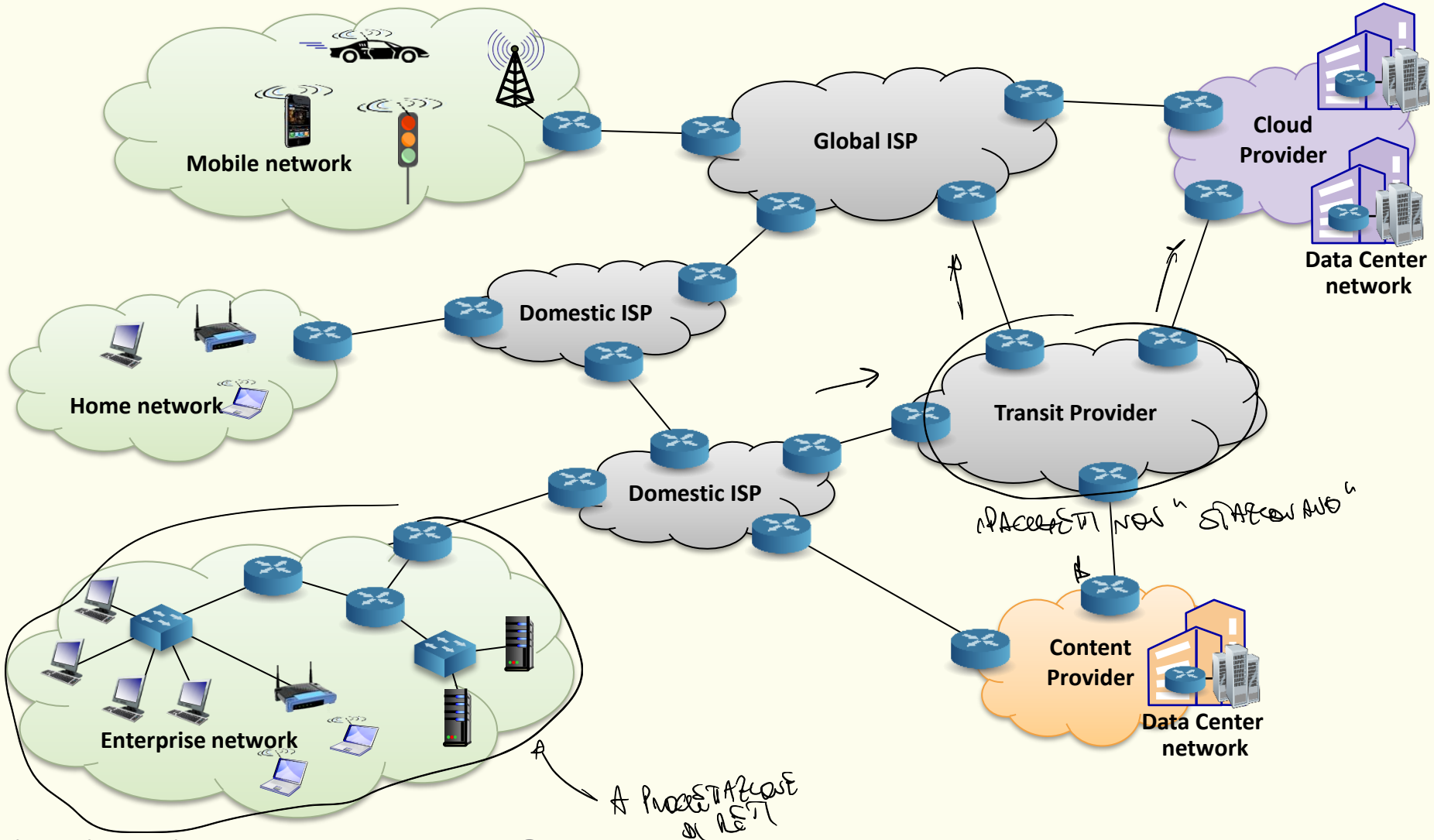
Advanced Network Architectures & Wireless Systems

L.M. Computer Engineering

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

Internet stakeholders



Internet-connected devices

Amazon Echo

Internet refrigerator

IP picture frame

Pacemaker & Monitor

Tweet-a-watt: monitor energy use

bikes

cars

Security Camera

Slingbox: remote control cable TV

Web-enabled toaster + weather forecaster

AR devices

scooters

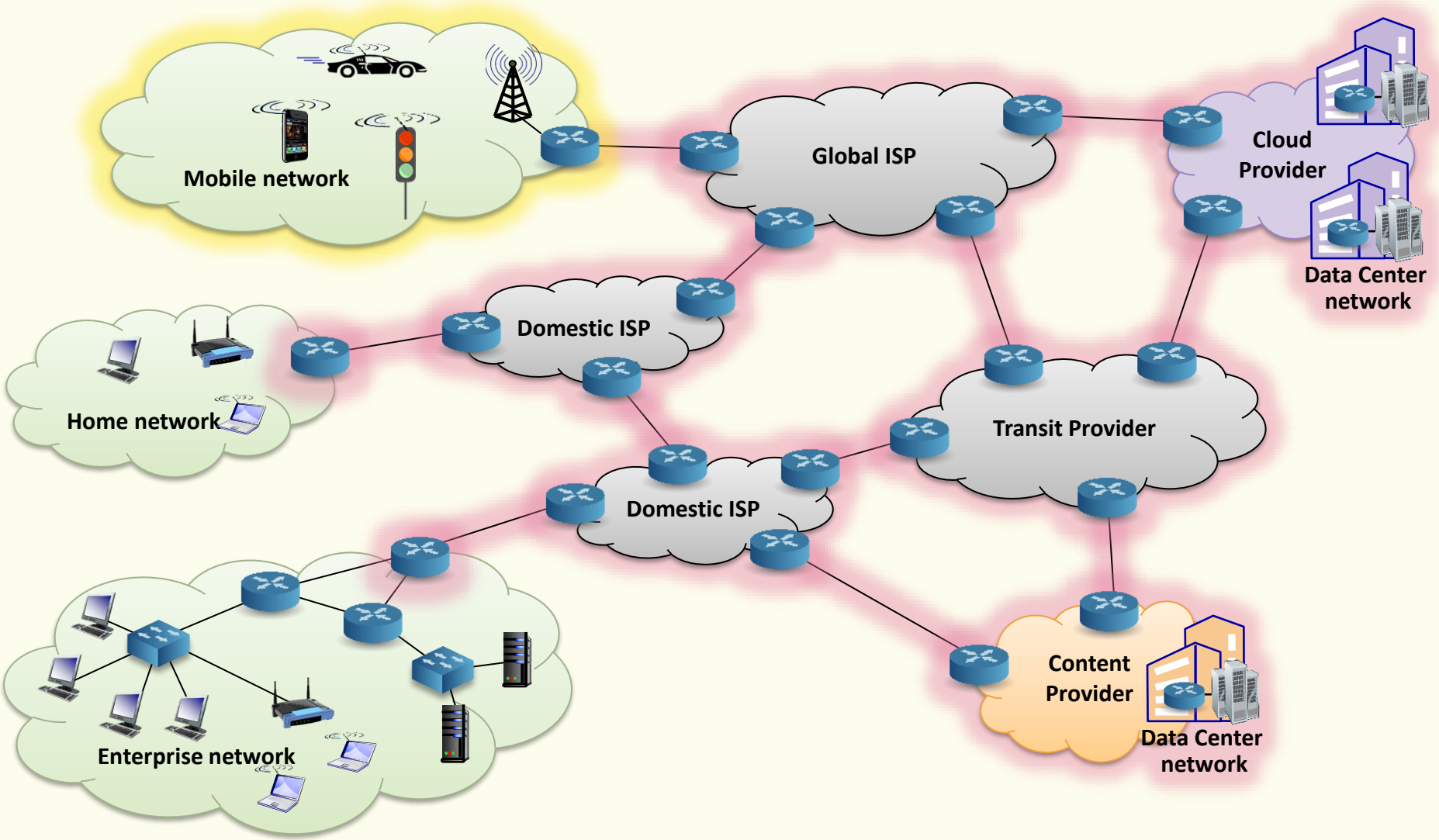
Internet phones

Gaming devices

sensorized, bed mattress

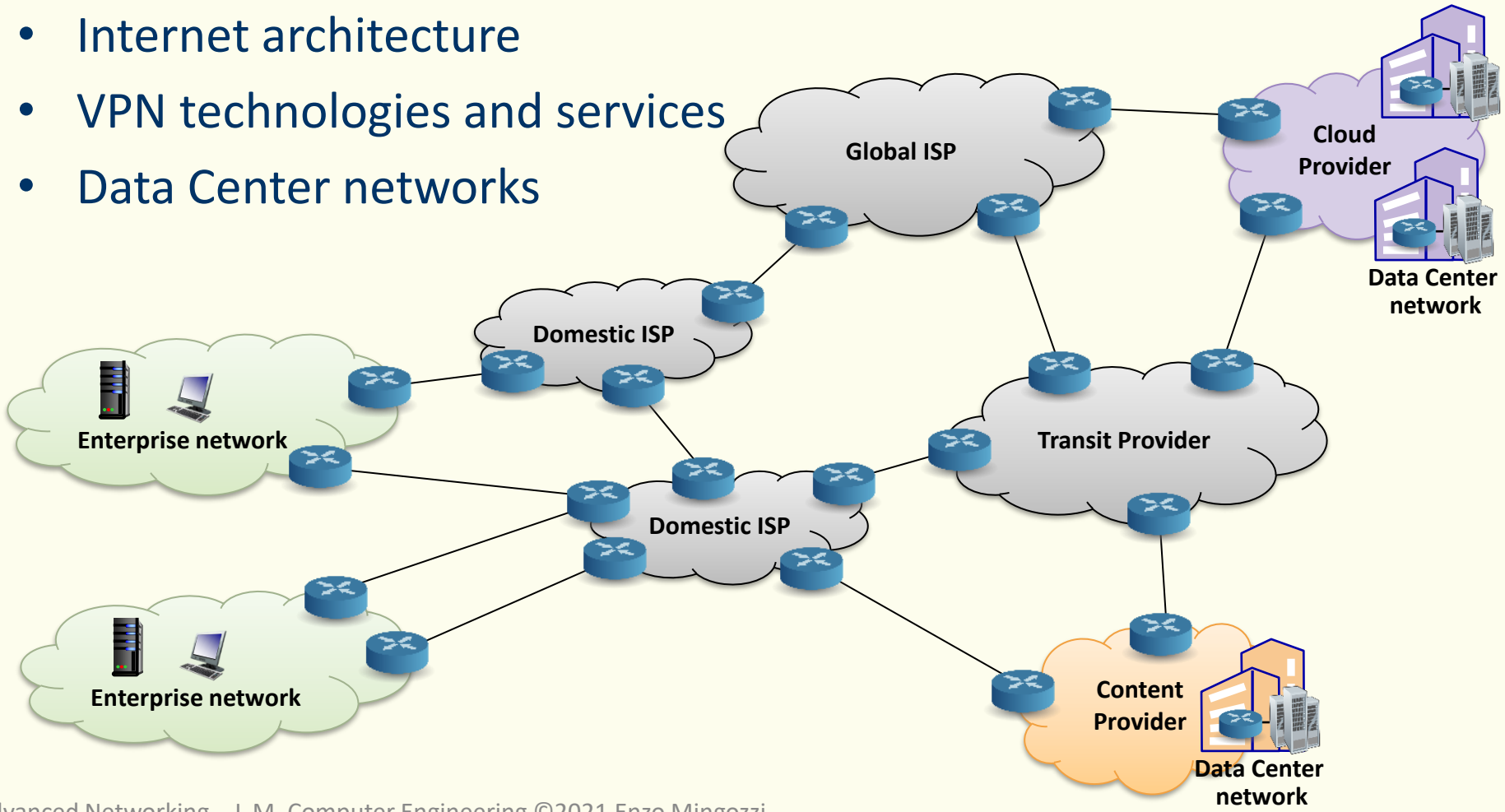
Fitbit

How it works behind the scenes?



