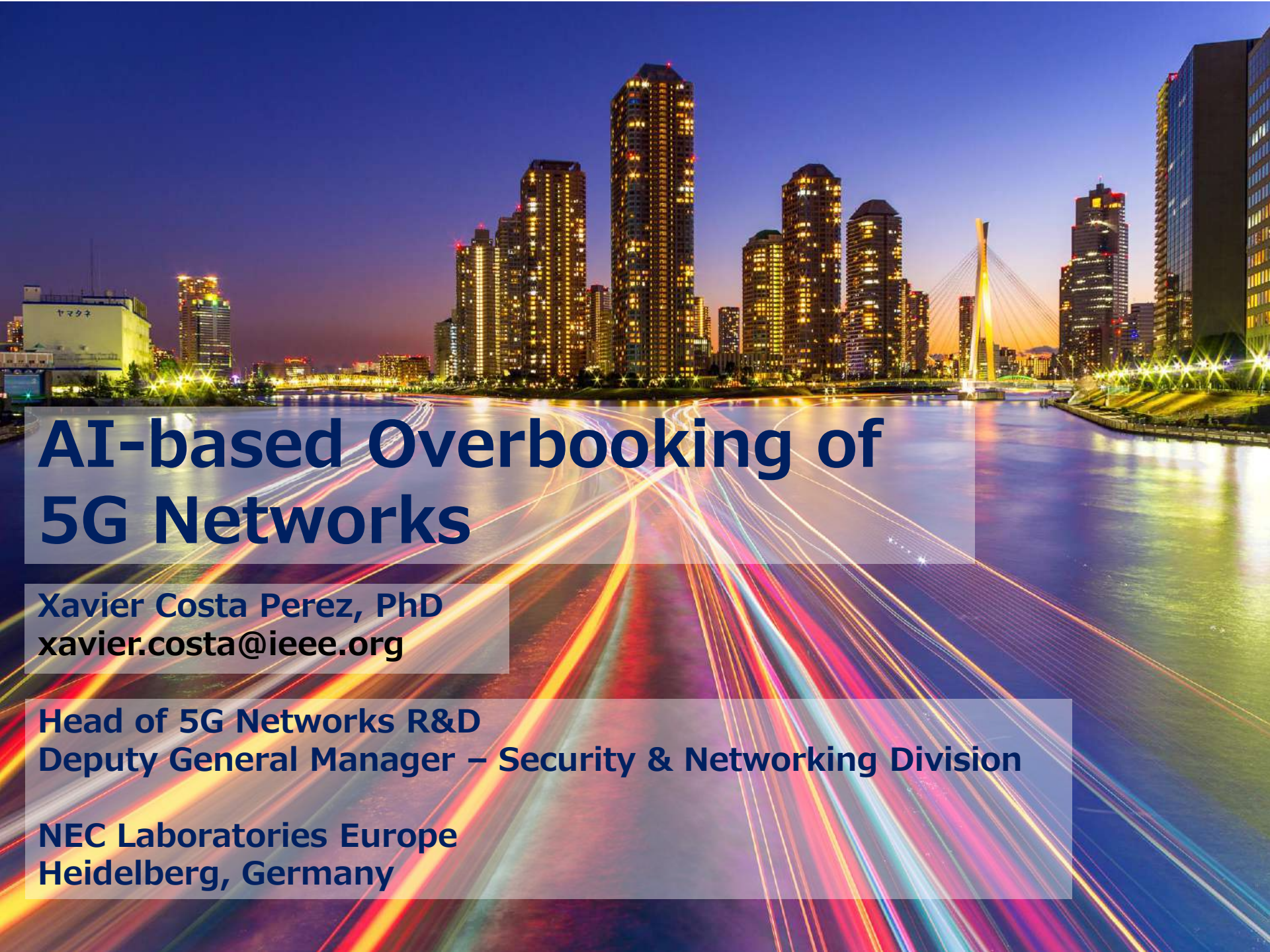

AI-based Overbooking of 5G Networks

