Panel on NETWORKING

Topic: Future Networks: IP 2020, 5/6G and Slicing Cohabitation

PANEL on Networking

Moderator

Eugen Borcoci, University "Politehnica"of Bucharest (UPB), Romania

Panelists

- **Ioannis Moscholios, University of Peloponnese - Tripolis, Greece**
- **Konstantinos Samdanis, Huawei - Munchen, Germany**
- **Alexandros Kaloxylos, University of Peloponnese, Greece**
- **Eugen Borcoci, University "Politehnica"of Bucharest (UPB), Romania**

Panel on Networking

- Topics to be discussed in this panel
  - Why IP 2020? What novel feature it offers?
  - 4G towards 5G evolution- current status and perspectives
  - 6G – next step after 5G? (global extension of 5G)
  - Network slicing (e.g. in 5G) – challenges and solutions
  - Network resource allocation
  - Management and control tools (SDN)
  - Virtualization (NFV,..)
  - Cloud-like techniques and networking (5G, IoT, V2X, ….)
    - Centralized data centers, Fog, MEC, VCC, …

Panel on Networking

- Thanks !
- Floor for the speakers…..

Panel on NETWORKING

Topic: Future Networks: IP 2020, 5/6G and Slicing Cohabitation

SDN, NFV, Fog in 5G/Internet of Vehicles (IoV) Environment

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Softnet 2017 Conference, October 8 - 12, Athens

SDN, NFV, Fog in 5G/IoV Environment

Facts:

- *5G – strong candidate to support IoT (including IoV)*
- *Supporting technologies*
  - *Cloud Computing*
  - *Fog/Edge Computing /Mobile Edge Computing /Cloudlets*
  - *Software Defined Networks (SDN)*
  - *Network Function Virtualization (NFV)*

SDN, NFV, Fog in 5G/IoV Environment

- **Software Defined Networking (SDN)**
  - **SDN – applicable in Clouds, WANs, IoT, vehicular, 5G**
- **SDN concepts and advantages:**
  - **Control Plane (CPl) and Data Plane (DPl) separation**
  - **centralized logical control and view** of the network
    - underlying network infrastructure is abstracted to applications
    - common APIs (northbound I/F)
  - Open I/Fs Southbound I/F CPl (controllers - DPl elements)
    - E.g. OpenFlow
  - **Network programmability**: by external applications, including network management and control
  - **Independency of operators** w.r.t. network equipment vendors

SDN, NFV, Fog in 5G/IoV Environment

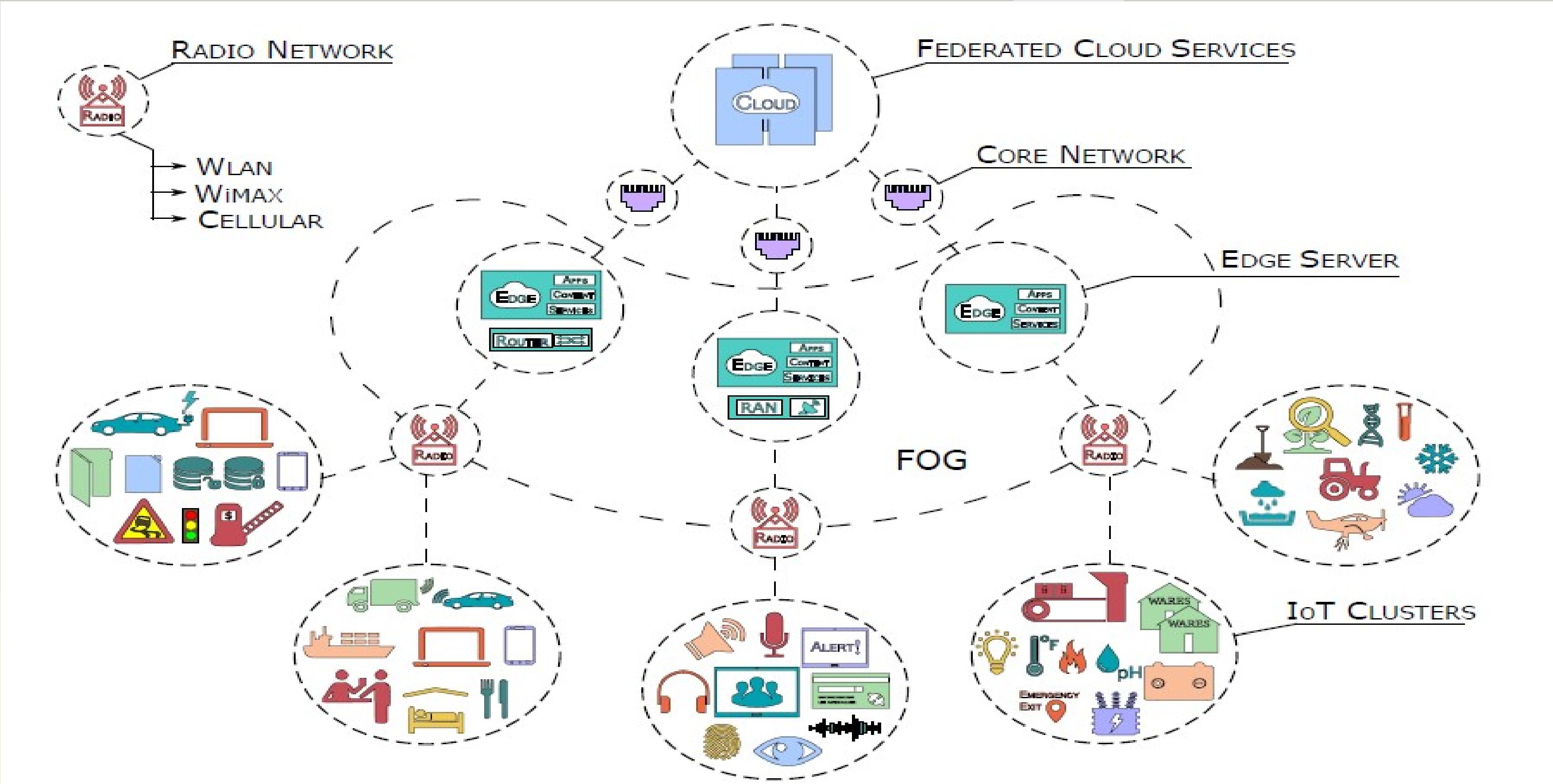
- **Network Function Virtualization (NFV)**
  - Using COTS computing HW to provide **Virtualized Network Functions (VNFs)**
    - Sharing of HW and reducing the number of different HW arch.
  - **High flexibility in assigning VNFs to HW**
    - better scalability (hope)
    - decouples functionality from location
    - enables time of day reuse
    - **Virtualization- (VMs)→** flexibility and resource sharing
  - **Rapid service innovation** through SW -based service deployment
  - Higher **operational efficiencies**
  - **Reduced power consumption**
    - (VNF migration, instantiation, …)
  - **Standardized and open I/Fs**: between VNFs infrastructure and mgmt. entities

SDN, NFV, Fog in 5G/IoV Environment

- **Fog computing and networking**
  - **Fog: decentralized** computing infrastructure
    - computing resources and appl. services are distributed in the most logical, efficient places, **at any point along the continuum from the data source to the cloud**
    - Higher efficiency: lower amount of data to be transported to the cloud for data processing, analysis and storage, faster real time response, locl context awareness
  - Attractive for IoT, 5G (e.g Cloud -Fog- terminals hierarchy)
  - **Management,** control and configuration, can be performed at or near the end-user
  - **SDN, NFVcan be used to control FC**

SDN, NFV, Fog in 5G/IoV Environment

- **Fog architecture**



Source: A.Munir, et.al., "IFCIoT: Integrated Fog Cloud IoT Architectural Paradigm for Future Internet of Things", arXiv:1701.08474v1 [cs.DC] 30 Jan 2017

SDN, NFV, Fog in 5G/IoV Environment

- **Internet of Vehicles (IoV) (~ special case of IoT)**
- **Main objectives**
  - **extended business models and the range of applications** w.r.t current vehicular networks and Intelligent Transportation Systems (ITS)
  - **extension of VANETs**, while re-using framework of ITS
  - **communications, processing, storage, intelligence, learning and strong security** capabilities
  - **distributed transport fabric**
  - **to be integrated in IoT** framework and smart cities technologies
  - to support **heterogeneous networking and peripheral devices access**

SDN, NFV, Fog in 5G/IoV Environment

- **Example of**: **Five layer IoV functional architecture**
  - similar to IoT architecture- high level view
  - **Architectural planes: Operational, Management, Security**

