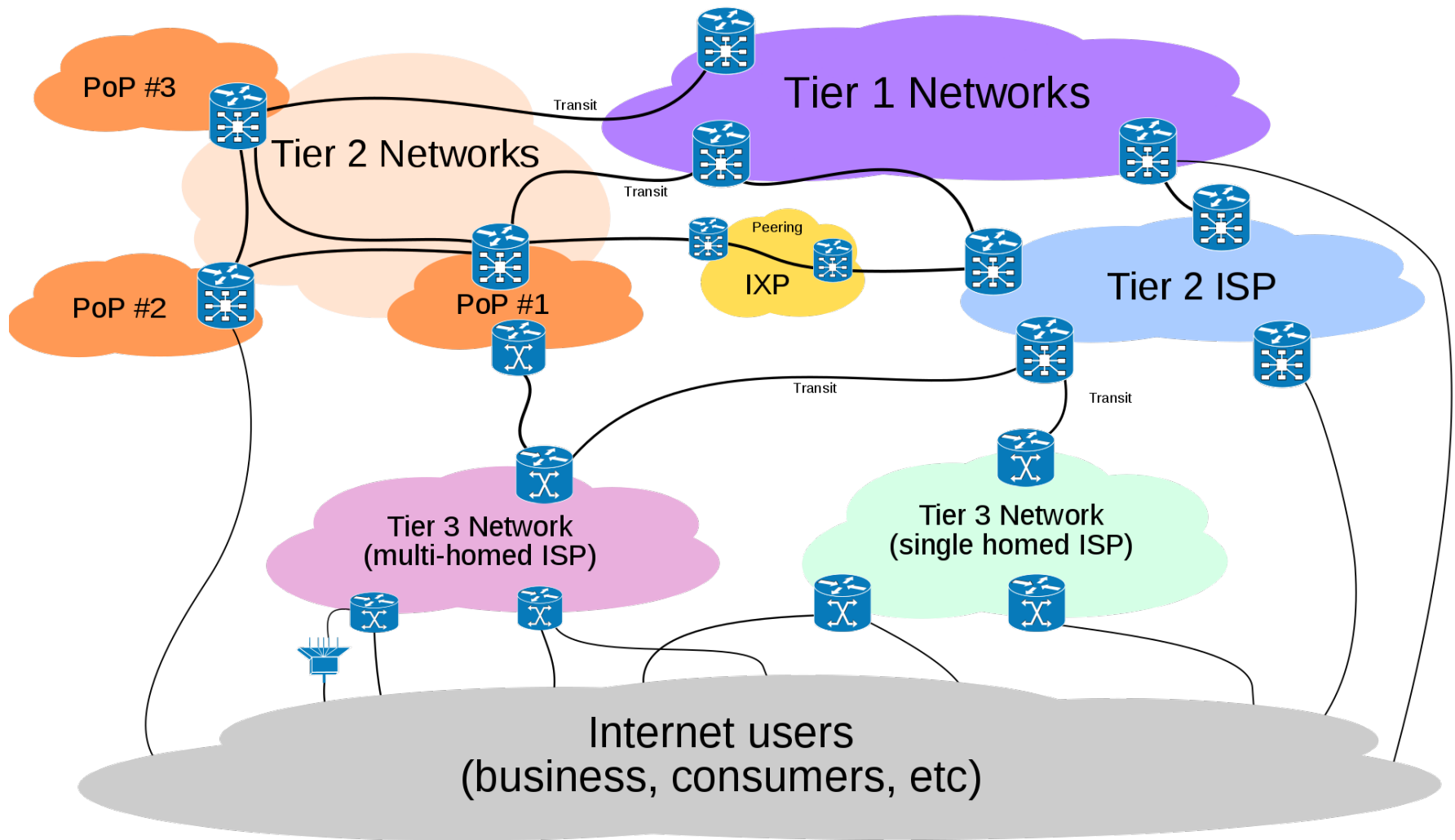
# Characteristics of AS Paths

- AS path may be longer than shortest AS path
- Router path may be longer than shortest path

