

# Programmable mobile networks

## ***Why? What? How?***

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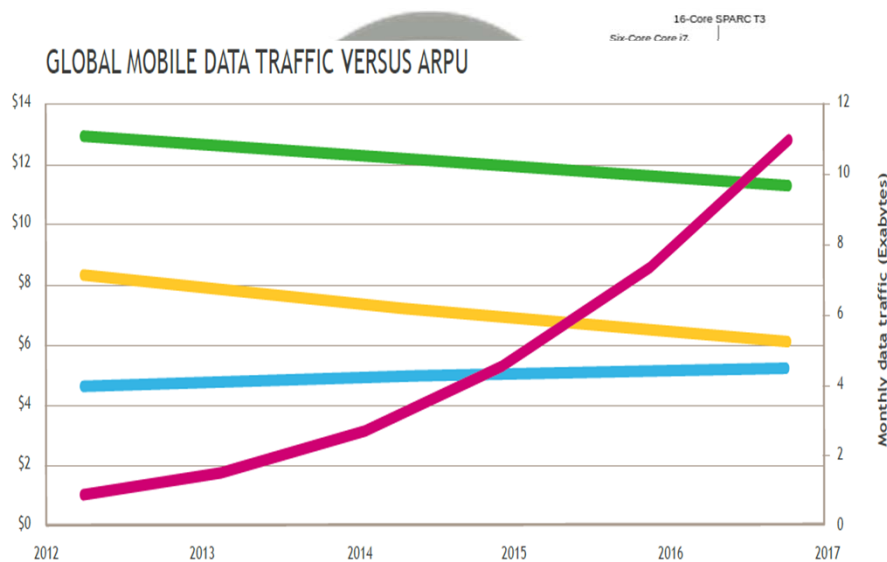


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# Context



Microprocessor Transistor Counts 1971-2011 & Moore's Law



↓ Voice revenue   
 ↑ Messaging and data revenue   
 ↓ Total revenue   
 ↑ Data traffic   
 New subscriber numbers have flatlined

Source: Alcatel-Lucent

## Trends

- Heterogeneous, dynamic, and complex networks
- Increasing computing and storage power
- Increasing number of services in the cloud
- Higher rates/volumes demanded but declining ARPUs

# *Internet ossification*



- Intellectual
- Infrastructure
- Systems

# ***Mobile network ossification***



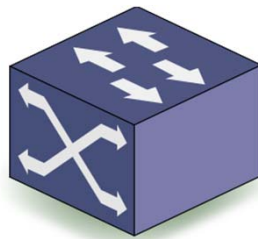
- Backward compatibility
- Circuit-switching legacy
  - Hierarchy
  - Different approach to reliability
  - Transport is transparent

# *“Isolated” domains*

- Mobile and transport and cloud are separate worlds



3GPP standards

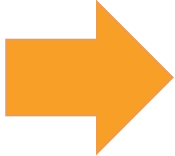
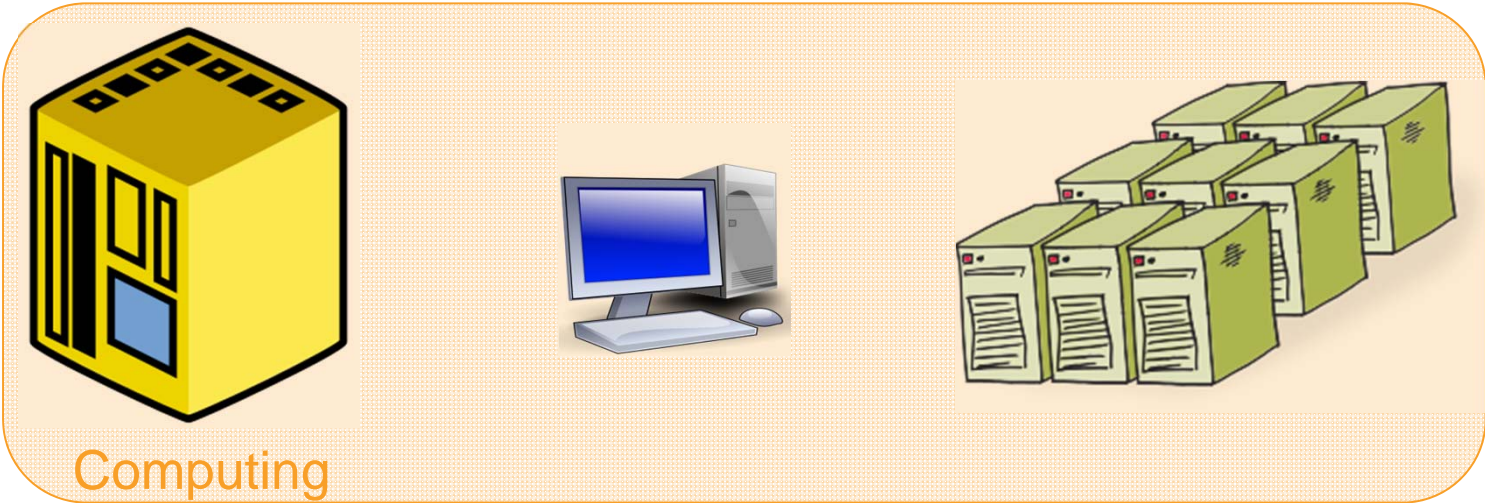


Data networking  
(e.g., IETF)



Web services  
(and server virtualization)

# How did we get here?



# ***Why programmable mobile networks?***



- Dynamic adaptation to changing user demands
- Flexible service composition
- Simple, automated, and homogeneous management of complex networks
- Cost reduction

# What is it about?

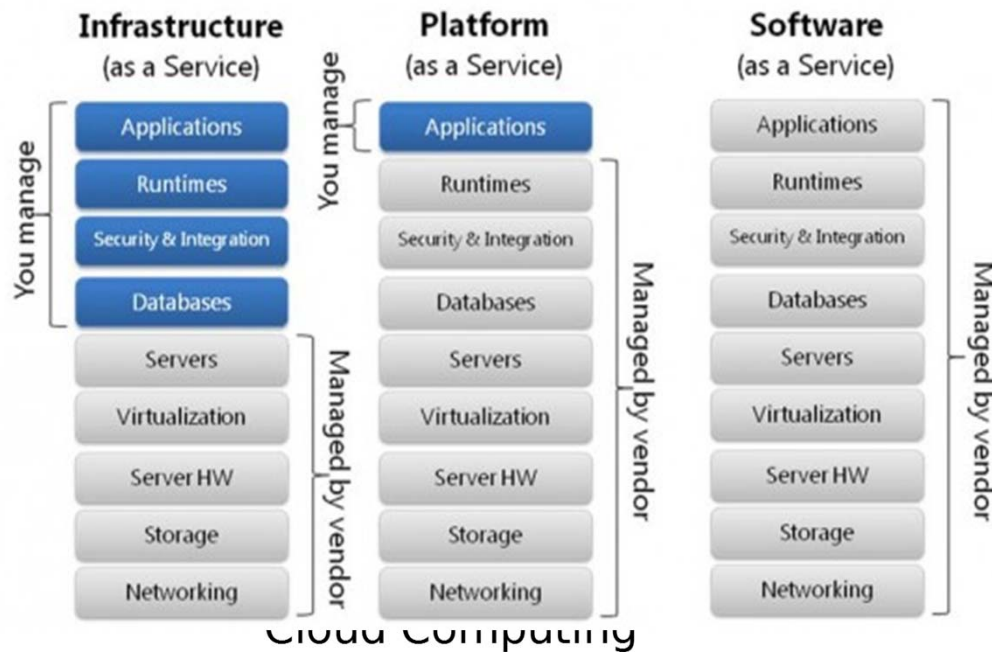


- Softwarization of the network
  - Programmability
  - Abstraction / Virtualization
- Putting it all together
  - Cloud brings scale
  - Software-defined Networking (SDN) brings softwarization of the control plane
  - Network Functions Virtualization (NFV) brings softwarization of the data plane (also control plane)

Open Interfaces



# Cloud Motivation



- Avoid upfront investment on IT
- Economies of scale of cloud provider
- Resource upscaling/downscaling
- Cloud service models

# ***Cloud / Web services***

## ***Motivation***



- Web service framework for service description, publication, discovery, and composition
  - Flexible interaction and composition of multi-domain services
    - Infra provider, service provider, third party service providers
- Web services/Cloud world would bring more flexibility to the telecom world, as systems for offering service there were
  - Constrained by the kind of services they could offer (e.g., voice)
  - Fully offered by a single operator to its clients without interaction/composition with third-party services