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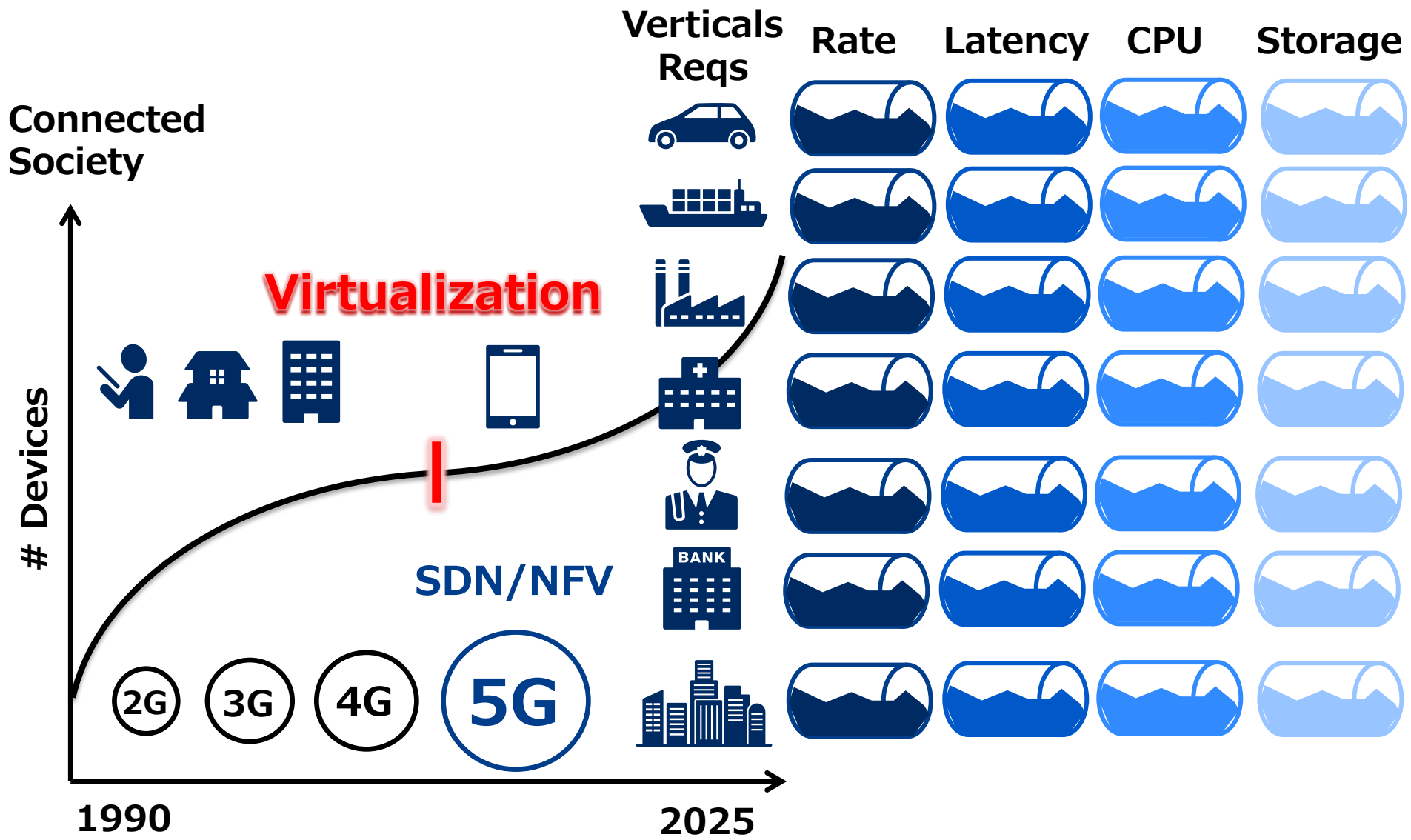
Heidelberg, Germany