Business : Graphs, Tables, Diagrams, Flowcharts

Application : Applications for vehicles and vehicular dynamics

Artificial Intelligence: Cloud computing, big data analysis, expert systems

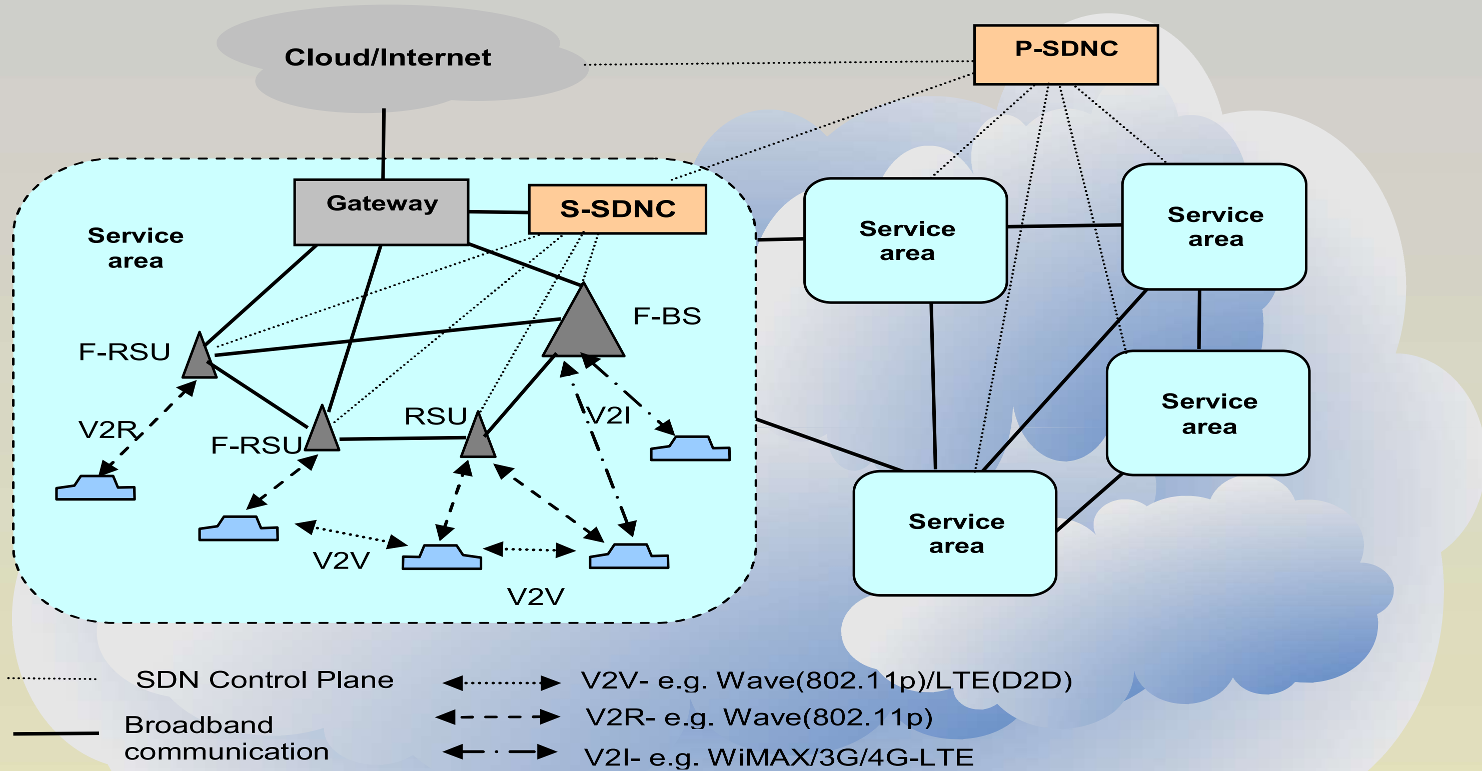
Coordination: Heterogeneous networks-WAVE, WiFi, LTE, etc.

Perception: Sensors and actuators of vehicles, RSU, personal devices

Source: O. Kaiwartya, et.al., "Internet of Vehicles: Motivation, Layered Architecture, Network Model, Challenges, and Future Aspects" IEEE Access, Special Section on Future Networks, Architectures, Protocols and Applications, Vol. 4, pp.5536-5372, September 2016

SDN, NFV, Fog in 5G/IoV Environment

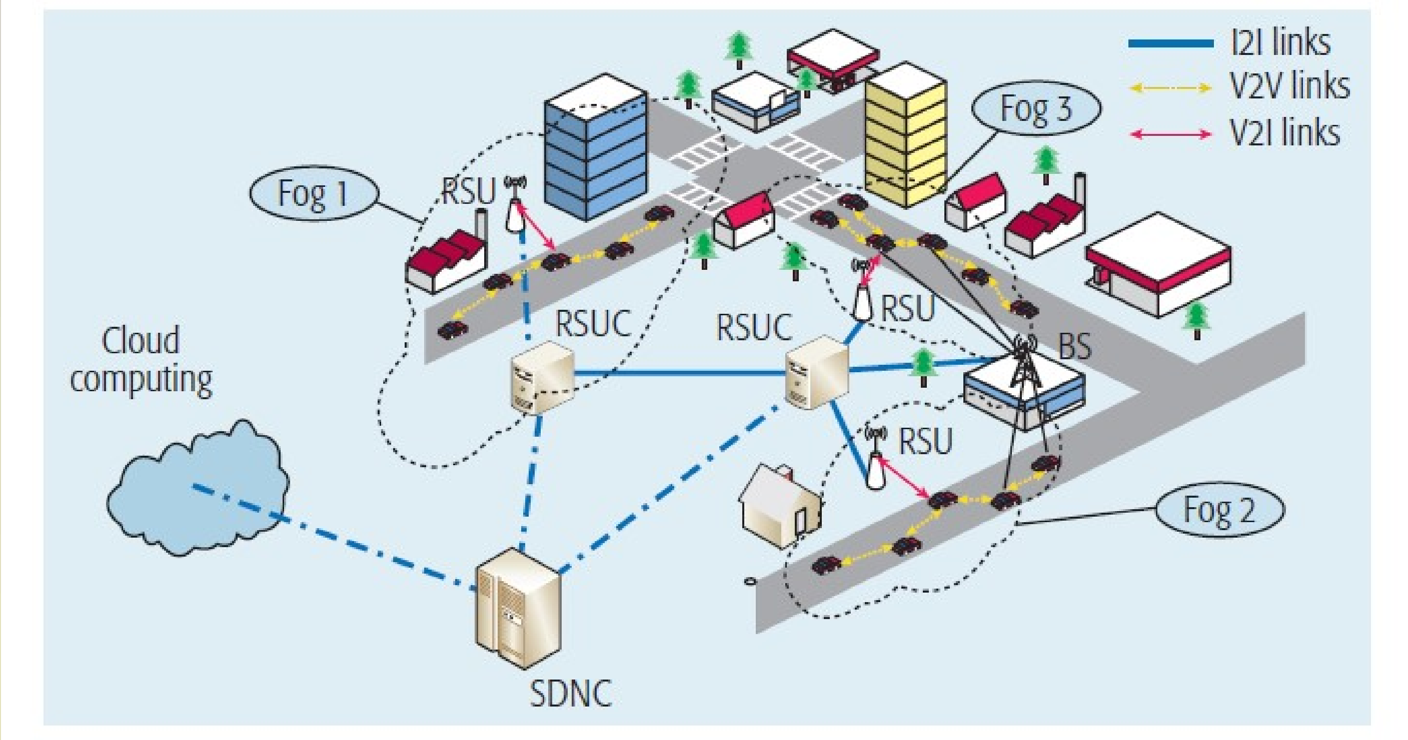
- **Example 1: SDN-FOG architecture for IoV**



Source: E.Borcoci, et.al., "Internet of Vehicles Functional Architectures - Comparative Critical Study", AFIN 2017, The Ninth International Conference on Advances in Future Internet
Extension of Source: N.N.Truong et.al., , "Software defined networking-based vehicular ad hoc network with fog Computing", Proceedings of the 2015 IFIP/IEEE International Symposium on Integrated Network Management (IM'15), May 2015