# ***Software-defined networking (SDN)***

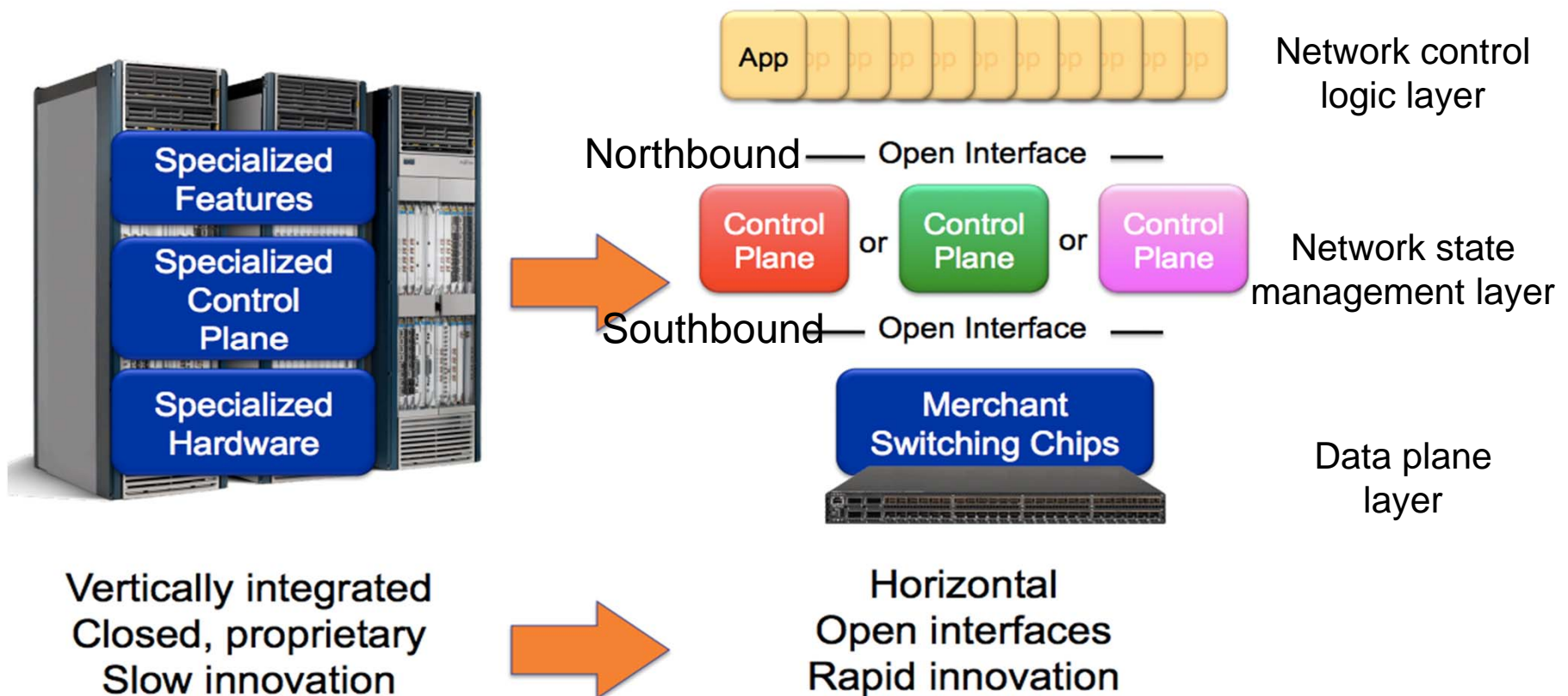
## ***Motivation***



- Similar to active networks
  - Long timescales to deploy new network services
  - Third-party interest in having application-oriented fine-grained control
  - Researchers' need for experimentation in production networks without disrupting regular operation
- Later
  - SDN as enabler of multi-tenancy in datacenters
  - Also moving towards wide area networks to exploit these benefits

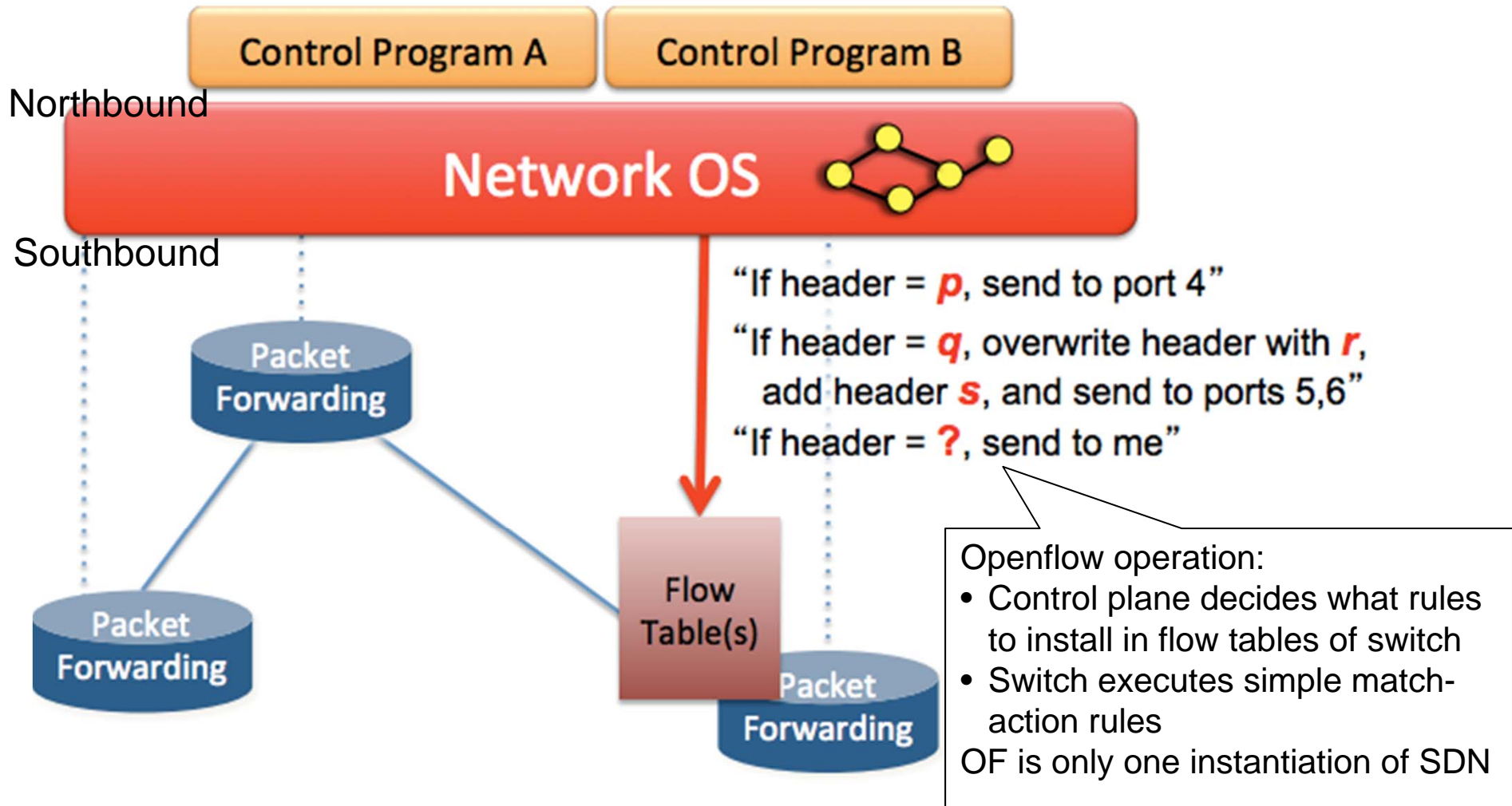
# SDN Main Idea (I)

- SDN is a tool for enabling network innovation, based on
  - Control/Data plane separation
  - Abstractions for distributed network state



# SDN Main idea (II)

Control/Data Plane Separation and Abstractions for distributed network state



# *Network Functions Virtualization (NFV)*

## *Motivation*



- Need for **cost** reduction
  - Increasing capacity demand, but declining ARPU
  - Operators want to benefit from the economies of scale of the IT industry
  - Reduced power usage achieved by migrating workloads and powering down unused hardware
- Rapid **service** innovation through software-based deployment and operationalization of network functions and e2e services

# ***NFV***

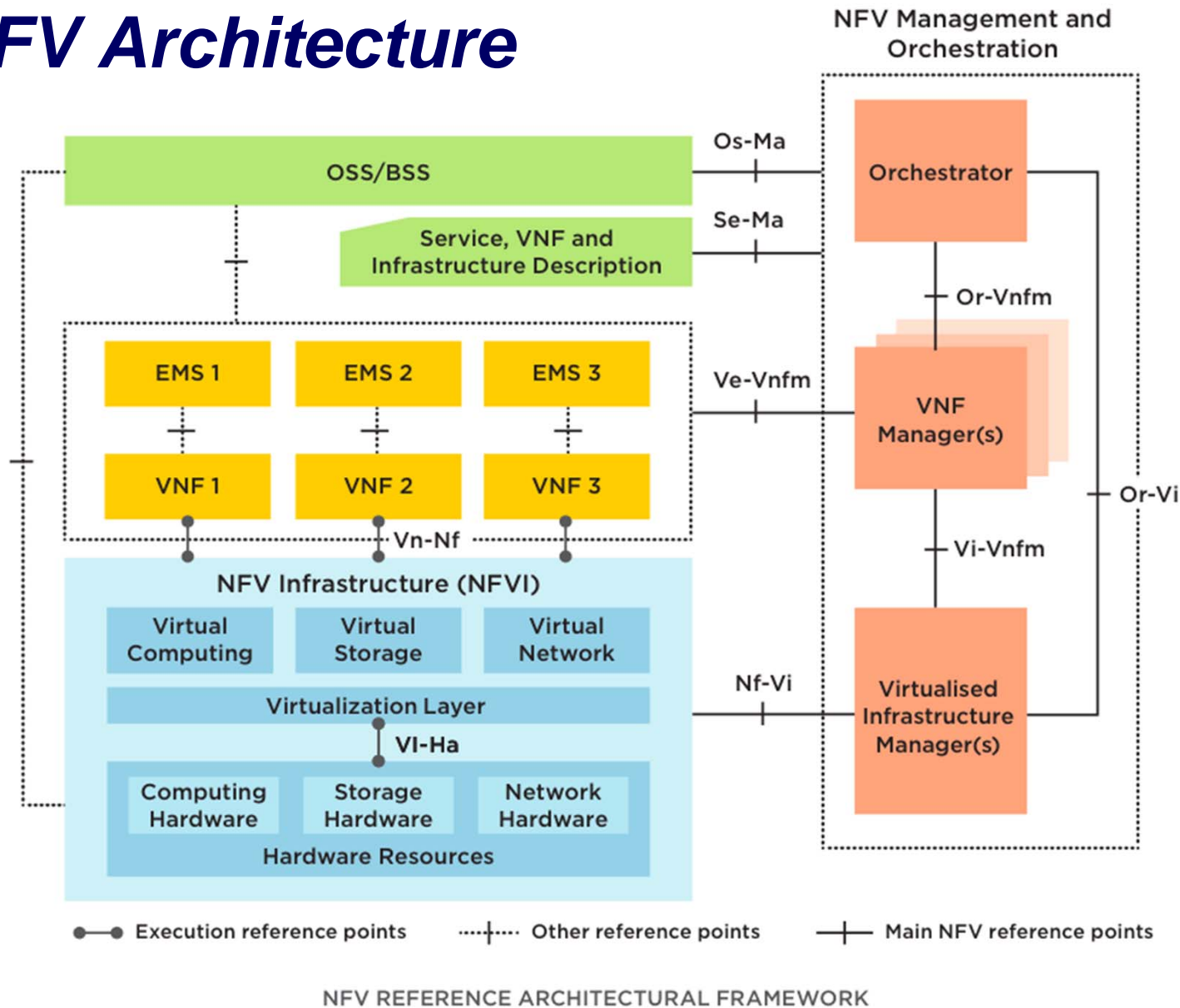
## ***Motivation***



- Standardized and **open interfaces** between network functions and their management entities so that such decoupled network elements can be provided by different players
- Operators want to simplify network configuration and operation, yet being able to dynamically adapt to unexpected demands
  - Greater flexibility in assigning VNFs to hardware



