Software Defined Networks
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Current Challenges on SDN Research

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creating and sharing knowledge for telecommunications

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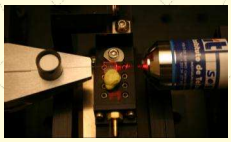
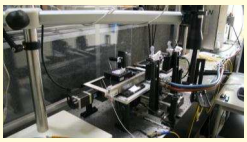
PhD researchers	~80
PhD students	~94





Optical communications

Radio communications

Networking, mobile networks, future internet

Electronic design for telecommunications

ATNOG – Advanced Telecommunications and Networking group

- 12 PhD, ~50 members
- **IEEE Distinguished Lecturer – Communications**
- Multiple lines of work
  - Research
  - Industry cooperation
  - Standardization
- High practical component
  - Testbeds, implementations, tools...
- Open Source contributions
  - https://github.com/ATNoG
  - Test infrastructures

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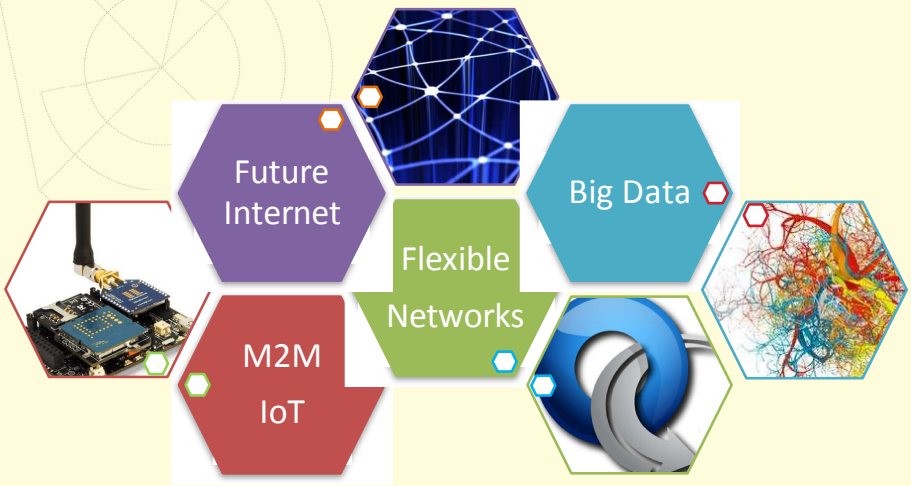

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Related Activities for SDN

Research Projects:

- Implement vCPE system with real equipment (for Telco)
- Implement MEC Host and Cloudlet mecanisms (for Telco, EU Project)
- SDN based mobility (Cellular offload, Handover)
- SDN+NFV testbed (EU project)
- Coordination of NFV activities between Portugal and Brasil

Participation in the 5G PPP steering board

- Rui Aguiar

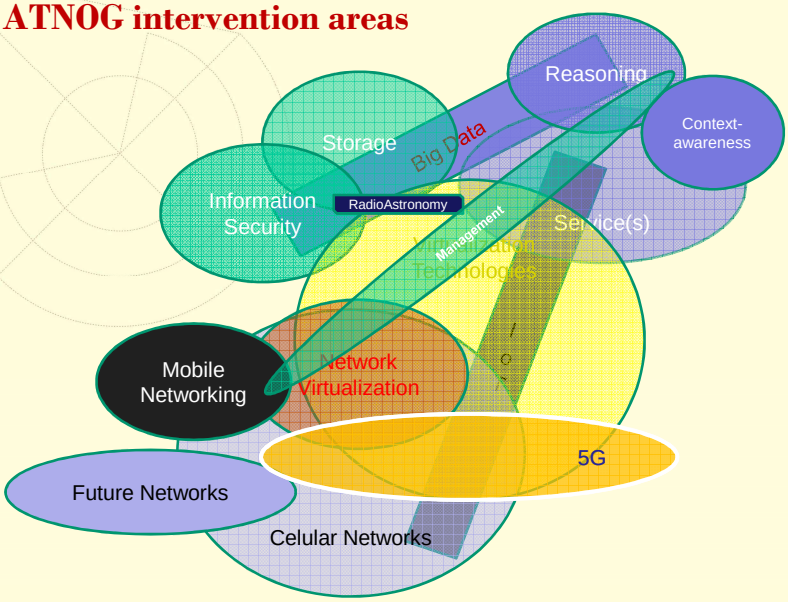
Participation in IETF and contribution to Openstack and OpenFlow