2 AS hops,  
8 router hops




# A Review of Internet Connectivity



# Routing

*intra-* and *inter-domain* routing



inter-domain  
routing

Find paths between networks

intra-domain  
routing

Find paths within a network

# Routing

inter-domain  
routing

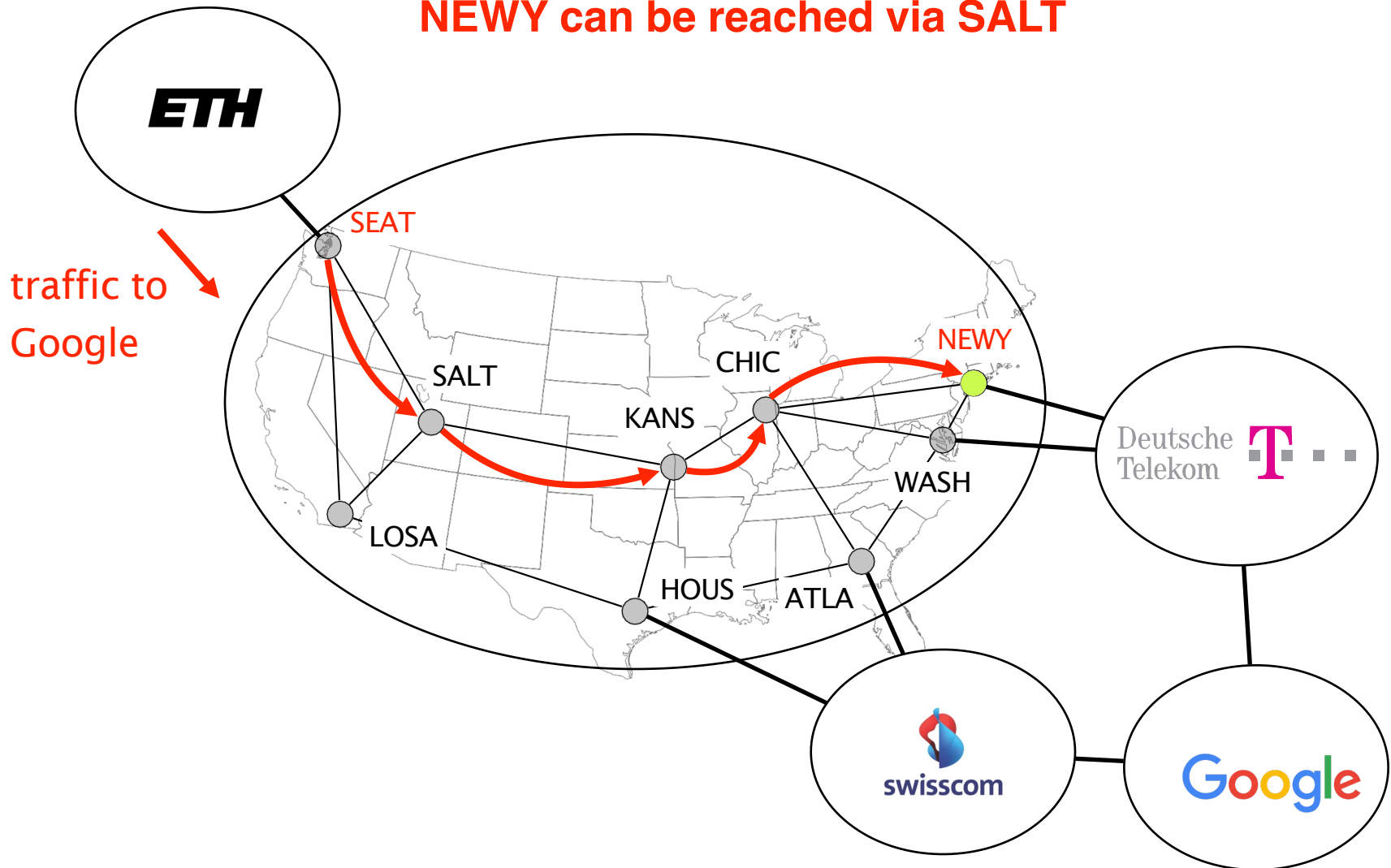
intra-domain  
routing

Find paths **within** a network


OSPF, ISIS, RIP, ...

# Intra Domain Routing

**NEWY can be reached via SALT**



# Inter Domain Routing



inter-domain  
routing

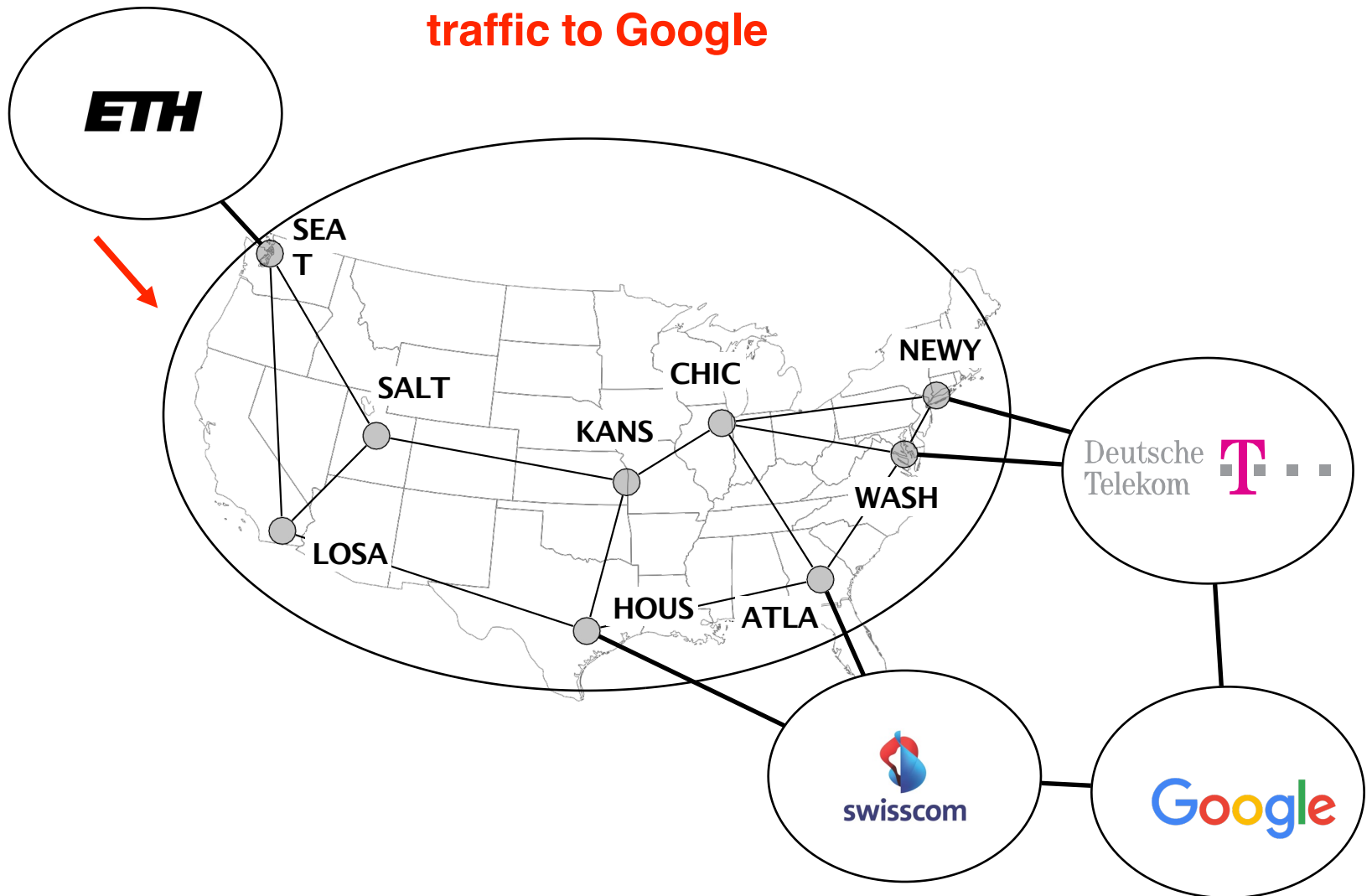
The diagram consists of two rectangular boxes. The left box is light green and contains the text 'inter-domain routing'. The right box is light orange and contains the text 'intra-domain routing'. Both boxes have a thin black border.