Our main focus

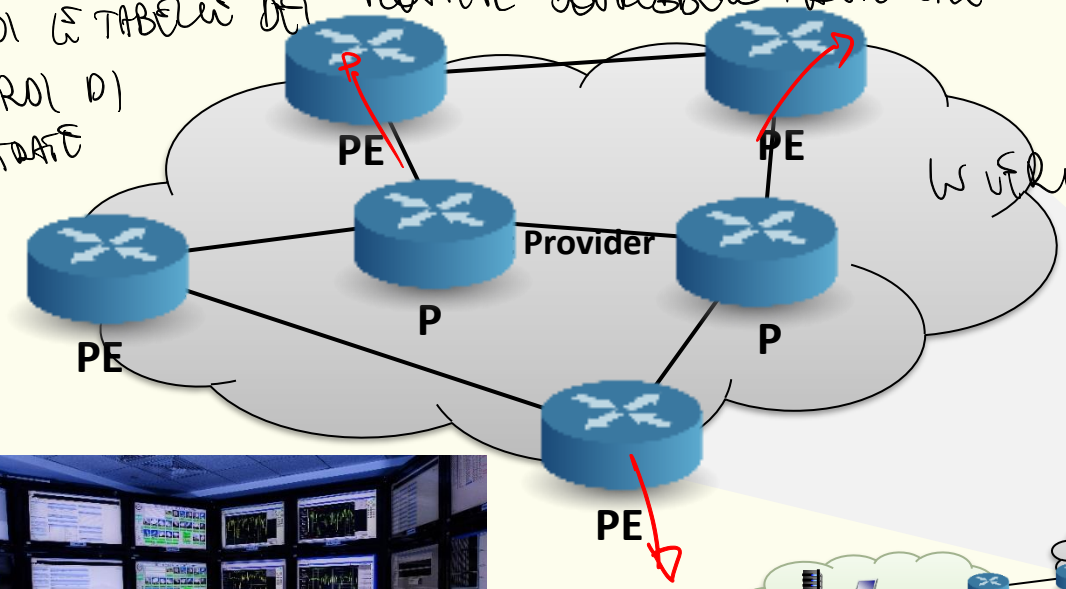
- Core backbone architecture and protocols
- Internet architecture
- VPN technologies and services
- Data Center networks

