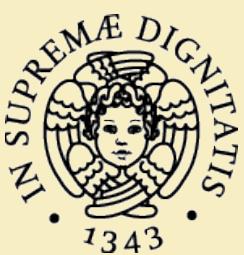


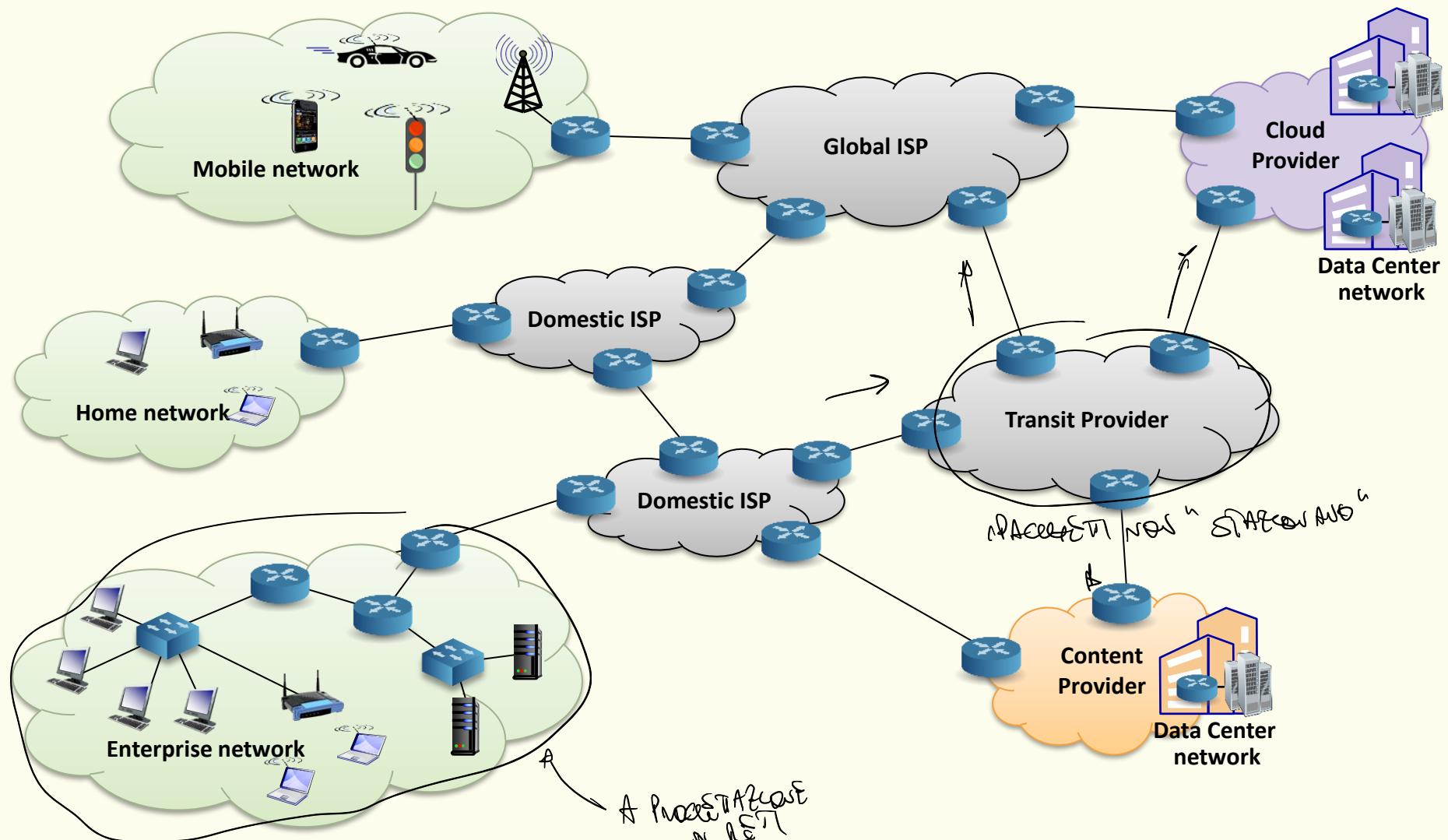
Advanced Network Architectures & Wireless Systems

L.M. Computer Engineering

Enzo Mingozzi
Professor @ DII – University of Pisa
enzo.mingozzi@unipi.it



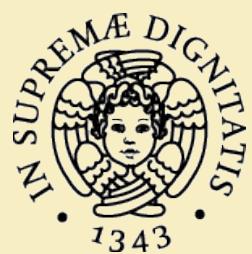
Internet stakeholders



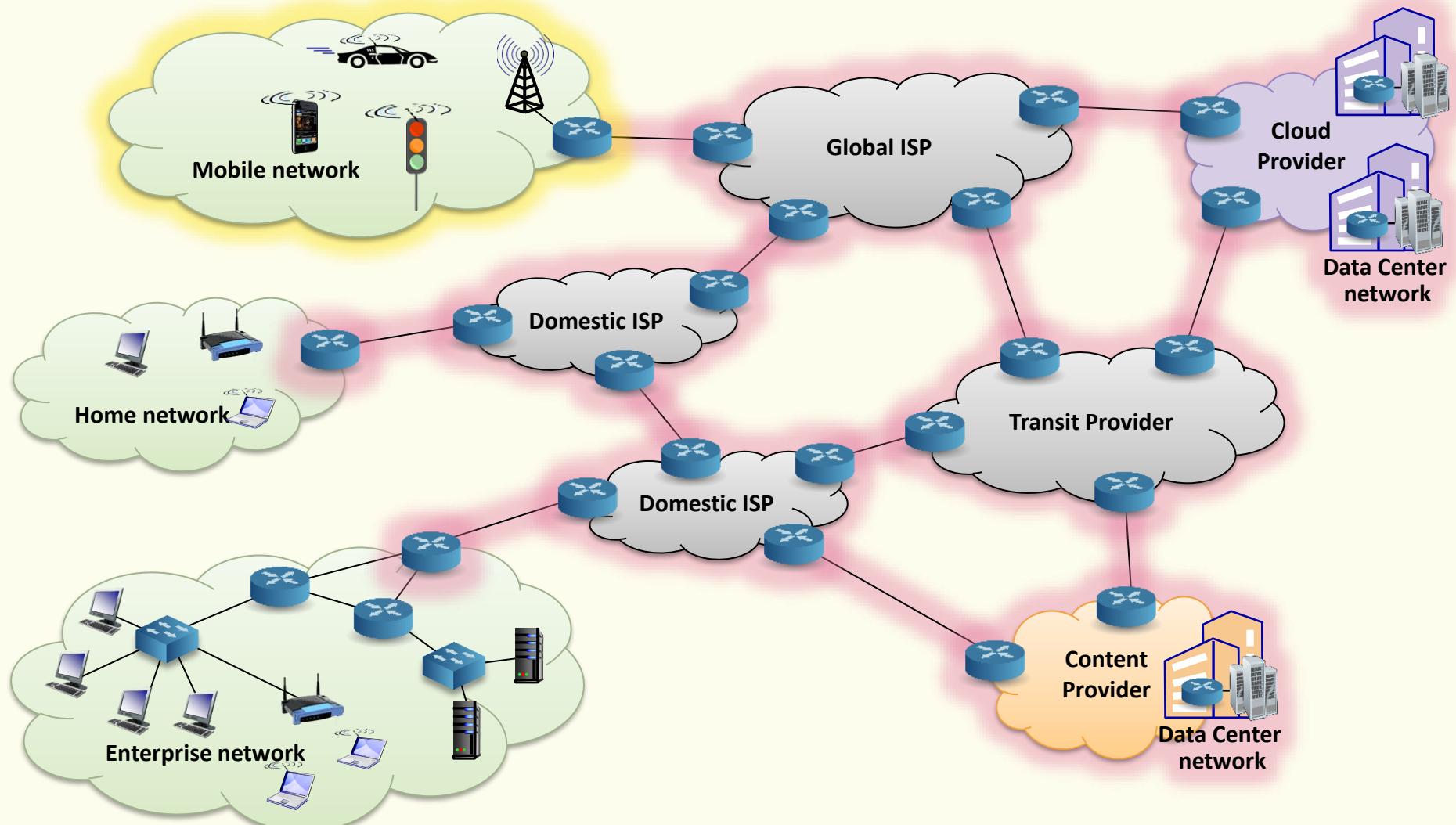


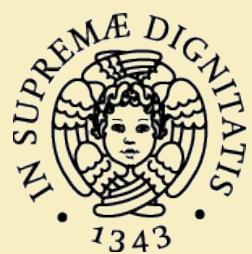
Internet-connected devices





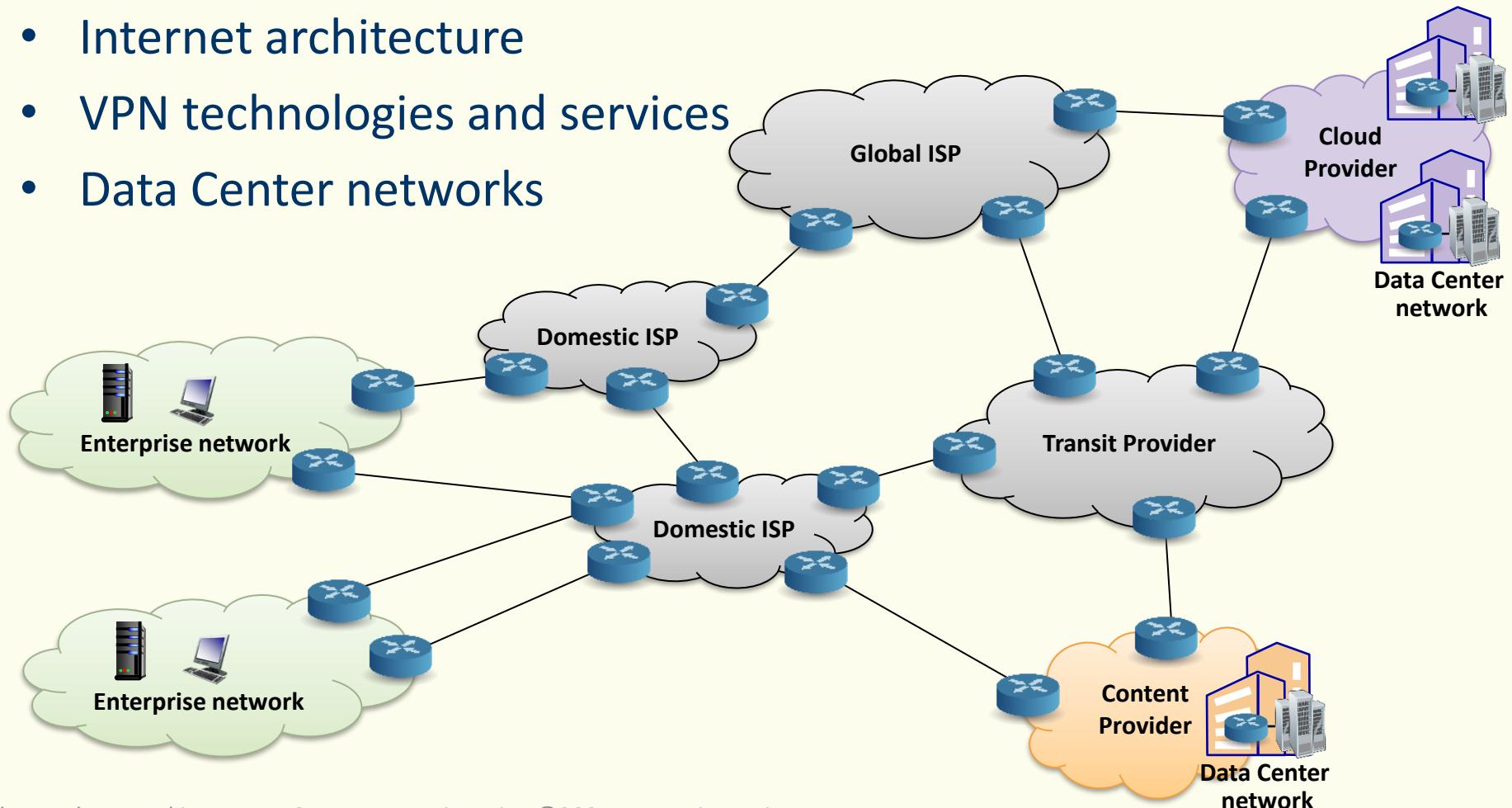
How it works behind the scenes?