intra-domain  
routing

Find paths **between** networks

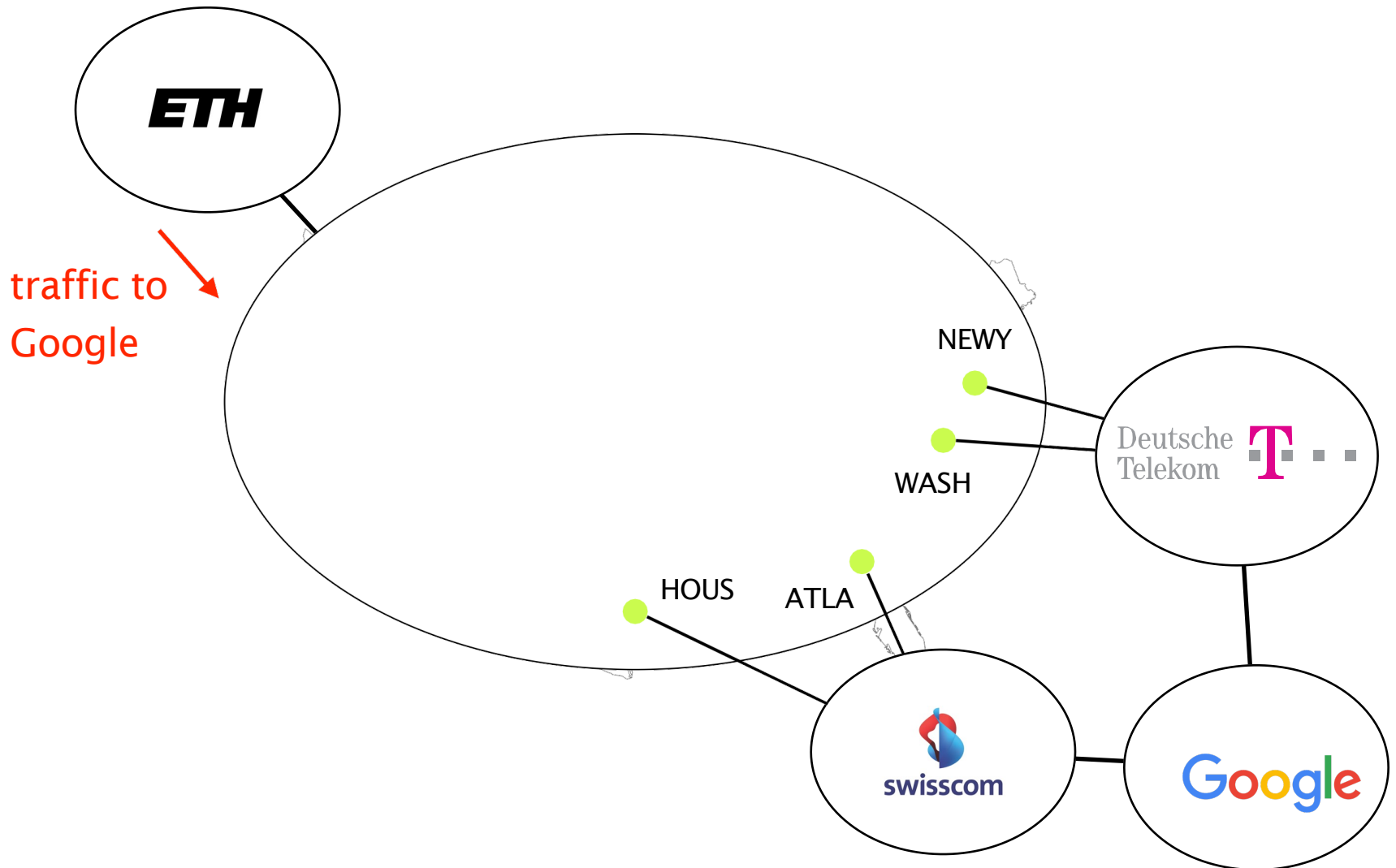
BGP, BGP, BGP !