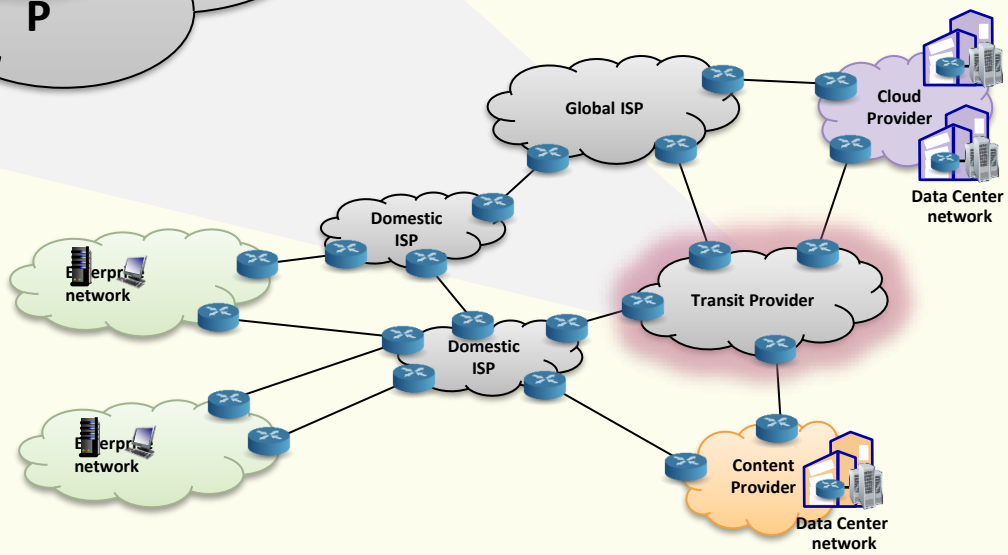


Multi-Protocol Label Switching

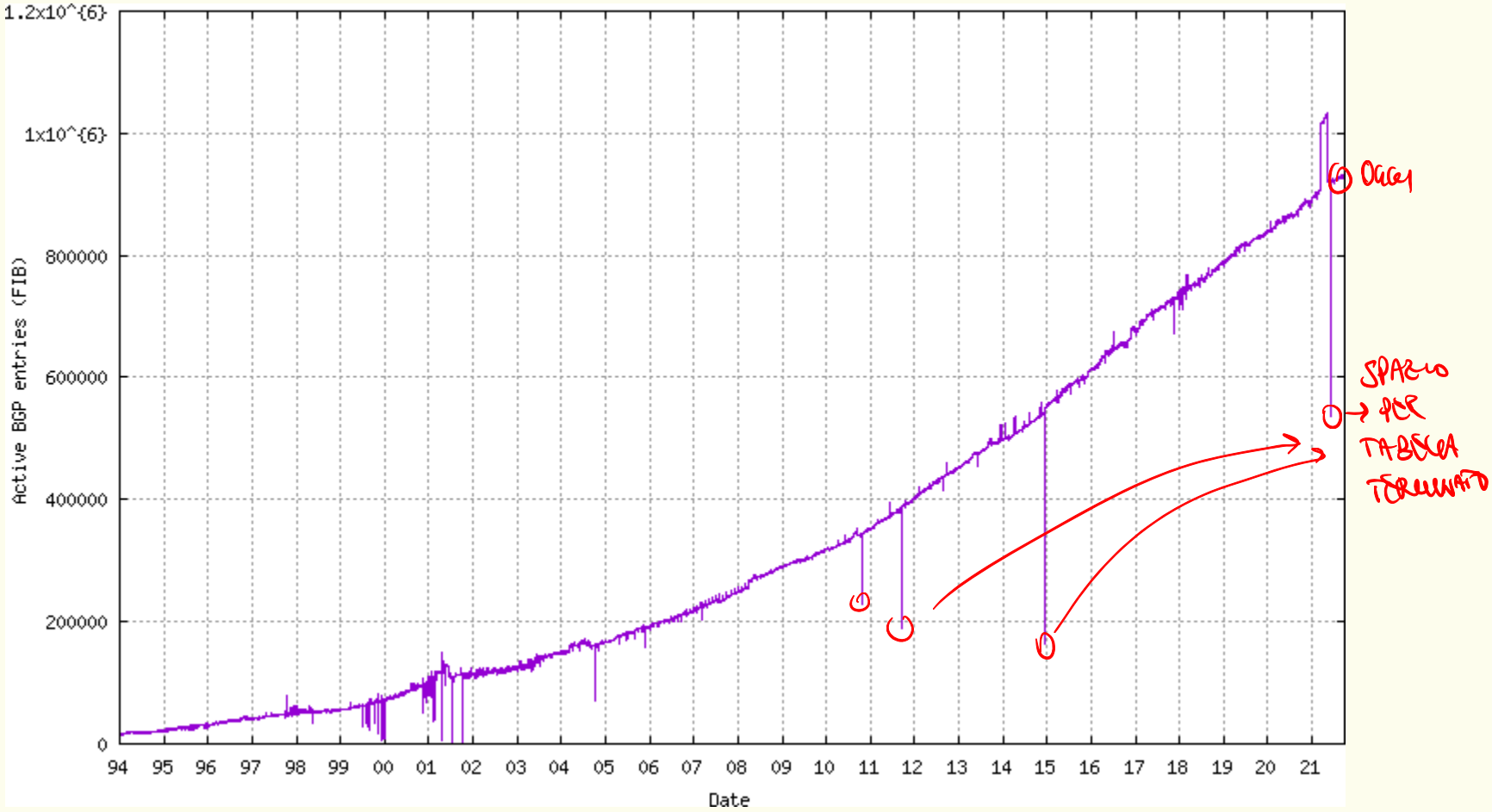
- Routing scalability

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



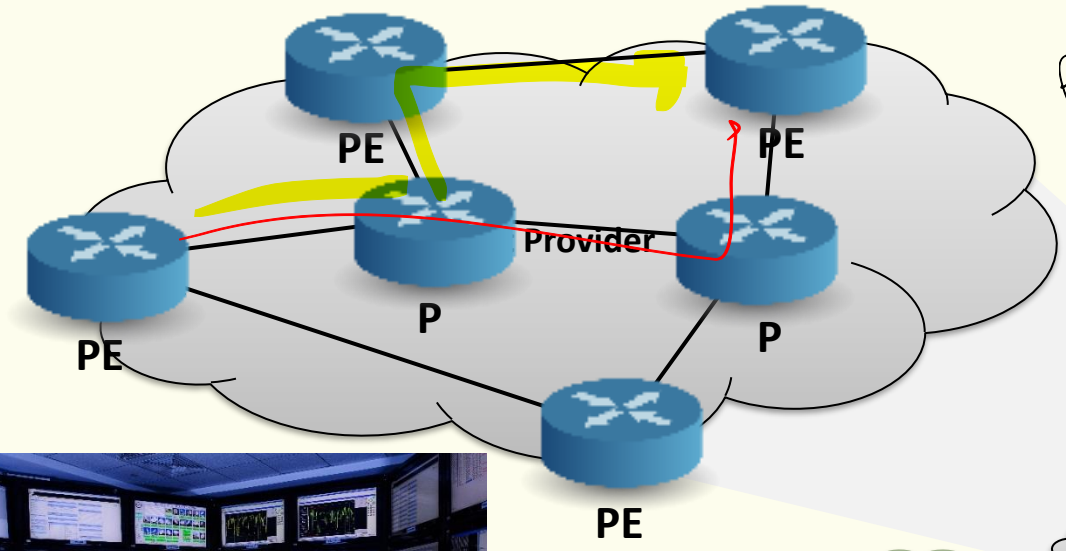


Active BGP entries as of Sept. 26, 2021

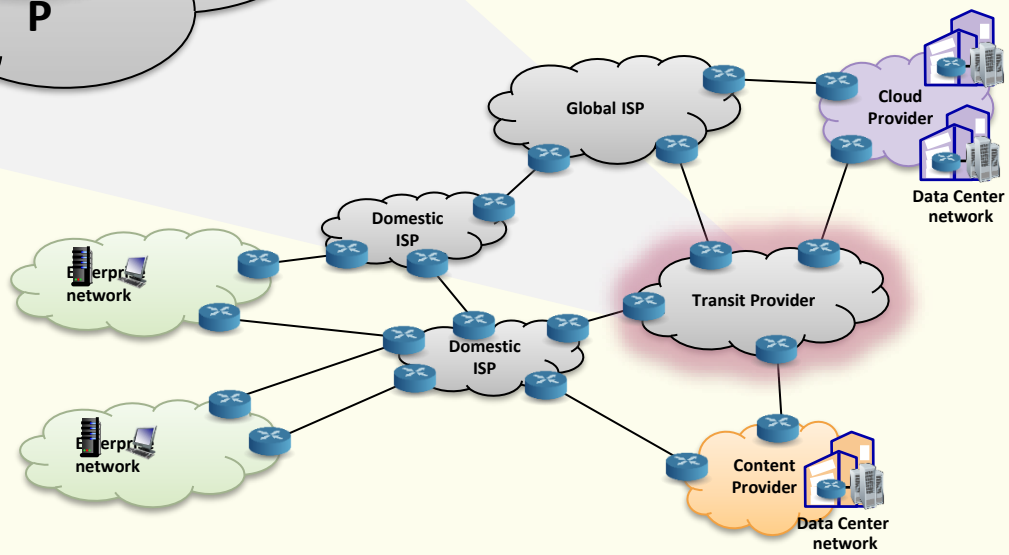


MPLS-based Traffic Engineering

- Routing flexibility

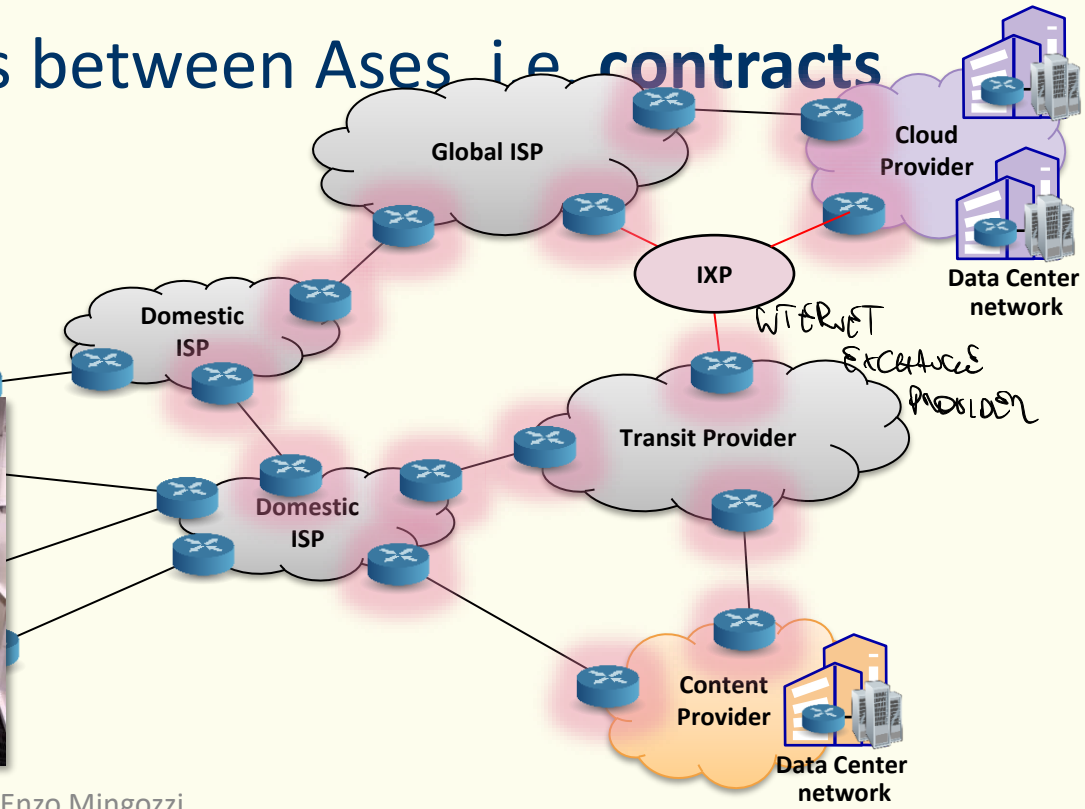


PATH DIVERSI NON SOLO IN BASE AL COSTO