Overbooking 5G Networks



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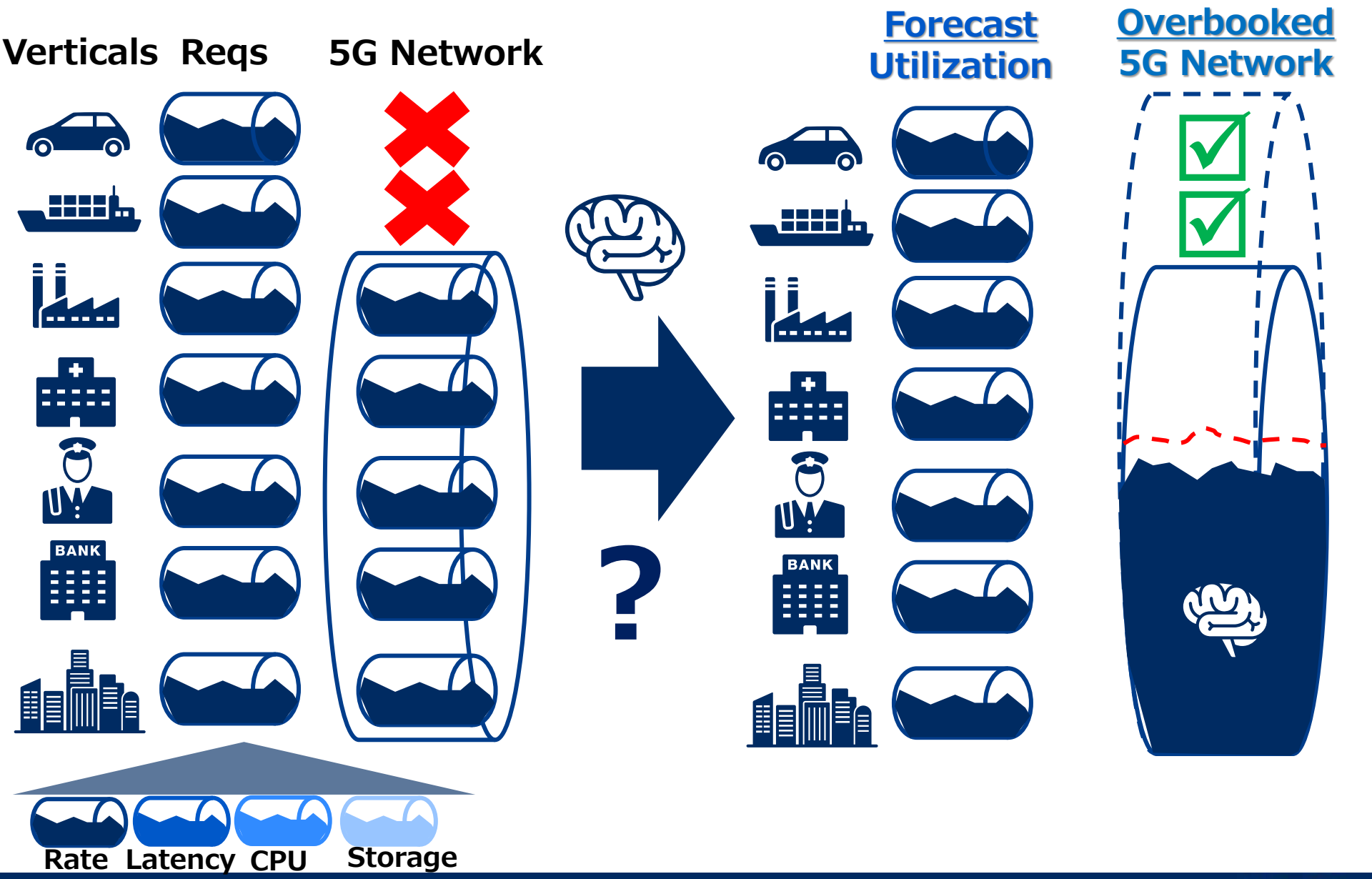
Overbooking 5G Networks