- Seil Jeon, Daniel Corujo, Igor Cardoso, Carlos Gonçalves, João Paulo Barraca

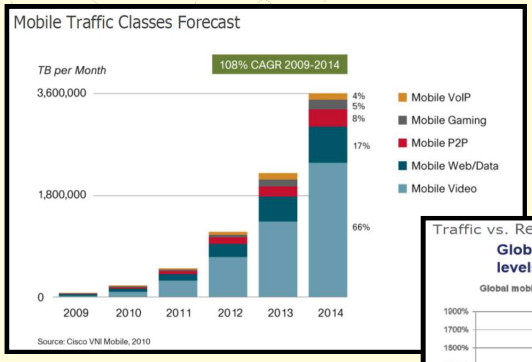
Research students on

- Reliability, Migration, Mobility, Interoperation

ATNOG intervention areas

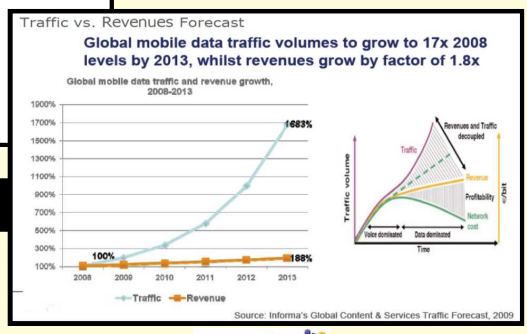


Old trends in Mobile Communications



Key fact

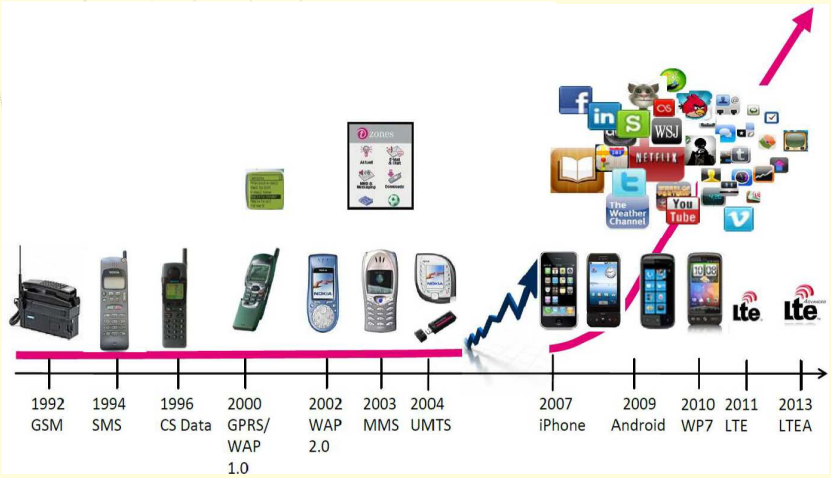
Fast growing mobile data volume and number of subscribers.



Impact

Gap between mobile data volume and revenues is growing.

The history of mobile phone: market explosion after iPhone



Source: Network Under Fire. Smartphone Signaling Challenges. Grant Castle, VP, Engineering Services & QA

Networks require (complex) infrastructure

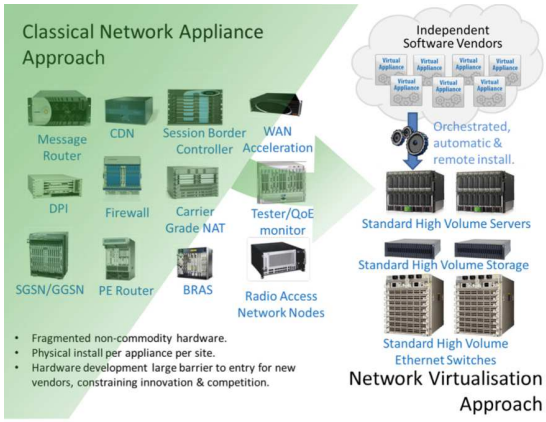
Well known figure …

Current infrastructure.