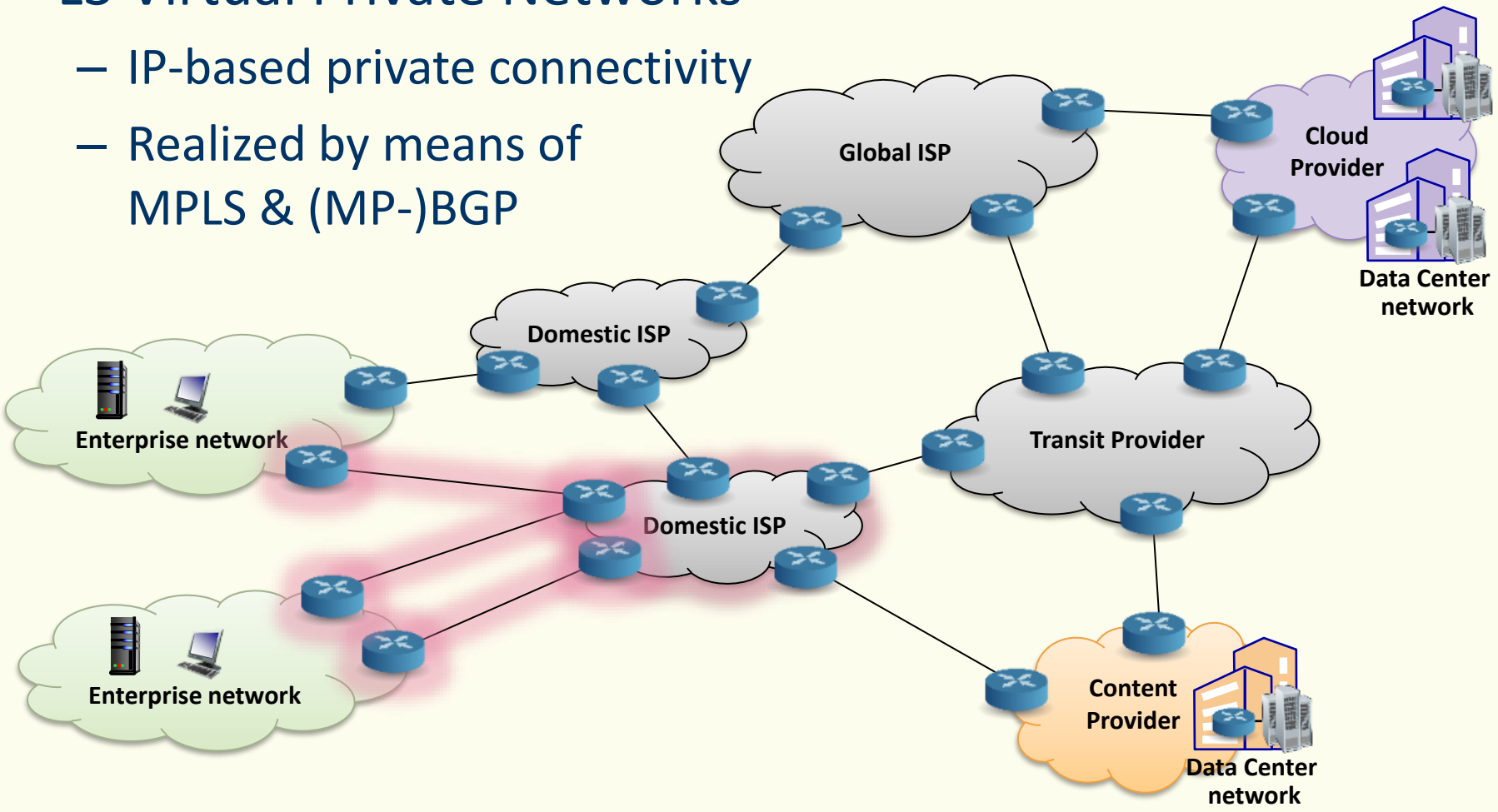
InterAS routing

- 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**



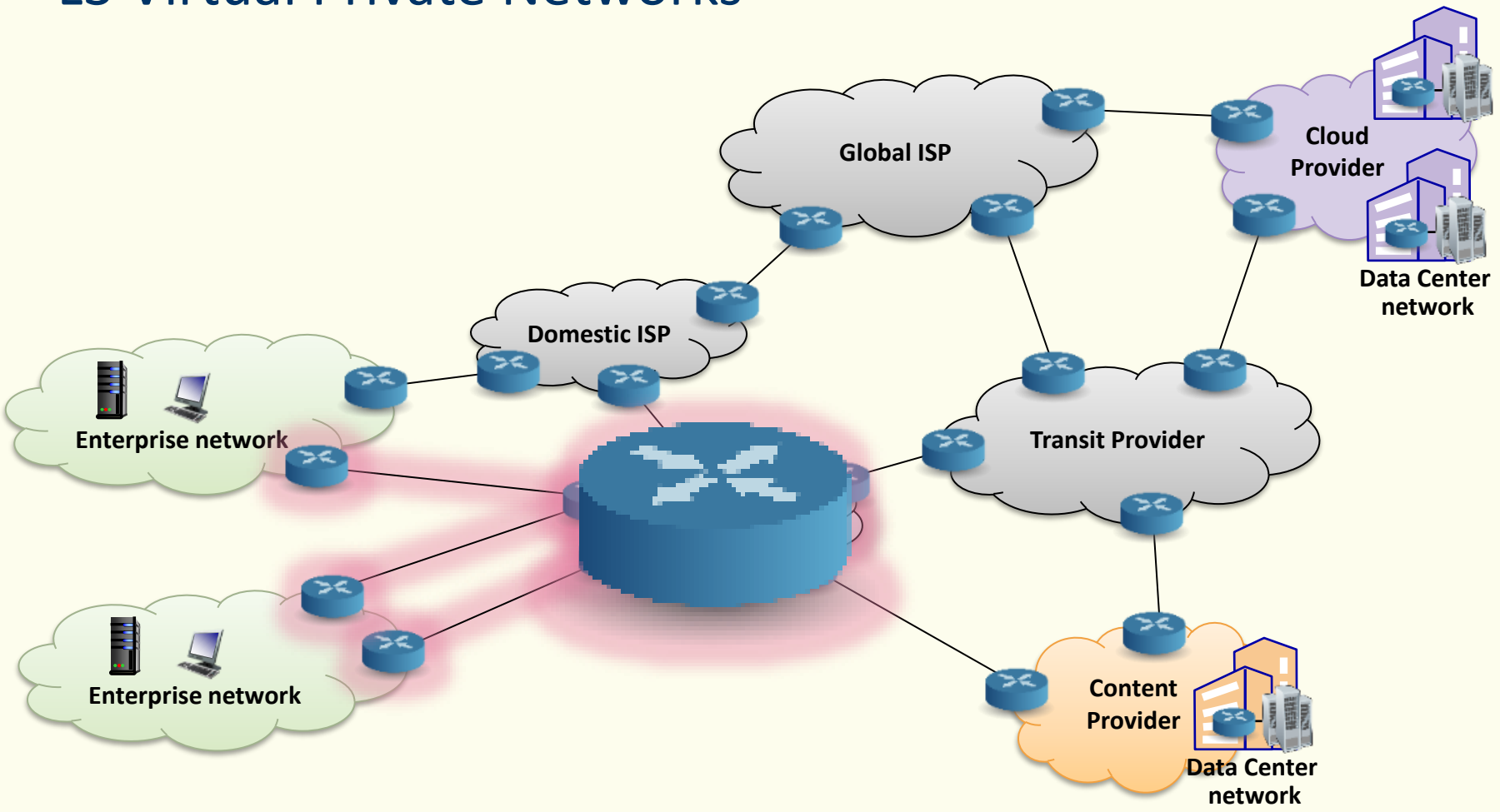
Network virtualization

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



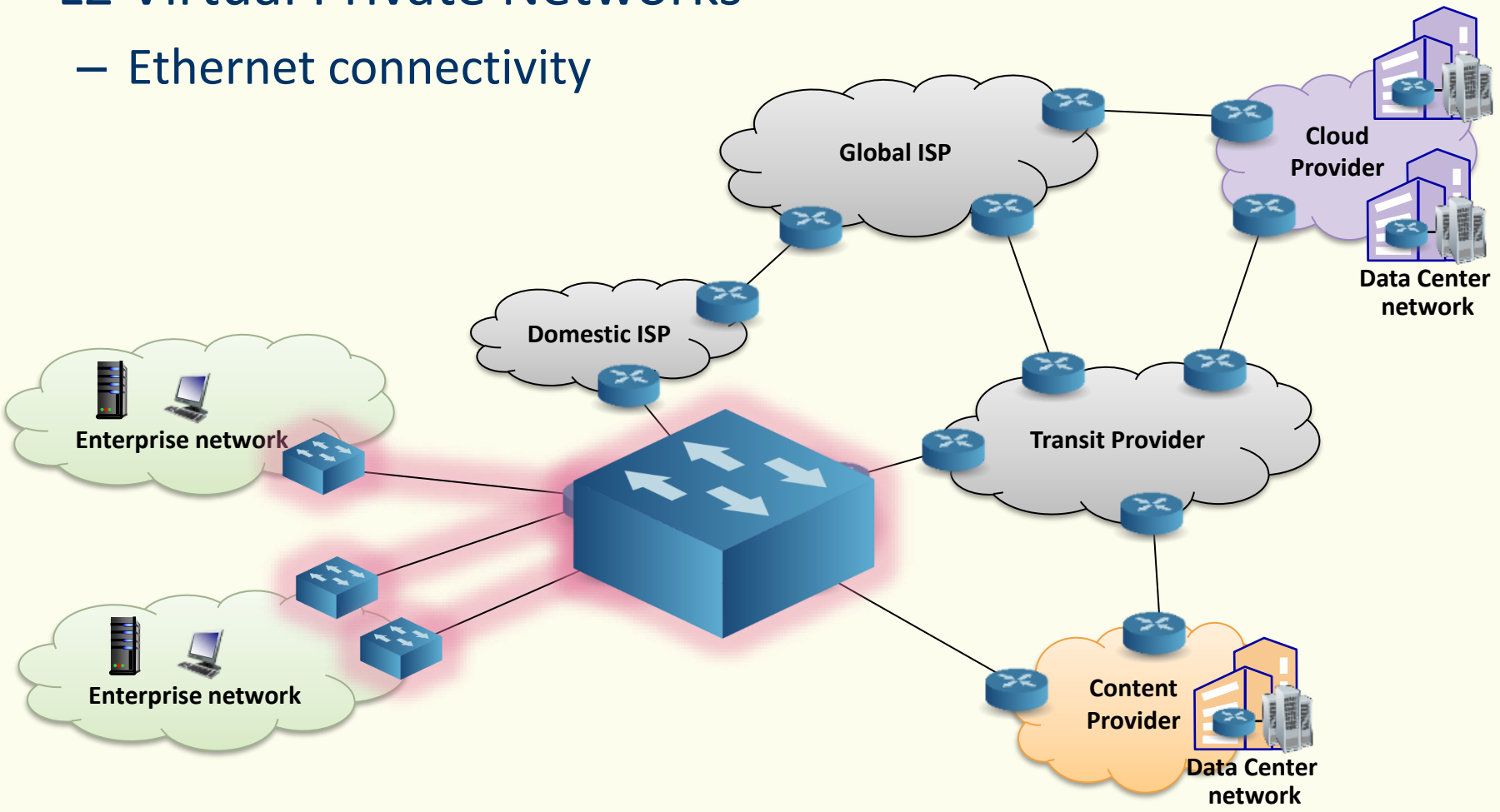
Network virtualization

- L3 Virtual Private Networks



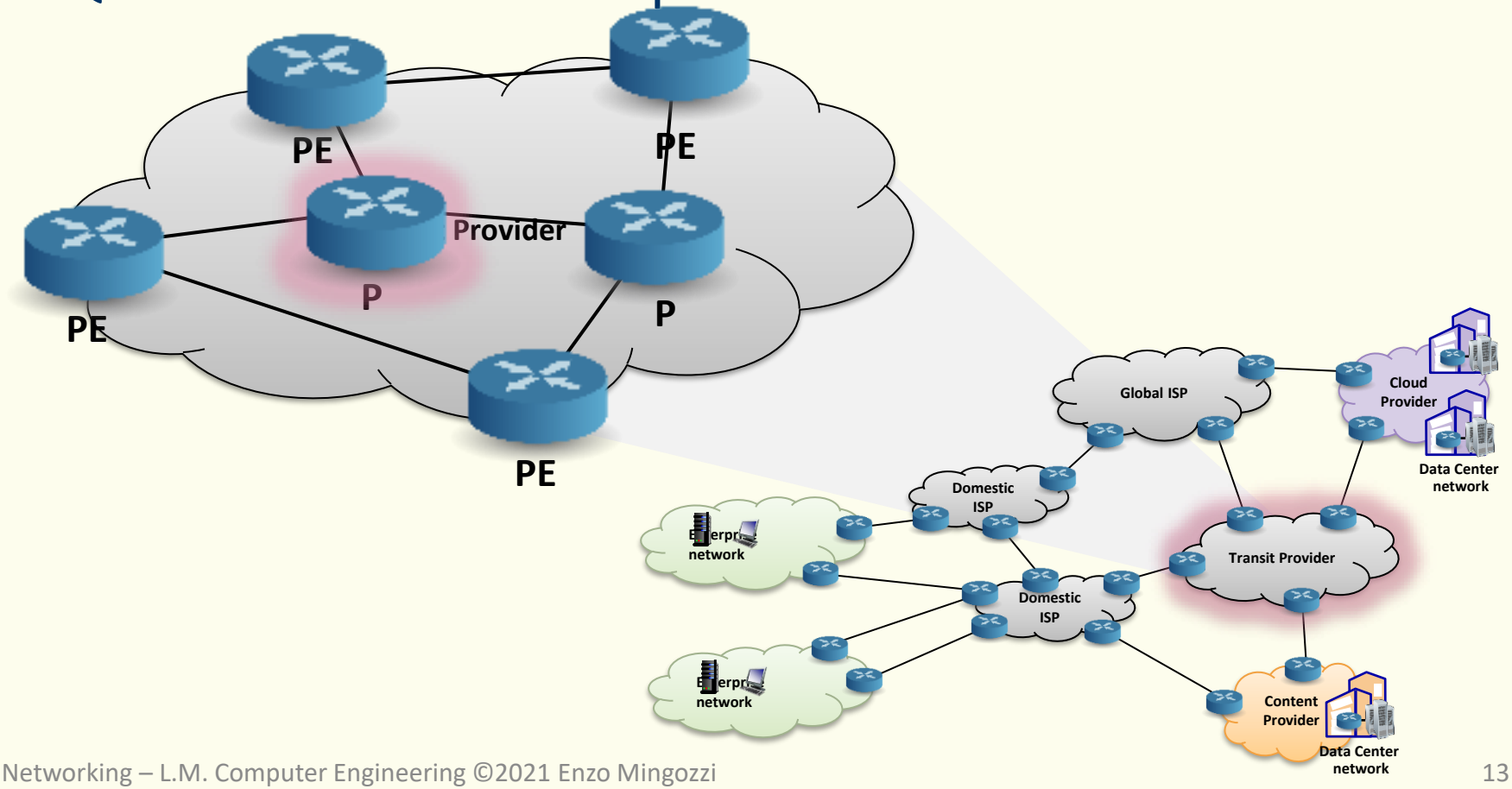
Network virtualization

- L2 Virtual Private Networks
  - Ethernet connectivity



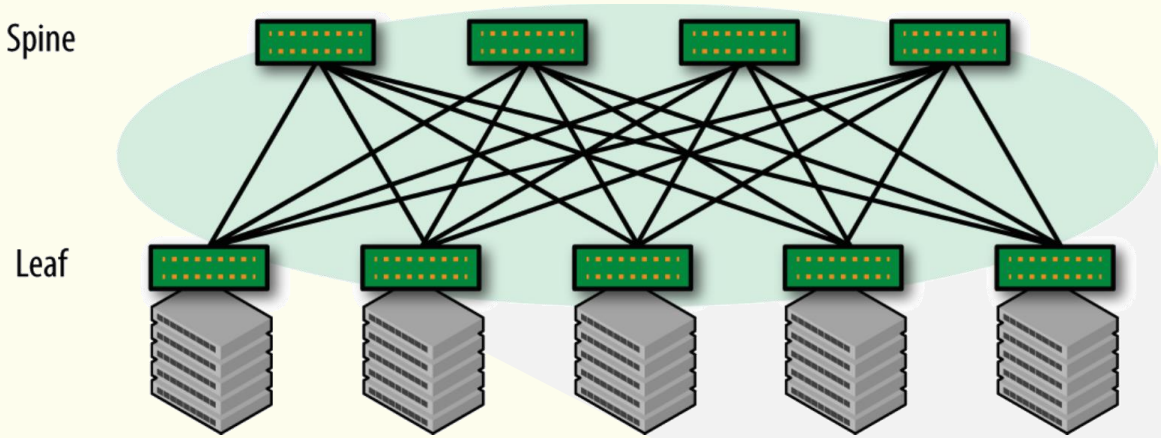
