GRS (short)

Management vs. Operations

- **Management**:
  - Conceptual, high-level dimensions to keep network running smoothly;
  - **Smoothly**: Quality of Experience (QoE), reliability, security, etc.
  - Manage monitoring, configurations, performance, faults, security, accounting, etc.
- **Operations**:
  - People, processes, and tools to make management happen; Typically in the network operations center.

Network planes

- **Data plane**:
  - Packet switch and forwarding (microseconds);
  - Looks up rules, e.g., packet header, in/out interfaces, time-slot;
  - **Protocols**: IP header parsing.
- **Control plane**:
  - **Switching control/Network functions** (milliseconds): routing, Quality of Service (QoS), firewall, etc.
  - Reacts to changes (interfaces, links, etc.);
  - Control is centralized or distributed (neighboring routers);
  - Update switching rules;
  - **Protocols**: OSPF, BGP.
- **Management plane**:
  - Orquestração e operação de redes;
  - **Protocols**: Telnet, SSH, SNMP.

Traditional development vs. DevOps

Traditional release deployment

- Gather specifications;
- UML architecture diagrams;
- Implement, test, deploy;
- **Fence between *dev team* and *ops team***;
- Dev not consider operational requirements;
- Broken deployments => long feedback to dev.

DevOps approach

- Quick deployment cycle (agile, test-driven, sprints);
- Write code thinking about other phases (deployment, testing, etc.);
- Build rather than buy;
- Automate test and deployment (repeatable and predictable);
- Embrace failure: fail fast, find errors/vulnerabilities, recover quickly.

FCAPS

Framework for network management.

Component	Explanation
Fault	Recognize, isolate, correct and log faults in the network
Configuration	Focus tracking and managing deployments in a centralized manner. Streamline device configuration and provisioning to ensure quicker configuration and flexibility
Accounting	gather usage statistics for users
Performance	ensuring performance remains at acceptable levels
Security	controlling access to assets in the network

Monitoring entra em todas exceto configuration.

Monolithic vs. microservice

Monolithic

All functionalities of a project exist in a single codebase.

Good	Bad
Simpler to develop	Becomes too large with time => difficult to manage
Easier to deploy	Need to redeploy the whole application with every change
Network latency and security not as relevant	High barrier of entry to new devs
Developers focus on single application	Even if single part is suffering load, need to replicate instances for the entire application
–	Difficult to adopt new techs
–	Not very reliable as single bug can bring everything down

Microservices

Architectural development style where the application is made of smaller services. These communicate with each other directly using lightweight protocols like HTTP.

Good	Bad
Single responsibility	More complex (distributed system)
Built around business capabilities - freedom to choose the best technologies for each business part	Independent deployment of services is hard
Design for failure - designed with failure cases in mind. A single service failing, doesn't bring everything down	Debugging is difficult

Virtualization vs. containers

Virtualization	Containers
Needs hypervisor	Shares the OS kernel
Brings a whole system (OS and virtual hardware)	Shared parts are read-only
Moving VMs between clouds can be challenging	Doesn't allow running other OSes

Quality Network

Application quality requirements

- Capacity (bit/s) - bandwidth intensive applications:
  - Bursts: o quão frequentes e de quão grandes;
  - Capacity vs. throughput vs. goodput.
- Delay - real time, interactive applications:
  - End-to-end delay (control);
  - Round-trip delay (teleconference);
  - Delay variation/jitter - visualization.
- Reliability - mission critical applications:
  - Error rates nos bit/packets;
  - Mean time between failures (MTBF);
  - Mean time to recover (MTTR);
  - Availability = $MTBF/(MTBF + MTTR)$;
  - Uptime(%) = 1 - Availability;

QoS and traffic engineering

- **Best effort networks**:
  - Não tem preocupações de qualidade (e.g., queues);
  - Serve pacotes por ordem de chegada;
  - Light used => quality OK;
  - Heavily used => quality degradation.
- QoS:
  - Queue management - choose packet, different queues;
  - Load-balancing algorithms - Round-robin, token bucket, RED, etc.
- **Circuit Switching Networks**:
  - Bandwidth is divided into chunks;
  - The Bit delay is constant (during the connection);
  - Once path/circuit is established, data rate is constant;
  - **Admission control** - validation step in communication systems to see if there are sufficient resources for the connection.