# Inter Domain Routing





# Inter Domain Routing



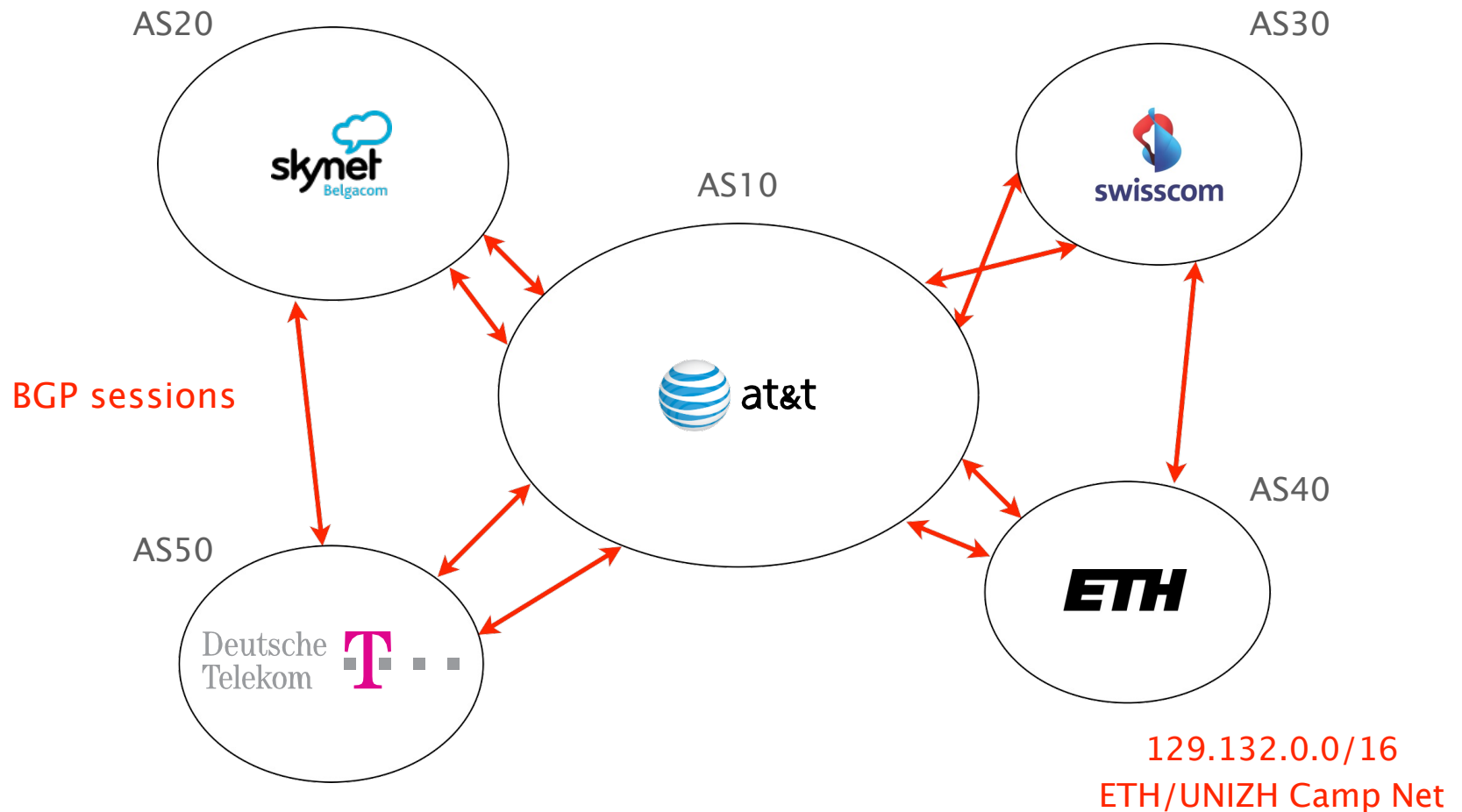
# Inter Domain Routing

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

best exit point

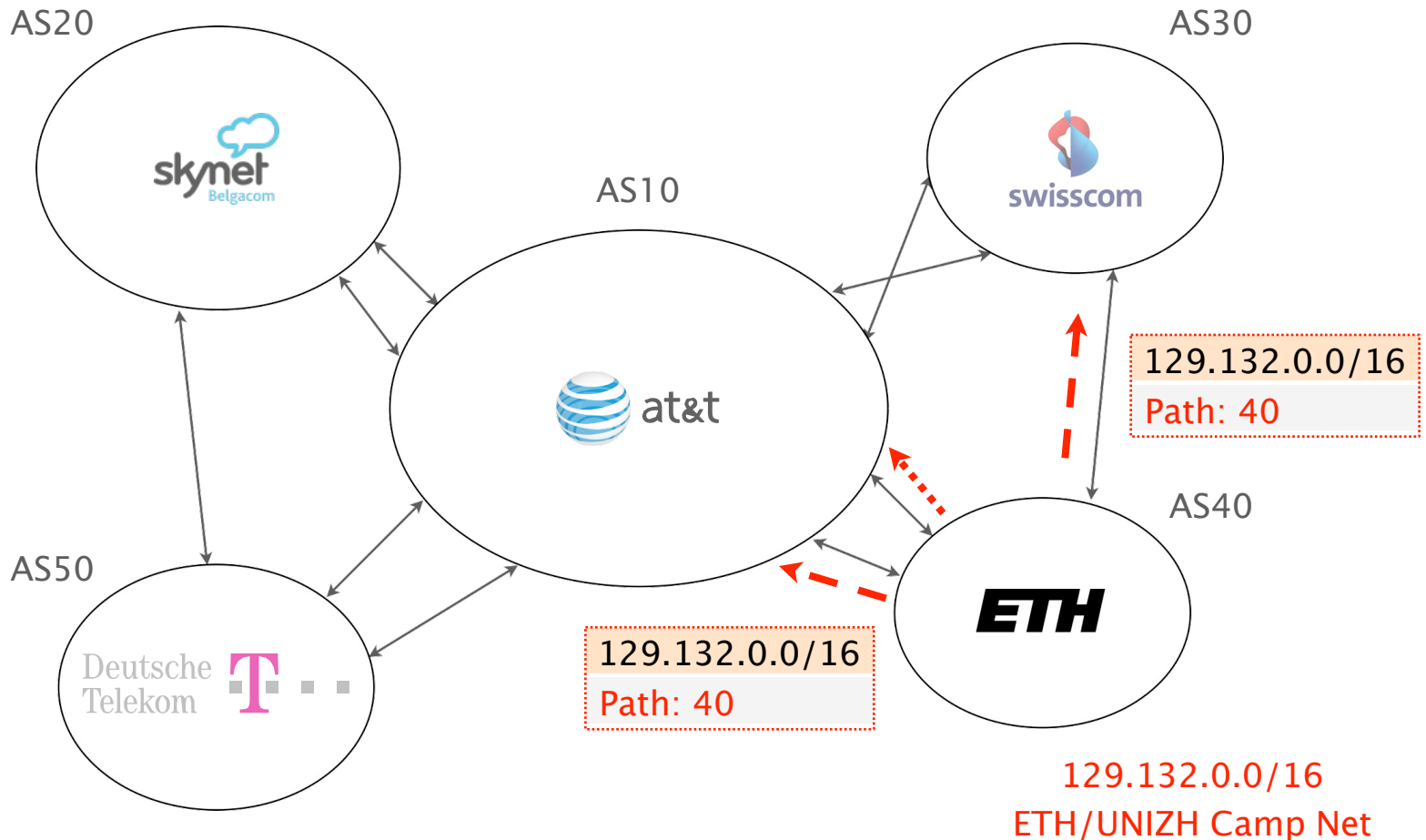
based on money,  
performance, ...