QoS/QoE

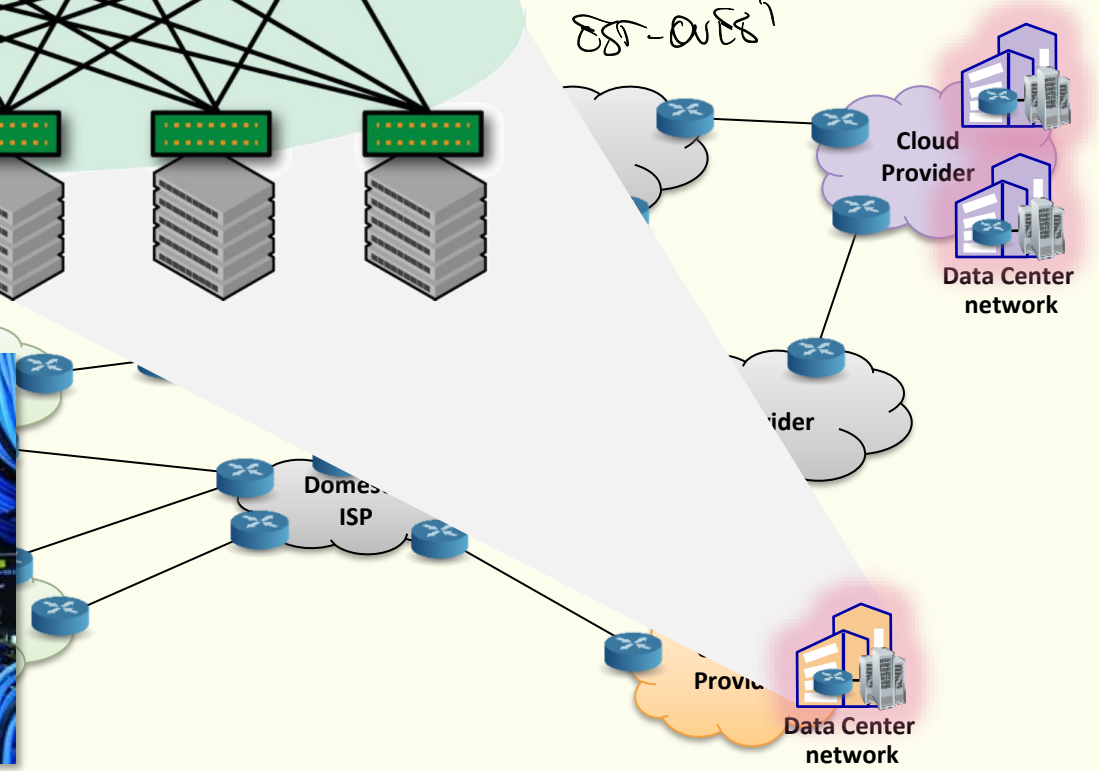
- Multimedia data characterization and requirements
- IP QoS architectures and protocols



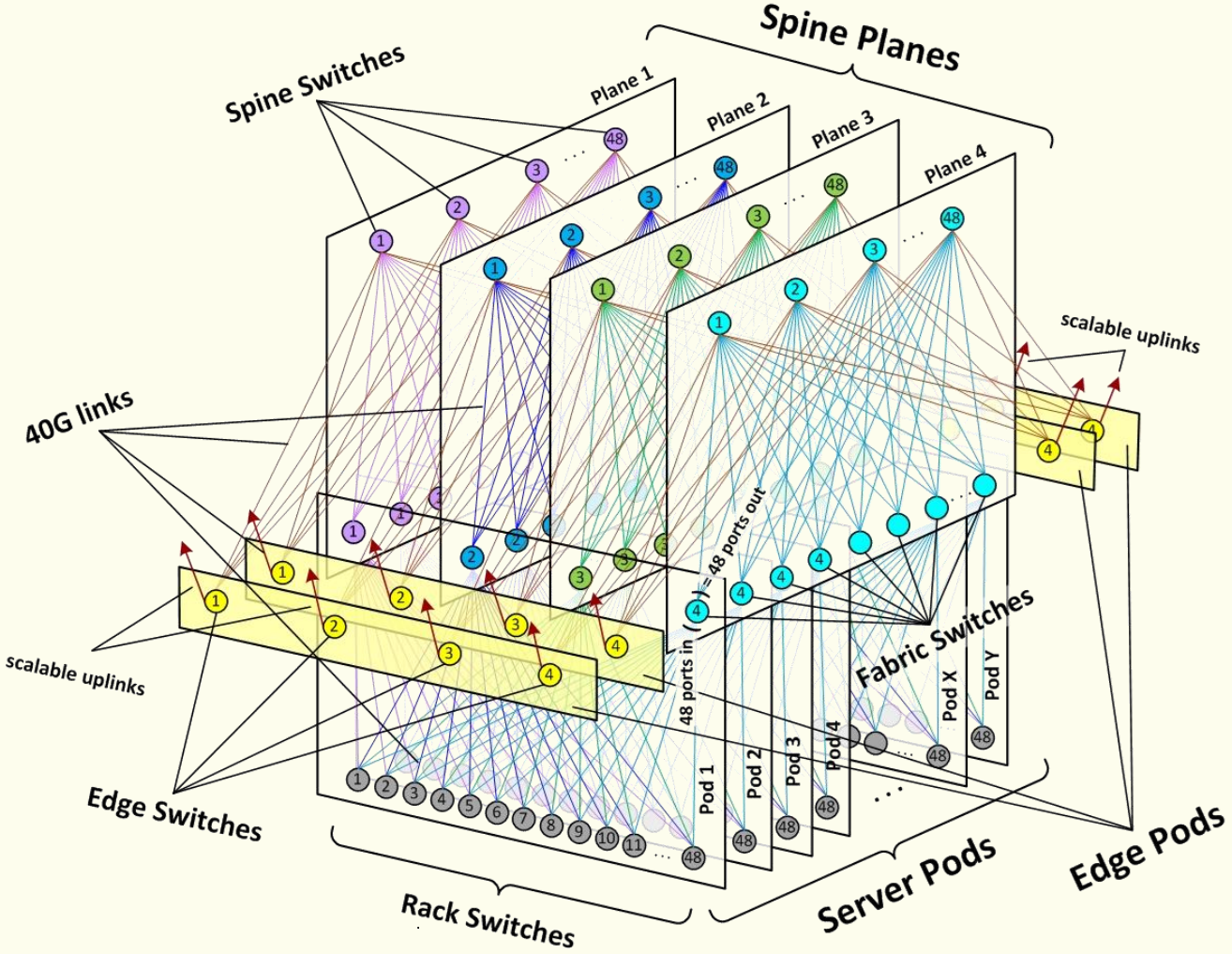
Data Center networking

- DC network architectures





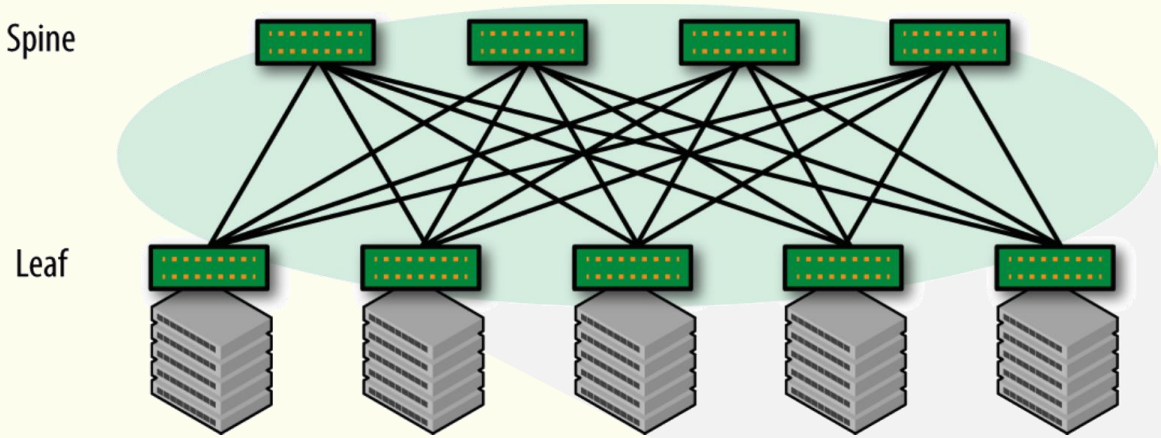
Data Center networking

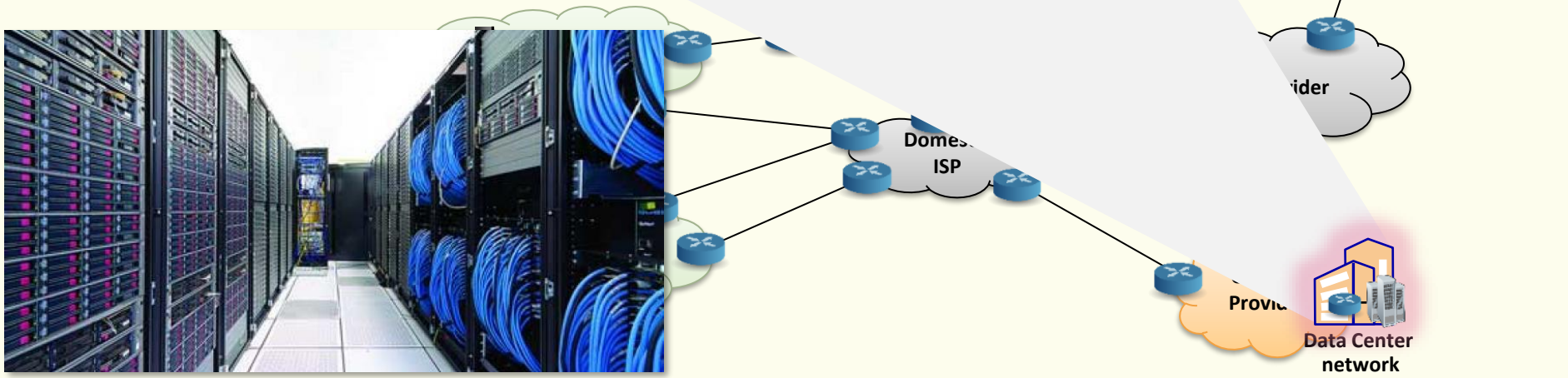


Introducing data center fabric, the next-generation Facebook data center network - Facebook Engineering (fb.com)