Monitoring

- Get a sense of how the network is performing;
- Make sure we're still offering a quality network;
- Essential for **FCAPS**;
- **Short-term measurements**: identify faults, congestions, and attacks;
- **Longer-term measurements**: traffic engineering (reroute or negotiate new agreements with peers), upgrade link and device capacity;
- **Accounting** - so you know how each client of the network is using the network.

Passive vs. Active network measurements

- **Passive**:
  - Get a sense of the existing traffic in the network;
  - Have devices report how much traffic is going through (SNMP, netflow);
  - **Port mirroring** - Tap a link or copy traffic to monitoring port;
  - For measuring production traffic and its characteristics.
- **Active**:
  - Inject (new) measurement packets in the network;
  - Get a sense of how the network reacts to these packets;
  - Including responses (e.g., ICMP req/rep for RTT);
  - For measuring the properties of the network (delay, jitter, topology, etc.);
  - **Tools**: ping + traceroute + lperf + owamp + twamp.
- **Não precisamos de ferramentas de medidas passivas para fazer medidas ativas**.

IP Addressing

Classes

Class	Format
A	`/8`
B	`/16`
C	`/24`
Classless (CIDR)	Specify n bits in network part (`/n`)

Special cases

Meaning	Address
Network address	host part all 0s
Broadcast address	Host part all 1s
This network, this host	`0.0.0.0/8`

Meaning	Address
Loopback	`127.0.0.0/8`
Link local	`169.254.0.0/16`, `FE80:0:0:0:<Interface ID>`
Private, NAT	`10.0.0.0/8`, `172.16.0.0/12`, `192.168.0.0/16`

Splitting networks

Example: split `200.17.30.0/24` ($2^{32-24} = 2^8 = 256$ addresses).

- How many 32 address networks fit in this `/24` network?
- $32 = 2^5 \rightarrow 5$ bits => `/27` network;
- $8 - 5 = 3$ bits for subnetting => $2^3 = 8$ subnets;
- `200.17.30.xxxyyyyy`, where x=subnet, y=host.

Aggregating networks

Example: is it possible to aggregate any pair of `/27` into one `/26`?

- 2nd and 3rd `/27` subnets;
- 2nd: `200.17.30.32` to `200.17.30.63` - `200.17.30.00|1yyyyy`
- 3rd: `200.17.30.64` to `200.17.30.91` - `200.17.30.01|0yyyyy`
- Even though it is continuous, it doesn't work.

How to?

- Networks must be contiguous: no missing addresses between first and last addr;
- All addrs in same network must have same **network ID bits**.

DNS (port 53)

- Establish the map between domain names and IPs;
- Answer queries from users:

Domain name hierarchy

DNS message format

Timeouts

- **Expire** - number of seconds after which **secondary name servers** should stop answering requests for this zone **if the master does not respond**:
  - Should be higher than $Refresh + Retry$.
- **Refresh** - period of refreshing;
- **Retry** - quanto tempo pode estar sem conseguir dar refresh até dizer "primary server failure".

Resolvers and caches

- Não tem propriamente load-balancing:
  - Cliente tem info de primários + secundários;
  - Pergunta ao primário e depois aos secundários por ordem quando as coisas falham.

Routing

Centralized routing

- Nodes report link status to central location;
- Central location runs optimization algorithm;
- Return routing table to each router;
- **Uses => SDN-like solution** - data centers.