# Example



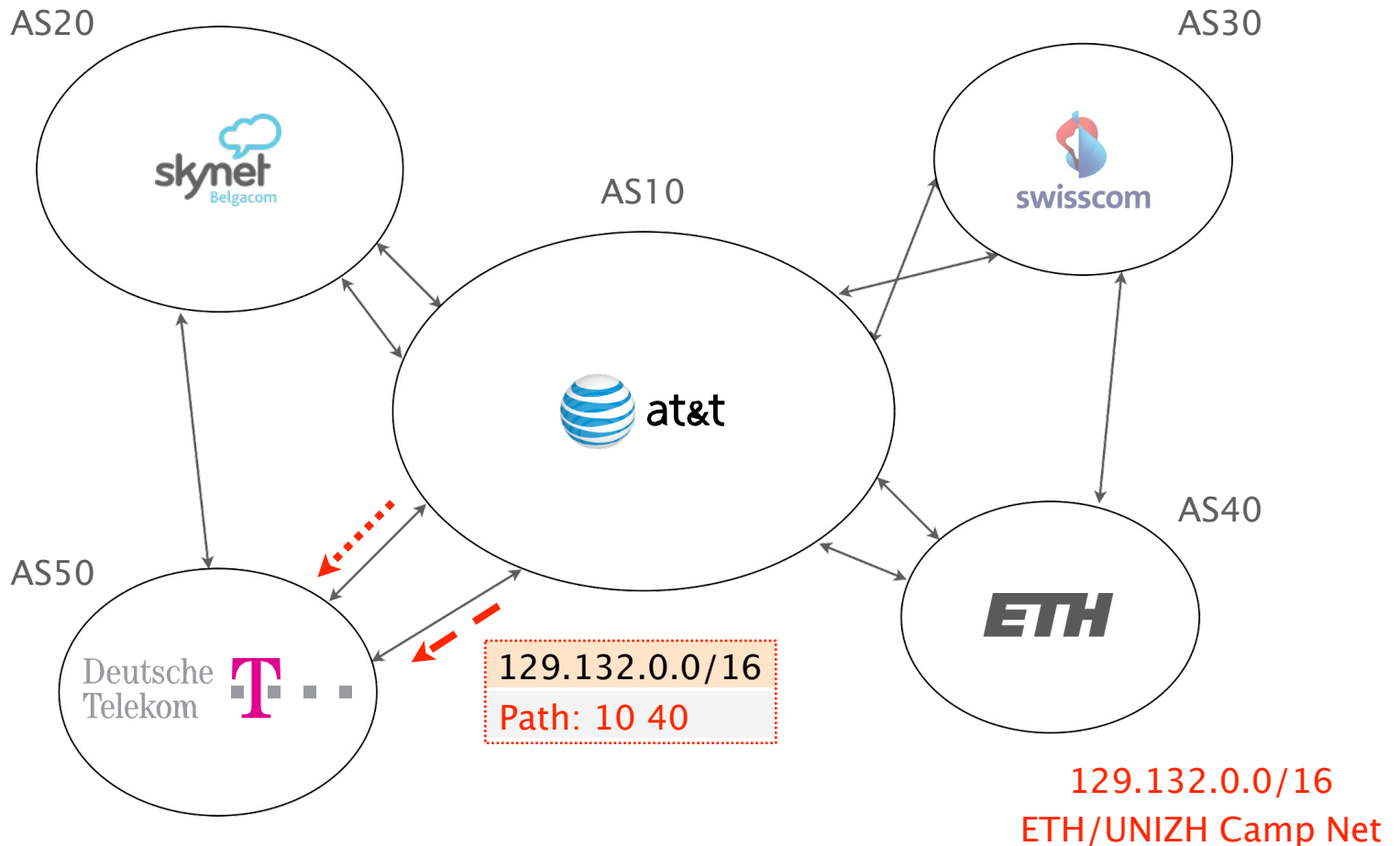
# BGP is Path Vector Protocol

BGP announcements carry complete path information instead of distances



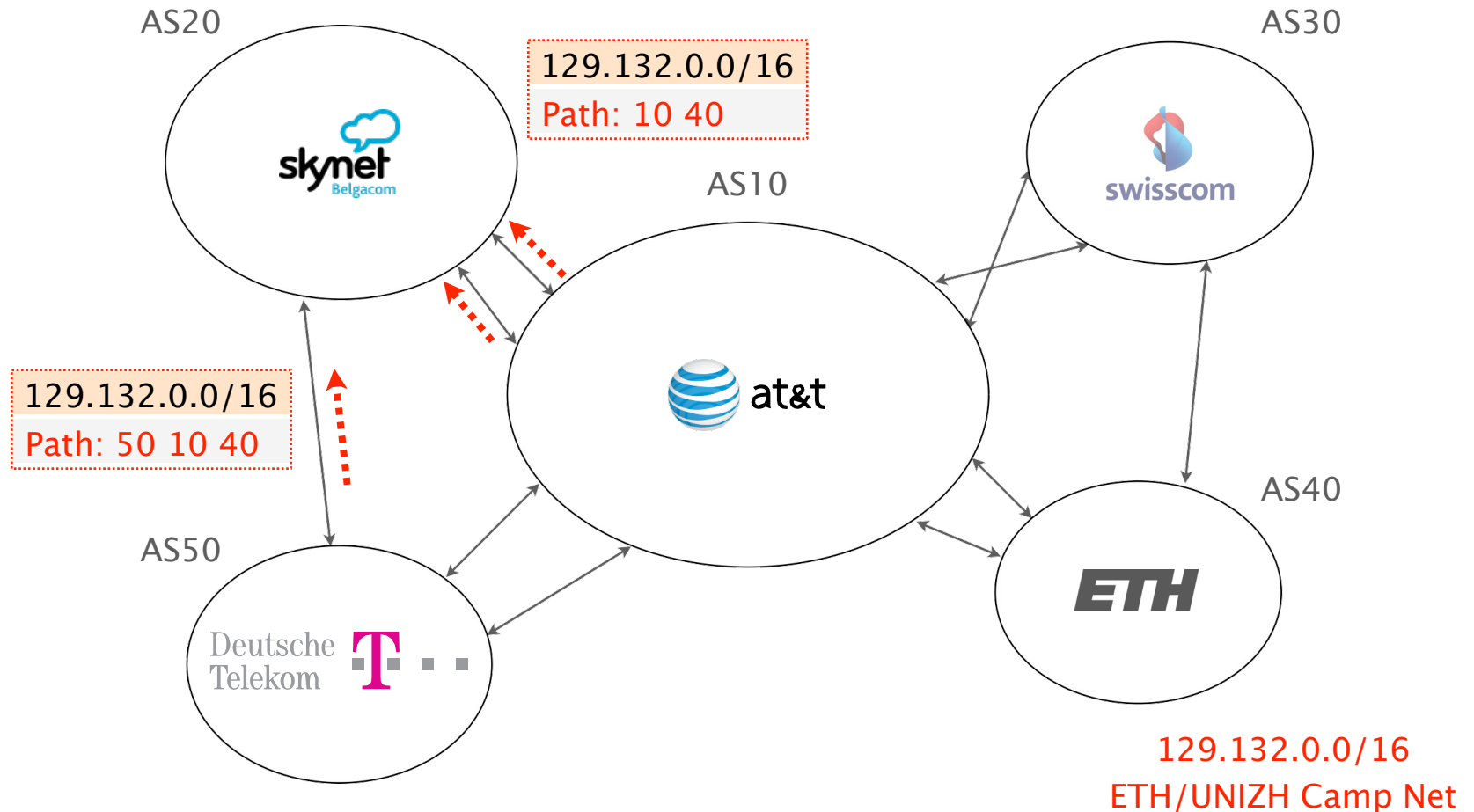