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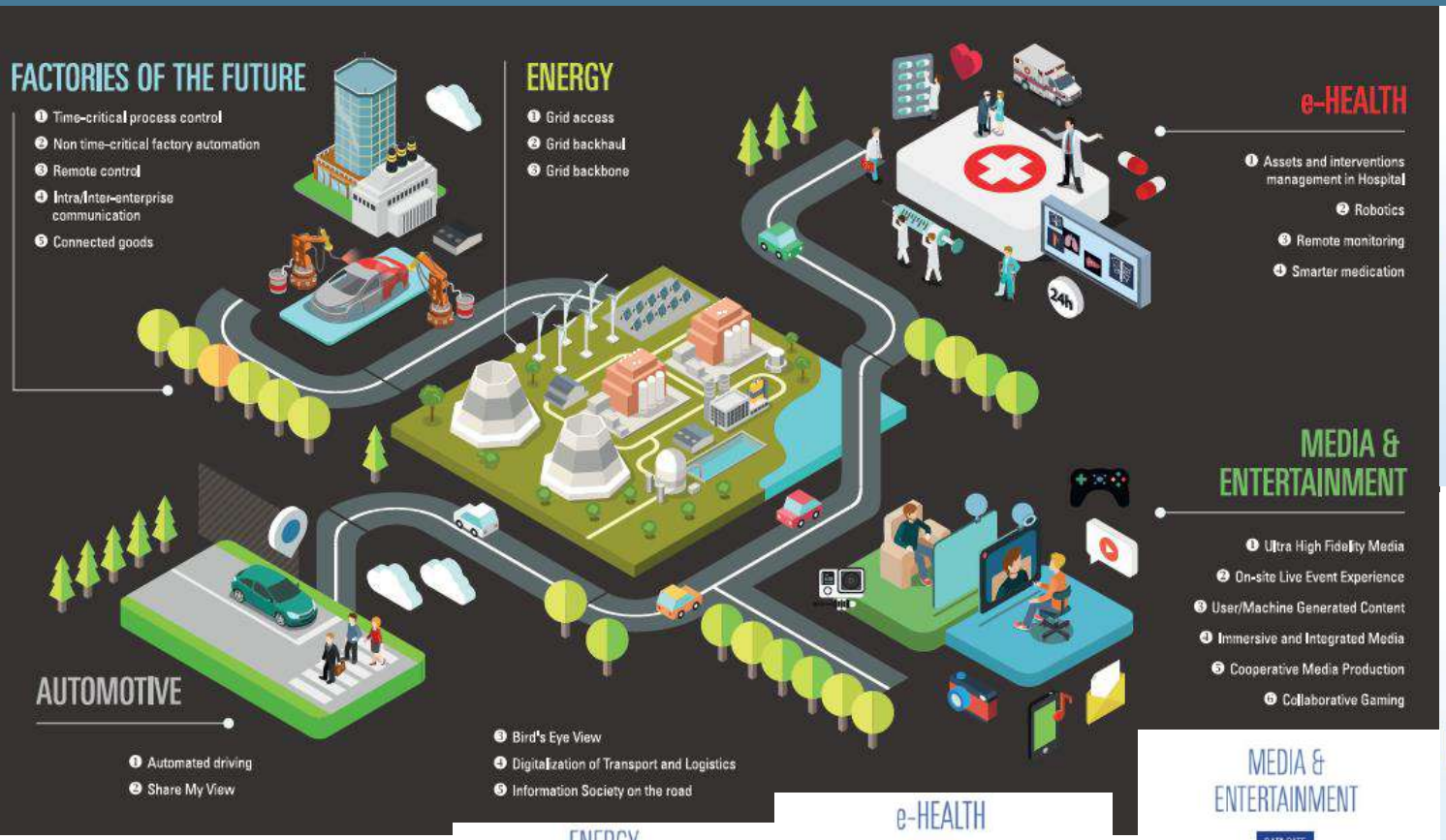
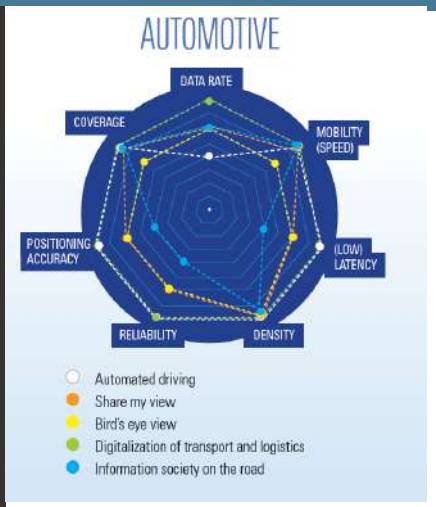
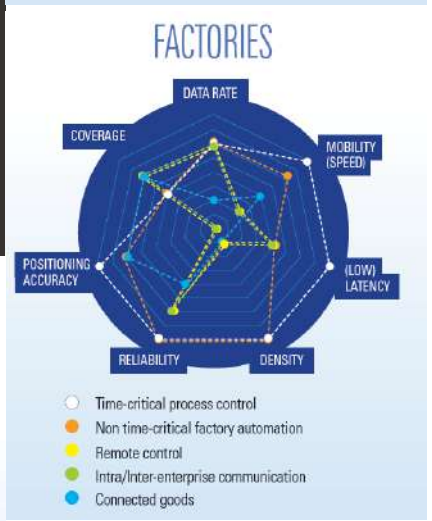
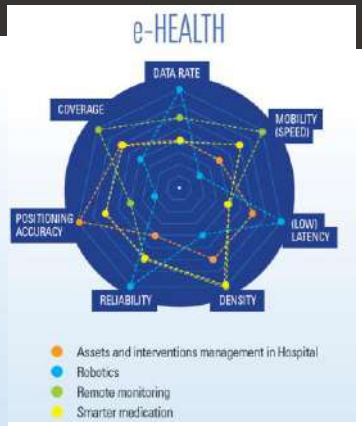
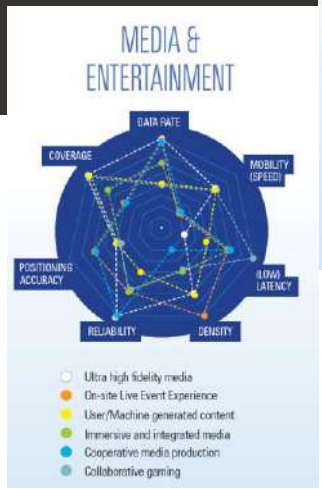
Overbooking 5G Networks – Industry Verticals Needs