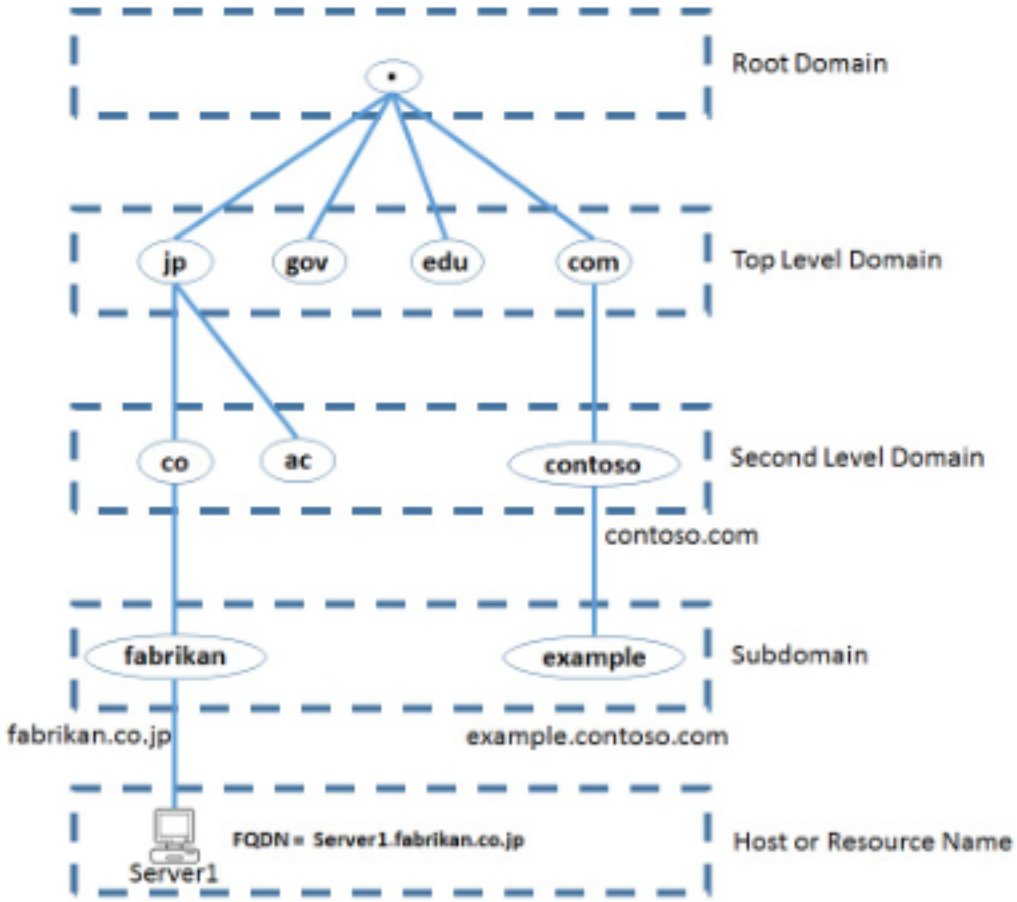


Figure 1: domain name hierarchy

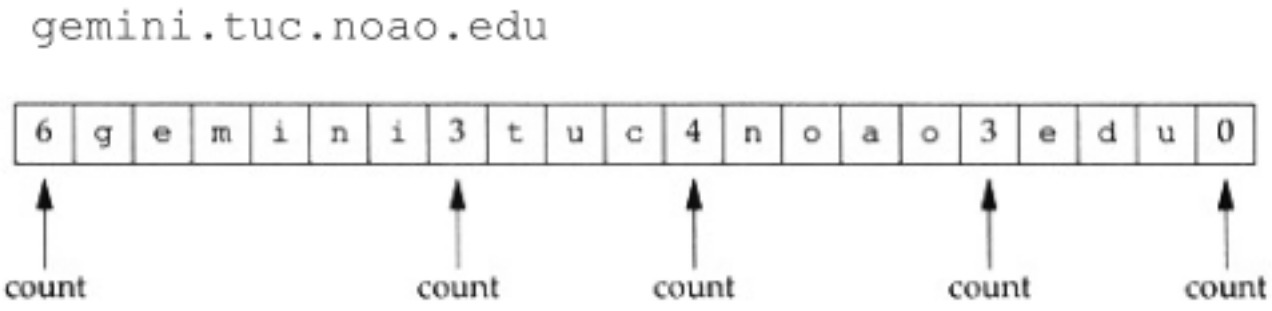


Figure 2: domain_name_to_query

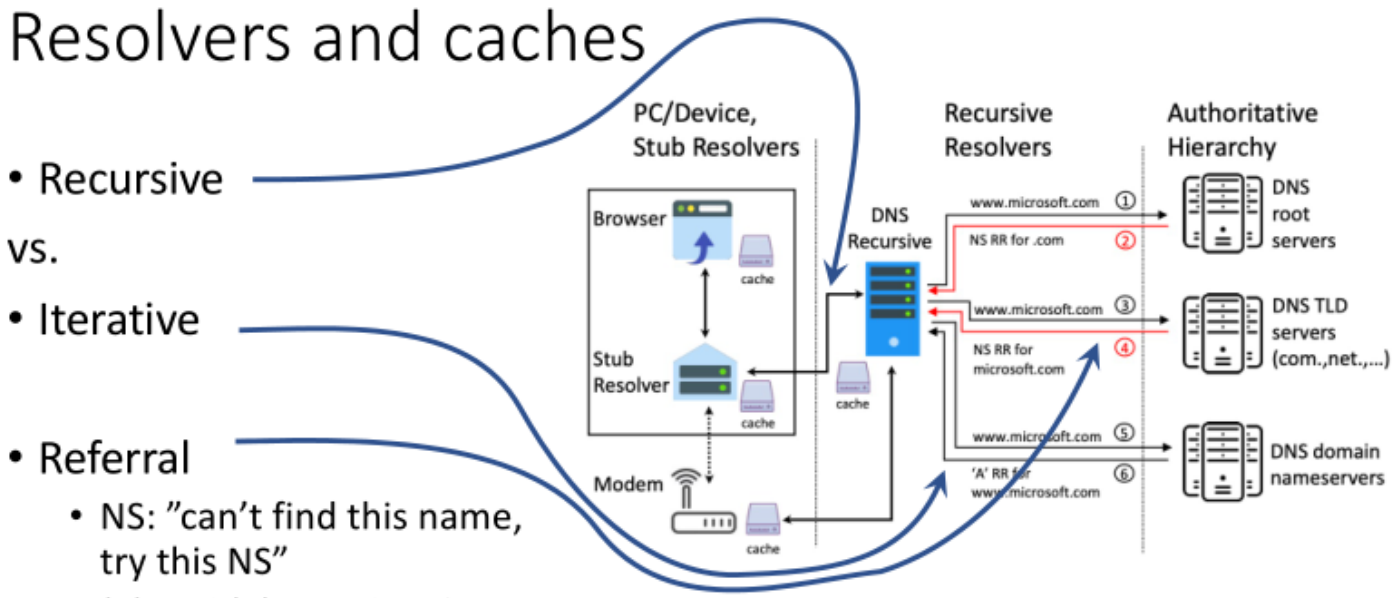


Figure 1: The resolution process, in theory, for the domain www.microsoft.com. The red steps represent NS referral responses.

Figure 3: Resolvers and Caches

Distributed routing - algorithms

- **Link state**:
  - Full topology of the network then Dijkstra;
  - Distributed: flood link state announcements - OSPF.
- **Distance vector**:
  - Distance to destination node, Bellman-Ford;
  - Distributed: update distances, resend to neighbors.
- **Path vector**:
  - List of nodes to destination node, local preferences;
  - Distributed: update path vectors, resend to neighbors.

Interior routing

- Same administrative domain:
  - All networks and devices administered by same entity;
  - Typically the internal network of an organization.
- Protocols:
  - RIP (outdated) - distance vector;
  - EIGRP (Cisco) - distance vector, optimized, hybrid;
  - **OSPF - link state**.

OSPF

- Messages:
  - Hello packets between routers to establish adjacency;
  - Link state advertisement, link-state database.
- Designated routers, network adjacency vs. point-to-point link;
- Cost metric manually defined, or multiple of reference bandwidth;
- Backbone area, separate link-state database, Area Border Router.

Exterior routing

- Different administrative domains:

  - Each node in this network has a different administrator;
  - The Internet;
  - Each node is an Autonomous System - and a network by itself.
- Protocols:
  - **BGP - path vector**.