SDN, NFV, Fog in 5G/IoV Environment

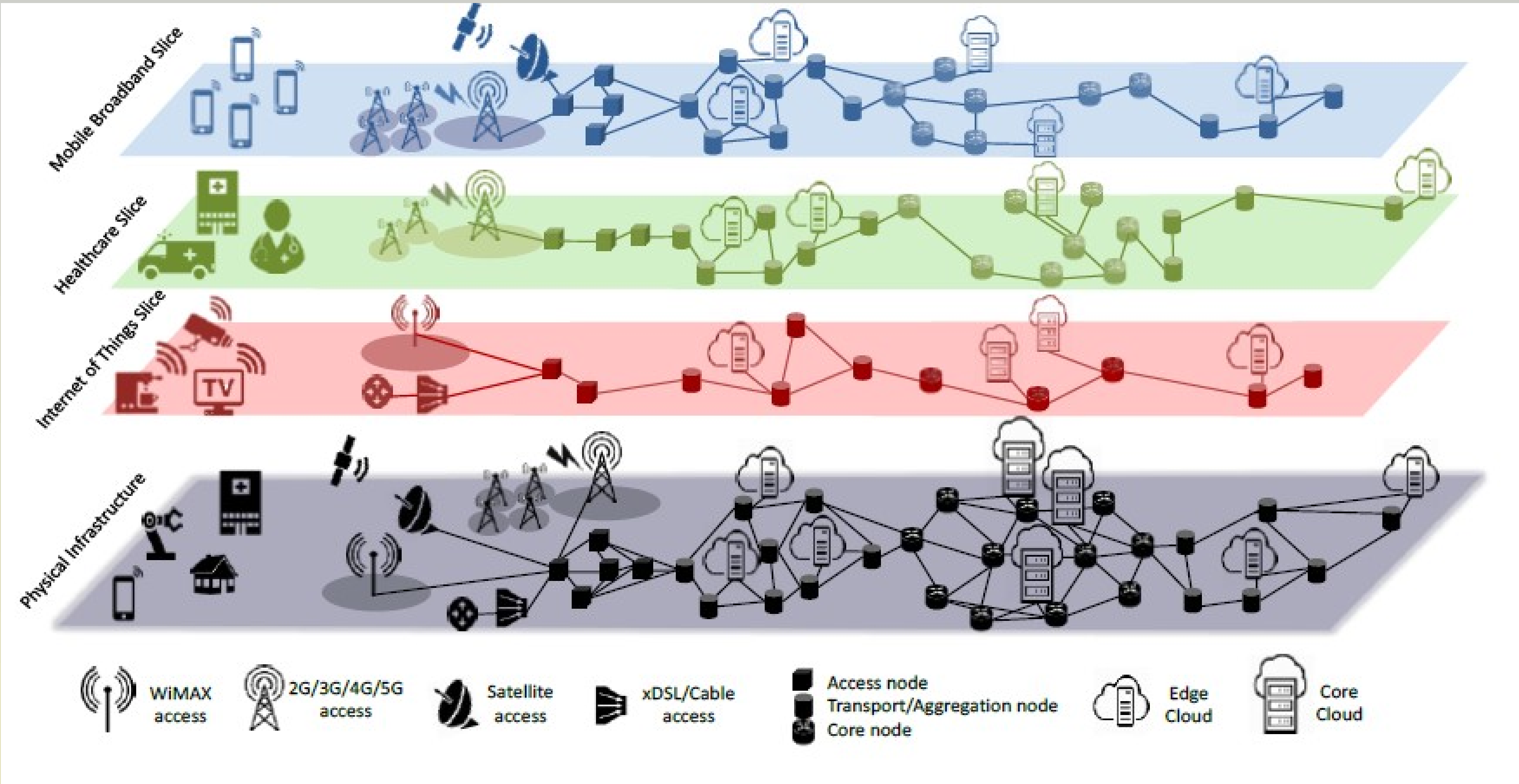
- **Example 2 5G Software Defined Vehicular Networks (SDVN) + Fog**
- IoV architecture based on 5G technology
  - **fog cells are** proposed to flexibly cover vehicles and avoid frequently handover between vehicles and road side units (RSUs)



Source: Xiaohu Ge1, et.al., 5G Software Defined Vehicular Networks, IEEE Communications Magazine, July 2017, http://ieeexplore.ieee.org/document/7981531/

SDN, NFV, Fog in 5G/IoV Environment

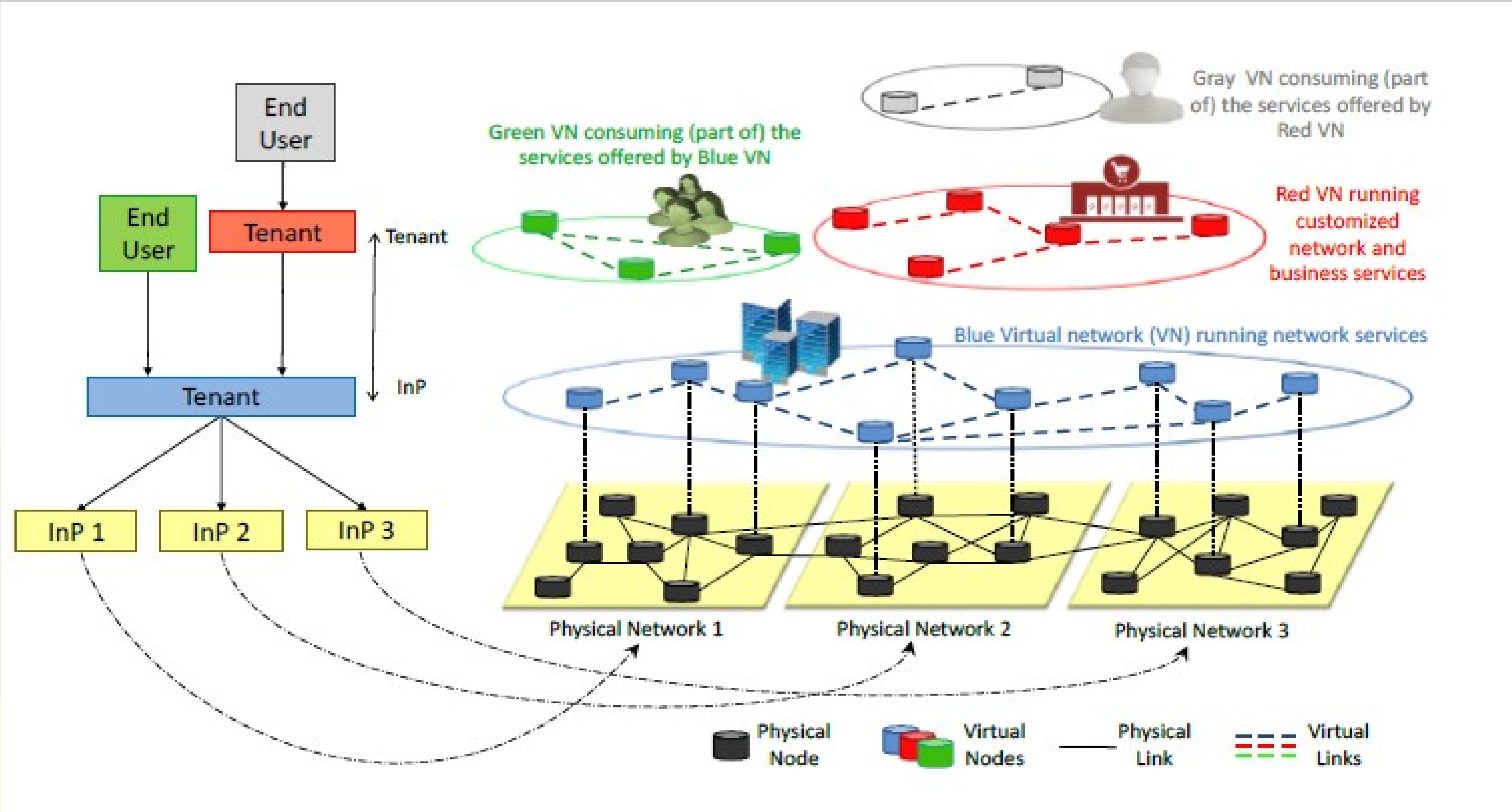
- **Network slicing - example**



Source: J. Ordonez-Lucena et. al., , Network Slicing for 5G with SDN/NFV: Concepts, Architectures and Challenges " IEEE Comm. Magazine, 2017

SDN, NFV, Fog in 5G/IoV Environment

- Network slices: recursive model



Source: J. Ordonez-Lucena et. al., , Network Slicing for 5G with SDN/NFV: Concepts, Architectures and Challenges " IEEE Comm. Magazine, 2017

SDN, NFV, Fog in 5G/IoV Environment

- **Conclusions**

- **5G can efficiently support IoV**
- **SDN, NFV, Fog technology can be integrated**
- **Different functional and business aspects- still open issues**
  - Management and control
  - Virtualization and slicing and
  - Security, privacy
  - Scalability (horizontal, vertical)
  - Interoperability
  - Seamless deployment characteristics
  - Support for apps and services

SDN, NFV, Fog in 5G/IoV Environment

- **Backup slides**

Features/Advantages of 6G Technology:

•Ultra fast access of Internet.

•Data rates will be up to 10-11 Gbps.

•Home automation and other related applications.

•Smart Homes, Cities and Villages.

•May be used in the production of Energy from galactic world.

•Space technology, Defense applications will be modified with 6G networks.

•Home based ATM systems.

•Satellite to Satellite Communication for the development of mankind.

•Natural Calamities will be controlled with 6G networks.

•Sea to Space Communication.

•Mind to Mind Communication may be possible

•Standards :- The Global Position System(GPS) by USA, the Galileo by Europe, the COMPASS by China and the GLONASS by Russia.