- Current network equipment designed for special use case

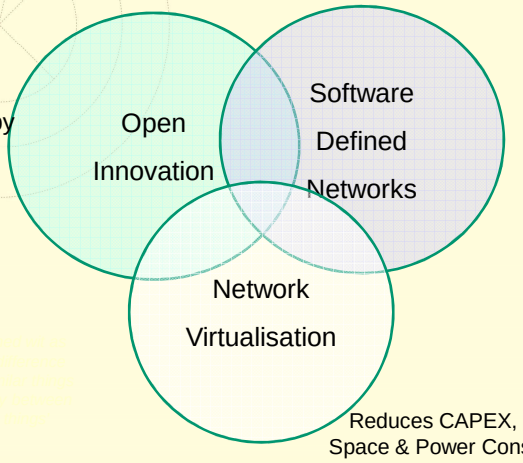
Software Defined Networking and Network function Virtualization:

- Special use cases as software release running on top of standard hardware
- Virtualization will become a key issue to reduce OPEX and CAPEX



Three Strategic Networking Paradigms…

Creates competitive supply of innovative applications by third parties.



Separate control plane from data plane, centralised and programmable control, APIs towards applications

Create abstractions to enable faster innovation.

Reduces CAPEX, OPEX, Space & Power Consumption.

Software-Defined Network

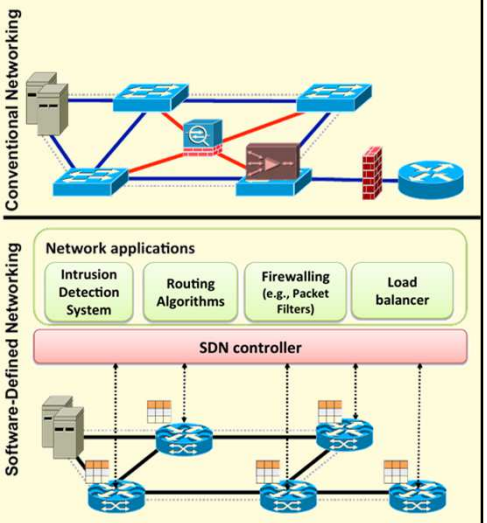
Developed at Stanford in 2008

Concept “new”

Although is hard to define what is the difference from previous telecom strategies.