Source: 5GPPP

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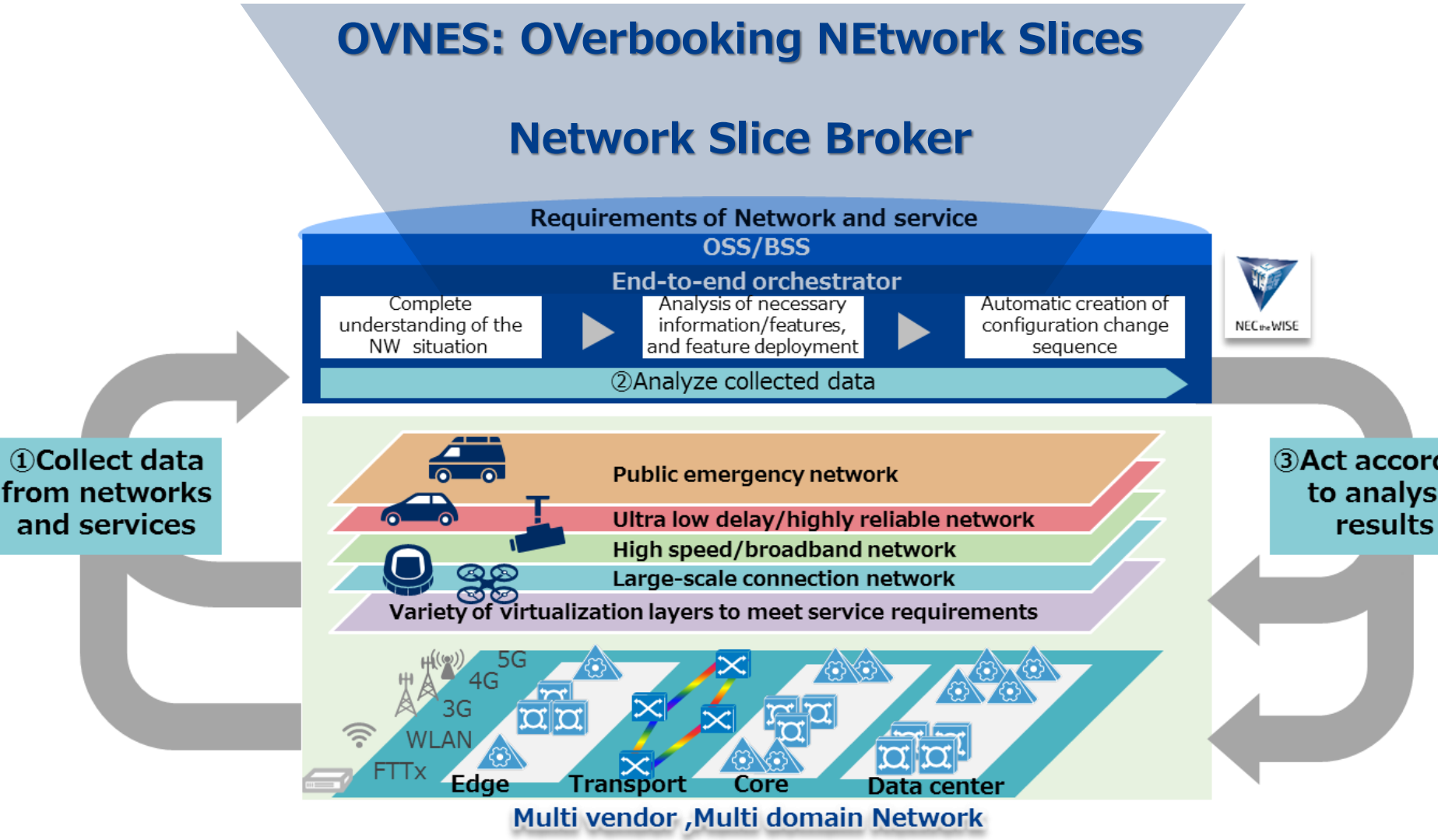
Overbooking 5G Networks – Network Slice Broker