# NFV Architecture



Source: ETSI NFV ISG through sdxcentral



# *What's new now?*

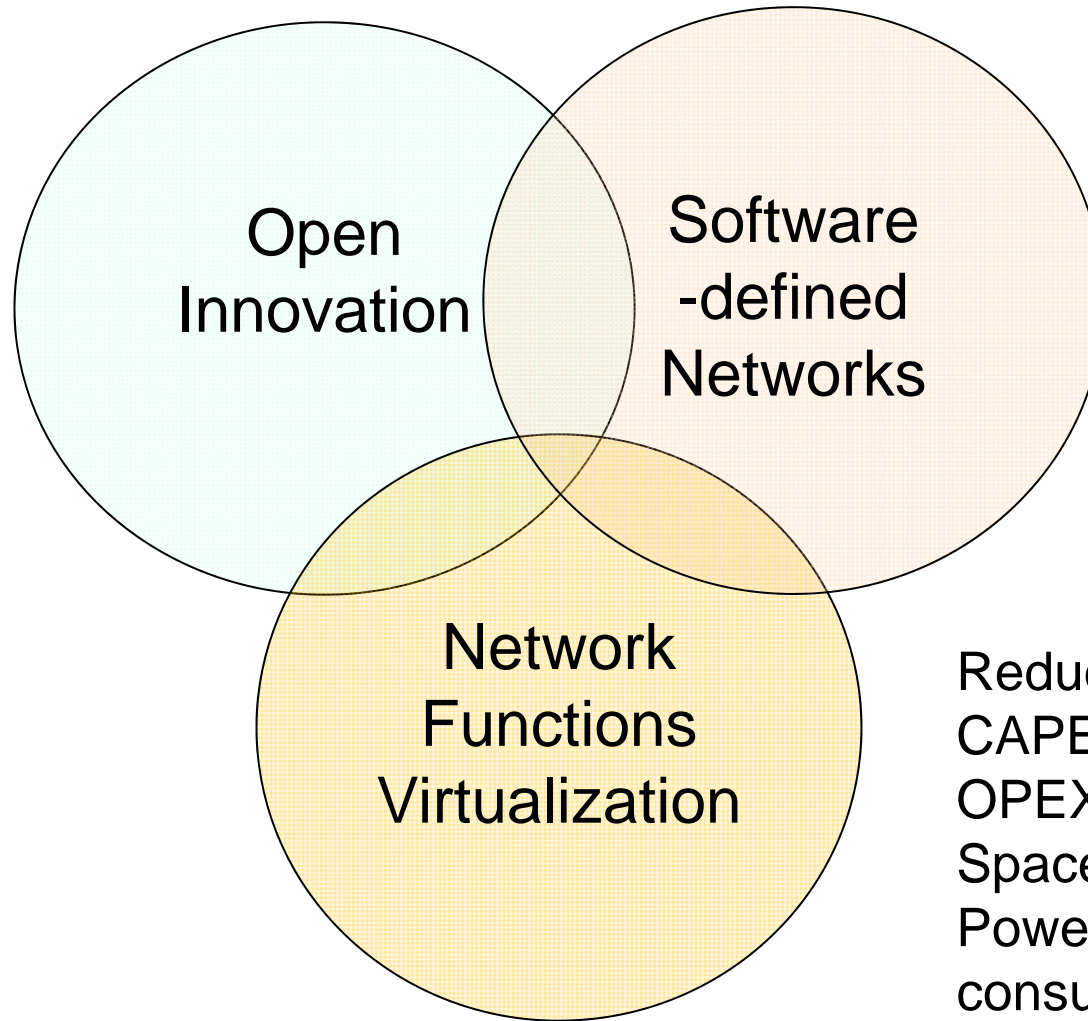


- Previous work done on
  - Active Networks
  - Control-Data separation
  - Network Virtualization
  
- Practical pressing needs (clear use case)

# SDN and NFV



Creates competitive supply of innovative applications by third parties



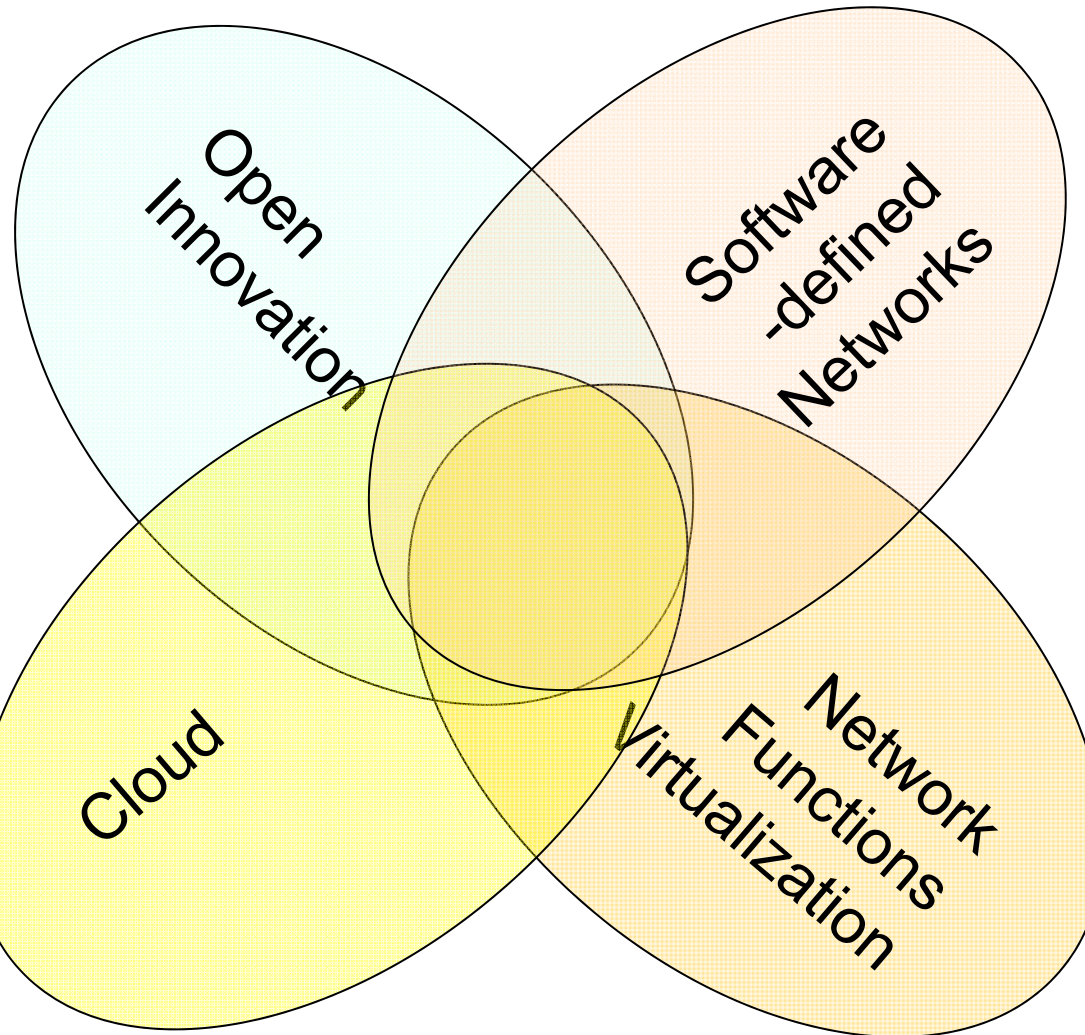
Creates network abstractions to enable faster innovation

Reduces CAPEX, OPEX, Space & Power consumption

# SDN and NFV and Cloud



Creates competitive supply of innovative applications by third parties



Creates network abstractions to enable faster innovation

Offers flexibility in service deployment and scalability

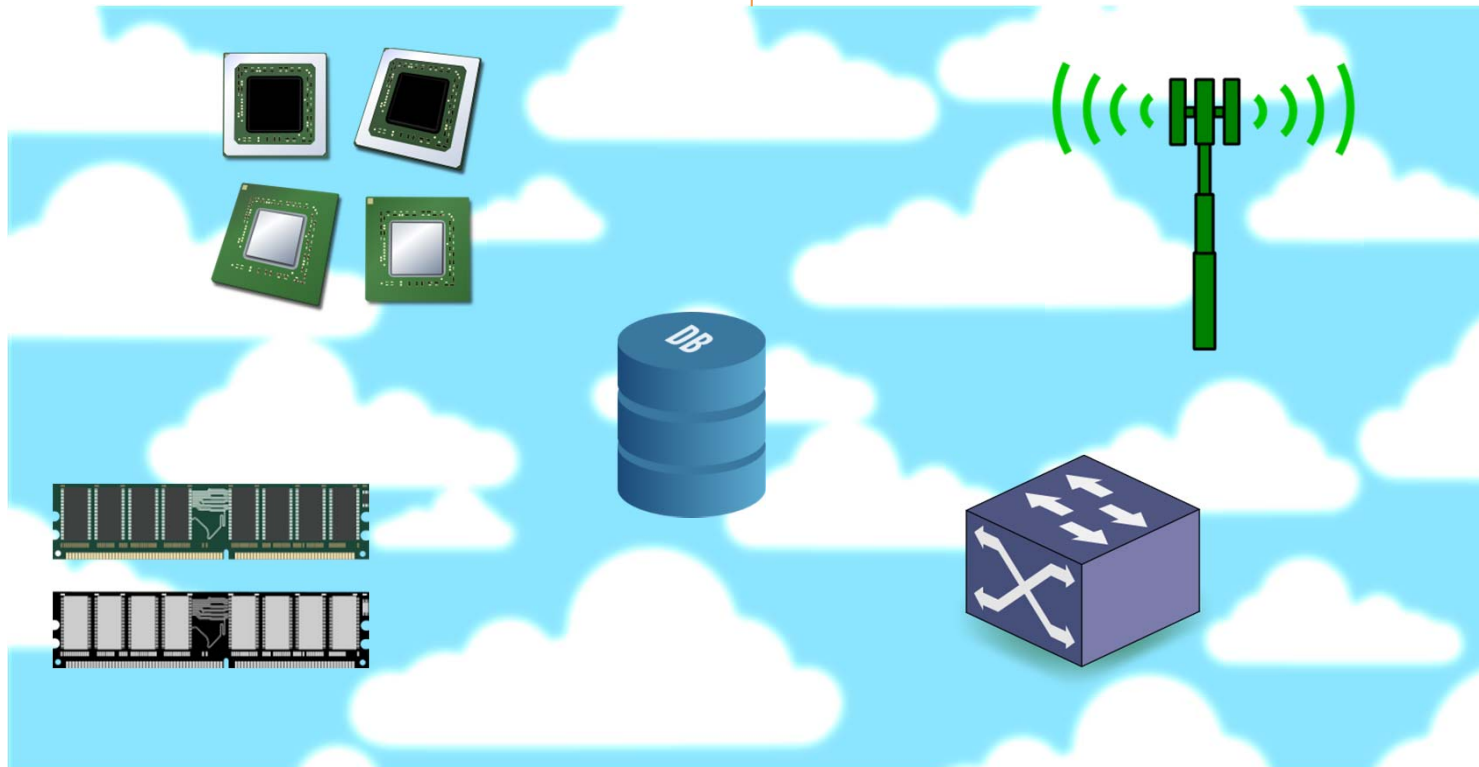
Reduces CAPEX, OPEX, Space & Power consumption