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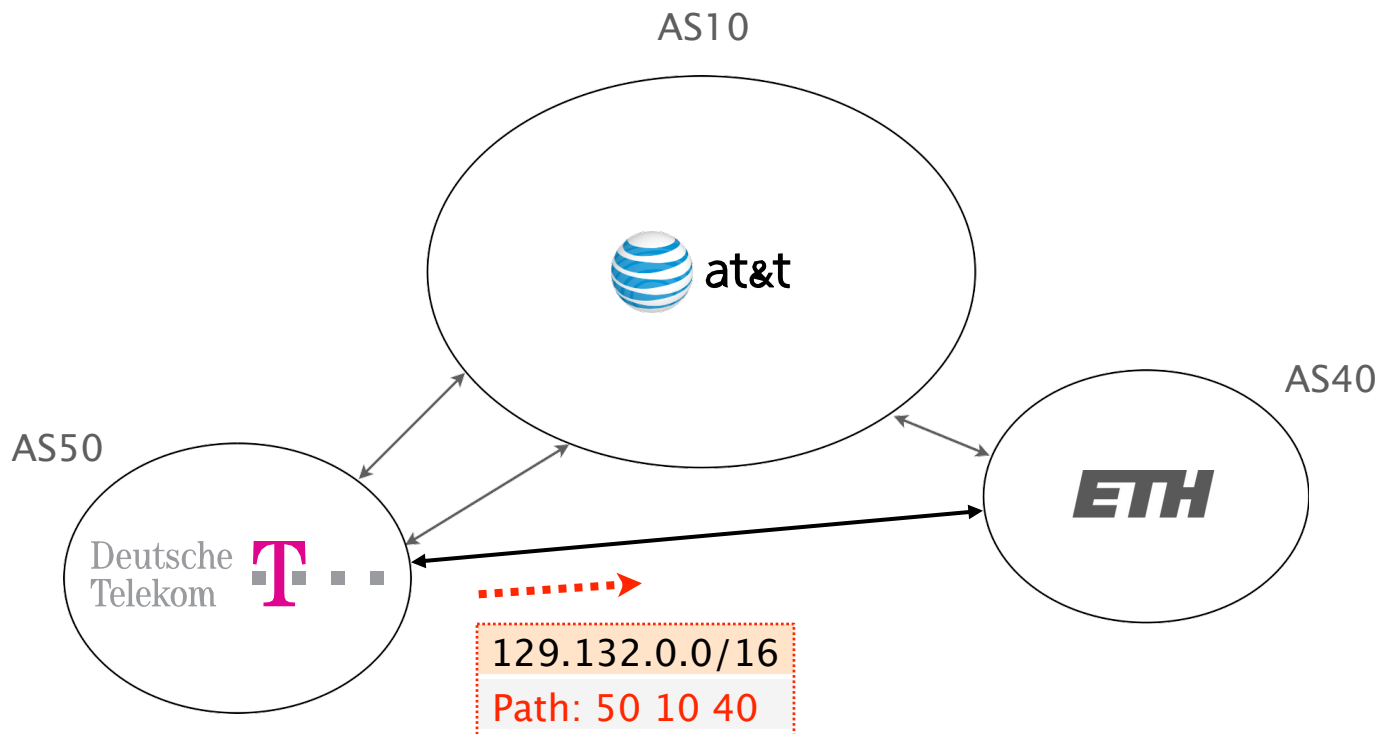
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# BGP is Path Vector Protocol