BGP

- **TCP port 179**;
- Messages:
  - Keep-alive;
  - Update.
- Exchange path-vector routes to other BGP routers:
  - For each network;
  - Select one route, announce it to neighbors, add it to routing table.
- Route map: set of rules to check what to do with route:
  - Drop route, modify route, and add it to the routing table.
- Uses route selection criteria, e.g.:
  - Weight - local to each router;
  - AS-local preference for route - local to each AS;
- Authentication: MD5 hash of password;
- IP header TTL set to 1;
- Route aggregation: `32.32.32.0/24`, `32.32.33.0/24` announced as `32.32.32.0/23`

Peering

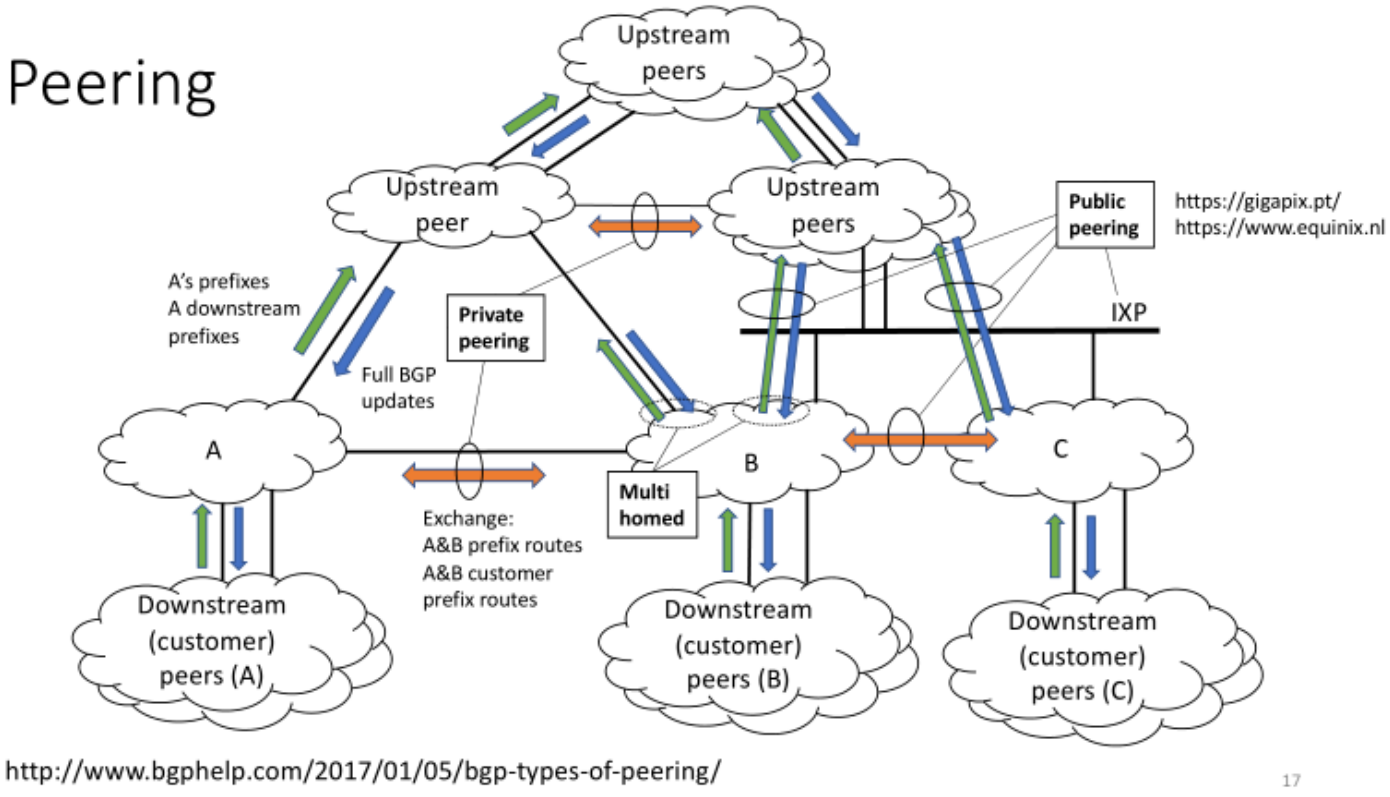


Figure 4: peering

Software Defined Networking (SDN)

Switch

- No control, just forwarding.