Decoupling data plane from control plane

Overlay network



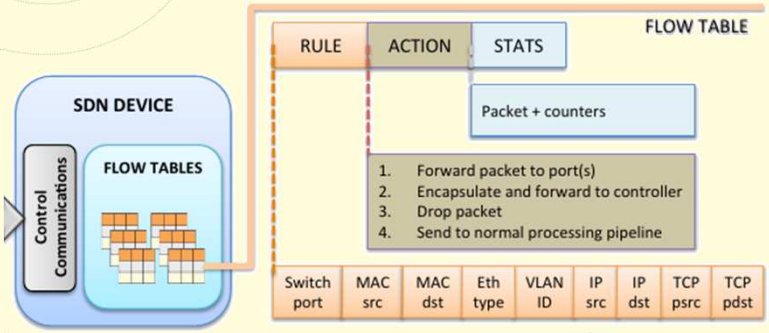
Software-Defined Network: OpenFlow

OpenFlow

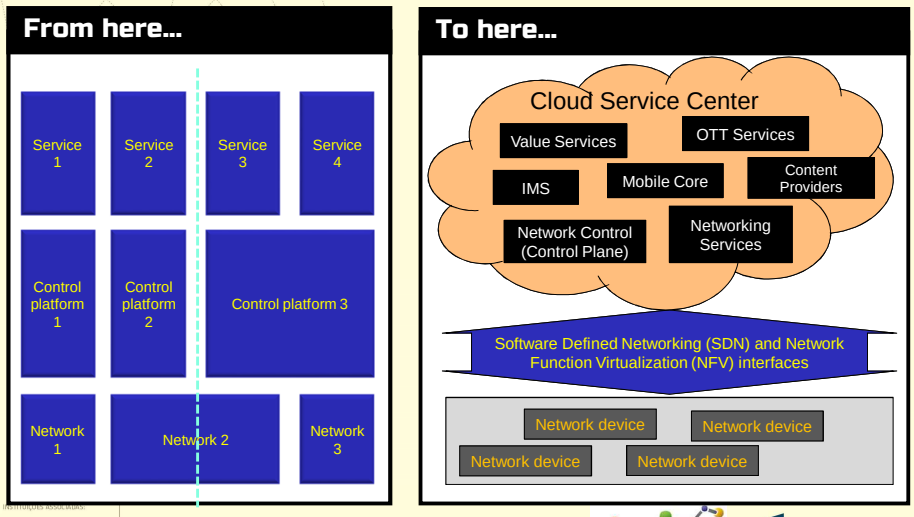
Open-Source configuration and control protocol

Manufacturer-independent

Objective: enabler for researchers to develop new networking protocols



Evolving complex infrastructure



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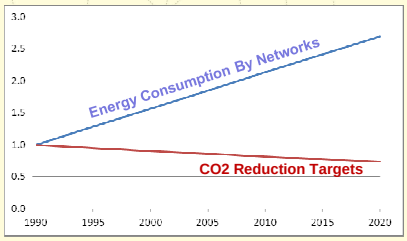
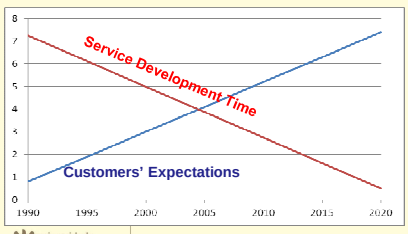
Network Operator Challenges…





1) Electrical energy consumed by networks is increasing – but carriers and their customers are targeted with reducing CO2 emissions.

2) Hardware lifecycles are reducing - cost to integrate replacement is increasing with little or no revenue gain.

3) Service development time is increasing due to increasing:

- Complexity.
- Heterogeneity.
- Legacy.

whilst customers expect faster innovation.

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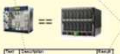
Why SDN+NFV is the future

Source: BT

PoC Performance Test Results

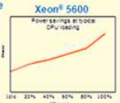


- Average 3 Million Packets Per Second per Logical Core for PPPoE processing.
  - Equivalent to 94 M PPS/97 Gbps per Blade = 1.5 G PPS/1.5 Tbps per 10 U chassis[1].
  - Test used 1024 PPP sessions & strict priority QoS.
  - Test used an Intel® Xeon® E5655 @ 3.0 GHz, 8 physical cores, 16 logical cores (not all used).
- Scaled to 9K PPPoE sessions per vBRAS.
  - Can support 3 vBRAS per server.
- Research underway on software Hierarchical QoS testing, early results look promising.

This is very useful performance that looks to have the potential to match the performance by footprint of existing BRAS equipment.

Typical ToD Traffic profile

Xeon® 5600

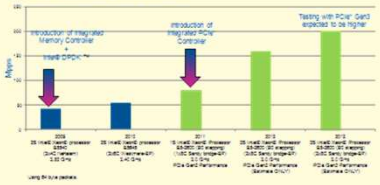


Workload consolidation

>50% Reduction in energy consumed by network equipment.

Performance Going Forward

IPv4 Layer 3 Forwarding on an IA Platform



PCIe* Gen 3 will offer better performance and more options

1. Standard high volume servers have sufficient packet processing performance to cost effectively virtualise network appliances.
   - The hypervisor need not be a bottleneck.
   - LINUX need not be a bottleneck.
2. Total Cost of Ownership advantages are scenario specific but expect significant benefits.
3. Plus a significant reduction in energy consumption.