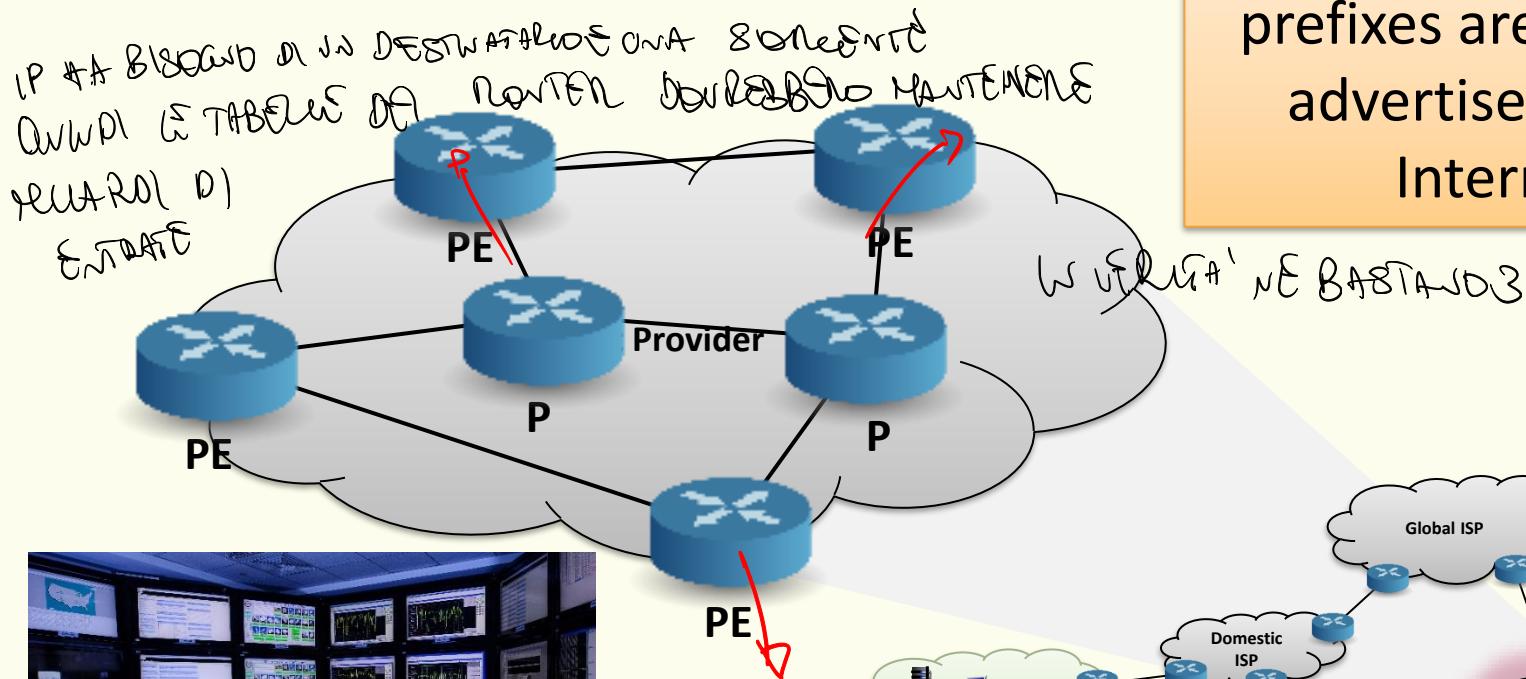
Our main focus

- Core backbone architecture and protocols
- Internet architecture
- VPN technologies and services
- Data Center networks

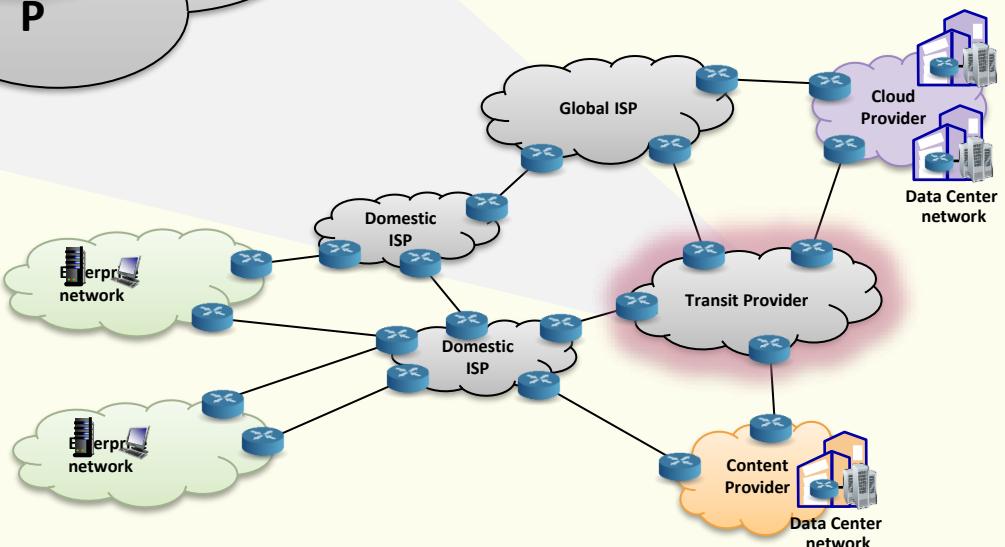


Multi-Protocol Label Switching

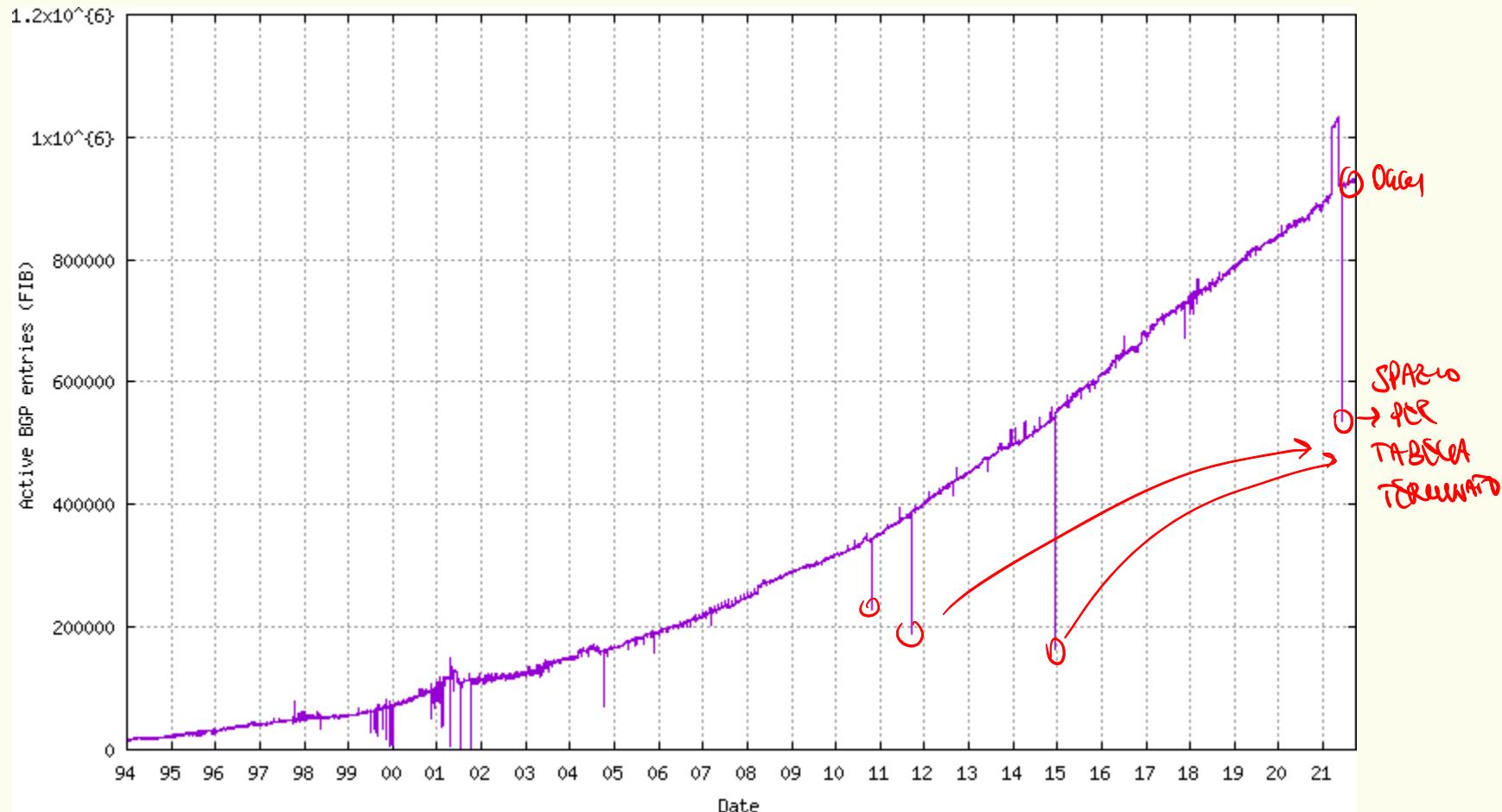
- Routing scalability



how many IP(v4)
prefixes are currently
advertised on the
Internet?