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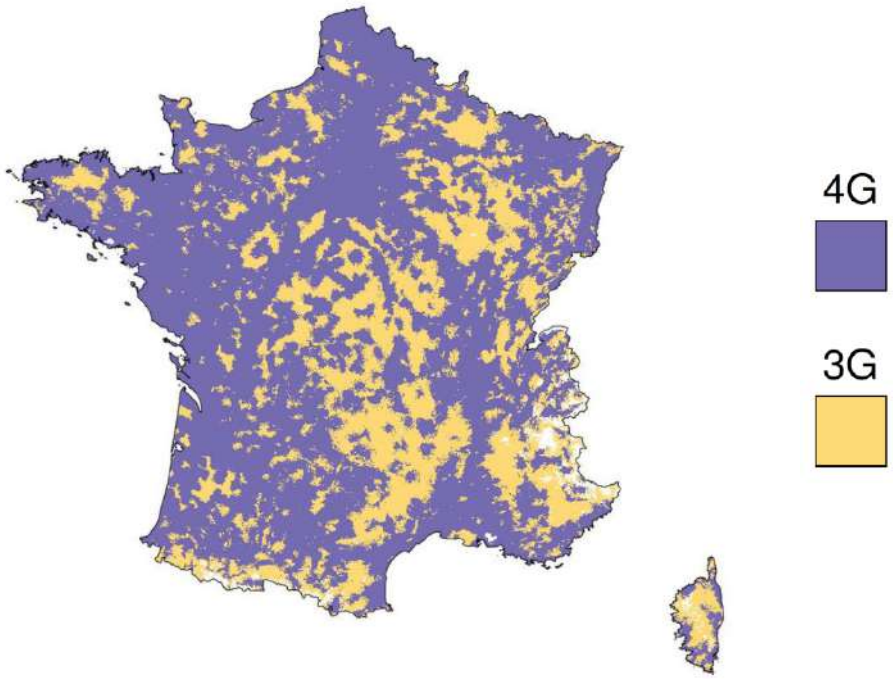
Is There Network Slicing Overbooking Potential?

Right-Sizing Network Slices – A Data-driven Study

Dataset collected at French Operator

User population ~**30 million individuals**
Distributed over > **550,000** km^2
Granularity **of 5 mins**

~25,000 base stations, distributed over > 36,000 *communes,* ~ 16 km^2 each



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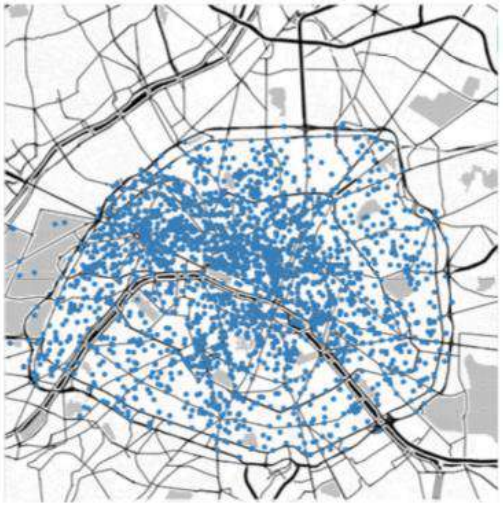
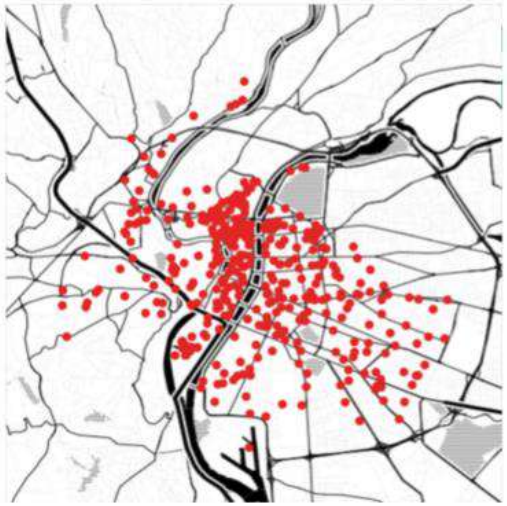
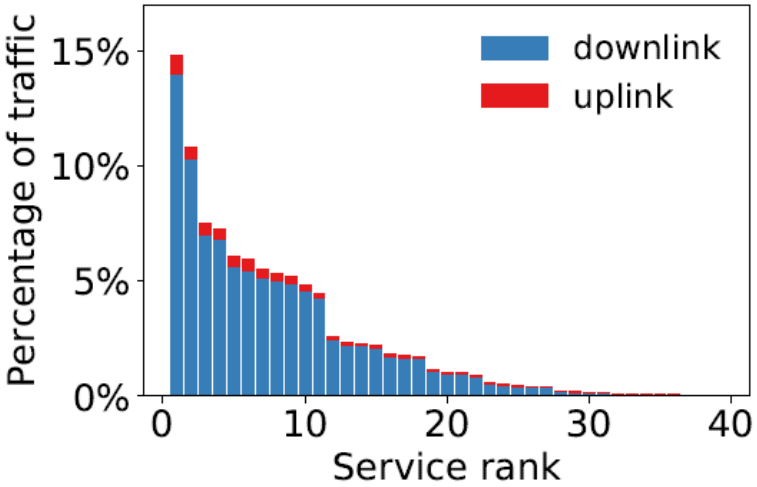
Right-Sizing Network Slices – A Data-driven Study