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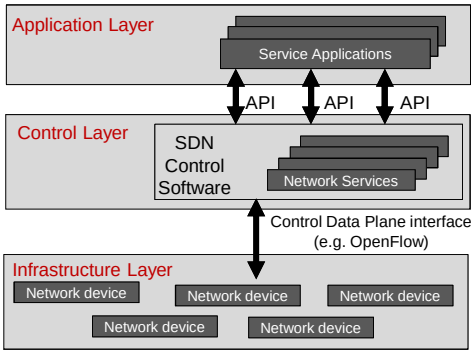
The purpose of SDN and NFV

Split of the control plane from the user/data plane

- User/data plane implemented by standard (low-cost) equipment
  - Reduction on the HW cost
- Control plane implemented in the cloud – Network Function Virtualization – with standardized and open interfaces to services/business applications
  - Easy service development
- Software maintained by the operator
  - Change on the value and revenue model



Source: ONF (Open Network Foundation)

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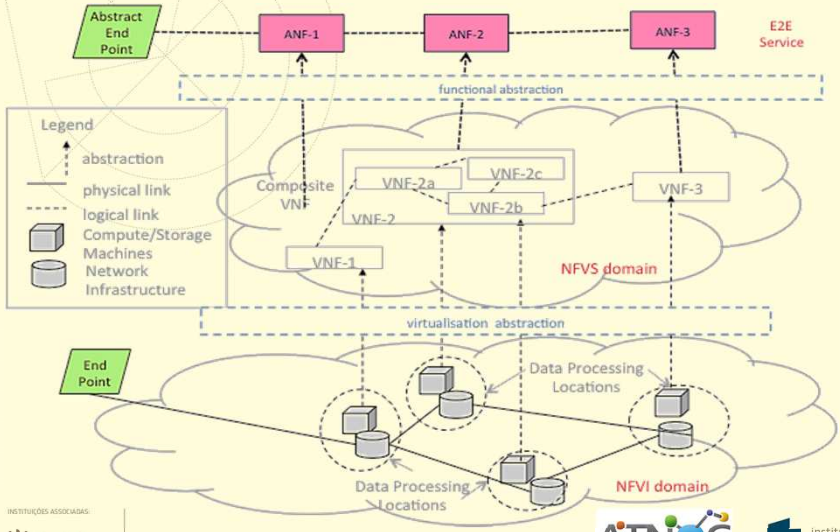
Example Mapping of an E2E Network Service to Network Functions and Infrastructure

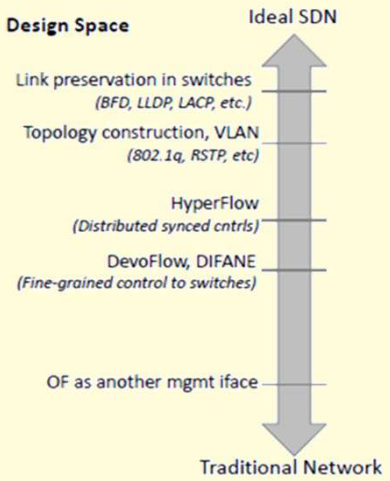


Souce: ETSI

Design Space for SDN

What have we found:

- In reality: extremes will (do) not work
- A trade-off will be required between Ideal SDN and network performance
- Transition will be challenging:
  - Green-field deployments (native) vs. Evolution (integration)
  - Operation of hybrid boxes (switches)



Nice! What is then missing?