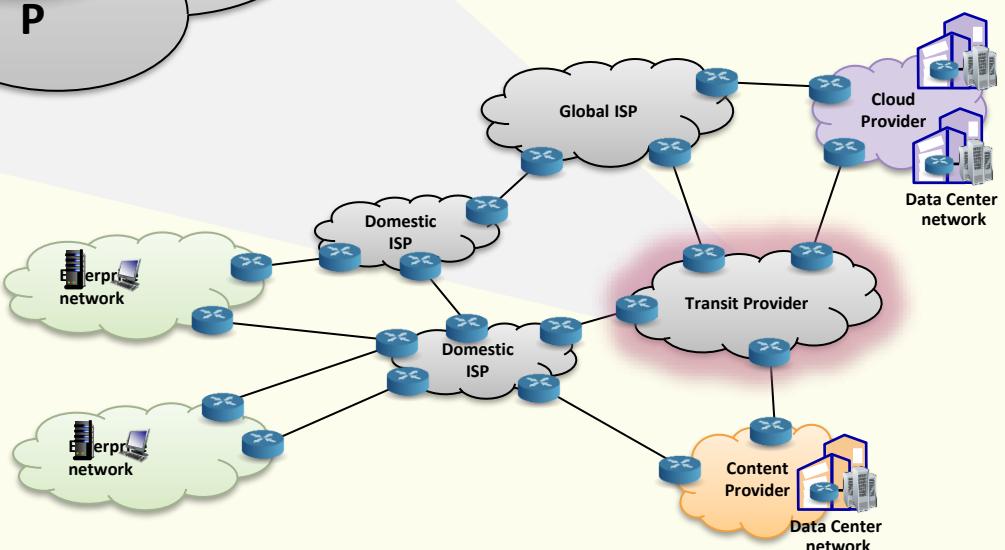
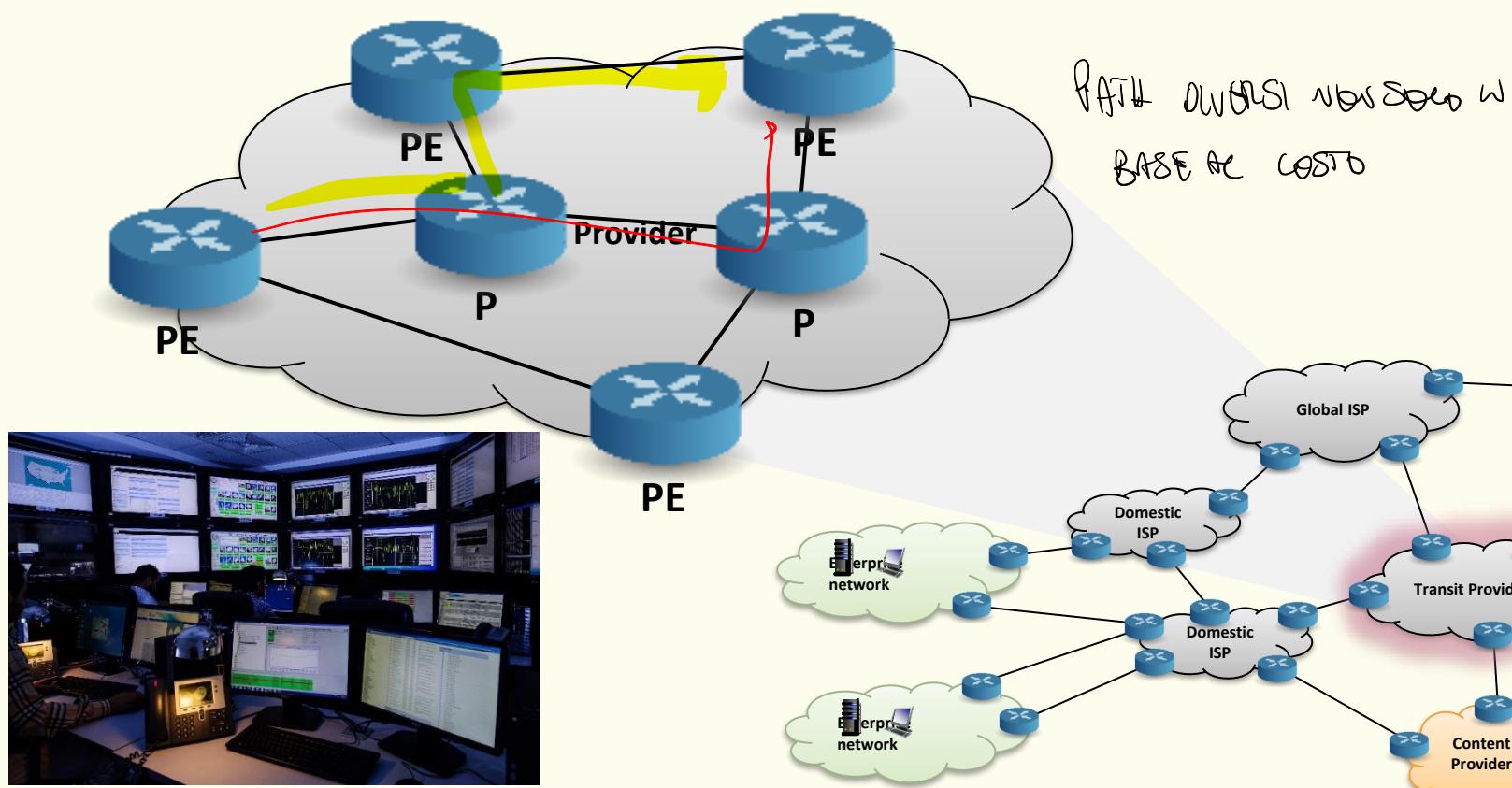


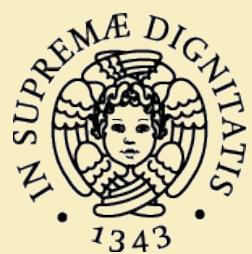
Active BGP entries as of Sept. 26, 2021



MPLS-based Traffic Engineering

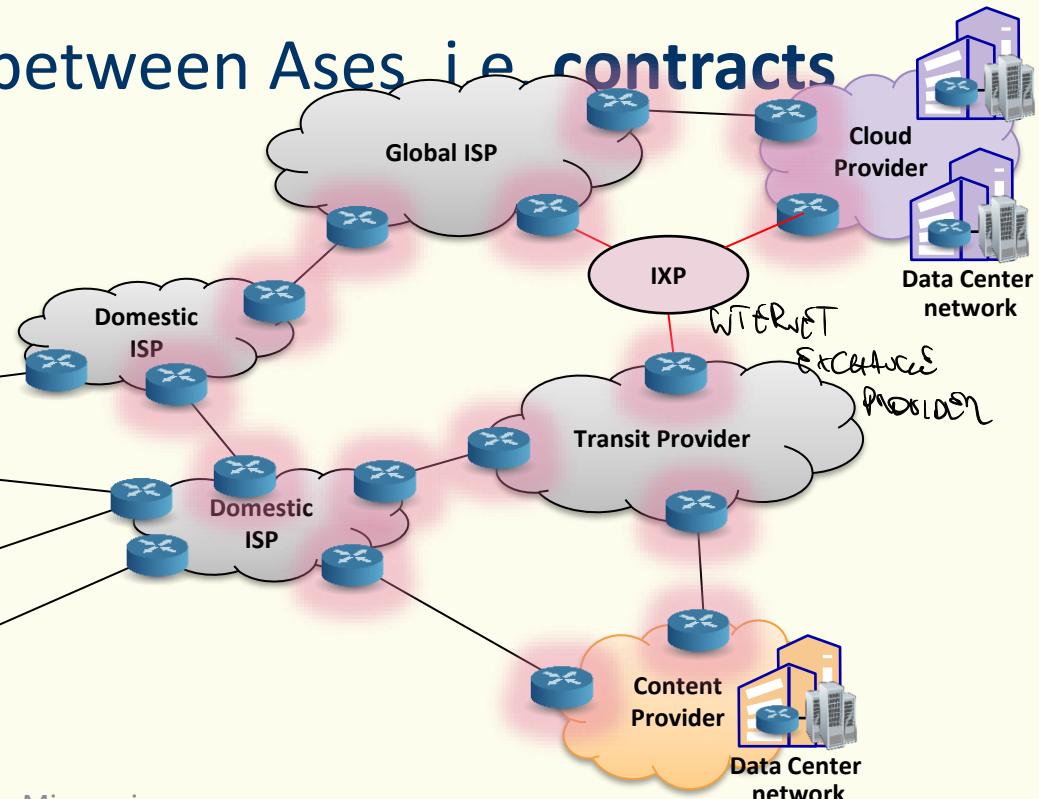
- Routing flexibility

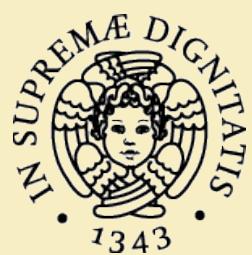




InterAS routing

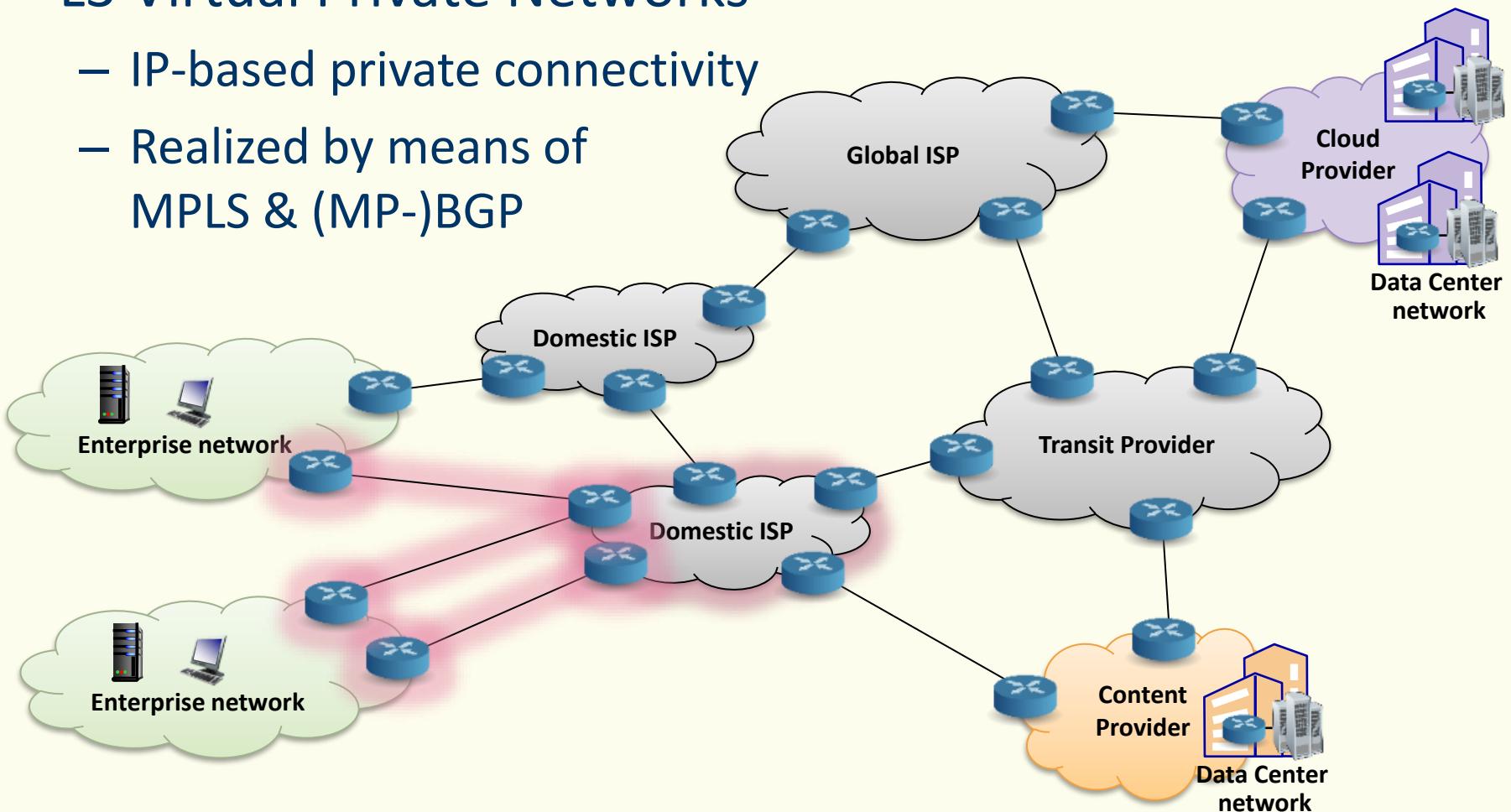
- Global connectivity ensured by peering between Autonomous Systems (AS)
 - Border Gateway Protocol (BGP-4)
- Business relationships between Ases i.e. contracts
 - pricing model
 - exchange of traffic