# *Programmable mobile network*

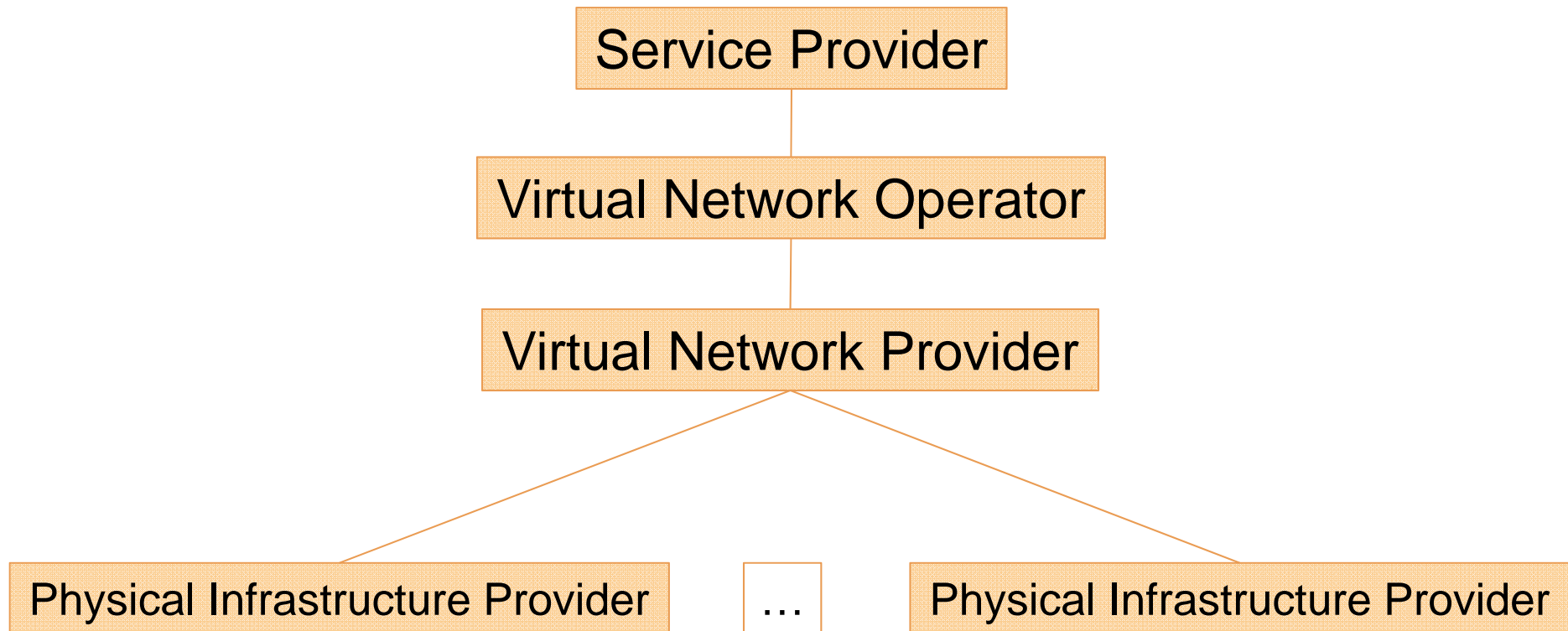
## *How does it look like?*

Network-Aware Application

Application-Aware Orchestration



# *Programmable mobile network Stakeholders*



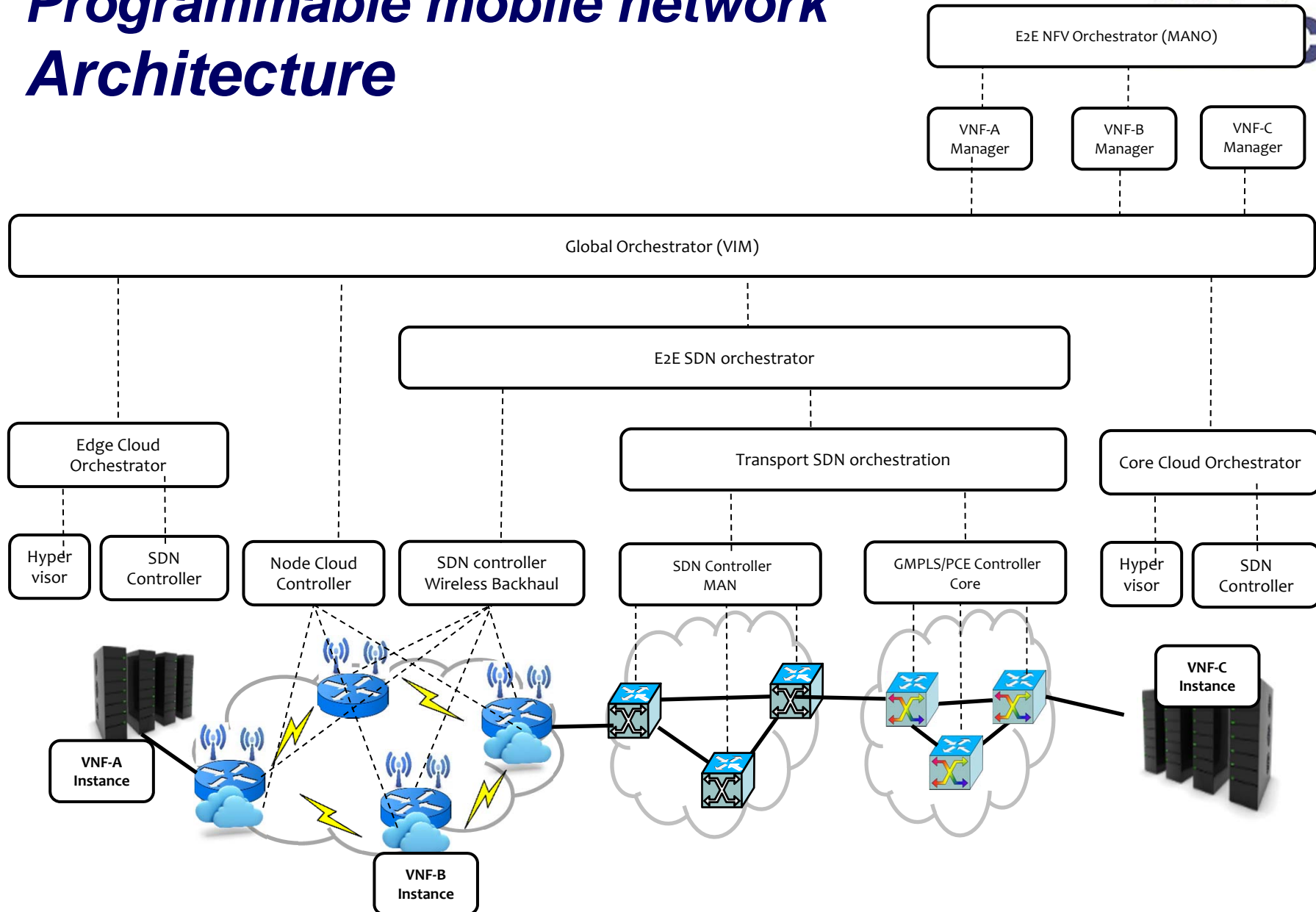
# ***Programmable mobile networks Implications***