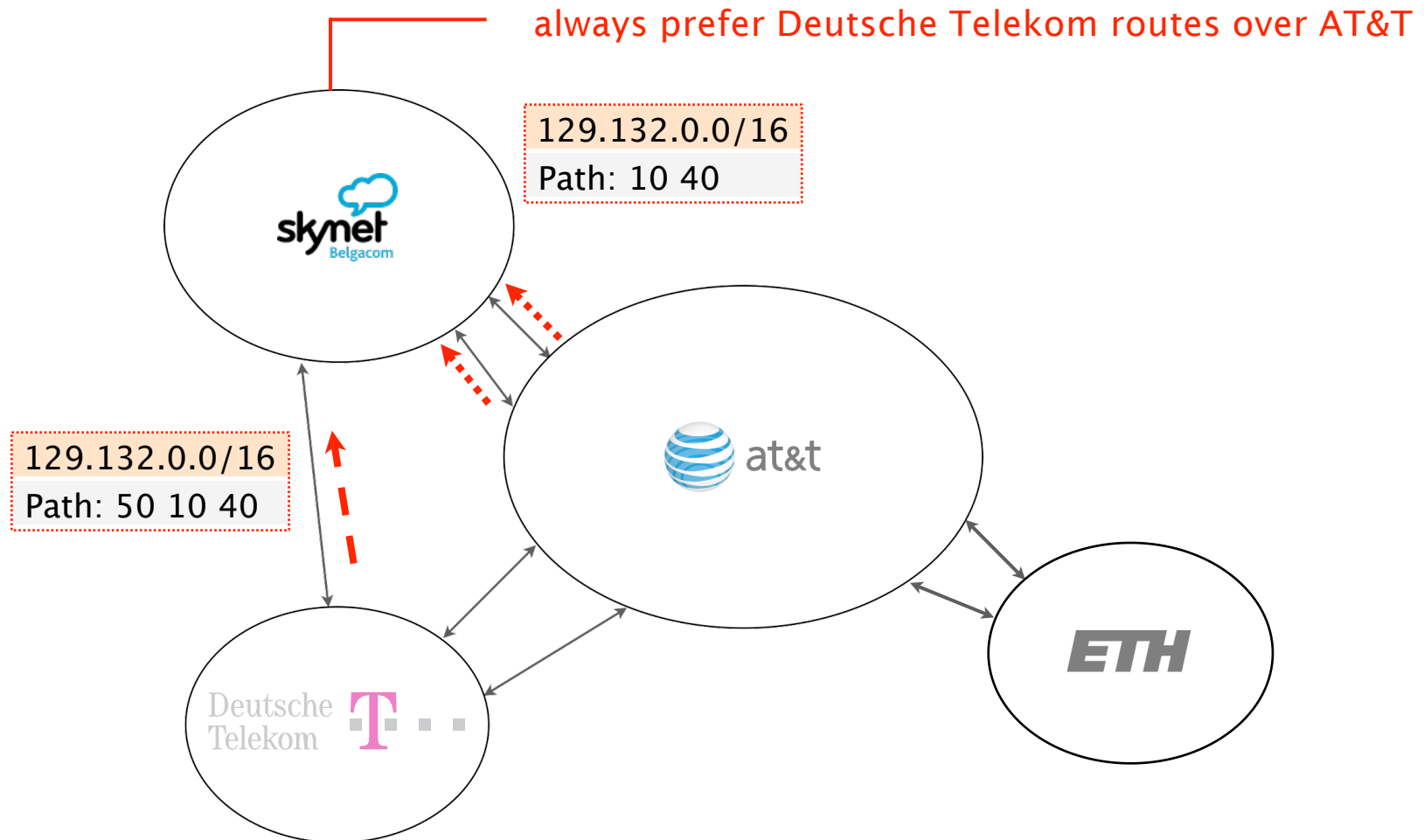
Complete path information enables Ases to easily detect a loop