• If 6G integrates with 5G with these satellite networks, it would have four different standards. So handoff and roaming will be can be a big issue in 6G

Source: http://vitorr.com/post-details.php?postid=2615

SDN, NFV, Fog in 5G/IoV Environment

- **References**

1. M.Mendonca, et. al., A Survey of Software-Defined Networking: Past, Present,and Future of Programmable Networks, 2014, http://hal.inria.fr/hal-00825087
2. ETSI- Network Functions Virtualization – Introductory White Paper,https://portal.etsi.org/nfv/nfv_white_paper.pdf
3. M.Peng, S.Yan, K.Zhang, and C.Wang, “Fog Computing based Radio Access Networks: Issues and Challenges”, IEEE Network, vol. 30, pp.46-53, July/August 2016
4. Y.Li, et.al, "A SDN-based Architecture for Horizontal Internet of Things Services", ICC Conference, 2016
5. Amr El-Mougy, et.al., “Software-Defined Wireless Network Architectures for the Internet-of-Things”, LCN 2015, Florida, USA
6. O. Kaiwartya, A.H. Abdullah, Y. Cao, A. Altameem, M. Prasad, et.al., “Internet of Vehicles: Motivation, Layered Architecture, Network Model, Challenges, and Future Aspects” IEEE Access, Special Section on Future Networks,
7. E.Borcoci, et.al., “Internet of Vehicles Functional Architectures - Comparative Critical Study”, AFIN 2017, The Ninth International Conference on Advances in Future Internet
8. N.N.Truong et.al., , “Software defined networking-based vehicular ad hoc network with fog Computing”, Proceedings of the 2015 IFIP/IEEE International Symposium on Integrated Network Management (IM’15), May 2015
9. J. Ordonez-Lucena et. al., , Network Slicing for 5G with SDN/NFV: Concepts, Architectures and Challenges “ IEEE Comm. Magazine, 2017

SDN, NFV, Fog in 5G/IoV Environment

- **List of Acronyms**

- BS Base Station
- BSS Business Support System
- CC Cloud Computing
- COTS Commercial-off-the-Shelf
- EC Edge Computing
- ETSI European Telecommunications Standards Institute
- FC Fog Computing
- FCN Fog Computing Node
- IoT Internet of Things
- LTE Long Term Evolution
- MEC Mobile Edge Computing
- M&O Management and Orchestration
- MME Mobility Management Entity
- NF Network Function
- NFV Network Functions Virtualization
- NFVI Network Functions Virtualization Infrastructure
- NO Network Operator
- NP Network Provider
- NS Network Service
- OSS Operations Support System
- SDN Software Defined Network
- SLA Service Level Agreement
- SP Service Provider

Bandwidth Sharing Policies in 5G Networks

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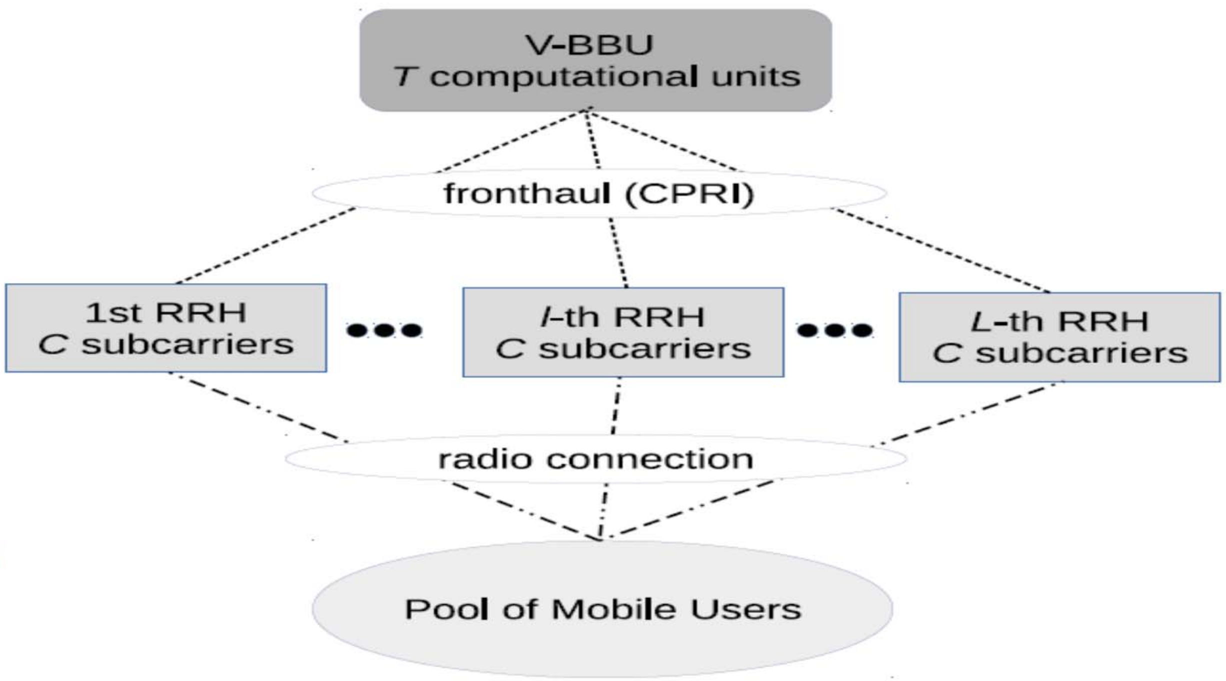
The 6th International Conference on Communications, Computation, Networks and Technologies (INNOV), Athens, Greece, Oct. 8-12, 2017

Bandwidth Sharing Policies in 5G Networks (1)

Consider the C-RAN model of the Fig where the RRHs are separated from the V-BBU, which performs the centralized baseband processing (of accepted calls).

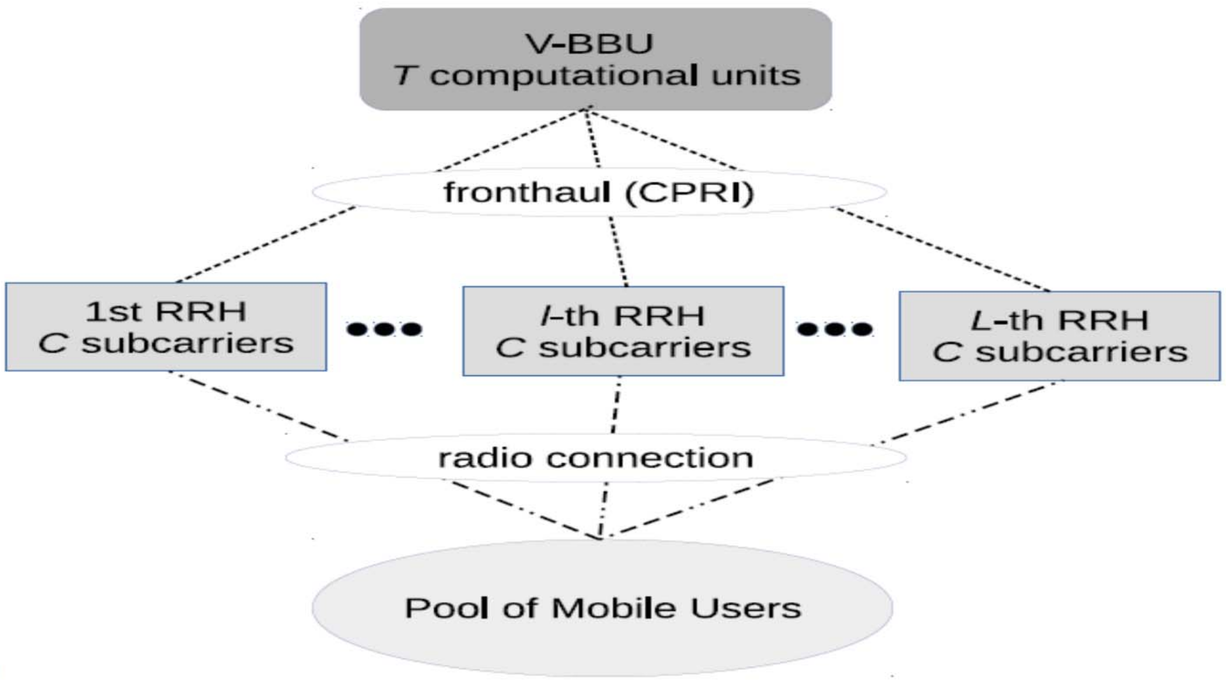
The total number of Remote Radio Heads (RRHs) is *L* and each RRH has *C* subcarriers, which essentially represent units of the radio resource and can be allocated to the accepted calls.

The V-BBU consists of T units (servers) of the computational resource, which are consumed for baseband processing.



Bandwidth Sharing Policies in 5G Networks (2)

Arriving calls follow a Poisson process with rate . An arriving call requires a subcarrier from the serving RRH and a unit of the computational resource. If these are available (CS policy), then the call is accepted and remains in the system for a generally distributed service time with mean μ^{-1}. Otherwise, the call is blocked and lost.