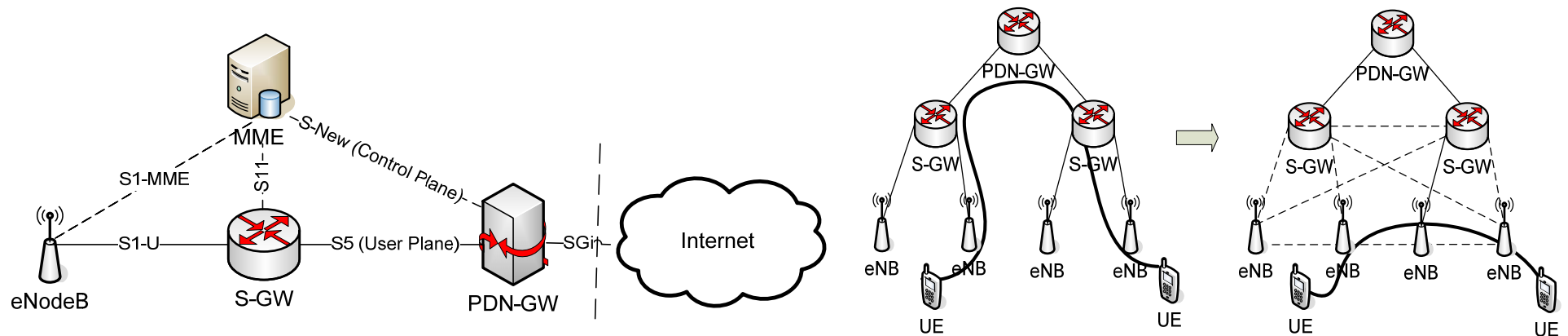
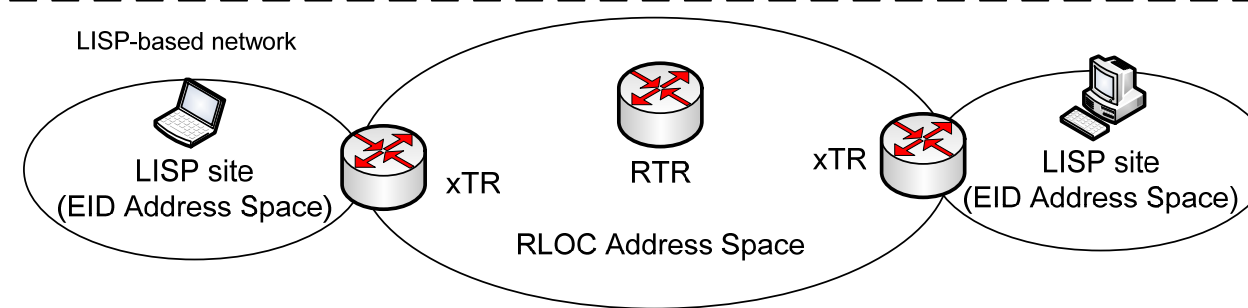
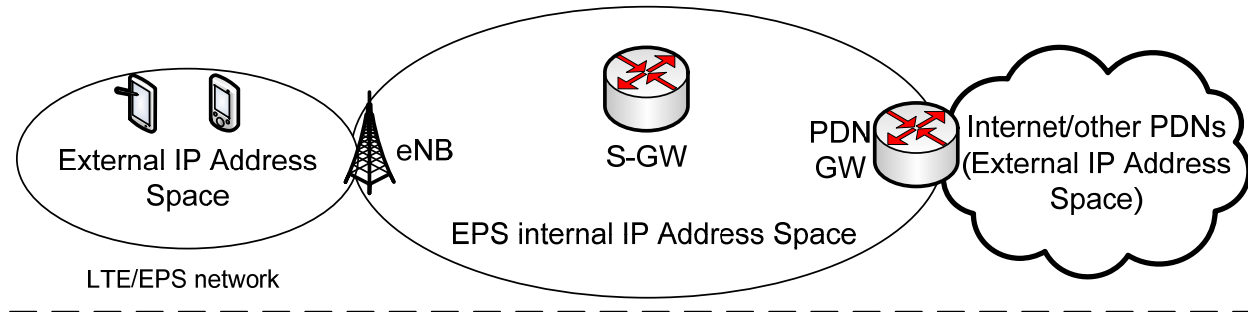
- Blurring borders between network components
  - Geographical
  - Domain
  - RAN - Core
  - RAN itself
- Business implications
  - Network - Service Provider borders
  - From hardware to software industry



# Programmable mobile network Architecture



# Mobile and data networking borders blurring Evolved Packet System evolution





# Programmable mobile network Instantiation

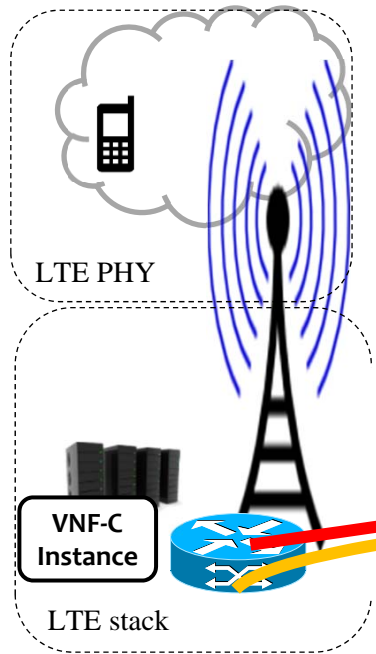
Xhaul

STRAUSS



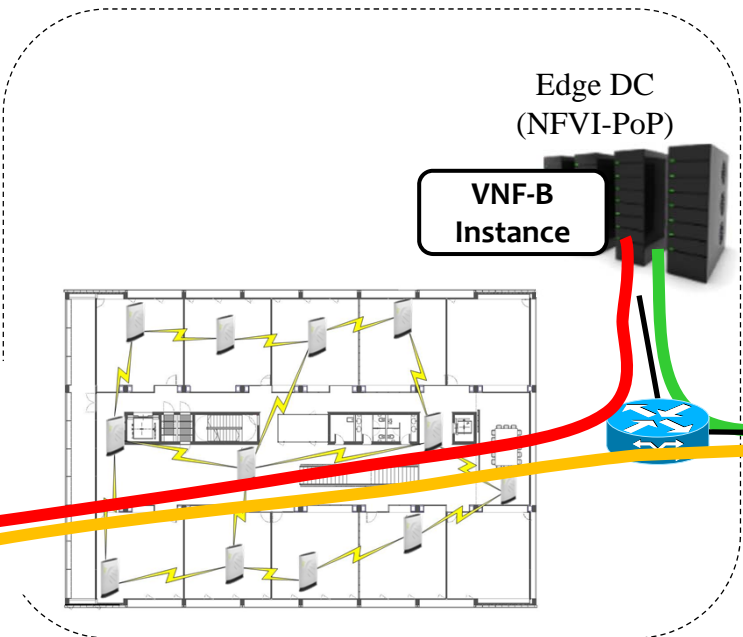
Flex5Gware

GEDOMIS® Testbed



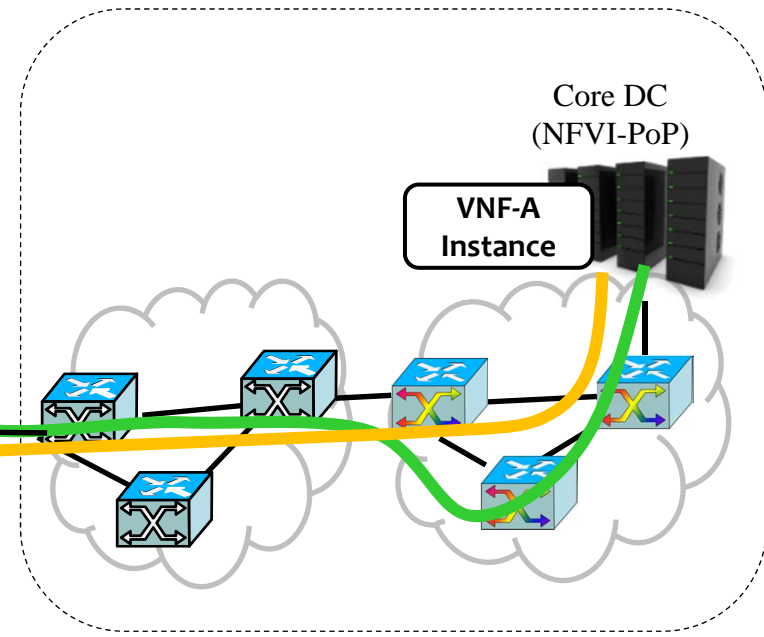
RAN

EXTREME Testbed®



Wireless backhaul and Edge Computing

ADRENALINE Testbed®

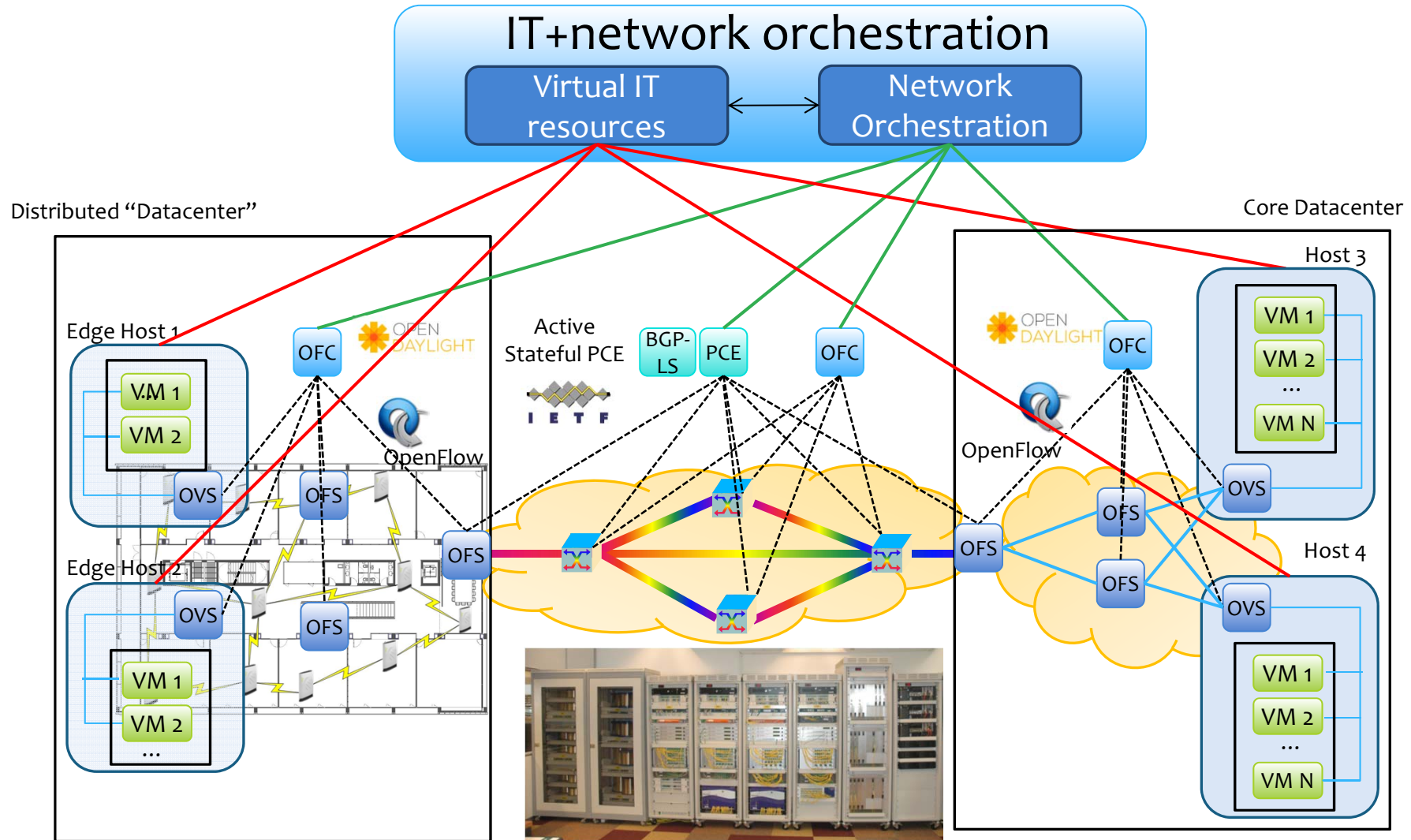


MAN  
(Packet Aggregation)