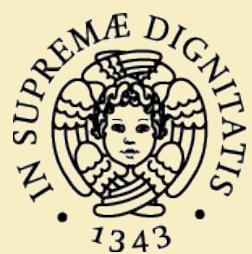




Network virtualization

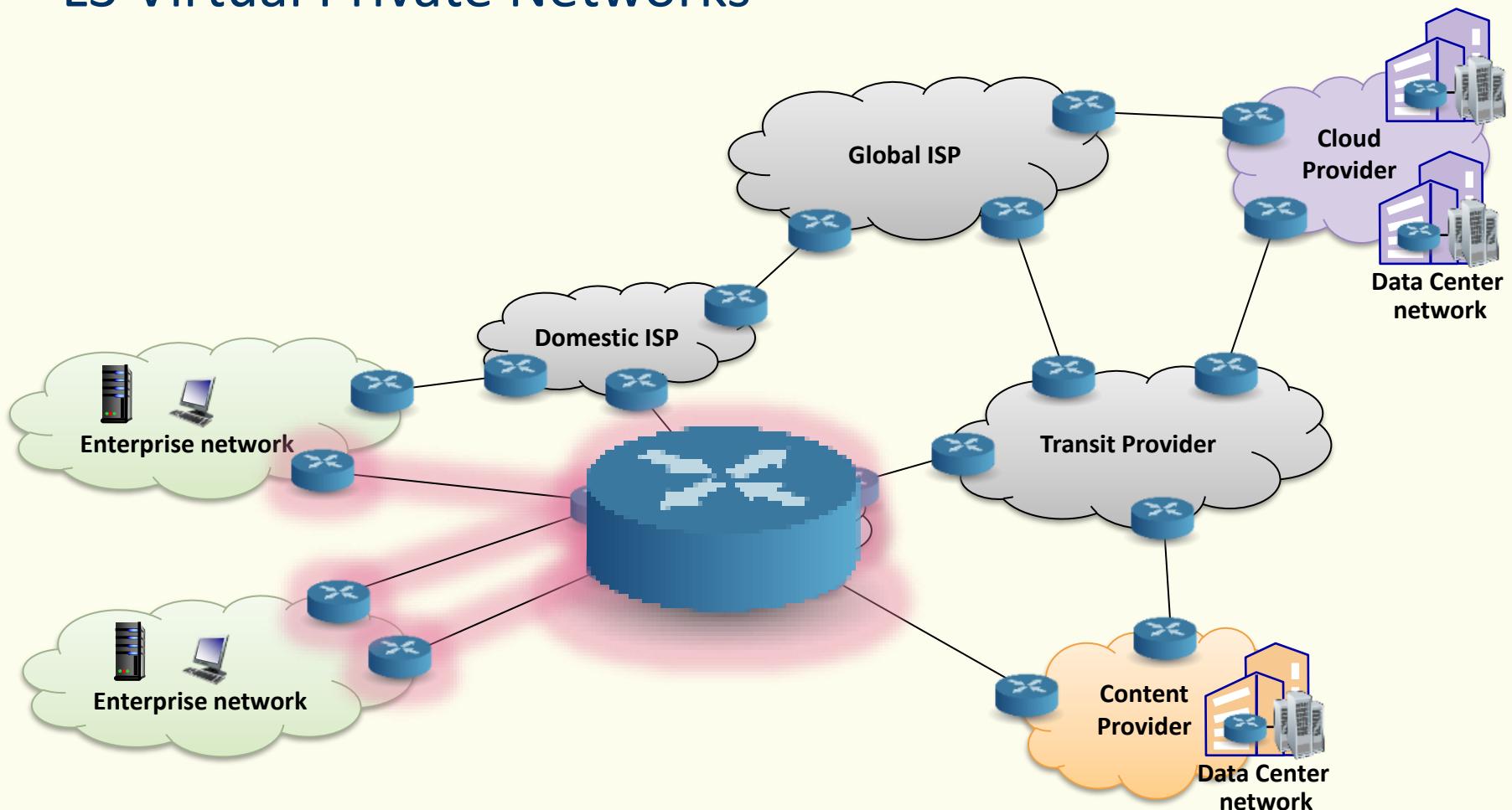
- L3 Virtual Private Networks
 - IP-based private connectivity
 - Realized by means of MPLS & (MP-)BGP