Data Center networking

- DC network virtualization



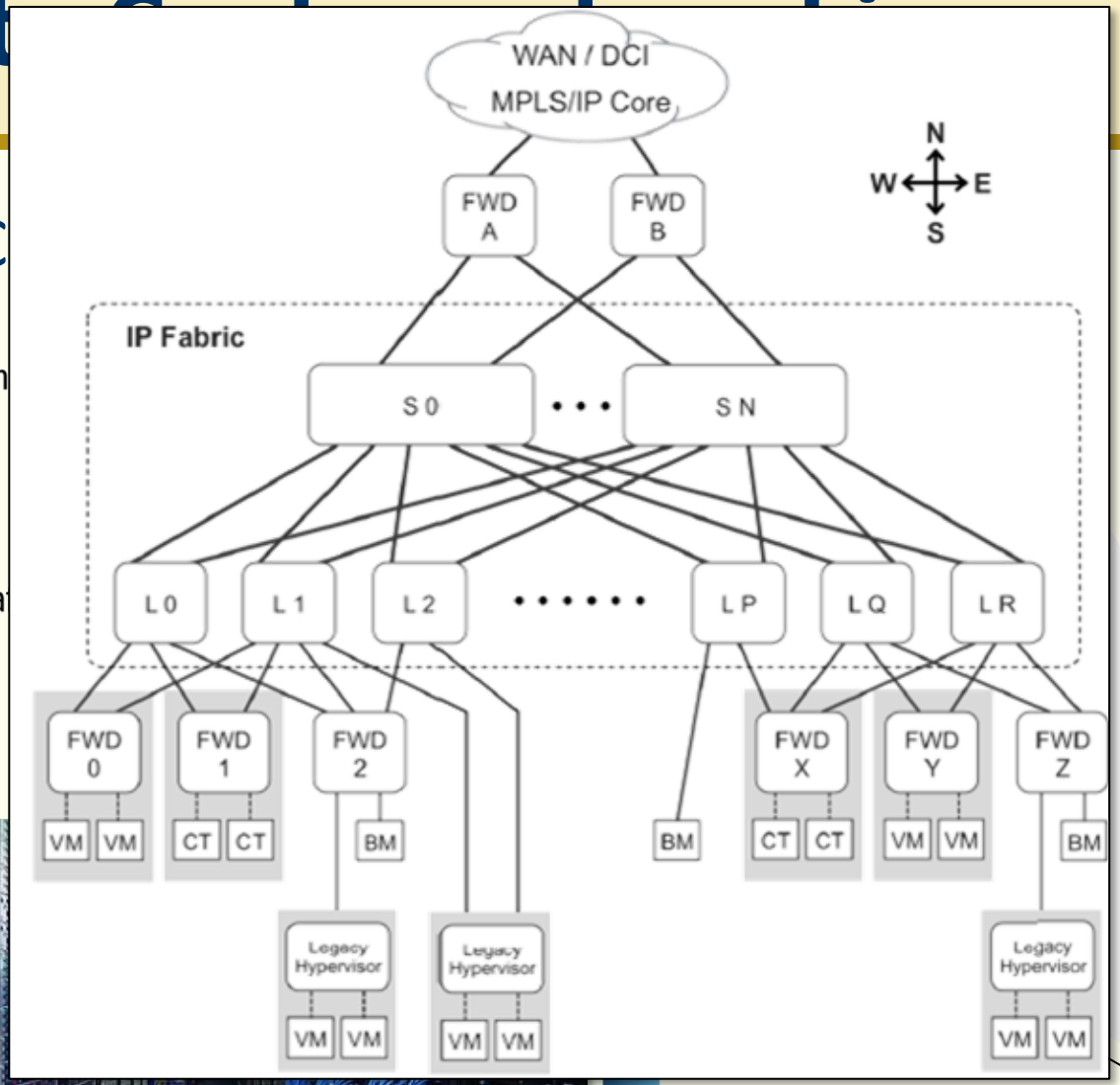


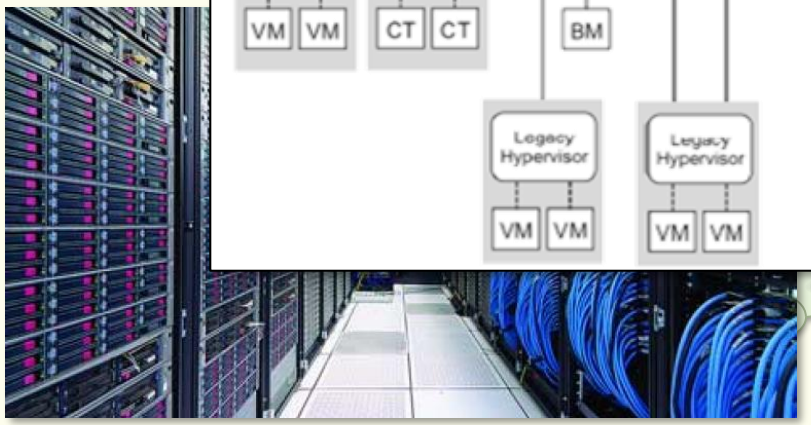
Dat

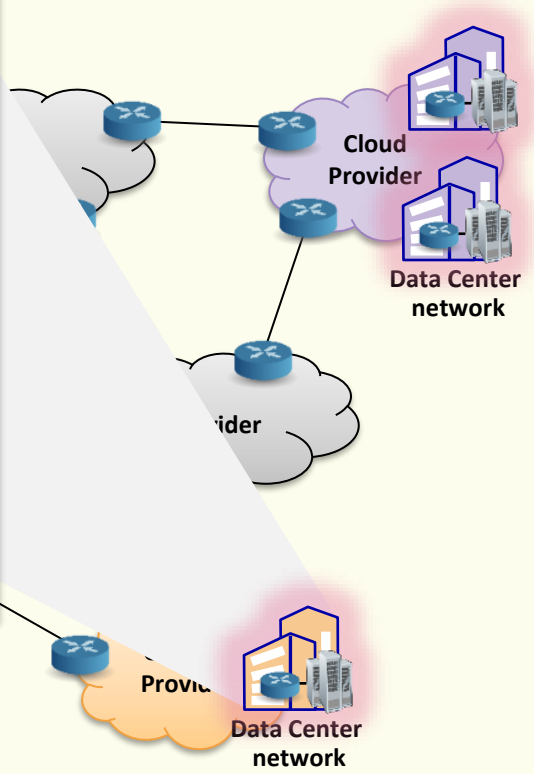
- DC

Spin

Lea







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
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Router(config-router)# exit
Router(config)# exit
Router# copy running-config startup-config
Router# disable
Router>
```
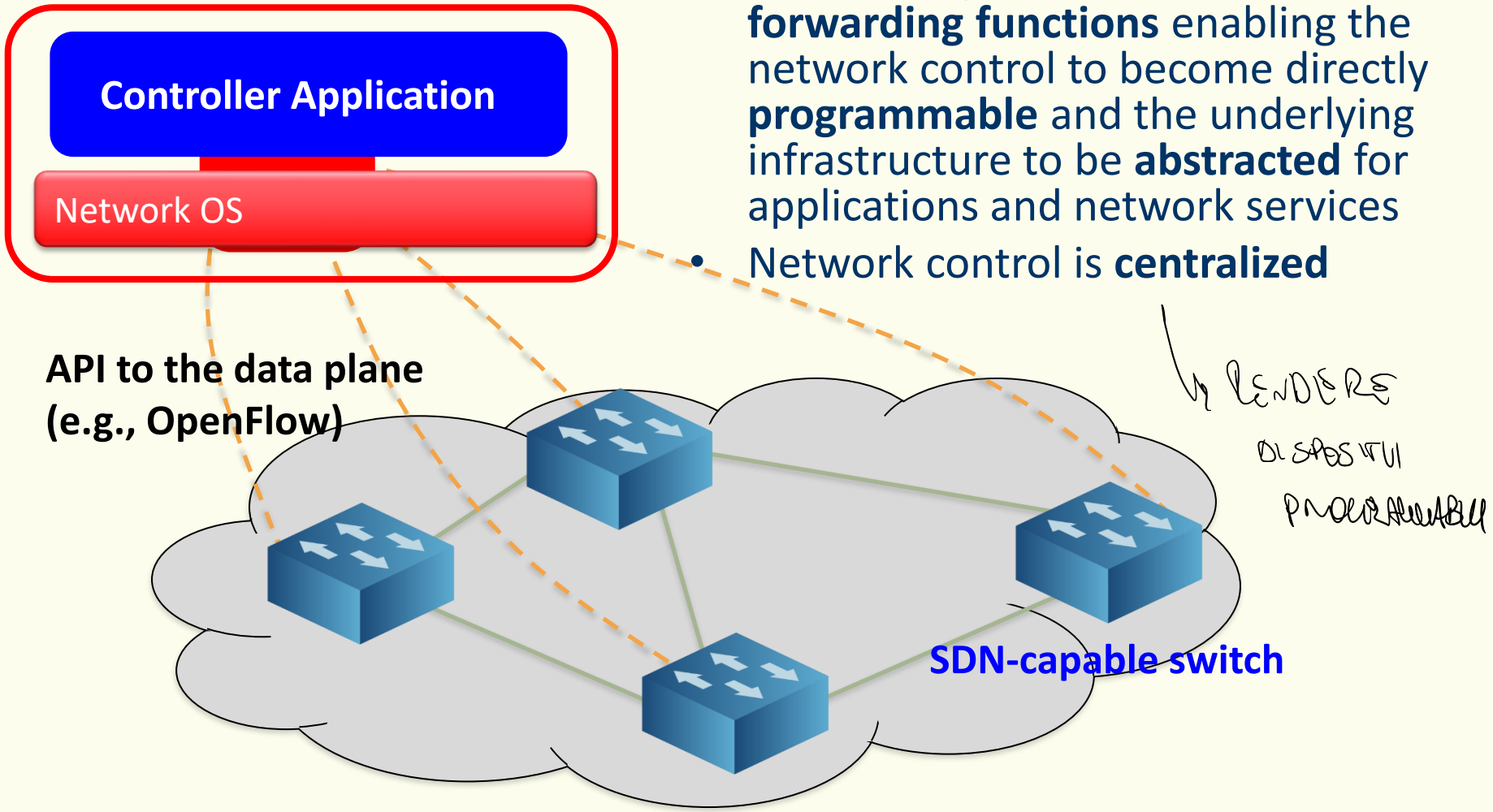
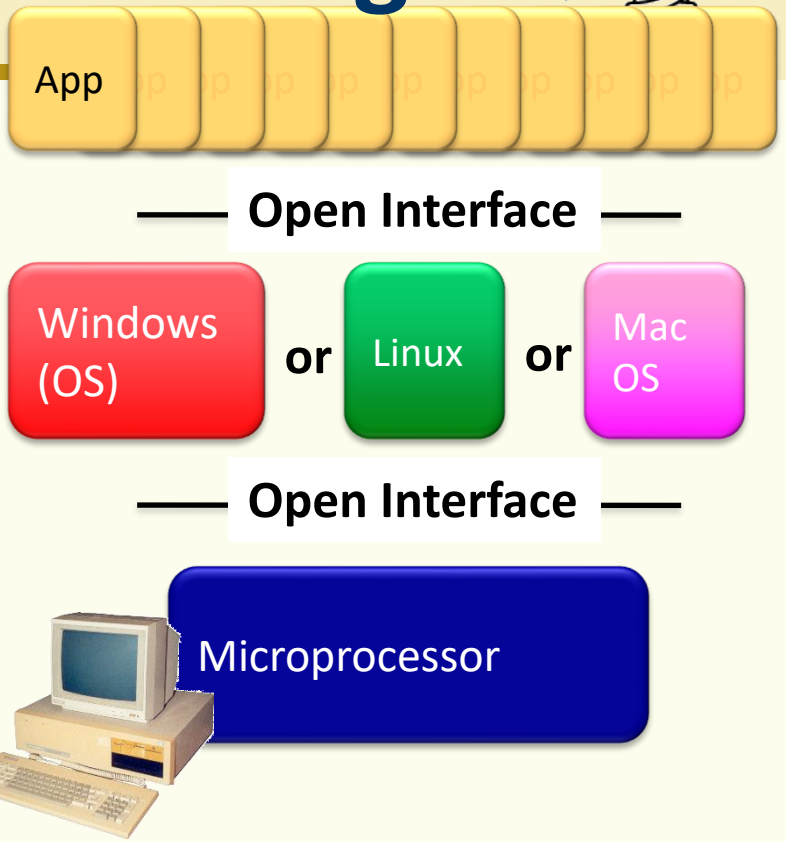

Terminal Protocol: **SSH**

Software Defined Networking

- SDN **decouples** the **network control** and **forwarding functions** enabling the network control to become directly **programmable** and the underlying infrastructure to be **abstracted** for applications and network services