Bandwidth Sharing Policies in 5G Networks (3)

The model has a PFS

$$P(\boldsymbol{n}) = \frac{\prod_{l=1}^{L} \frac{a^{n_l}}{n_l!}}{\sum_{\boldsymbol{n} \in \Omega} \prod_{l=1}^{L} \frac{a^{n_l}}{n_l!}}$$

$\boldsymbol{n} = (n_1, \ldots, n_l, \ldots, n_L)$ The number of in-service calls in all RRHs

α=λ/μ the offered traffic-load

To calculate the total CBP, B_{tot}, we distinguish two types of blocking events: 1) those that are caused due to insufficient subcarriers and are represented by the probability, B_{sub}, and 2) those that are caused due to insufficient units of the computational resource and are represented by the probability, B_{res}:

$$B_{tot} = B_{sub} + B_{res}$$

Bandwidth Sharing Policies in 5G Networks (4)

$$B_{sub} = G\frac{a^C}{C!}\sum_{\boldsymbol{n}\in\Omega_{<T}^{1,C}}\prod_{l=2}^{L}\frac{a^{n_l}}{n_l!}\qquad G=\left(\sum_{\boldsymbol{n}\in\Omega}\prod_{l=1}^{L}\frac{a^{n_l}}{n_l!}\right)^{-1}$$

$$\boldsymbol{\Omega}_{<T}^{1,C}=\left\{\boldsymbol{\Omega}^{1,C}\cap\boldsymbol{\Omega}_{<T}\right\},\ \boldsymbol{\Omega}^{1,C}=\left\{\boldsymbol{n}:n_1=C\right\},\ \boldsymbol{\Omega}_{<T}=\left\{\boldsymbol{n}:n_1+\ldots+n_L<T\right\}$$

$$B_{res}=\sum_{\boldsymbol{n}\in\Omega_{=T}}P(\boldsymbol{n})\qquad \boldsymbol{\Omega}_{=T}=\left\{\boldsymbol{n}:n_1+\ldots+n_L=T\right\}$$

[1] J. Liu, S. Zhou, J. Gong, Z. Niu and S. Xu, “On the statistical multiplexing gain of virtual base station pools,” Proc. IEEE Globecom, Austin, TX, Dec. 2014.

[2] J. Liu, S. Zhou, J. Gong, Z. Niu and S. Xu, “Statistical multiplexing gain analysis of heterogeneous virtual base station pools in cloud radio access networks,” IEEE Trans. Wireless Commun., vol. 15, no. 8, pp.5681-5694, Aug. 2016.

Bandwidth Sharing Policies in 5G Networks (5)

For an efficient calculation of B_{tot}, we can exploit the PFS and propose the following 3-step convolution algorithm:

Step 1) Determine the occupancy distribution of each of the L RRHs, $q_l(j)$, where j=1,…,C and l=1,…,L:

$$q_l(j) = q_l(0)\frac{a^j}{j!}$$

Step 2) Determine the aggregated occupancy distribution $Q_{(-l)}$ based on the successive convolution of all RRHs apart from the lth RRH:

$$Q_{(-l)} = q_1 * q_2 * \ldots * q_{l-1} * q_{l+1} * \ldots * q_L$$

I. Moscholios, V. Vassilakis, M. Logothetis and A. Boucouvalas, “State-dependent Bandwidth Sharing Policies for Wireless Multirate Loss Networks”, *IEEE Trans. Wireless Commun.*, vol. 16, issue 8, pp. 5481-5497, August 2017.

Bandwidth Sharing Policies in 5G Networks (6)

Step 3) Calculate the total CBP, B_{tot}, based on the normalized values of the convolution operation of step 2, as follows:

$$B_{tot} = B_{sub} + B_{res} = q_1(C)Q_{(-1)}(0) + q(T)$$

$$q(T) = G^{-1}\sum_{x=0}^{T} Q_{(-1)}(x)q_1(T-x)$$

Based on the above, the model can be extended to include:

a) multiple service-classes where calls have different subcarrier and computational resource requirements per service-class,
b) different call arrival processes per RRH or group of RRHs, thus allowing for a mixture of arrival processes (e.g., random and quasi-random traffic) and
c) different sharing policies (e.g. CS, BR, MFCR, PrTH) for the allocation of subcarriers in the RRHs or in the V-BBUs.

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Network slicing for 5G networks: Current status and open issues

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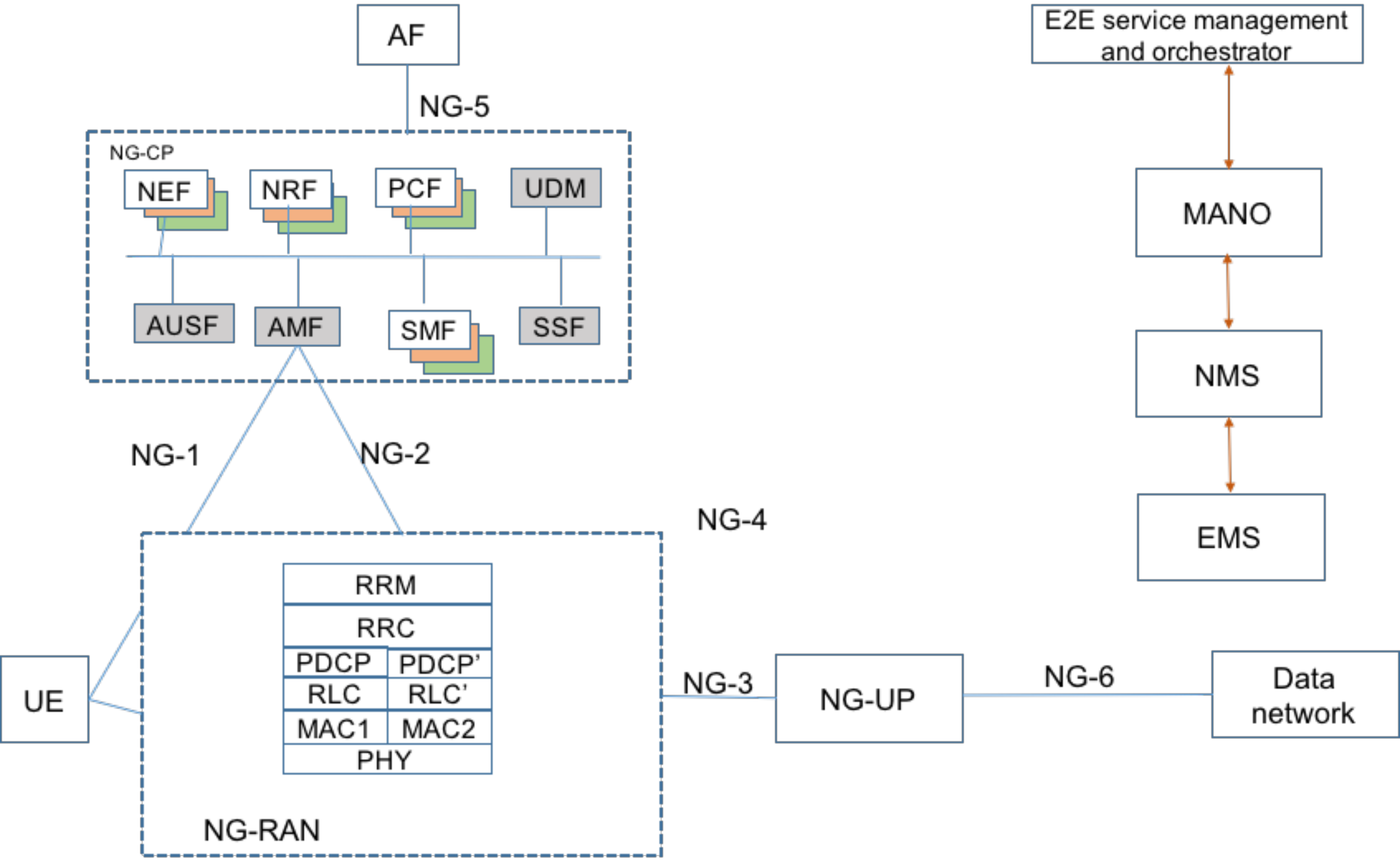
12/10/2017

What is a network slice?