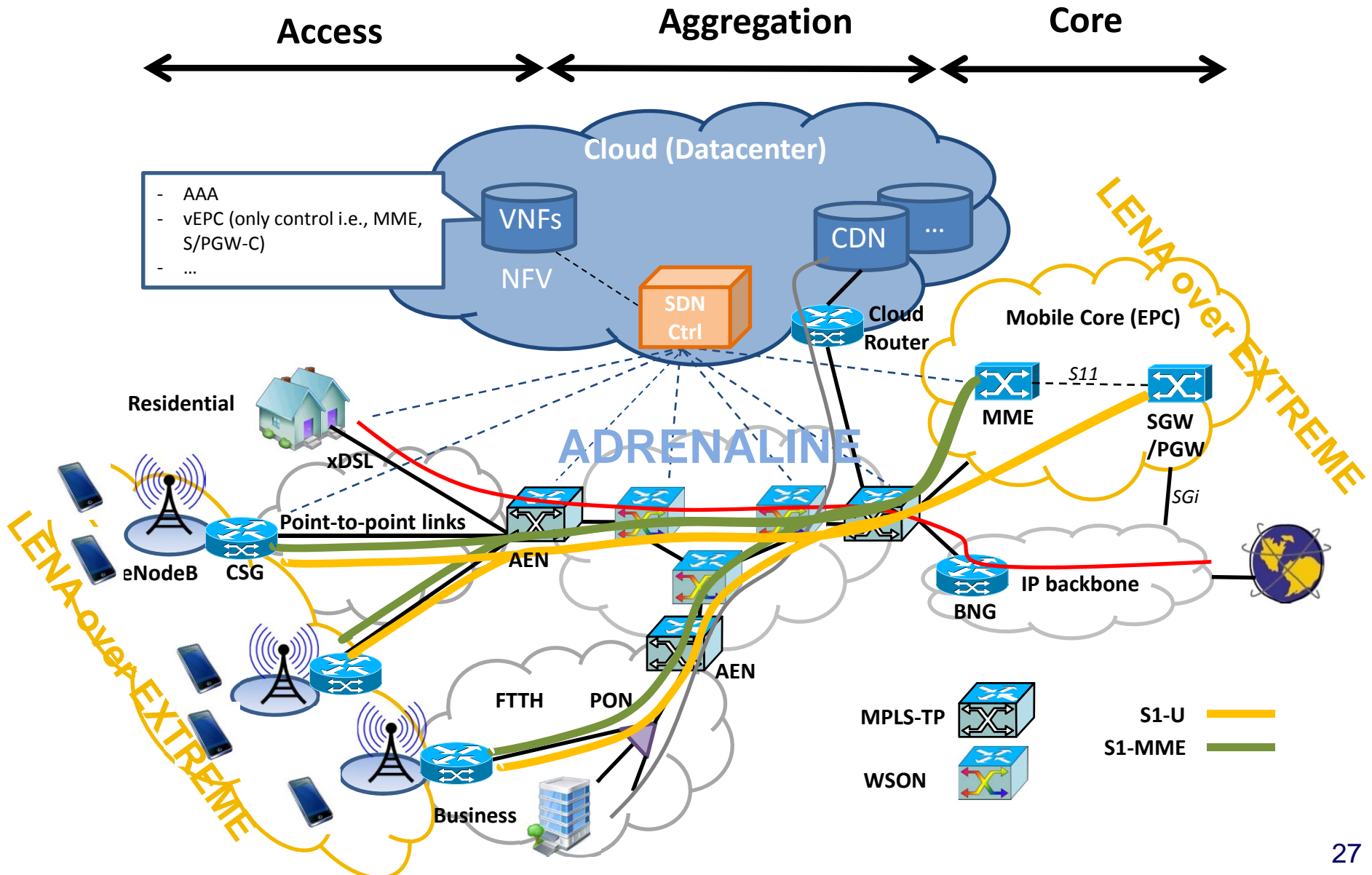
WAN  
(Optical Core)



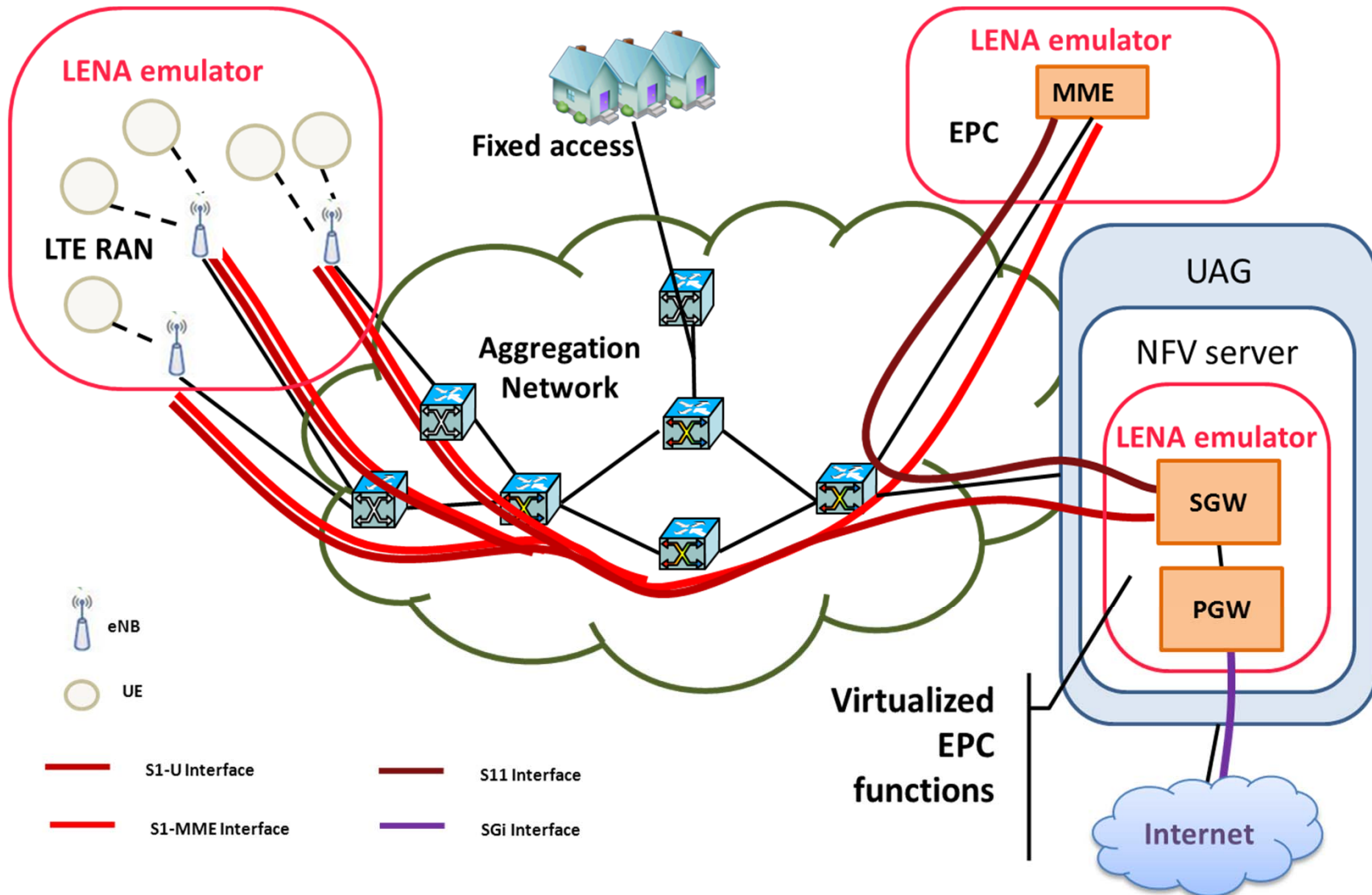
# Cloud-network borders blurring IT & network orchestration