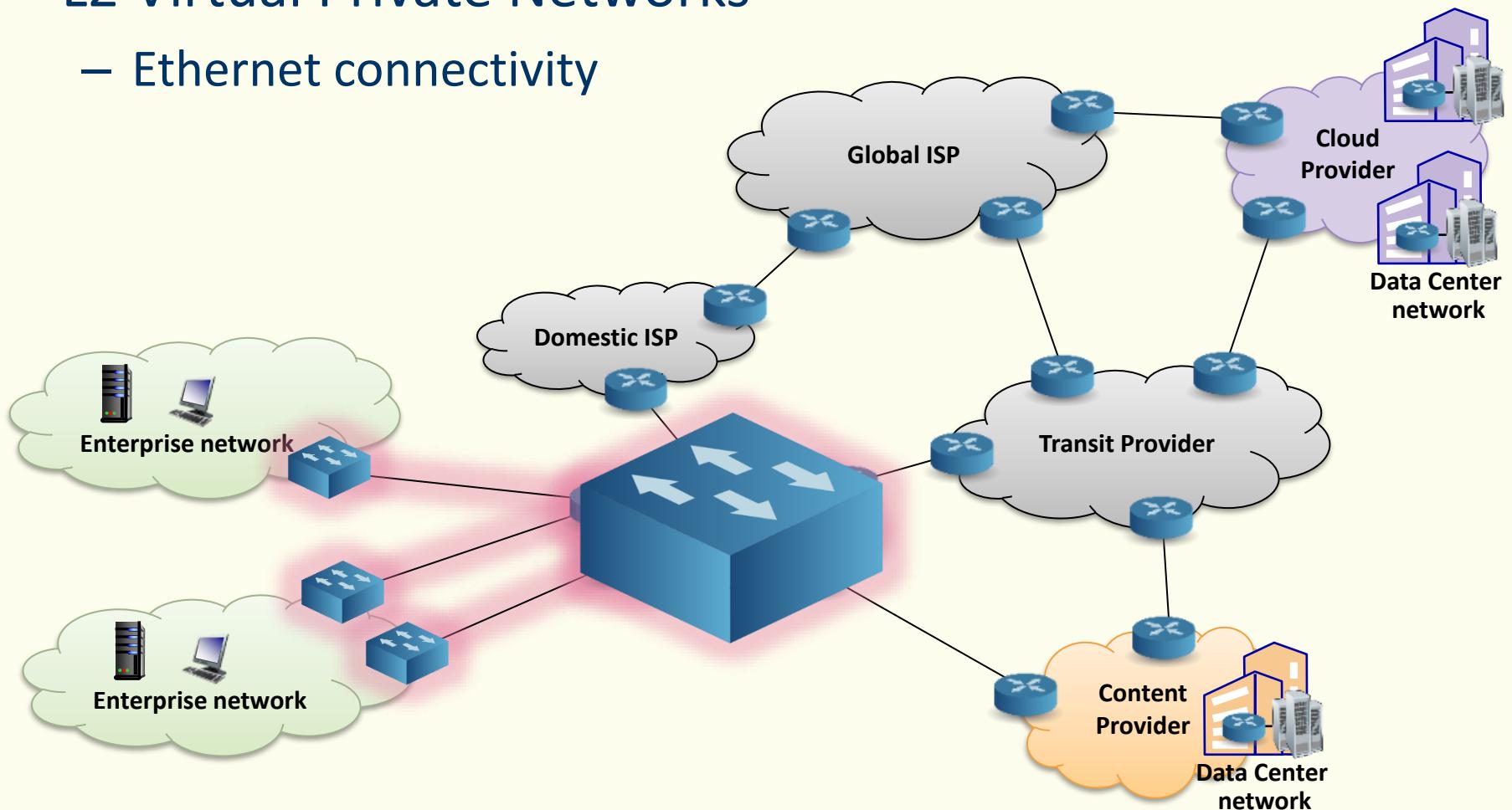
Network virtualization

- L3 Virtual Private Networks



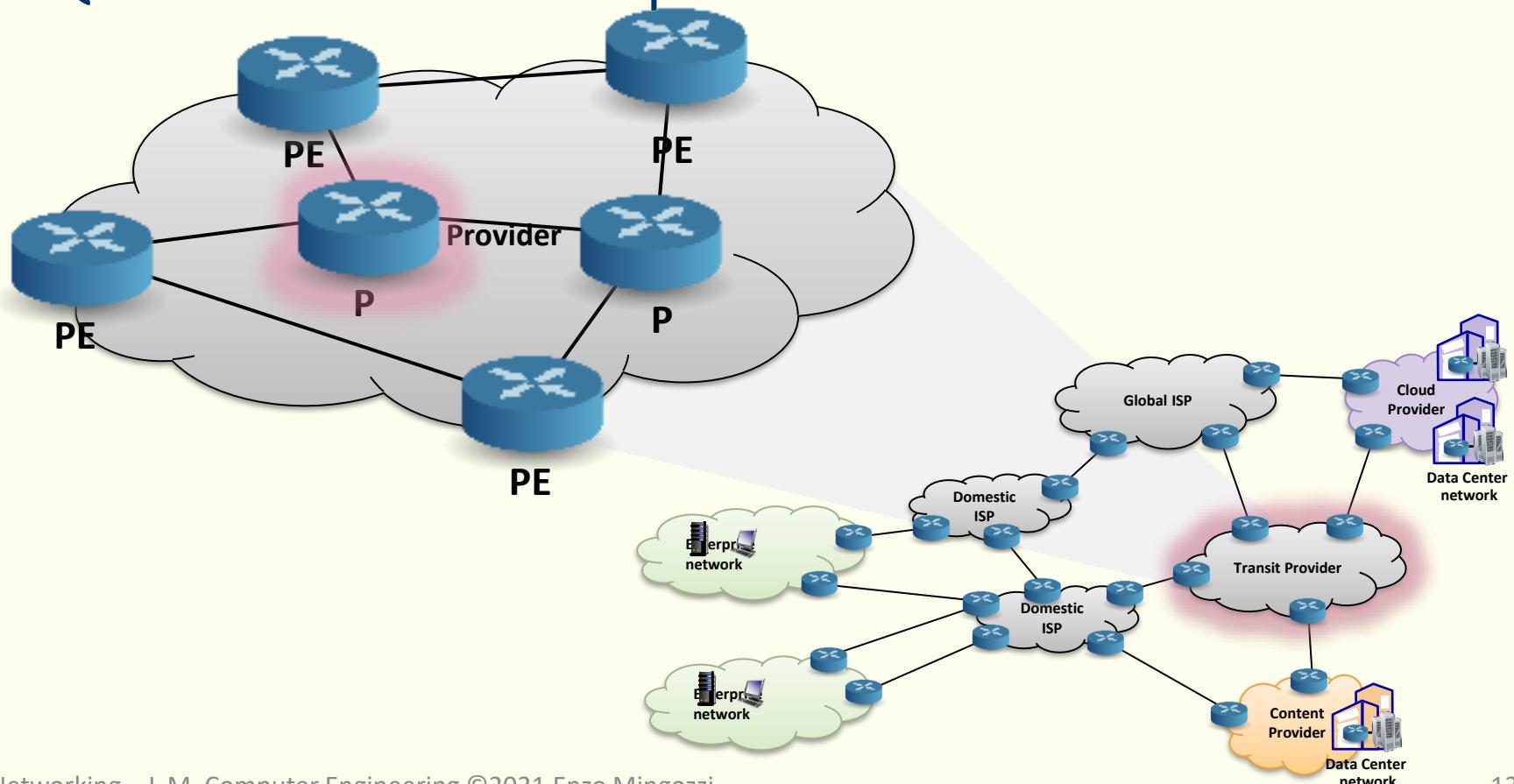
Network virtualization

- L2 Virtual Private Networks
 - Ethernet connectivity



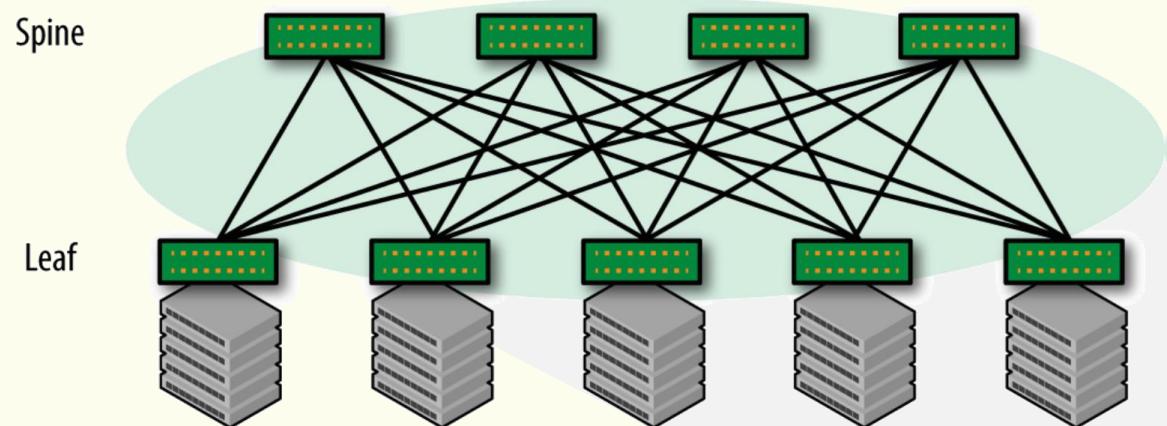
QoS/QoE

- Multimedia data characterization and requirements
- IP QoS architectures and protocols

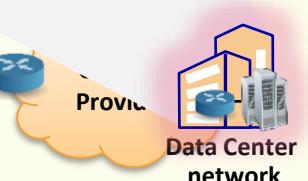
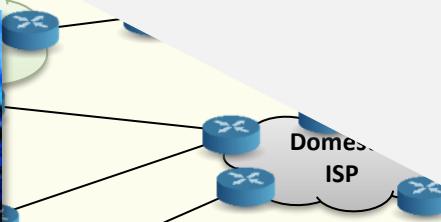
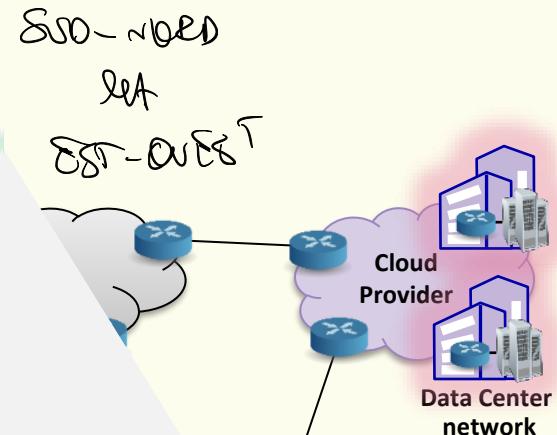


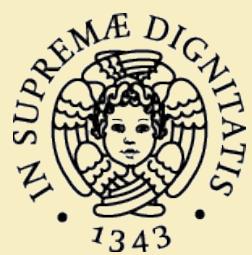
Data Center networking

- DC network architectures

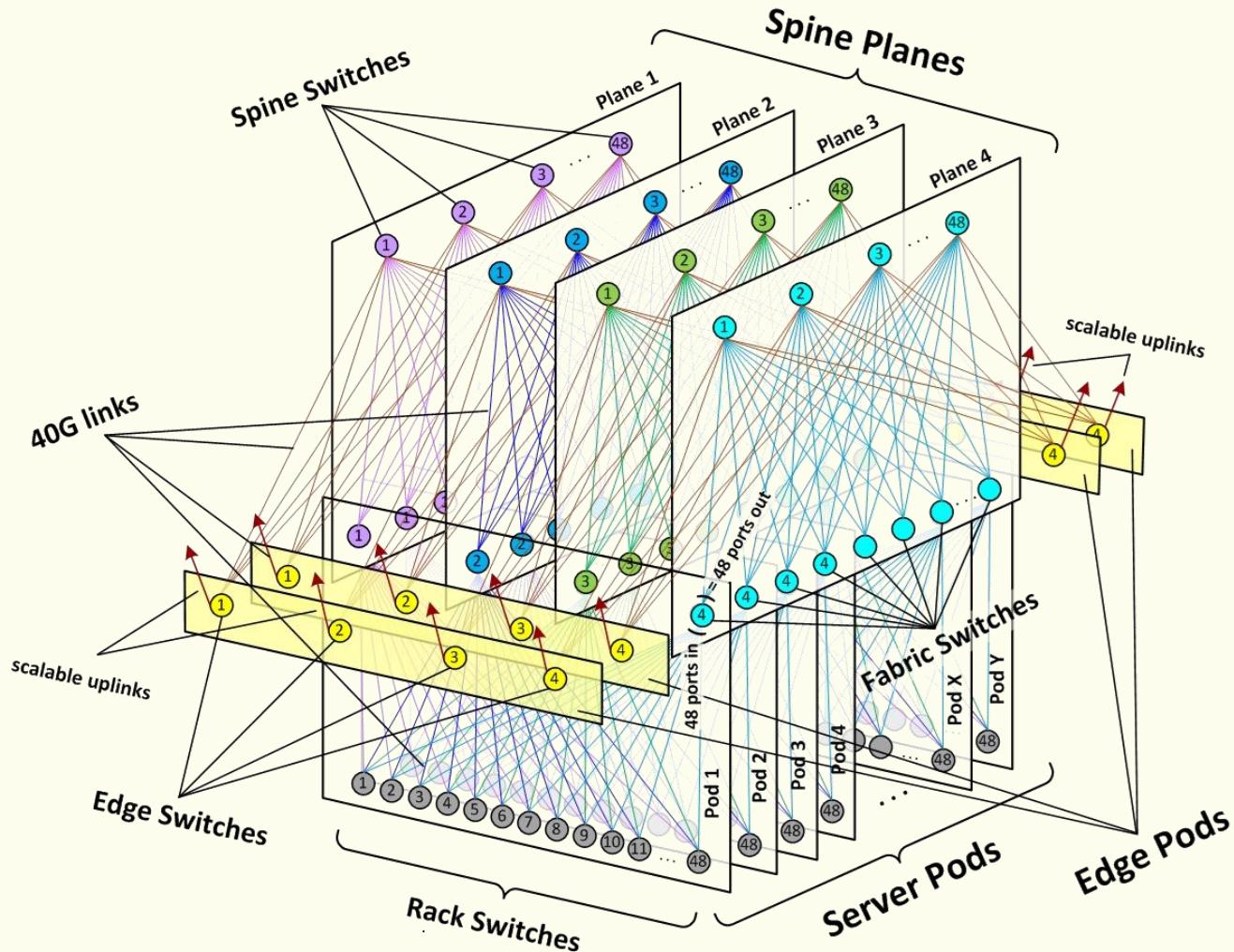


Now ORIENTED towards CLOUD/edge





Data Center networking

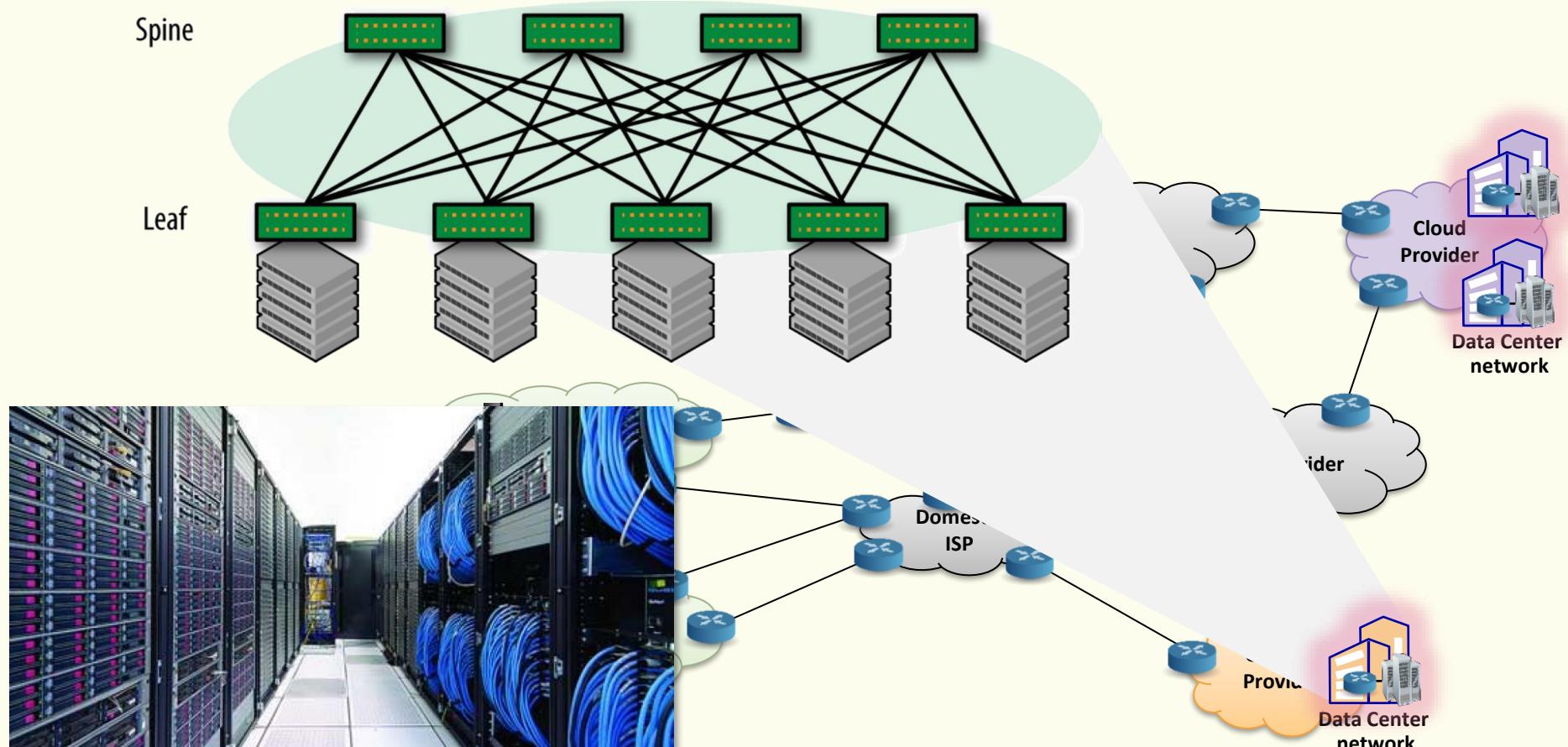


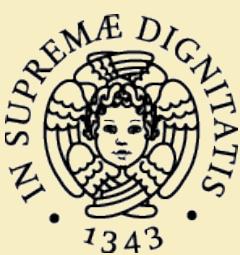
[Introducing data center fabric, the next-generation Facebook data center network - Facebook Engineering \(fb.com\)](https://www.facebook.com/notes/facebook-engineering/introducing-data-center-fabric-the-next-generation-facebook-data-center-network/)