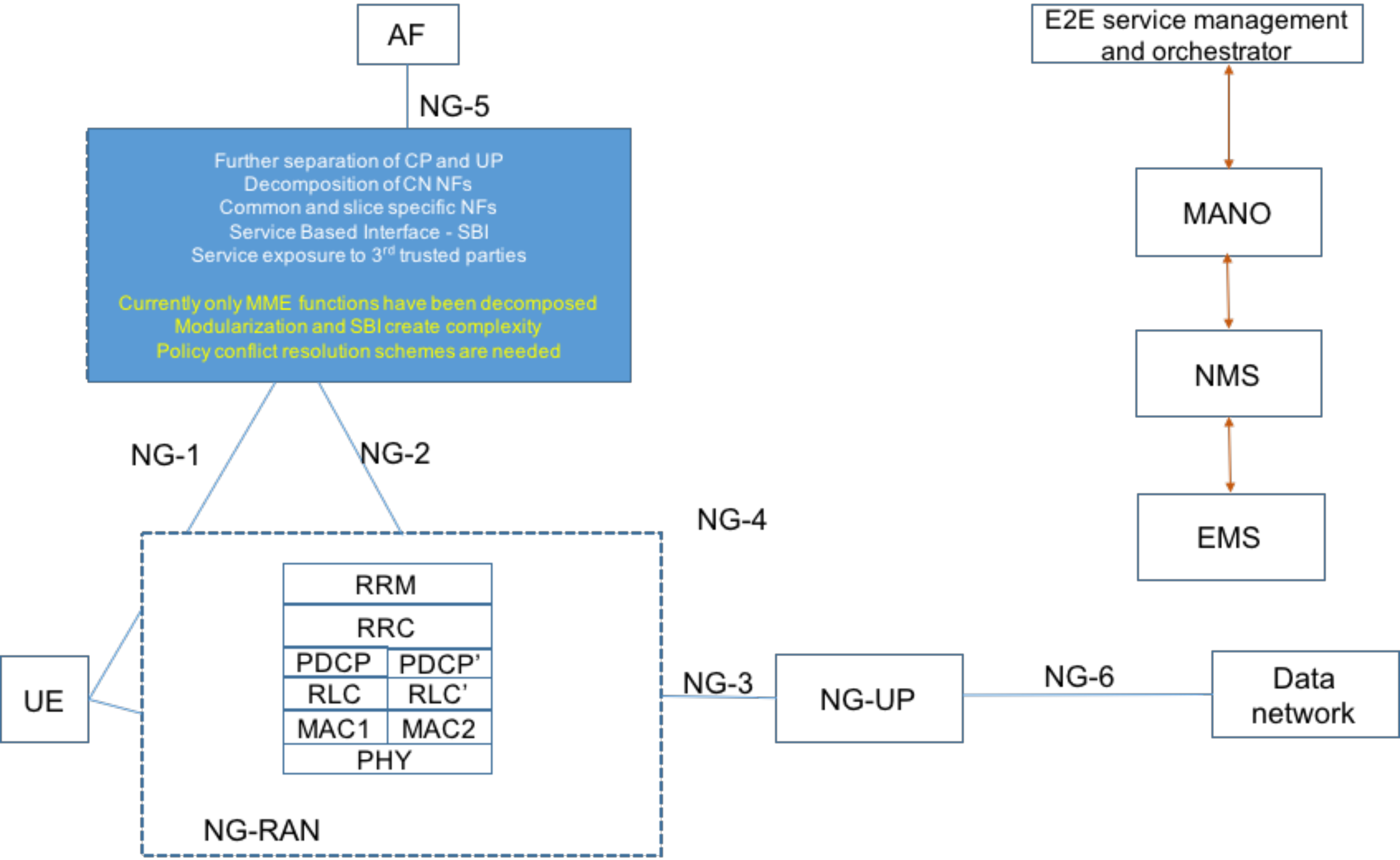
- A logical network that provides specific network capabilities and network characteristics”
- A “Network Slice” is implemented by a “slice instance”
- It is created by a “network slice template” that defines a complete logical network (NFs, interfaces and corresponding resources).
- With slicing an operator can deploy multiple logical networks over the same physical infrastructure.

Source: 3GPP, TS 23.501 “System Architecture for the 5G System”