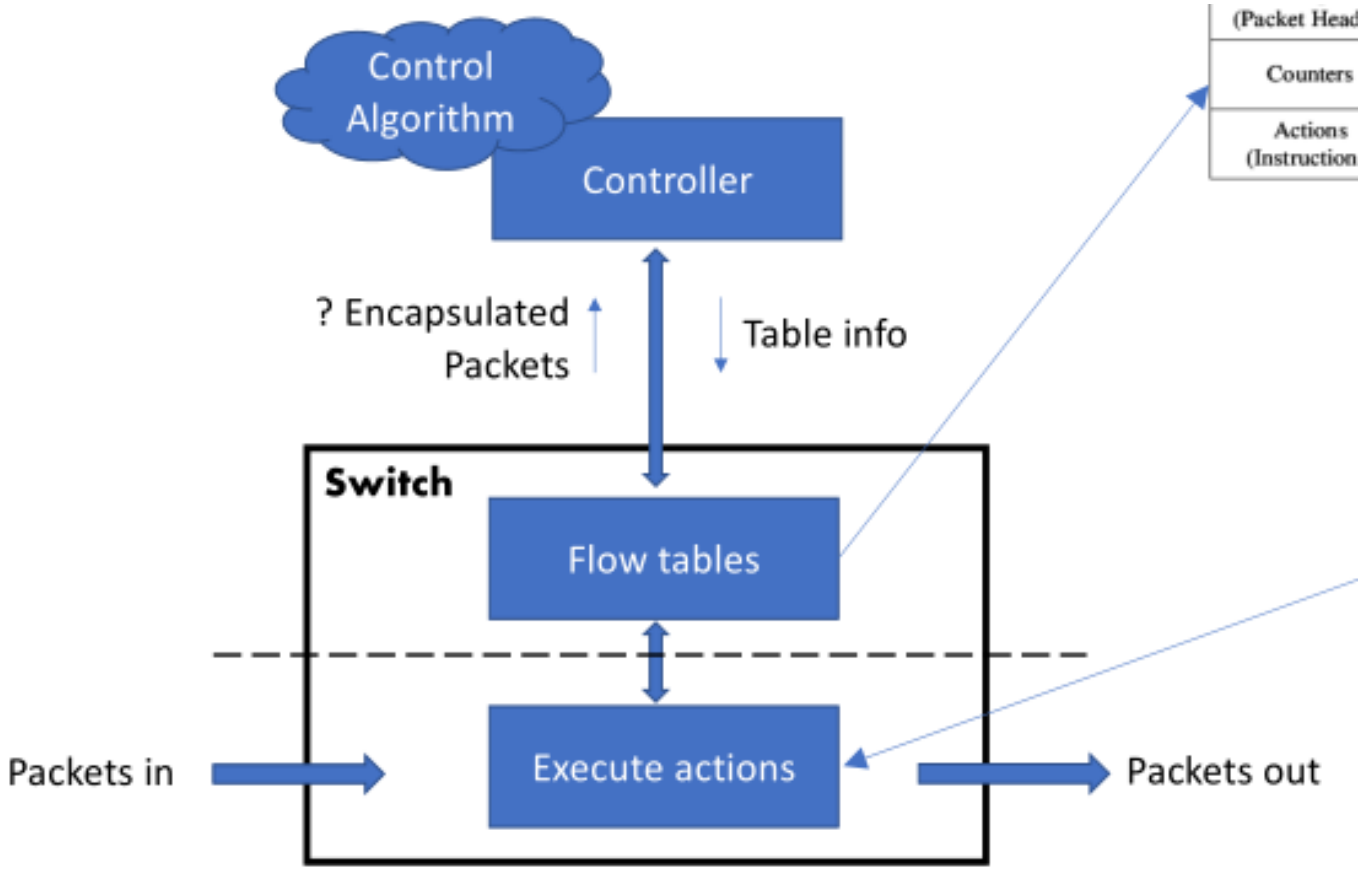


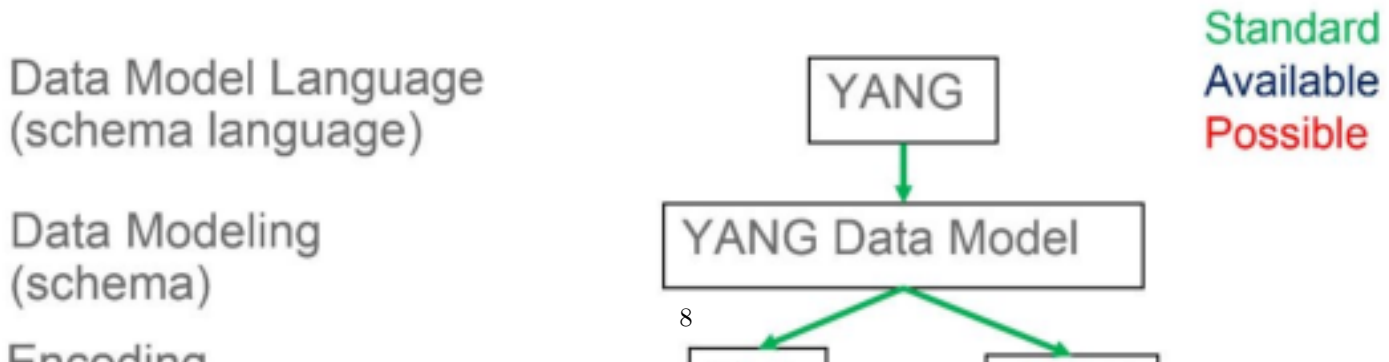
Figure 5: swtich_sdn

Default Behaviors	Description
drop all	:(
send to default processing	Switch SDN da cisco pode trazer a stack de software da cisco
encapsular e mandar para o controlador	útil para definir regras on-the-fly (controlador analisa pacote e manda decisão)
forward para o output	:)

Features of SDN

- Hardware abstraction - Control works on any hardware that implements API;
- Programmable:
  - Hardware/software bundles só permitem config de existing control algorithms;
  - SDN allows us to develop our own algorithms.
- Centralized control of policies:
  - Security policies, e.g., “node of type X can only talk with nodes of type Y”;
  - Routing policies, e.g., “route guest traffic through the firewall”;
  - QoS policies, e.g., “prioritize voice traffic”.

Device API and Automation tools



CI/CD

- Version control - found a problem with code => get back to older version that worked;
- Agile - divide in small parts, implement;
- Pipeline - workflow of code delivery process.

Steps

Figure 7: ci_cd_steps

Types of code

- **Application code** - the software you want to run (including docker/VM image);
- **Infrastructure code** - code that you write to set up the infrastructure;
- **Live infrastructure config** - frontend for infrastructure deployments. Parametrized for a particular deployment.

Code vs. build

- Some languages have a straight forward distinction (C or Java). Source code vs. executable binaries;
- Need a build phase for infrastructure?
  - Depends on the language of the infrastructure code and tools;
  - We actually deploy configuration files.

Test

- **Unit test** - Sandbox or dry run tests of individual components/configurations;
- **System test** - Deploy the different network components and test their interactions;
- **Staging environment** - Replica of production environment.

Release vs. deployment

- **Release** - software product ready to be deployed;
- **Deployment** - release configured for the target environment;
- For infrastructure, the difference is we're dealing with configuration instead of software.