Data Center networking

- DC network virtualization



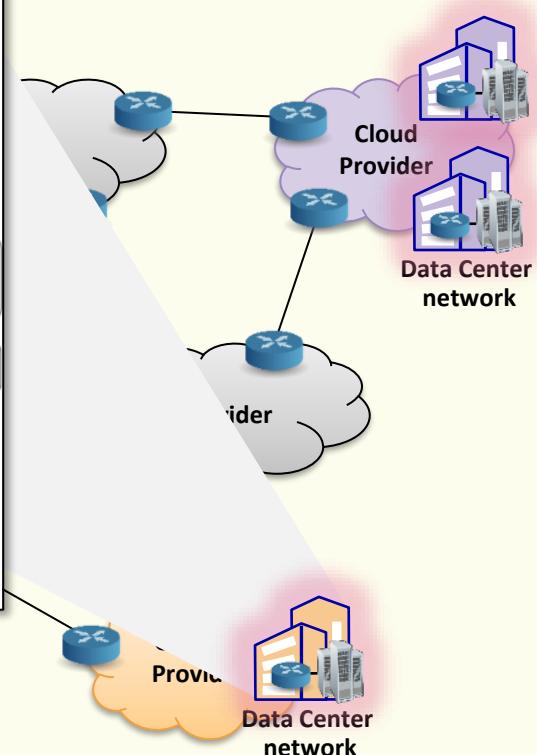
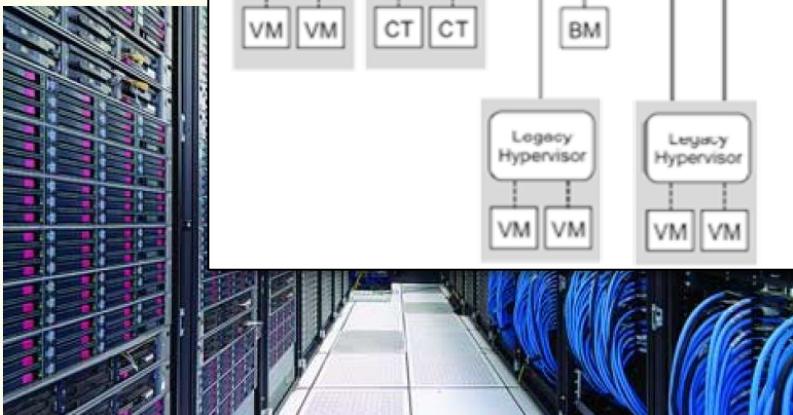
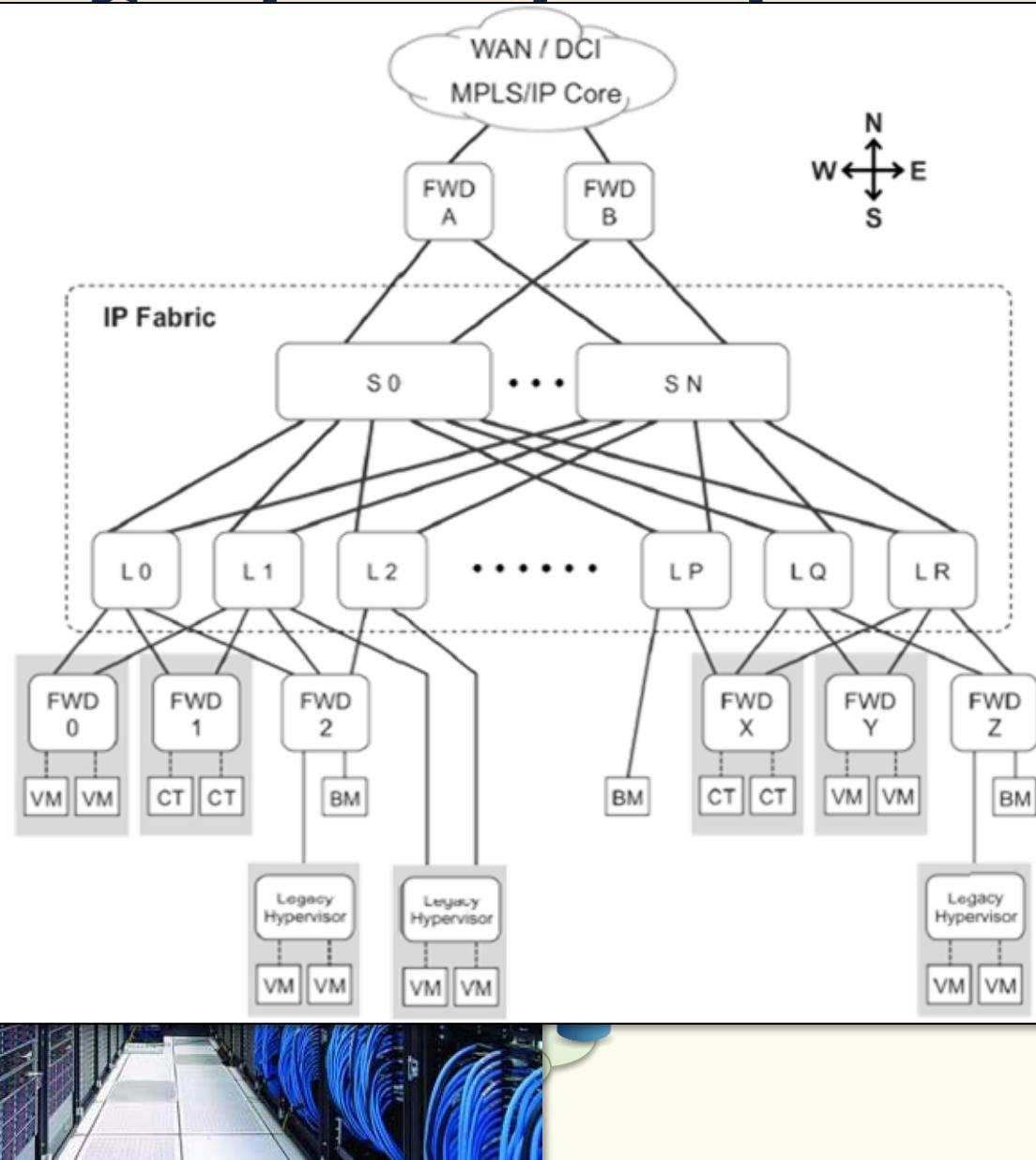


Data Center

DC

Spin

Leaf





Network programmability

PROBLEM: NETWORK AGILITY

Not Much has Changed in the Last 20 Years

1994

```
Router> enable
Router# configure terminal
Router(config)# enable secret cisco
Router(config)# ip route 0.0.0.0 0.0.0.0 20.2.2.3
Router(config)# interface ethernet0
Router(config-if)# ip address 10.1.1.1 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# interface serial0
Router(config-if)# ip address 20.2.2.2 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# router rip
Router(config-router)# network 10.0.0.0
Router(config-router)# network 20.0.0.0
Router(config-router)# exit
Router(config)# exit
Router# copy running-config startup-config
Router# disable
Router>
```

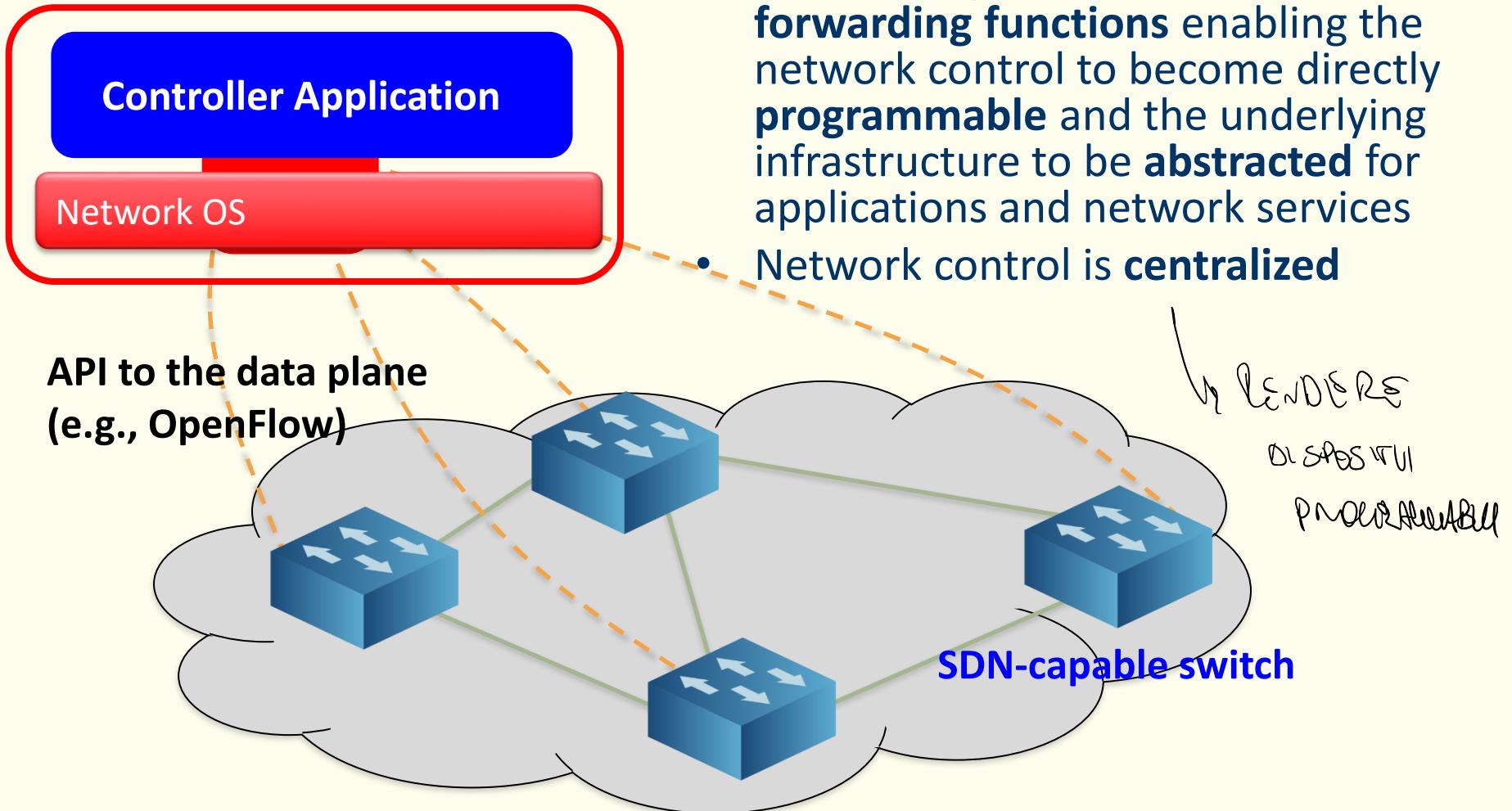
Terminal Protocol: **Telnet**

2014

```
Router> enable
Router# configure terminal
Router(config)# enable secret cisco
Router(config)# ip route 0.0.0.0 0.0.0.0 20.2.2.3
Router(config)# interface ethernet0
Router(config-if)# ip address 10.1.1.1 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
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Router(config-if)# ip address 20.2.2.2 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# router rip
Router(config-router)# network 10.0.0.0
Router(config-router)# network 20.0.0.0
Router(config-router)# exit
Router(config)# exit
Router# copy running-config startup-config
Router# disable
Router>
```