1. Carrier-graded quality
   - Protocol independence
   - Trustable
   - Resilient network
   - Scalability
   - Performance for COTS
2. Slicing
   - Wireless (and PHY)
   - Sandbox behavior
3. Heterogeneity handling
   - Migration strategies
   - Hybrid deployments
   - Multiple operators in shared environments

… plus lots of details on interfaces…

1. Carrier grade (I)

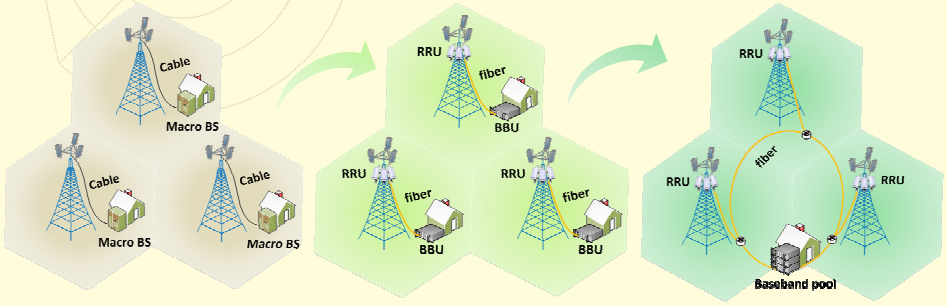
Protocol Independence

- Current solutions depend strongly on **stable** IP networks
  - Link layer solutions required
- Trust aspects
  - Network security in SDN neworks is not defined
  - Networks need to be dependable – not affected by apps
- Scalability
  - Performance decreases as complexity grows
    - In switches/routers
    - In the controllers (leading to multiple controllers)
- Resilience
  - Currently two aspects are being sought:
    - How to handle (fast) network/service faults
    - How to handle faults on the controllers
    - How to survive problems on verticals (…)

1. Carrier grade (II) : Performance Example

- Centralized baseband pool
  - stringent requirements in latency
  - stringent requirements in geo-architecture

RRU – radio head-end
BBU – Baseband Unit



Traditional macro base-stations

Distributed base-stations

C-RAN
Centralized baseband pool

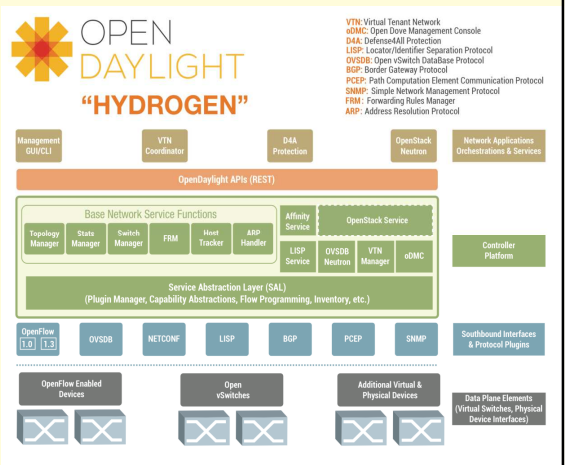
1. Carrier grade (III) :Critical Solutions

OpenDaylight

- OpenFlow 1.1+
- Notion of physical topology
- Host tracker
- Graph searching algorithm

Open vSwitch

- Support for OpenFlow 1.0
  - Groups (1.1) are already developed



1. Carrier grade (IV): security

- **How can one attack SDN – identified attack vectors**
  - *Until now* not different from any management platform (cmp. SNMP)
  - A0: Attack the OF traffic
    - Vectors: TLS config and implementation weaknesses, TLS environment abuse (trust)
    - Impact: credential extraction, snooping and injections, useful for multi-stage intrusions
  - A1: Get a switch and send rogue messages to controllers
    - Vectors: ID usurpation, existing switch vulnerabilities, weak authentication
    - Potential impact: full to partial network breakdown
  - A2: Attack the controller and own the network
    - Vectors: DDoS (produce rogue flows, rogue OF reqs), ctrl vulnerabilities, weak authentication
    - Potential impact: from DoS to full network control
  - A3: Attack the management platform
    - Vectors: weak admin auth, access to controller, controller vulnerability
    - Impact: full to partial network control

Compare
- D. Kreutz, F. M.V. Ramos, P. Verissimo, "Towards Secure and Dependable Software-Defined Networks", HotSDN 2013.
- K. Benton, L. J. Camp, C. Small, "OpenFlow Vulnerability Assessment", HotSDN 2013.