# Mobile and transport layers blurring

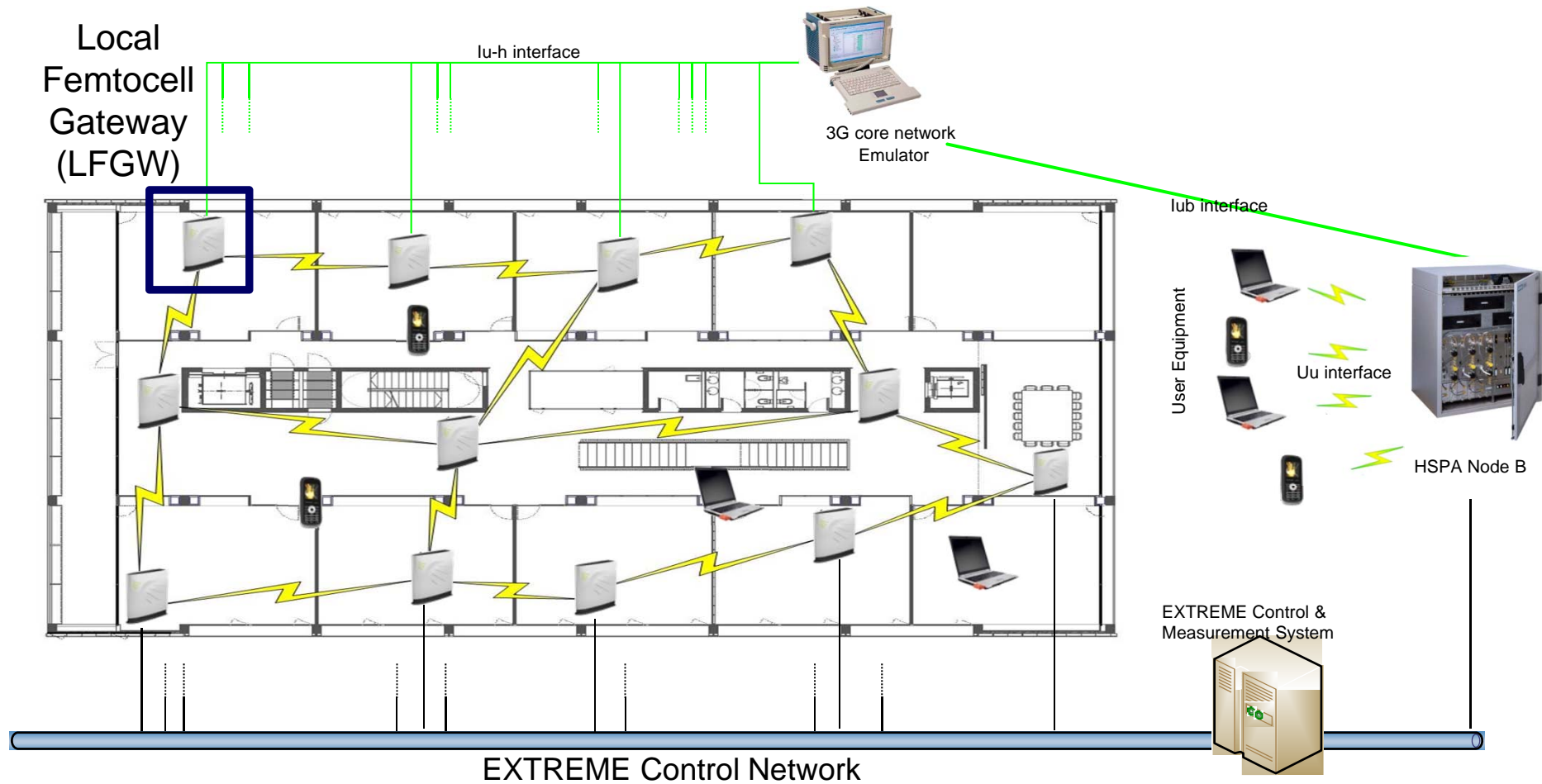


# Edge and core borders blurring

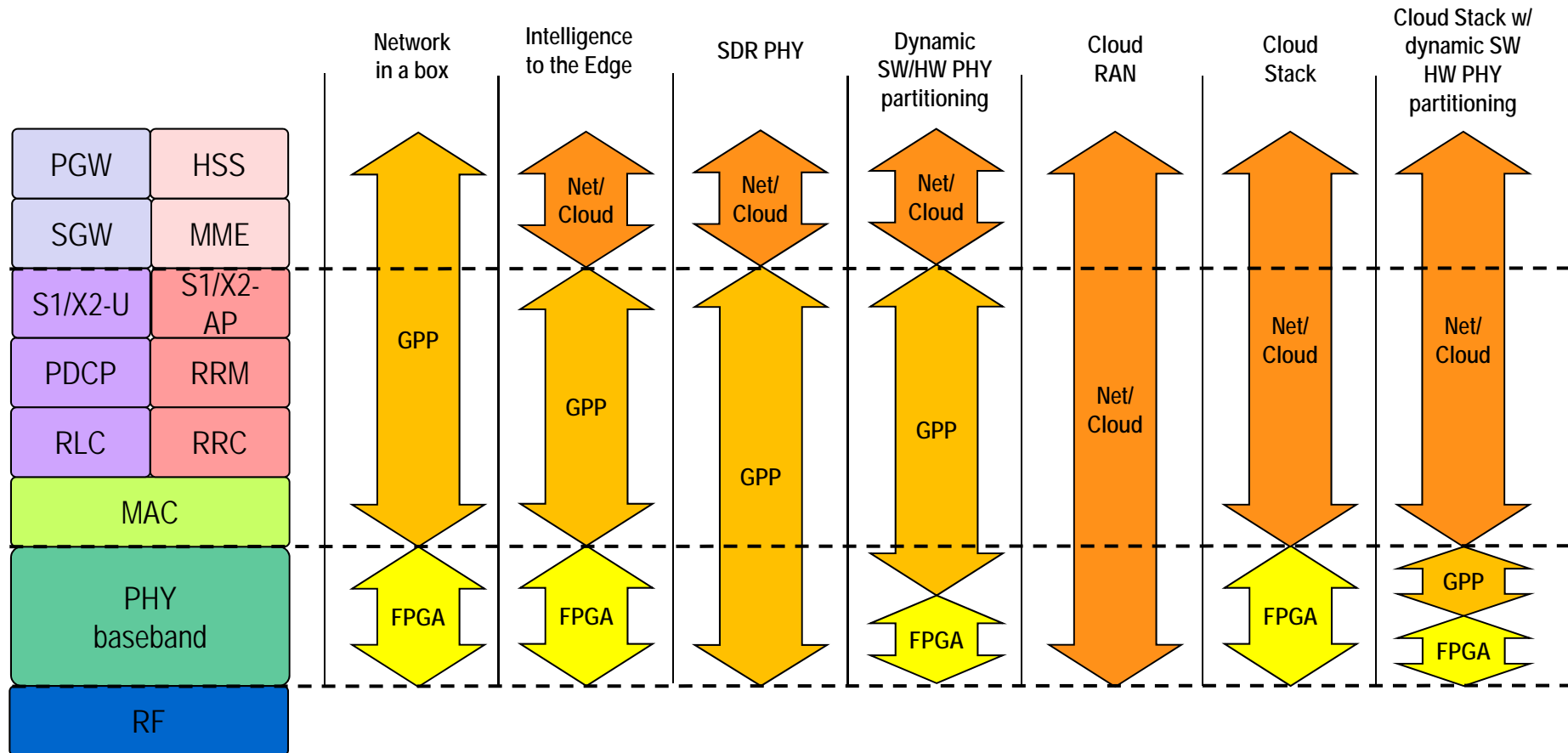




# Edge and core borders blurring



# RAN borders blurring

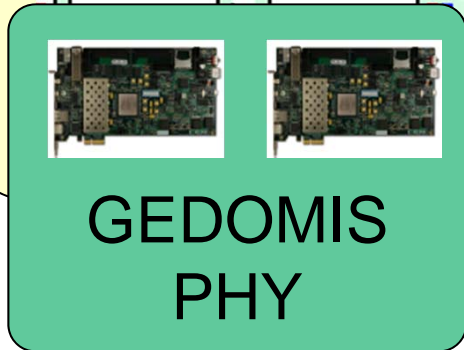
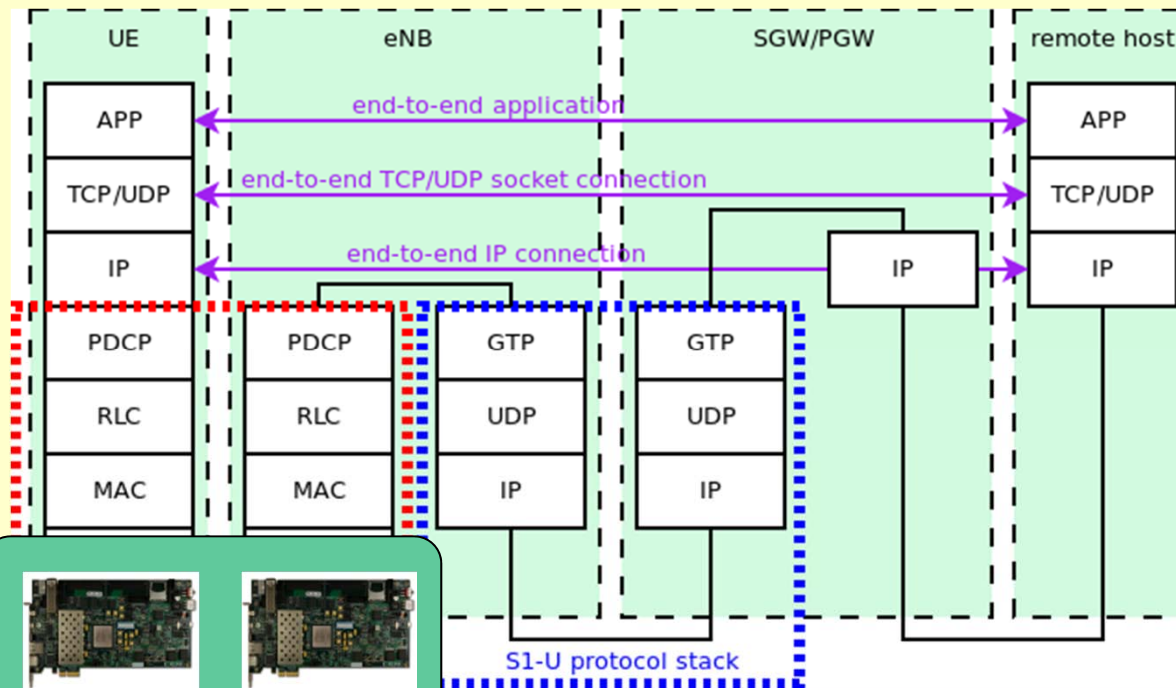