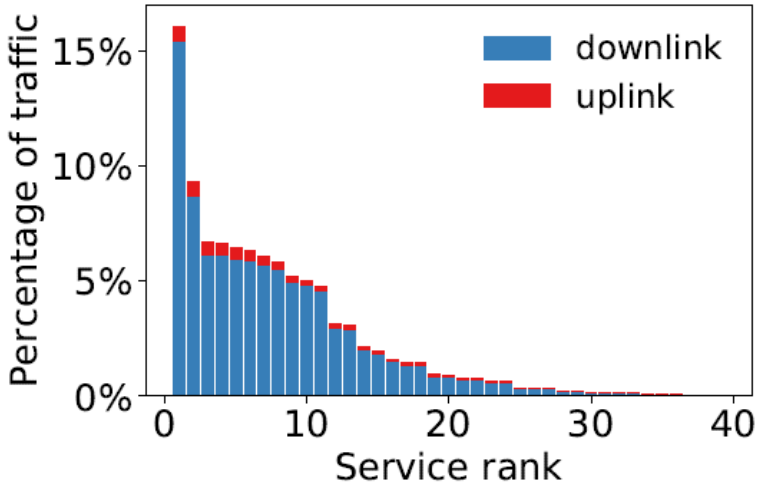


Large City



Medium-size City





Grouping of Traffic by 38 Service Types

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