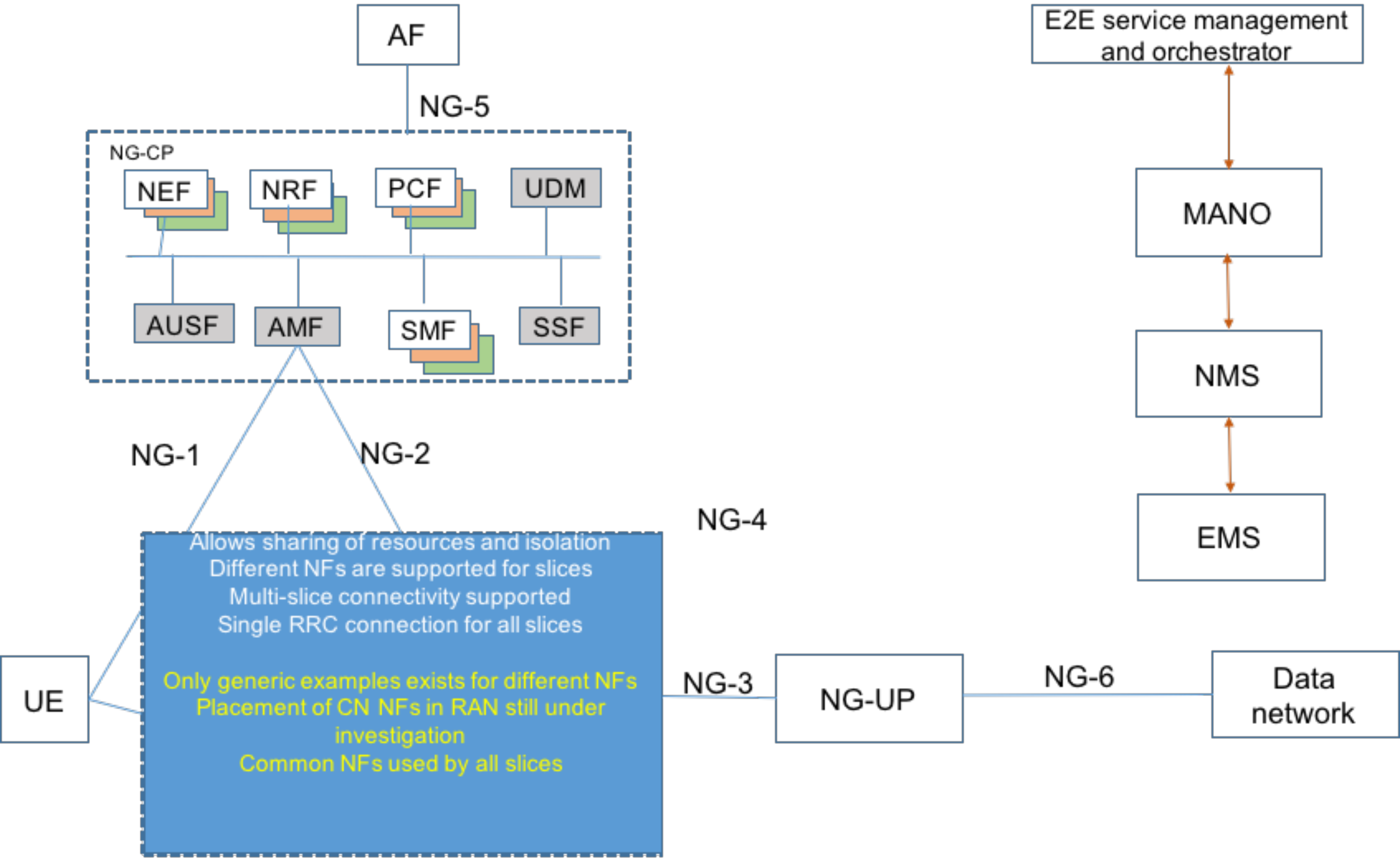
Current status in standardization



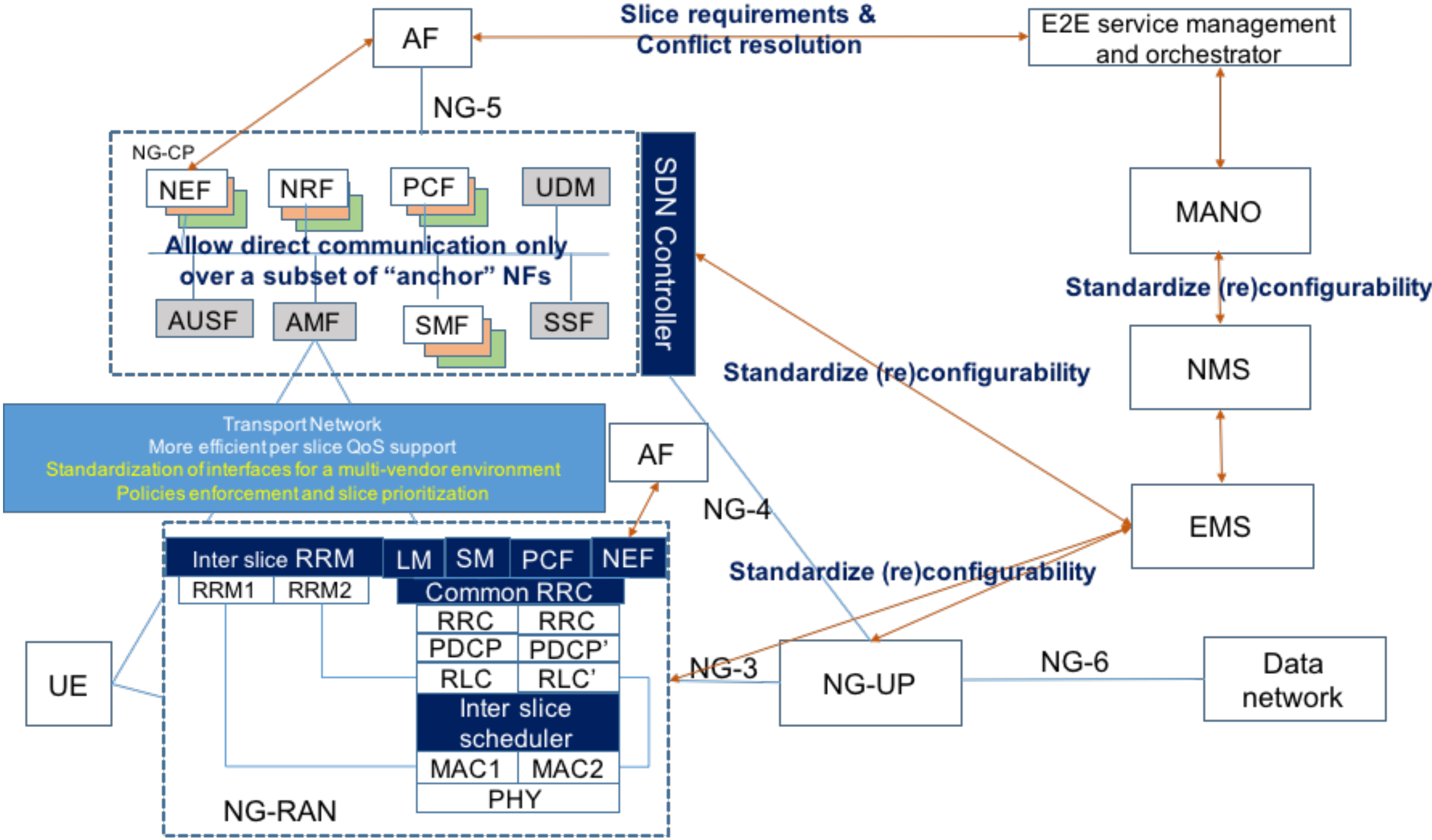
Current status and open issues



Current status and open issues



Next phase topics?



12th International Conference on Systems and Networks Communications (ICSNC 2017)

IARIA

5G Network Slicing: A Transport Network View

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BUILDING A BETTER CONNECTED WORLD

12th of October, 2017 - Athens, Greece

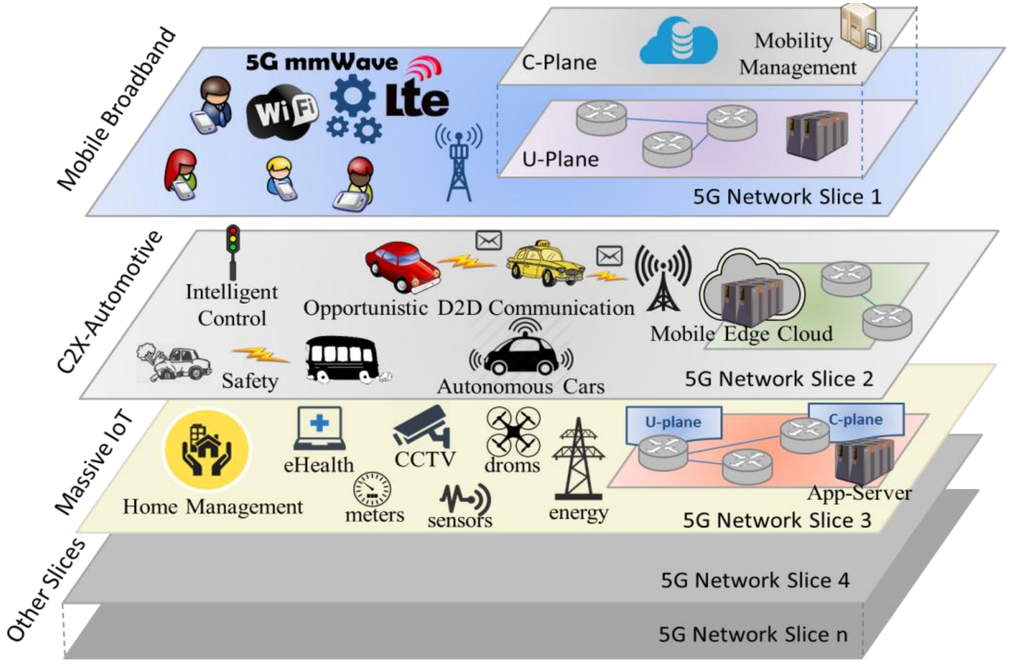
Huawei Technologies Duesseldorf GmbH

HUAWEI | EUROPEAN RESEARCH CENTER

Why Network Slicing?

- Traditional voice/SMS business will eventually die
  - Footprint of data becomes significant with emerging APPs and 5G Services but how operators can monetize mobile data via the bit-pipe model?
- Monolithic "one-fit-all" 4G architecture cannot fulfill at the same time
  - The requirements of 5G diverse APPs and services
- Carriers are interest on creating profit (NOT on CAPEX/OPEX reduction)
  - Create a market for new applications (Verticals)
  - Added value customer services (e.g. accelerators)
  - Monetize edge-cloud services
    - Content, processing, storage closer to user
    - Bid data, RAN-awareness / APP-awareness

Create a Network of Capabilities



3GPP Related Use Cases for Network Slicing

- Support 3GPP 5G business requirements on transport network
  - Enhanced mobile broadband: High speed mobility, densely populated areas
  - Critical communications: Delay sesitive, interactive communications, safety
  - Massive IoT: Connecting many devices
  - Enhanced Vehicular-to-everything: Autonomous driving, driving assistance
- Fixed-Mobile Convergence
  - Unified access and services
- Mobile Backhaul/Fronthaul
  - Indoor **Infrastructure provider** (enterprise, stadium, etc.)
  - Outsource Backhaul/Fronthaul connectivity in specific areas
- Launch new Services – testing before wide adoption