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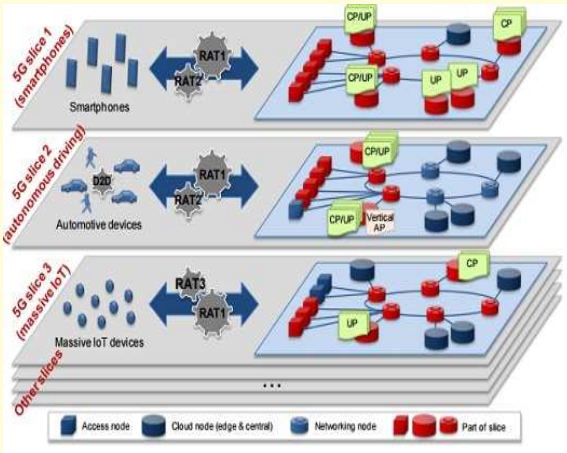
2. NFV/SDN and Slicing; infrastructure for 5G

- Virtual Networks creation
  - Slices: end-2-end networks
  - Network isolation
  - Vertical-oriented (business)
  - For different entities (MVNOs)
- Using shared resources
  - Connectivity (links)
  - Data center (VMs, VNFs, NSs)
- Includes management
  - Internal management
  - Orchestration
  - Control



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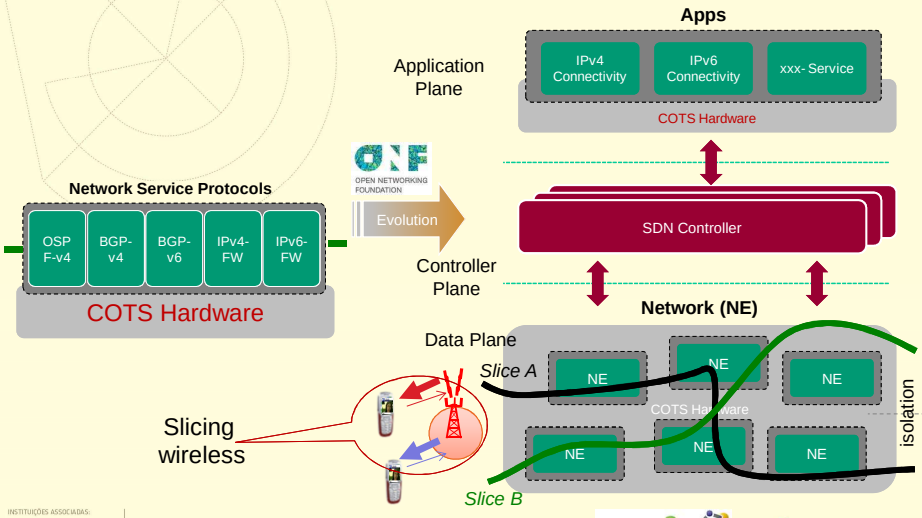
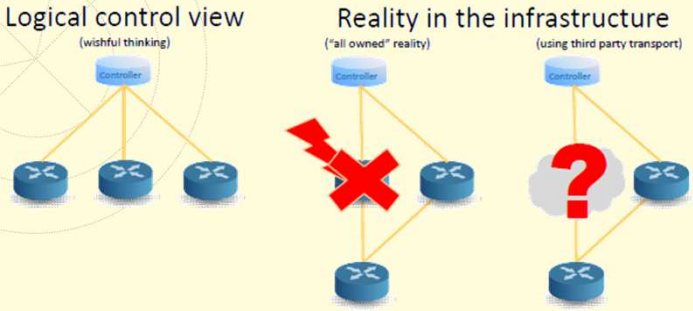
2. Slicing: Example



3. Heterogeneous networks



Dropping SDN in this environment requires a rethought of the "wonder view"!

- How to operate in this reality
- How to migrate a full network, timewise
- How to share multiple operators (i.e. controllers) over shared resources3. Heterogeneous networks

Conclusions

SDN is a technology that promises to address a large set of problems, presenting cost effective solutions for multiplexing at different layers.

Large-scale solutions in open environments require still a large set of developments both at fundamental concepts and in standardization

QUESTIONS?

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