Network Function Virtualization (NFV)

- Não é SDN;
- Pode ser feita usando SDN ou VLANs;

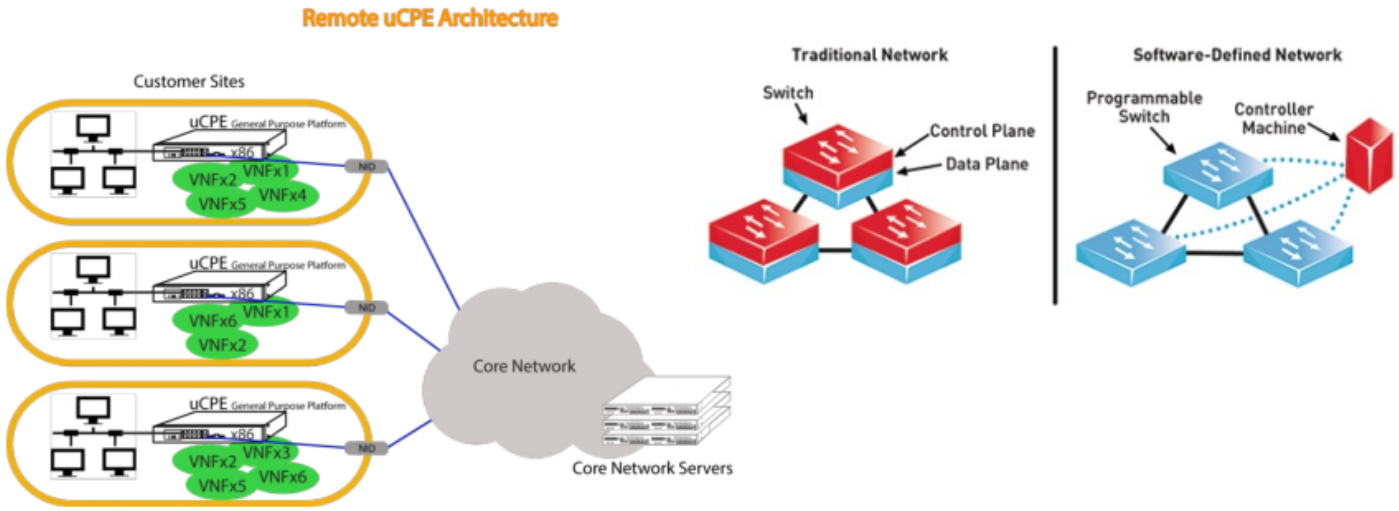


Figure 8: nfv_sdn

Customer-premises white box (uCPE)

- Run VNFs as VMs or container;
- E.g., DHCP, Routing, NAT, etc.

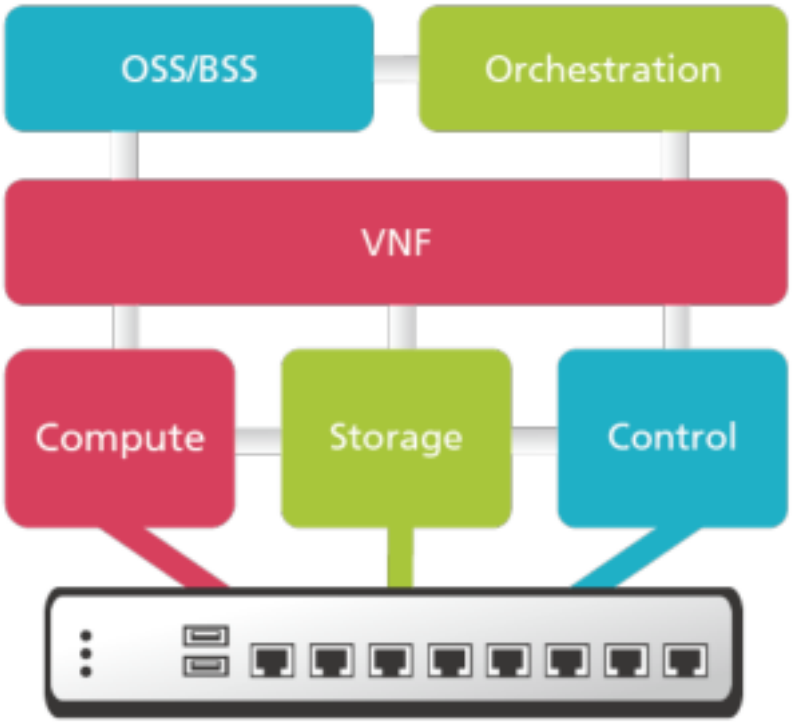


Figure 9: ucpe