Terminal Protocol: **SSH**

Software Defined Networking





Software Defined Networking

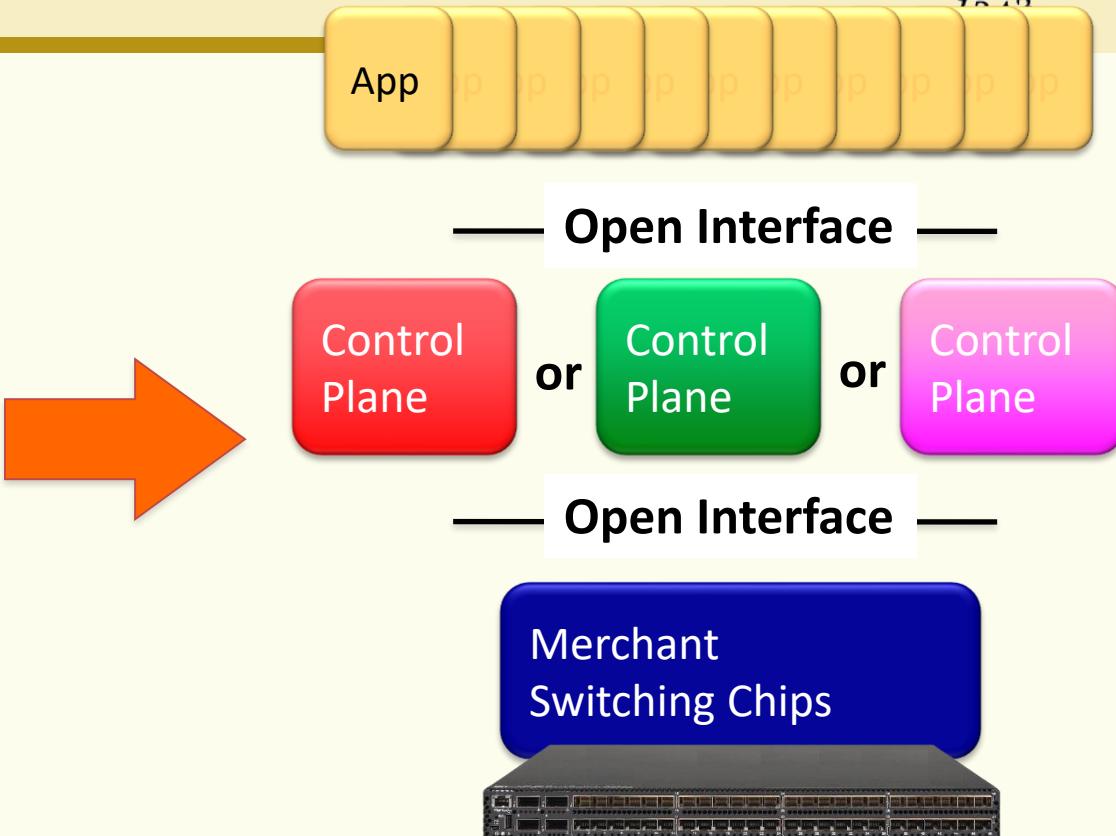
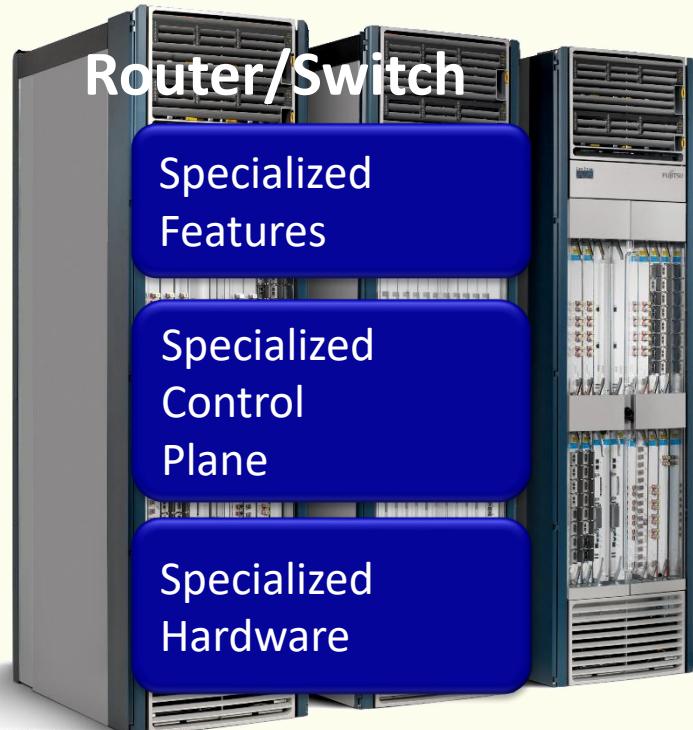


**Vertically integrated
Closed, proprietary
Slow innovation
Small industry**

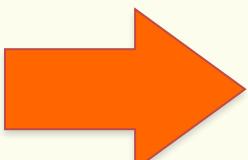
**Horizontal
Open interfaces
Rapid innovation
Huge industry**



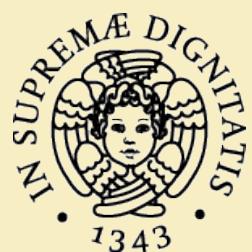
Software Defined Networking



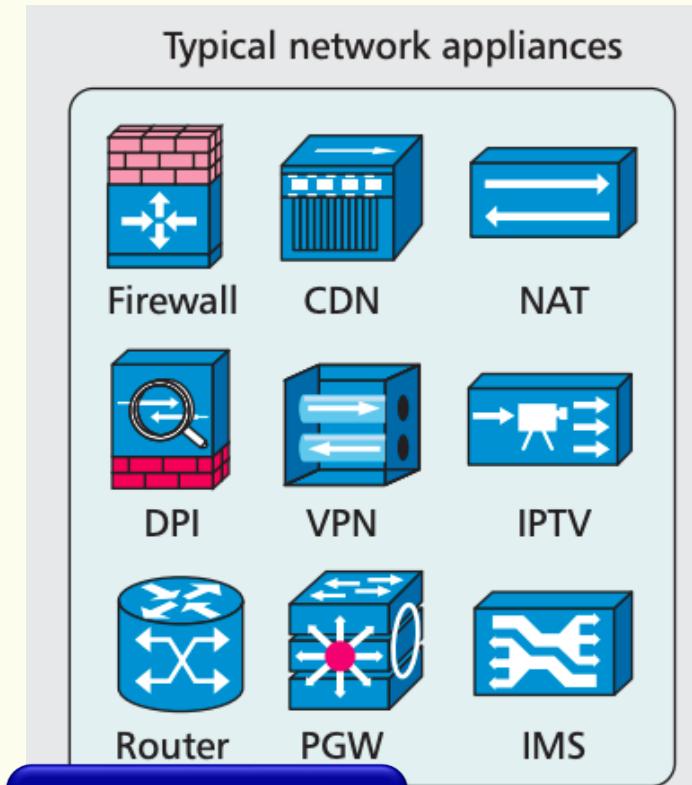
Vertically integrated
Closed, proprietary
Slow innovation



Horizontal
Open interfaces
Rapid innovation

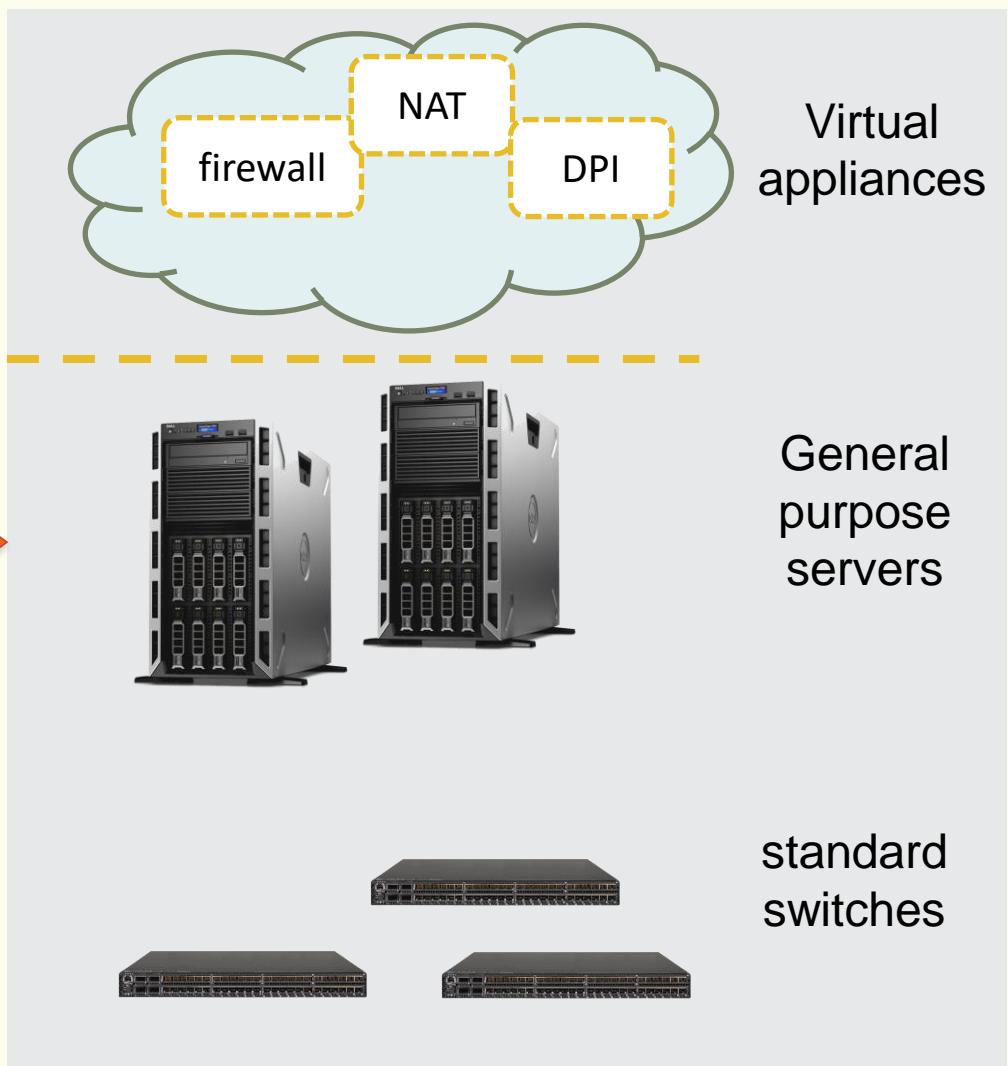
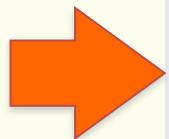