- Network control is **centralized**



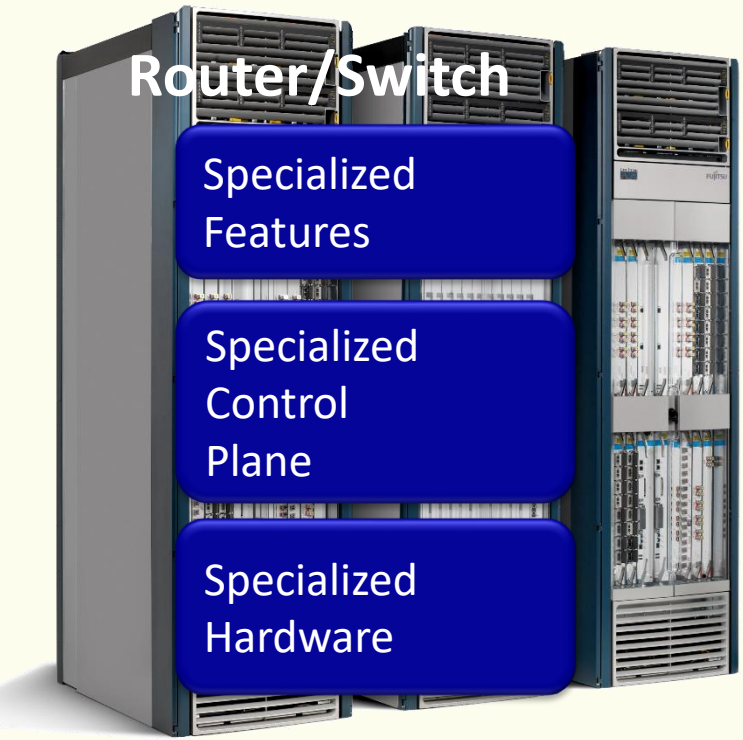
Software Defined Networking

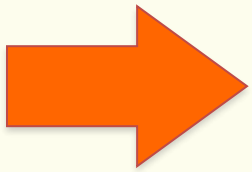


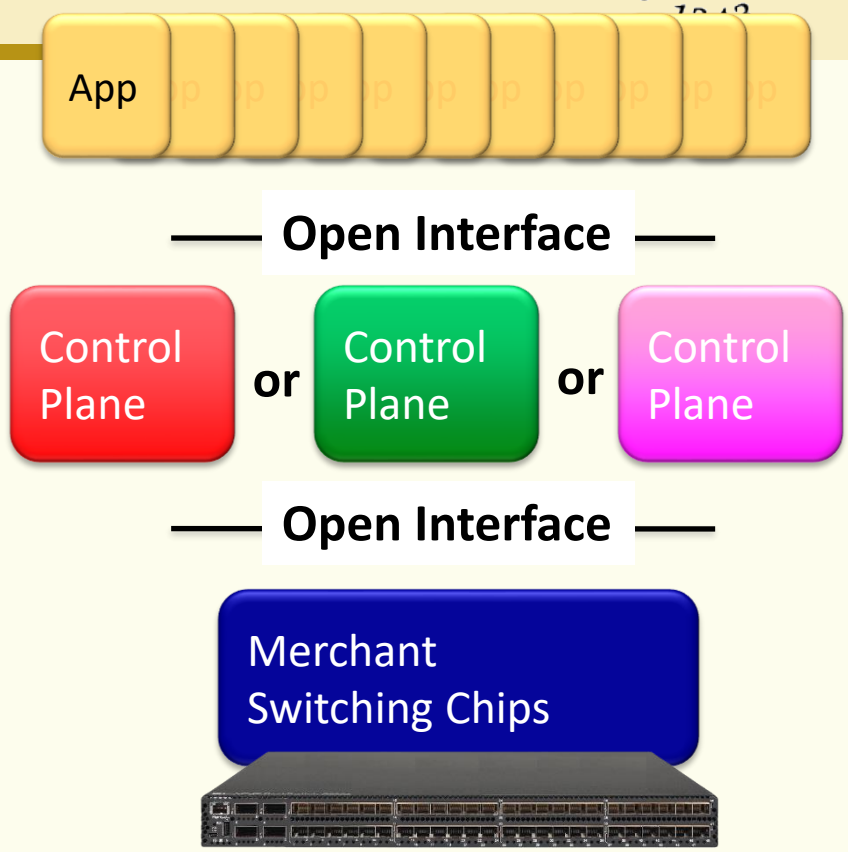
Vertically integrated
Closed, proprietary
Slow innovation
Small industry

Horizontal
Open interfaces
Rapid innovation
Huge industry

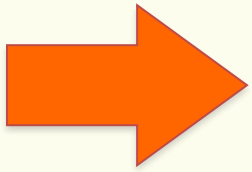
Software Defined Networking





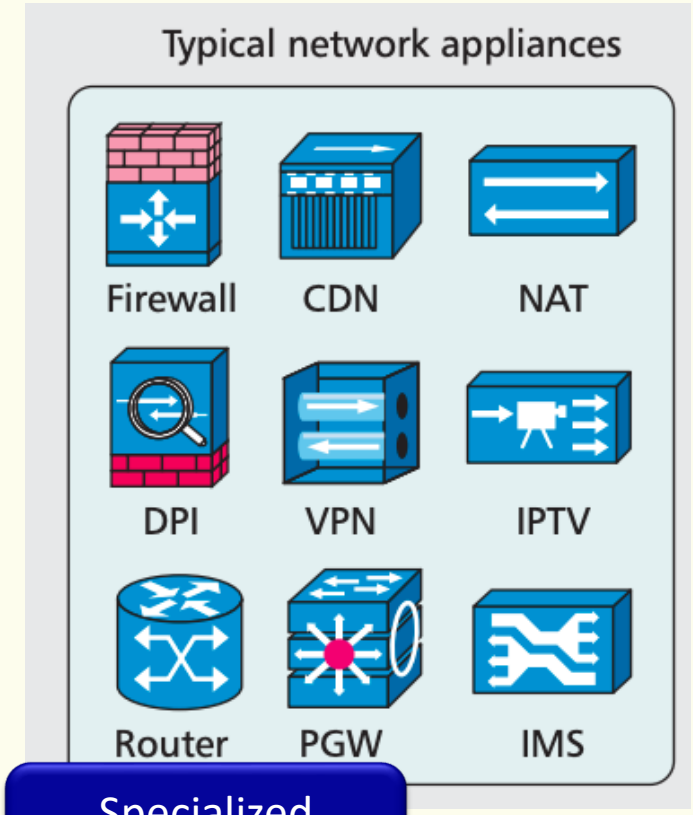


Vertically integrated
Closed, proprietary
Slow innovation



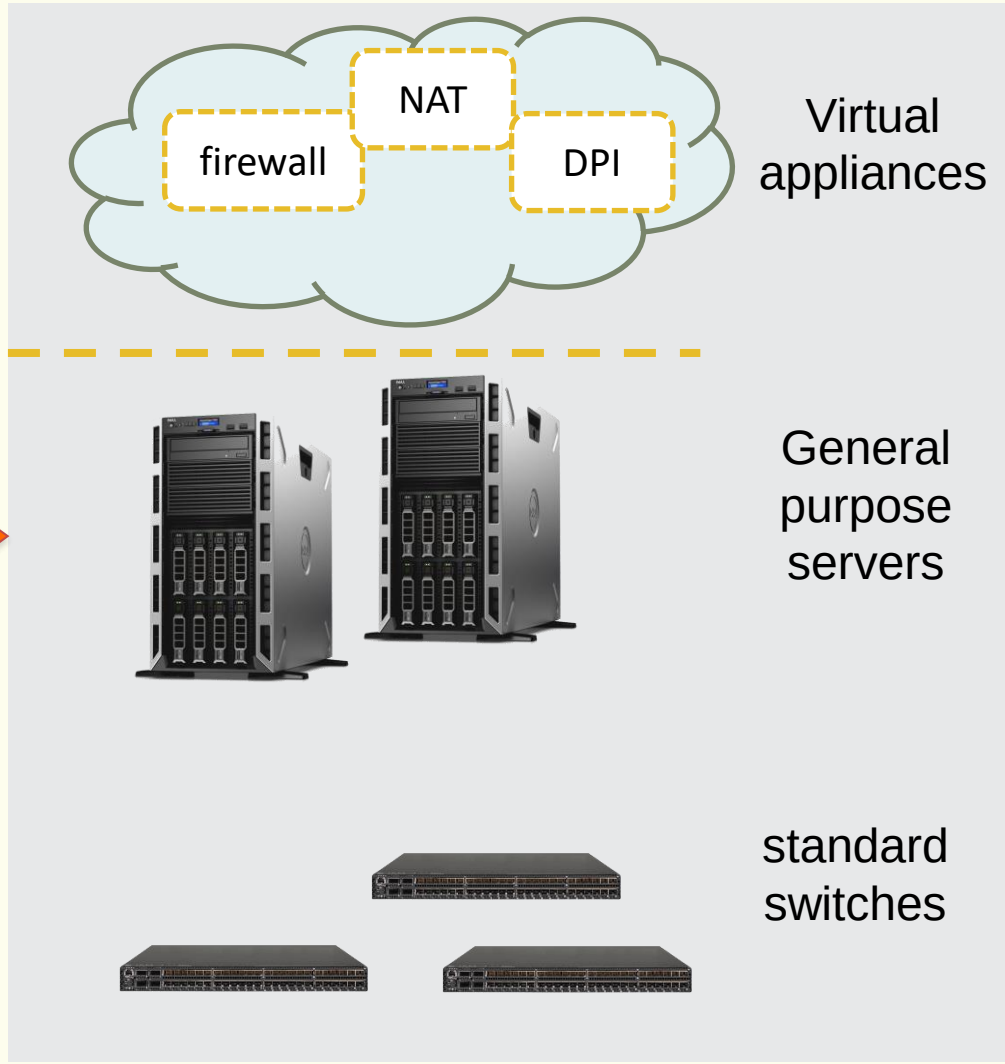
Horizontal
Open interfaces
Rapid innovation

Network Function Virtualization



Specialized Features

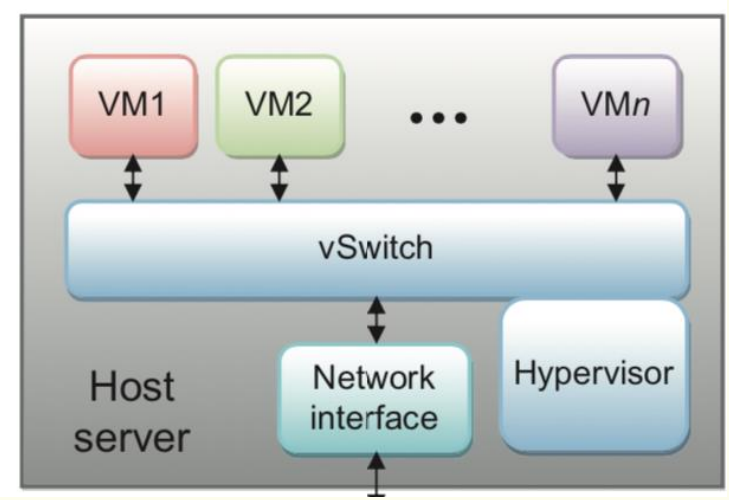
Specialized Hardware