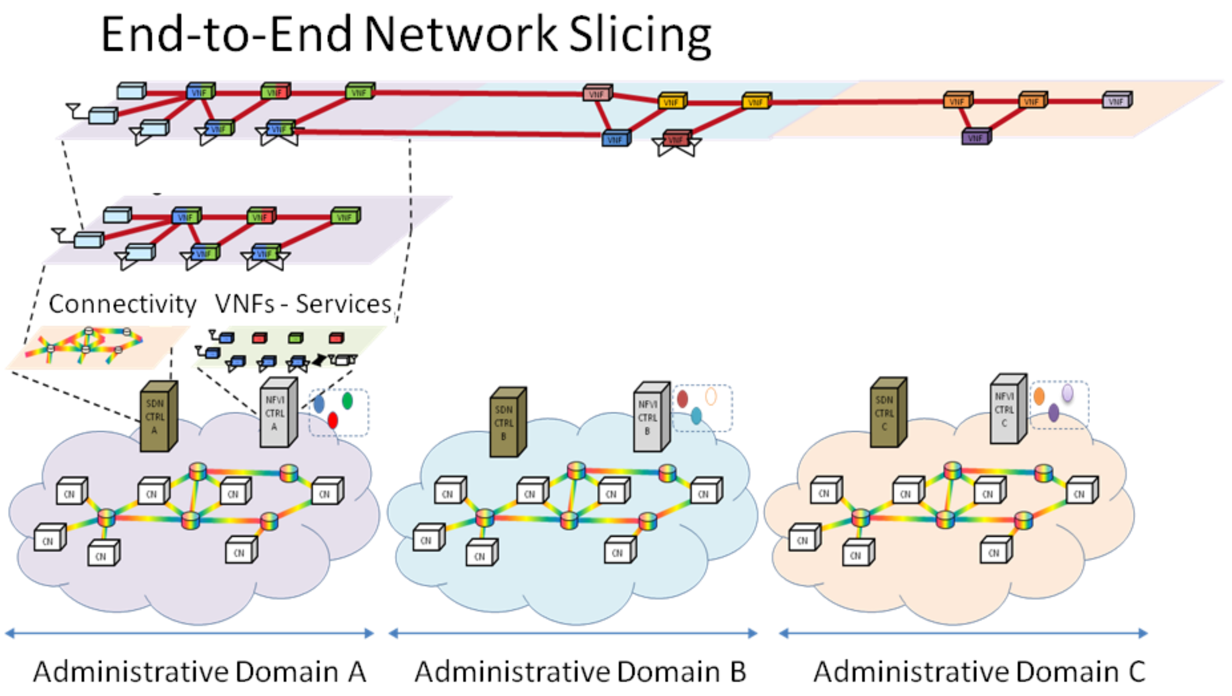




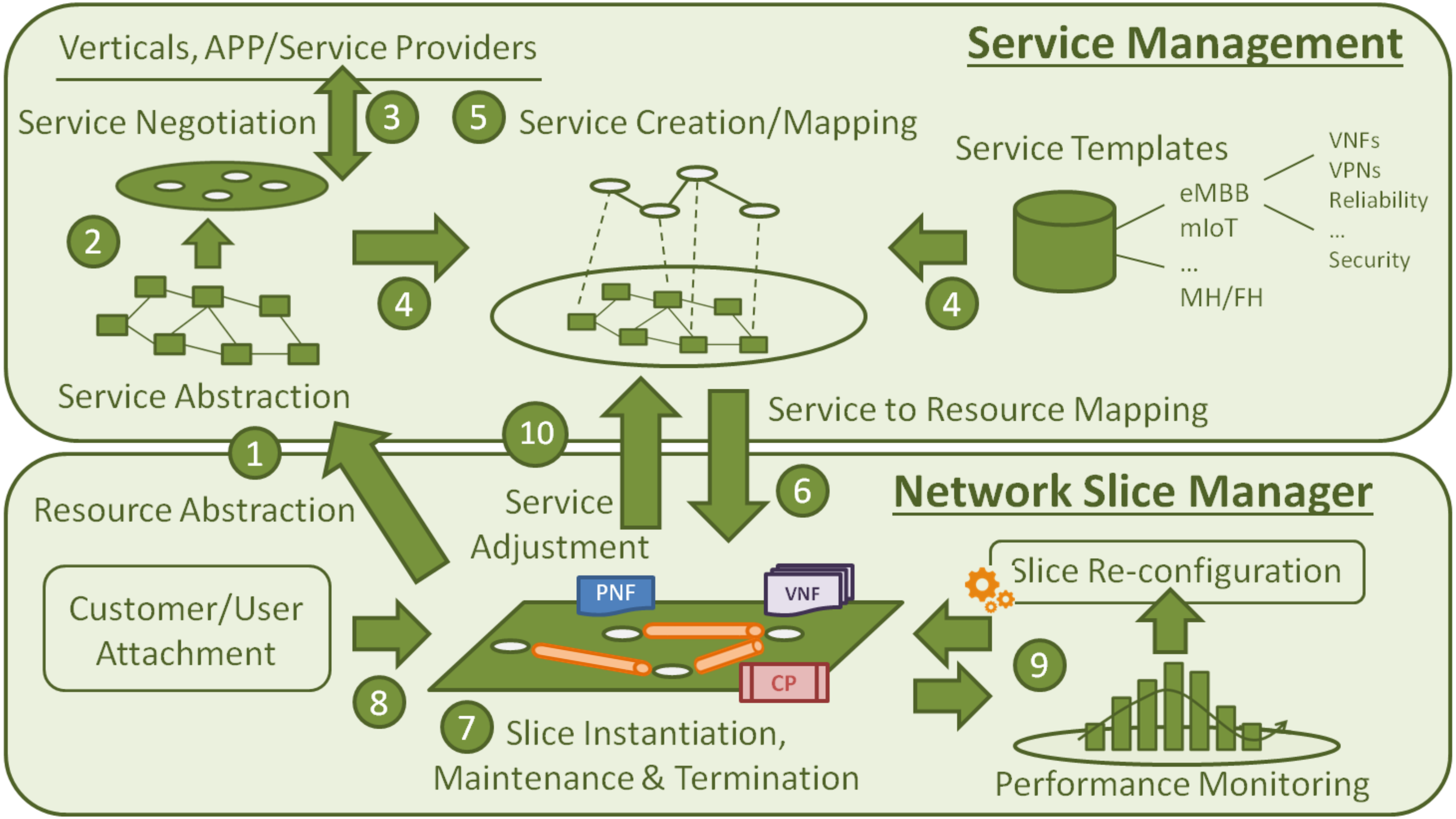



Network Slicing Priciples / Service Requirements

- Network Slicing is End-to-End
  - Across different administrative domains and technologies (incl. Fixed - FMC)
  - Hierarchical recursive business nature
- Slicing is on-demand service
  - Automation and programmability:
    - Time flexibility – when it starts, duration
    - A signaling based solution from 3rd party
  - Isolation: Control/Data plane – Shared resources
  - Customization/Softwarization: VNFs, policy, protocols/services, CP/DP separation etc.



Overview of Slicing Operations



Service Capability Exposure

Service Capability Exposure Options:

- ***No-control*** restricts slice tenants from interacting with allocated slice resources, only monitoring information about KPIs is provided
- ***Capabilities selection*** allows the slice tenant to select functions, control/data plane protocols, etc. from a catalogue offered by the infrastructure provider.
- ***Programmability*** allows slice tenants to create and operate a slice, using their own software functions and resource configuration parameters by:
  a) integrating a slice to own network and use own slice management
  b) instantiate a network slice management as a VNF for allocated slice

Overview of Data Plane solutions for Slicing

- Layer 2 Solution: FlexE (Flexible Resource Isolation – Interface):
  - Enables a flexible data rate allocation by decoupling the MAC from PHY layer
  - Channelization that can be used to partition an interface into several independent interfaces
- Layer 3 Solutions: DetNet and VNP+
  - DetNet (Real-time Critical Communications – Queuing Solution):
    - Concentrates on worst-case bounds instead of the conventional mean used by priority queuing
  - VPN+ based-on Segment Routing (Resource Selection/Separation Solution):
    - Can be used to select VNF (service chaining), queues inside routers, links within a bundle, etc.
- Overlay networks (Best-effort/Soft Reservation):
  - VPN/VLAN services without control on network resource allocation for performance isolation

Router Virtualization

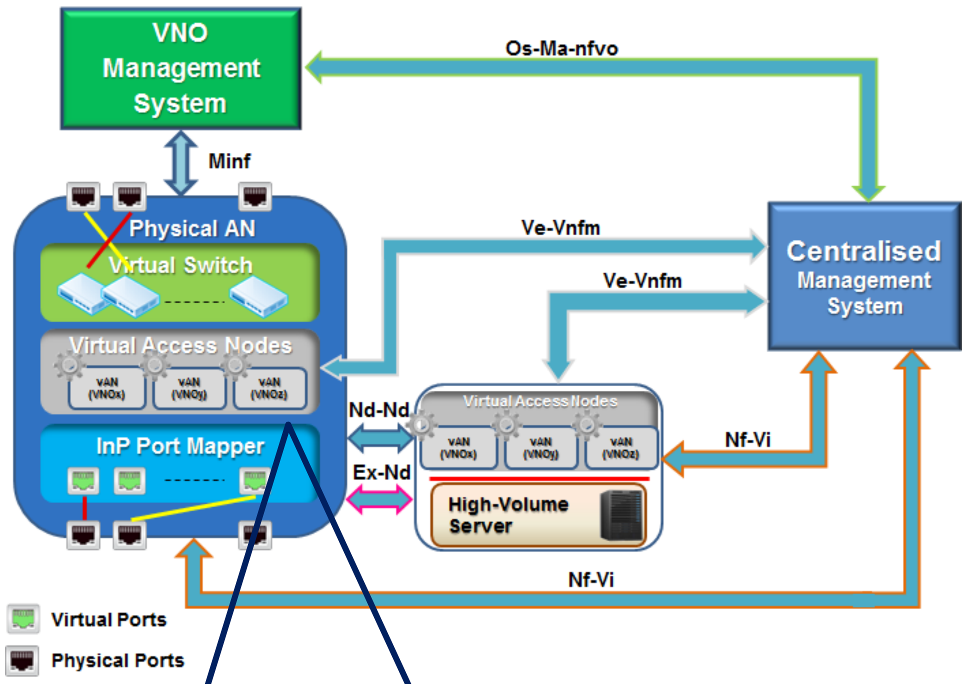
Two ways to virtualize resources of routers:

- Management System: policy-based
  - legacy approach in centralized manner
- Virtual Access Node: MANO-based
  - Physical equipment – introduce hypervisor to isolate resources
  - Date centre – introduce VM to host VNFs and hypervisor to manage resource allocation

Data/Control Plane multi-tenant ID enhancements:

- Tags/Labels/Encap. headers for indicating multi-tenants
- OAM related packets transferred over the appropriate slice
- Slice owners can select different protection degree

vAN in Physical Equipment & Data Centers



How virtualization is implemented is not clear, since the CPU in switching fabric is shared among slices

Conclusions

- On business value of network slicing
  - Providing programmability to slice tenant so that slice owner can operate it
  - Service isolation considering both data and control plane – Security/privacy and performance
  - Allow resource customization to accommodate SLA requirements
    - Customized VNFs, value added services and data/control plane protocols
    - Traffic steering considering physical condition of links and service requirements
    - Mapping from one technology into another, e.g. optical to IP
    - Combining cloud and network capacity resources
  - Slicing reflects a Service needs constant adjustments by orchestration
  - Dealing with shared/dedicated resources over a closed-loop service control

THANK YOU