# RAN borders blurring

## RAN virtualization testbed

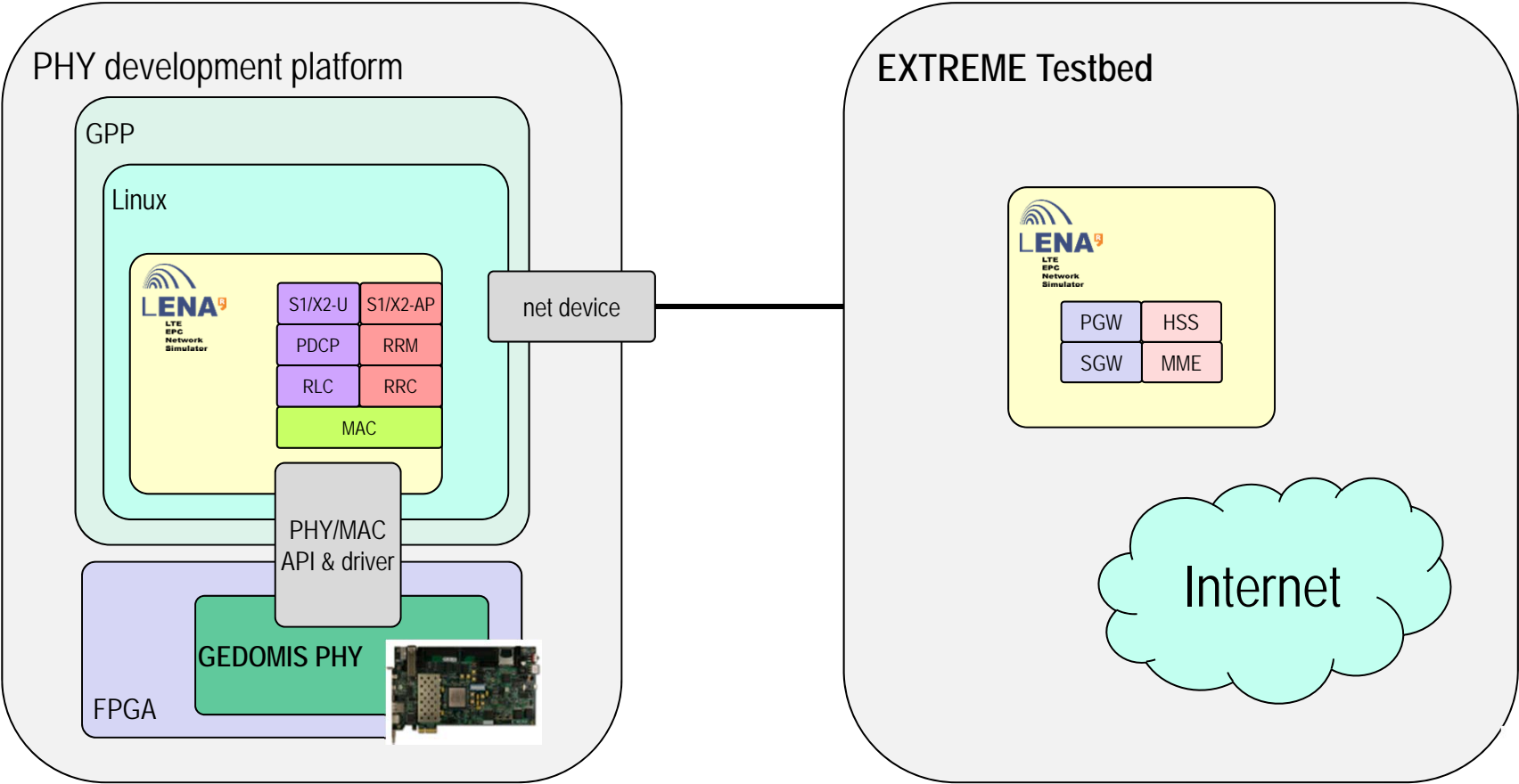


### LENA stack over EXTREME Testbed



# Examples of RAN borders blurring

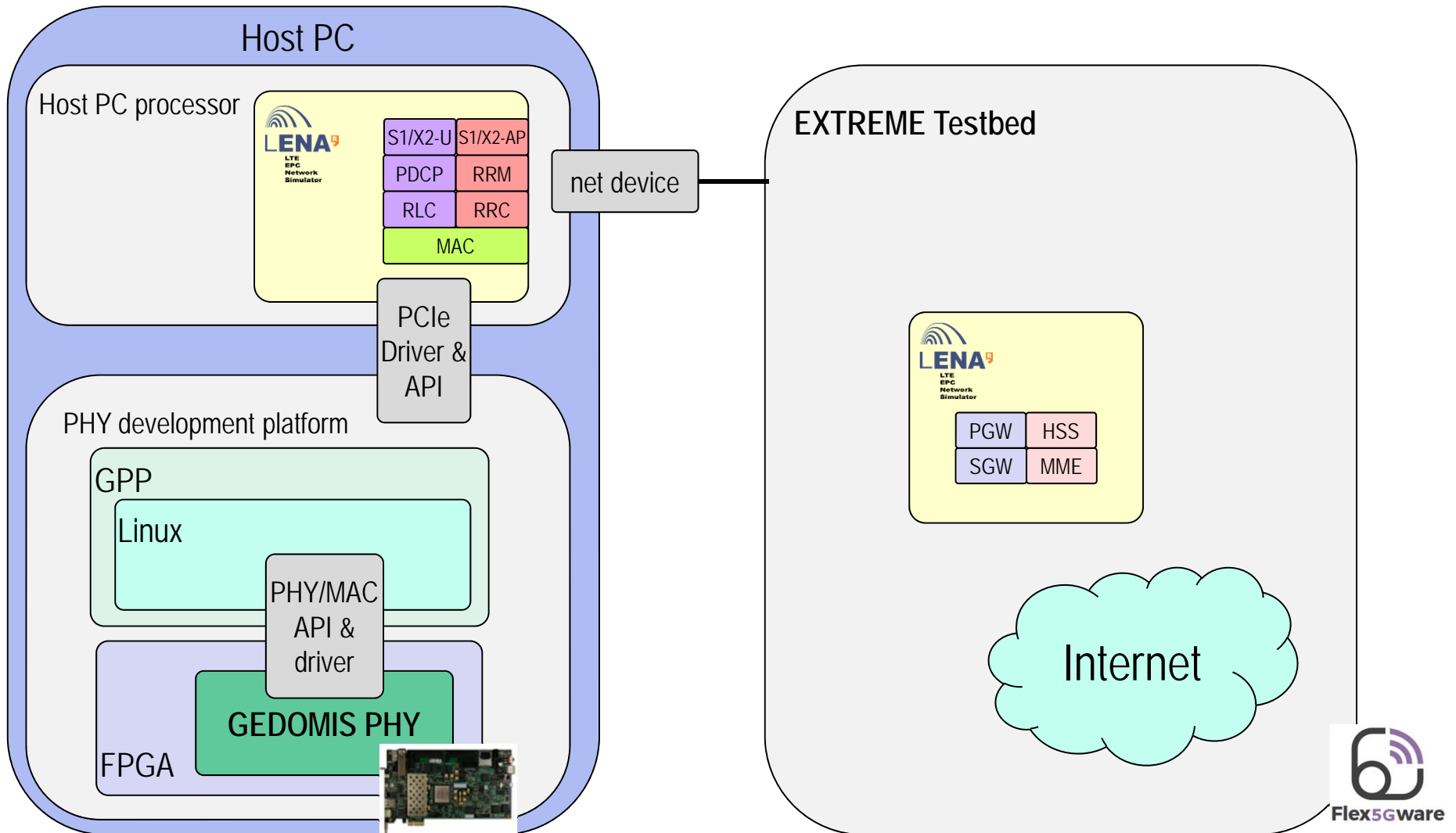
## Intelligence to the Edge approach (I)





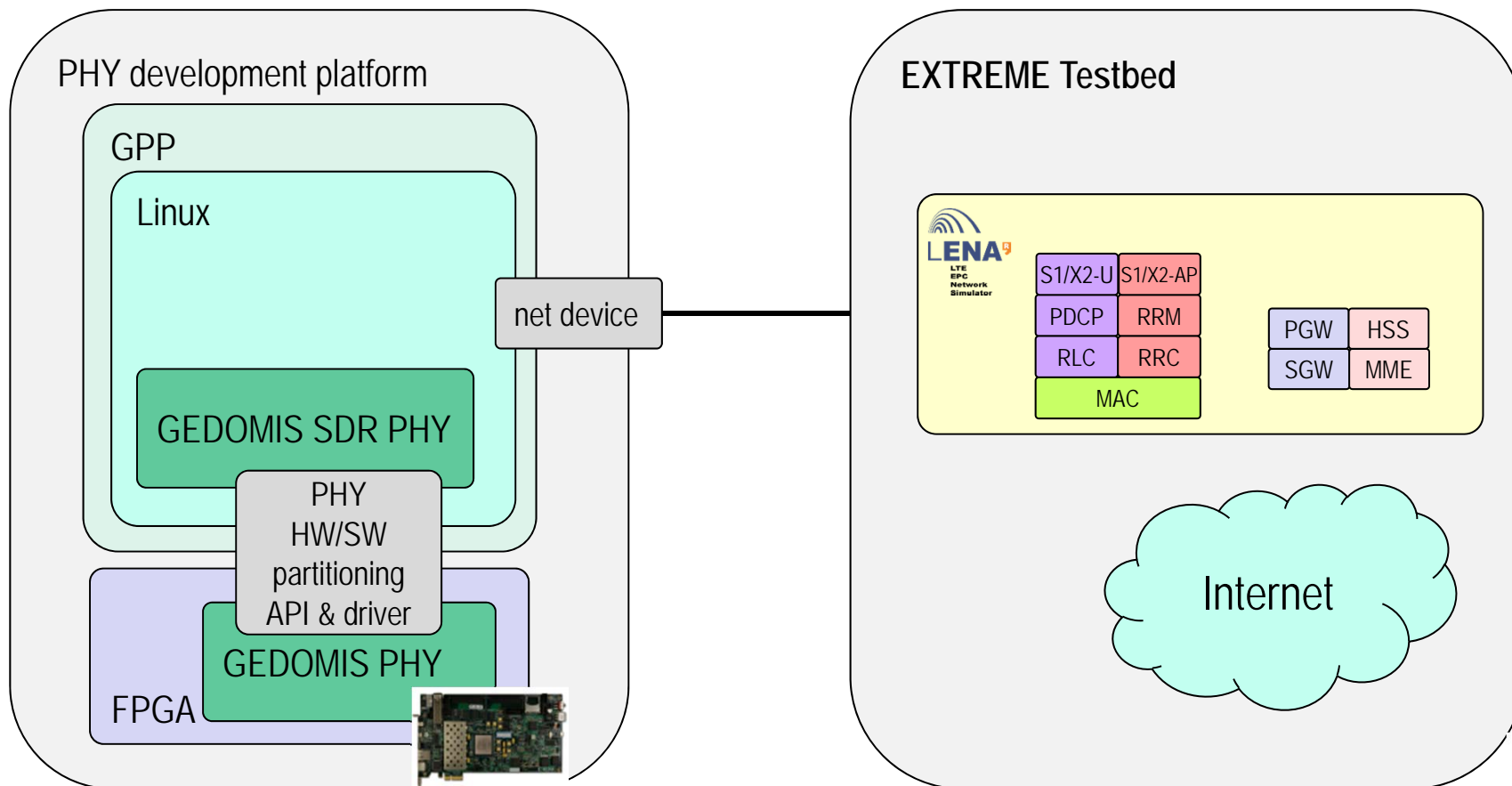
# Examples of RAN borders blurring

## Intelligence to the Edge approach (II)



# Examples of RAN borders blurring

## Cloud Stack with Dynamic HW/SW PHY partitioning



# *Methodological approach*



- Remarkable methodological novelty
  - Open source may become the new standardization process
- Dave Clark on IETF operation:
  - “We don’t believe in presidents, kings, or voting, we believe in rough consensus and running code.”
- Democratization of network design

## ***Conclusion***



- Brave new world in networking research

Let's go shape it!

# ***Thanks for your kind attention!***



- Questions?

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