ETH sees itself in the path and discard the route



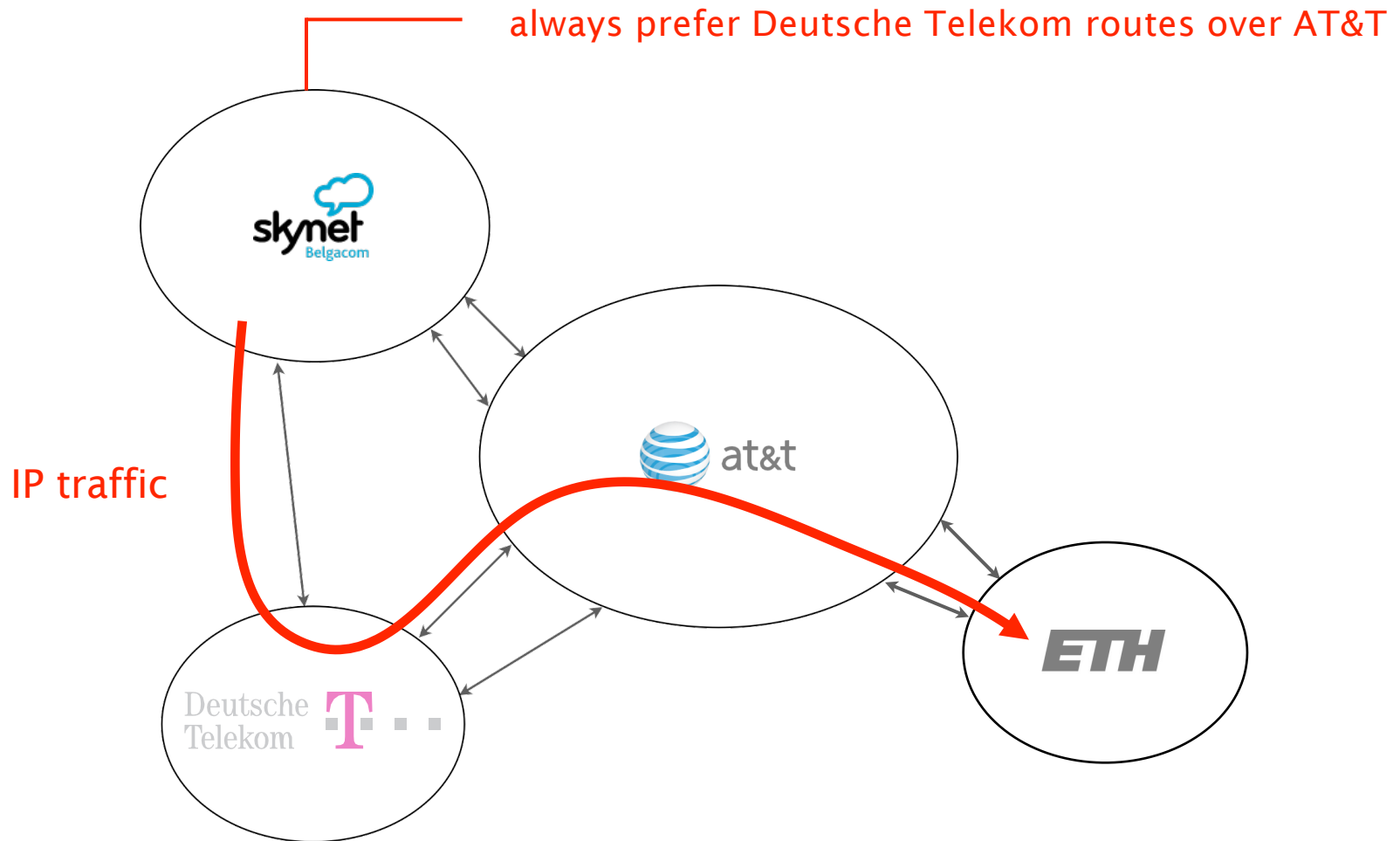
# BGP is Policy Based

Each AS is free to select and use any path preferably, the cheapest one



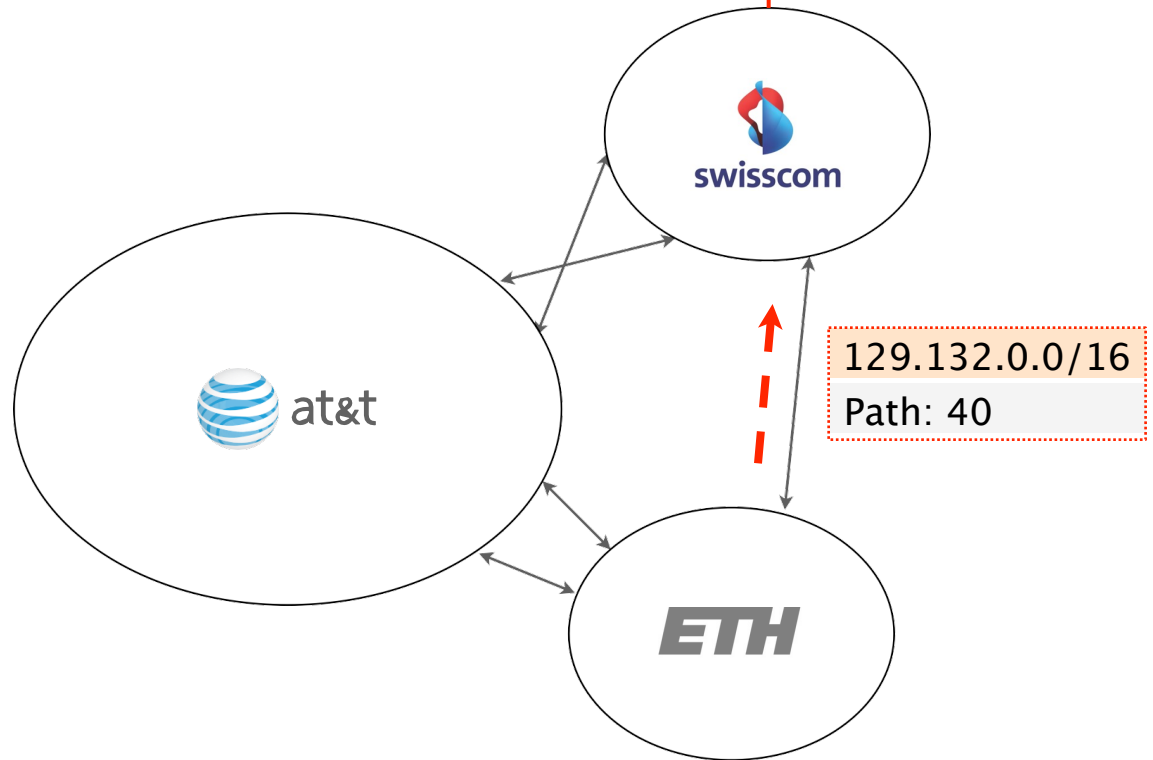


# BGP is Policy Based



# BGP is Policy Based

do not export ETH routes to AT&T



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do not export ETH routes to AT&T