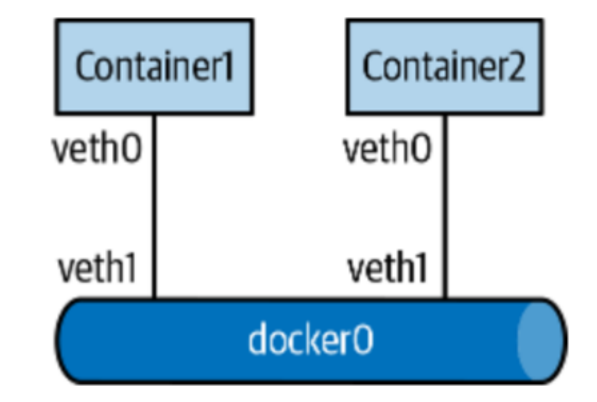


Network Function Virtualization

[vMX Virtual Router | Juniper Networks]

VM/Container networking





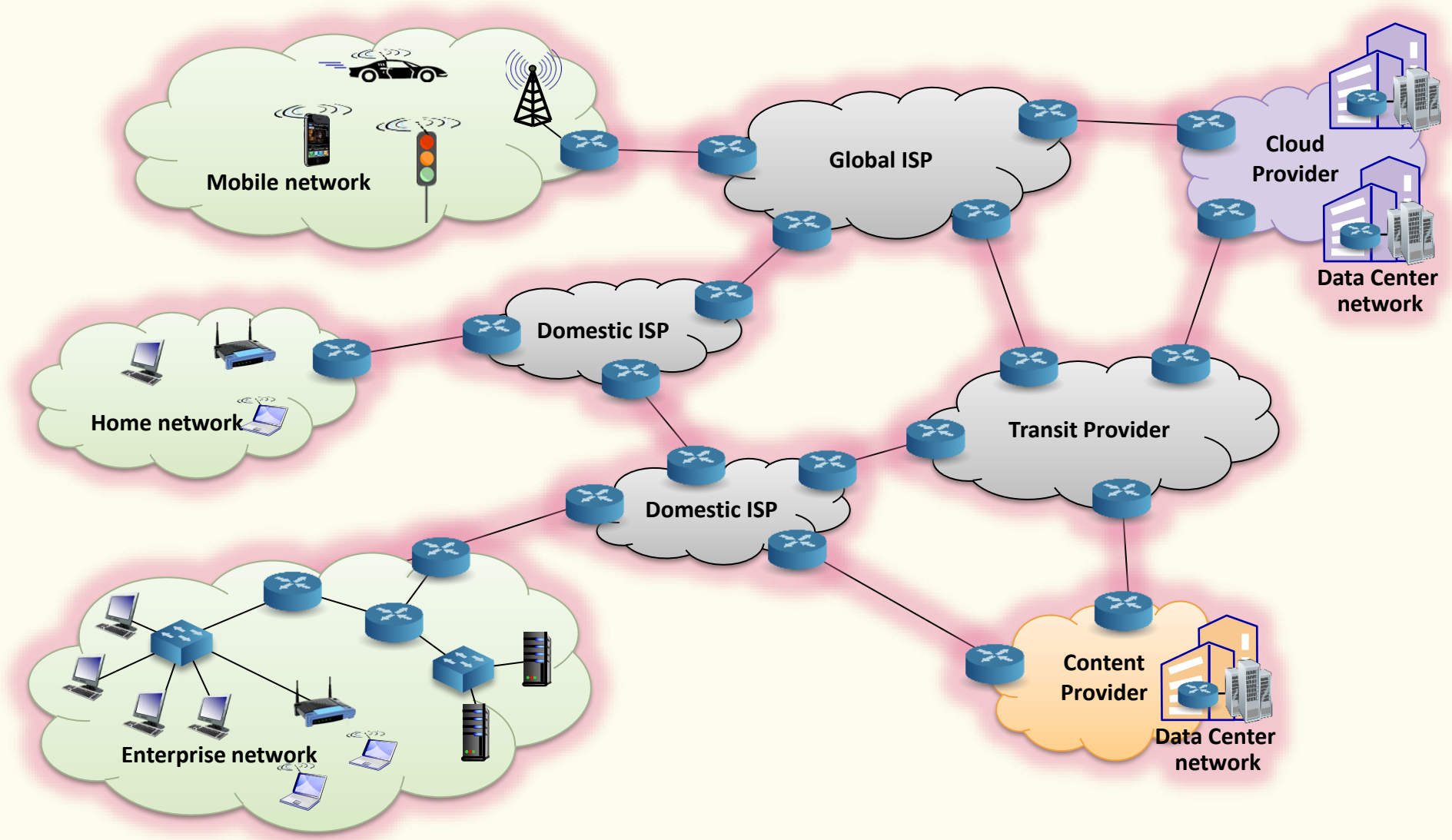
- "easy" networking
  - No network
  - Host-only network
  - Bridged
  - …
- "advanced" networking
  - custom software switches

Open vSwitch

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

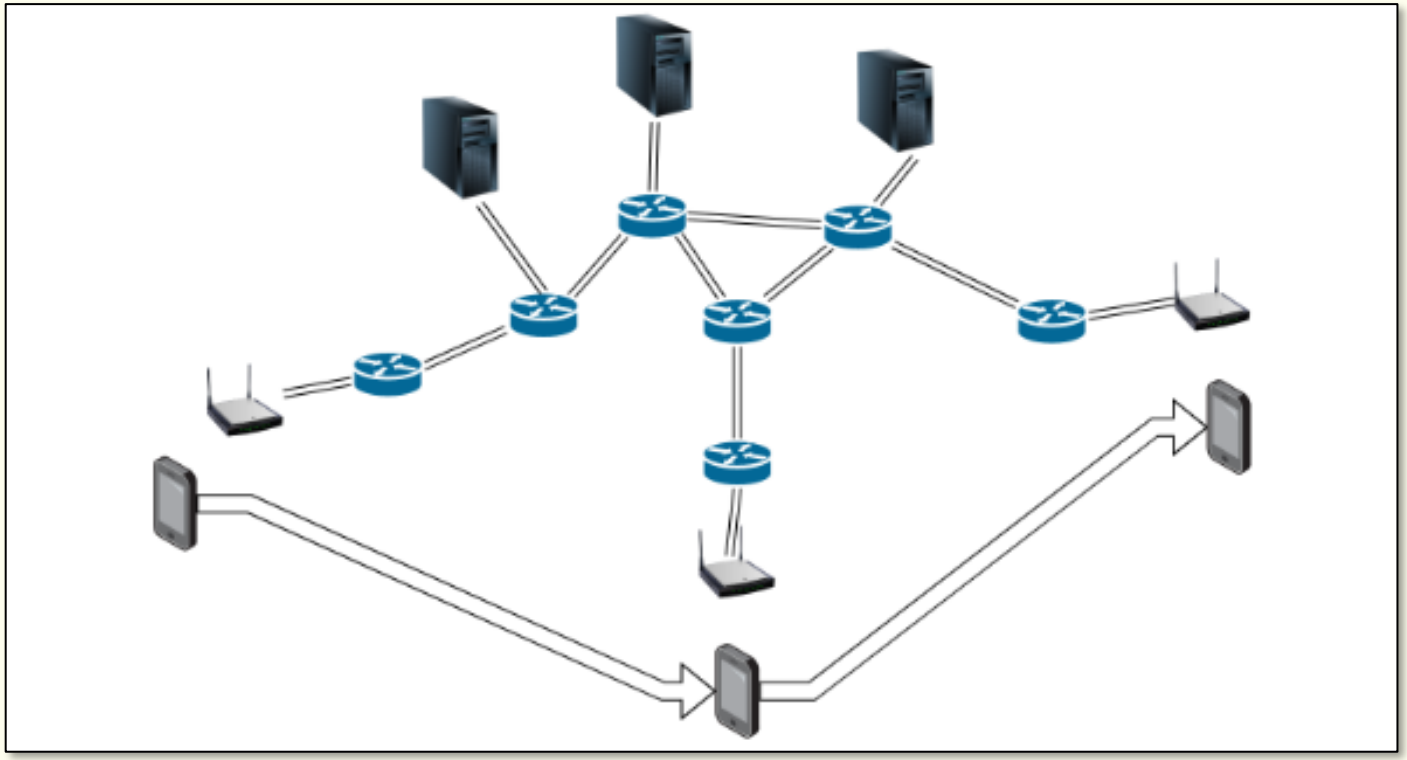
- 9 CFUs = 90 hours (~70h lessons + ~20h labs)
  - 6 CFUs with myself
  - 3 CFUs with Antonio Virdis
- Prerequisites
  - computer networking and programming
- Final exam
  - Team project (3 persons per team)
  - Oral Q&A

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 Mingozzi (enzo.mingozzi@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)