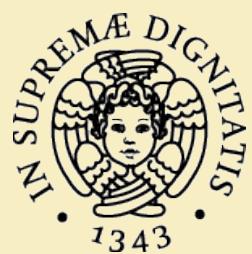
Network Function Virtualization



Specialized Features

Specialized Hardware





Network Function Virtualization



Engineering
Simplicity

Data Sheet



Product Overview

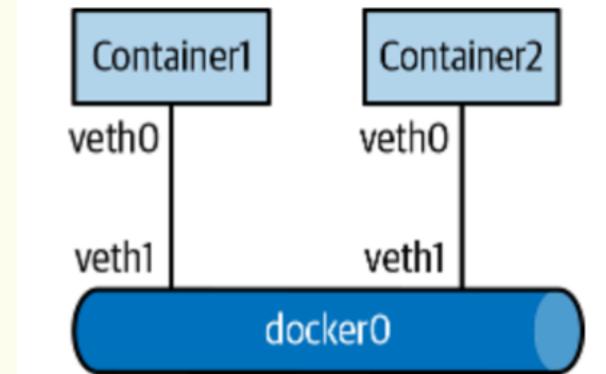
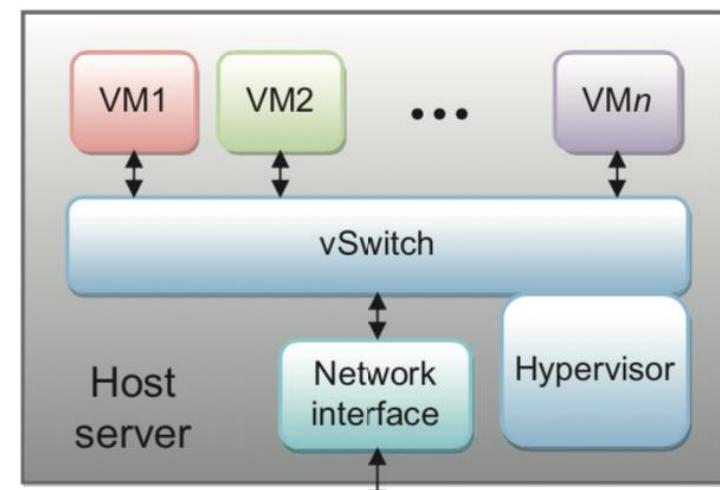
vMX VIRTUAL ROUTER

Product Description

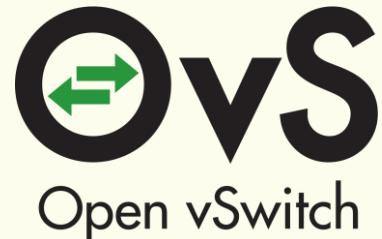
The Juniper Networks® vMX Virtual Router, available as licensed software for deployment on x86-based servers, Amazon Web Services (AWS), AWS GovCloud, and Microsoft Azure supports a broad range of broadband, cloud, cable, mobile, and enterprise applications. The vMX control plane is powered by Juniper Networks Junos® operating system, the same OS that powers the entire Juniper Networks MX Series Universal Routing Platform portfolio, and the forwarding plane is powered by vTrio, Juniper's programmable Trio chipset microcode optimized for execution in x86 environments. With Junos OS and vTrio, the vMX

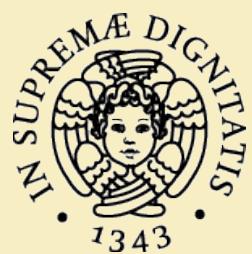
vMX Virtual Router | Juniper Networks

VM/Container networking



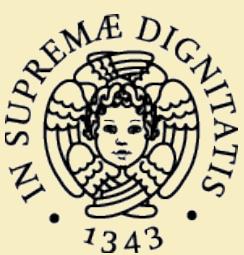
- “easy” networking
 - No network
 - Host-only network
 - Bridged
 - ...
- “advanced” networking
 - custom software switches



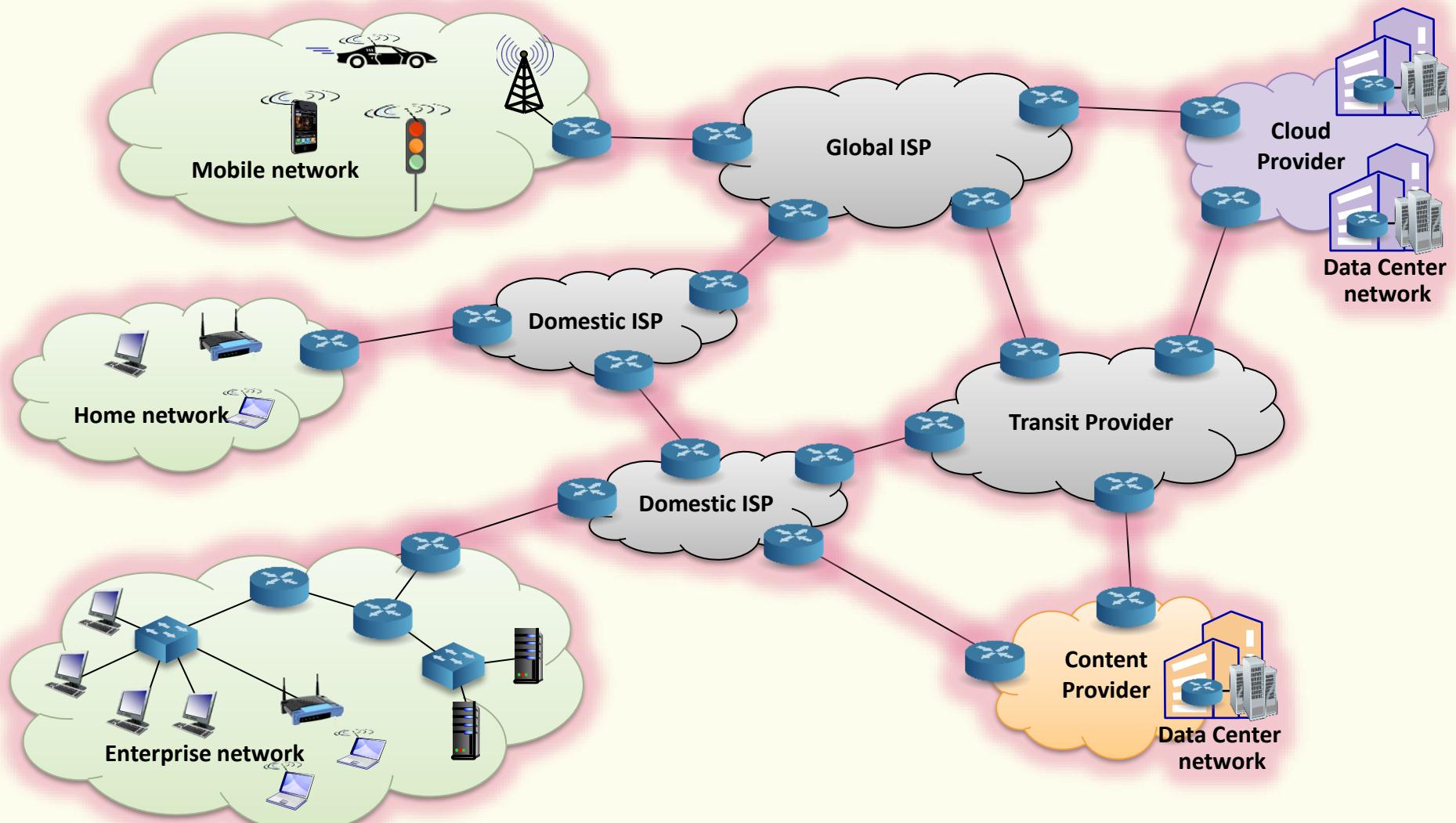


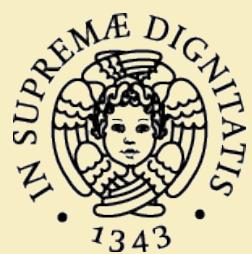
Network automation

- Take advantage of the programmatic interfaces being exposed by modern network devices that offer an API
 - Automating the configuration of network devices
 - Automating the process of troubleshooting
 - Aid in the day-to-day operations of managing networks for data gathering and automated diagnostics
- **Intent-based networking**
 - machine learning and cognitive computing used to enable more automation and less time spent on manual configuration and management



Internet Protocol v6 (IPv6)





Course figures

- 9 CFUs = 90 hours (~70h lessons + ~20h labs)
 - 6 CFUs with myself
 - 3 CFUs with Antonio Virdis
- Prerequisites
 - computer networking and programming
- Final exam
 - Team project (3 persons per team)
 - Oral Q&A

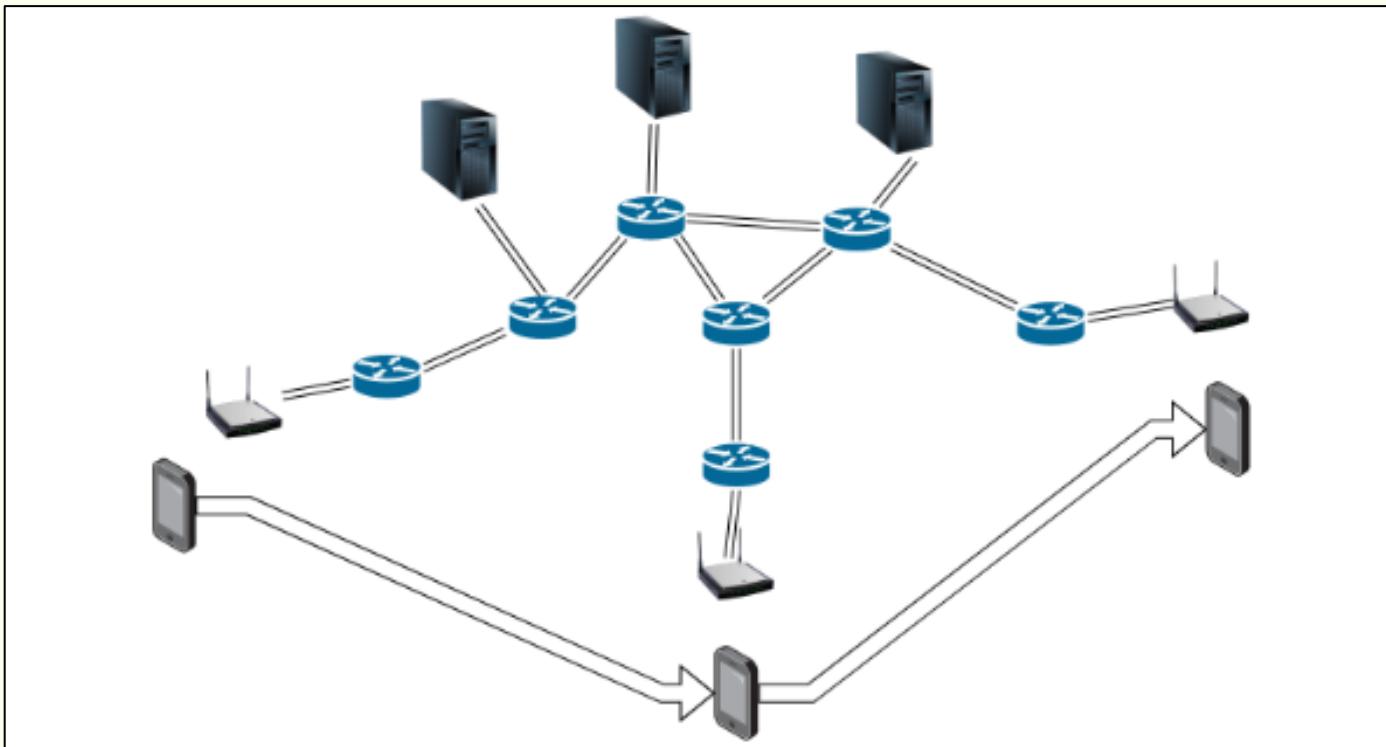


Course content

- **Lab activities:** hands-on labs on
 - Software Defined Networking (software)
 - Backbone router configuration (emulating software)
 - VM/Container networking

Project example: SDN

- SDN support for mobility: dynamically configure the network to allow a client to communicate with the closest server





Course material

- Microsoft Teams class
 - Syllabus, slides, readings, ...
 - Remote classes
- Web page
 - <http://www2.ing.unipi.it/~a009395/corsi/anaws/>



Contacts

- Prof. Enzo Mingozi (enzo.mingozi@unipi.it)
- Prof. Antonio Virdis (antonio.virdis@unipi.it)
- Dip. Ingegneria dell'Informazione
 - building A - Largo Lucio Lazzarino, 1
- Office hours for students
 - Weekly on MS Teams (day of the week TBD)