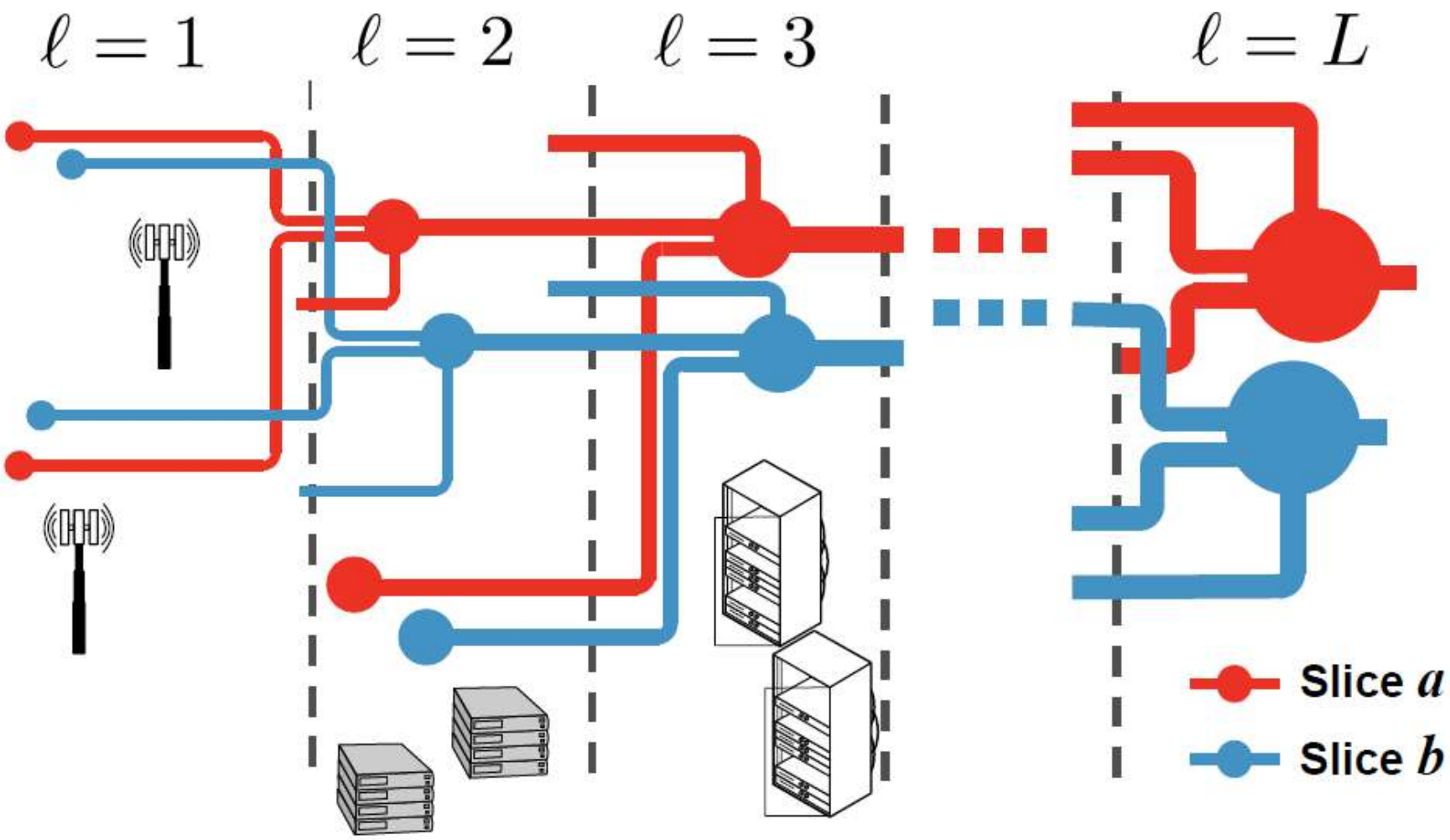
Right-Sizing Network Slices – Slicing Types



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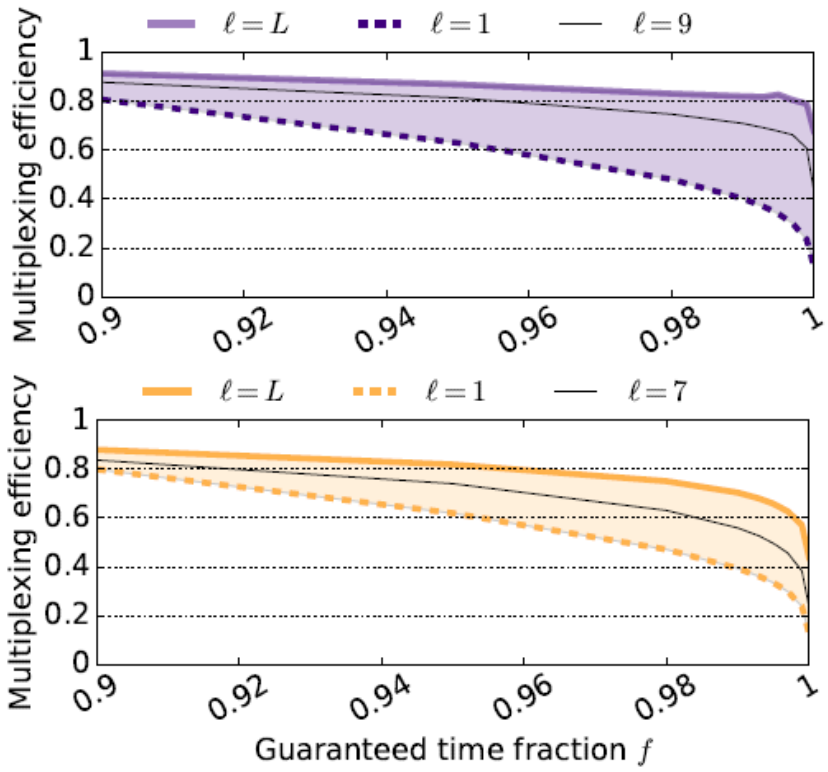
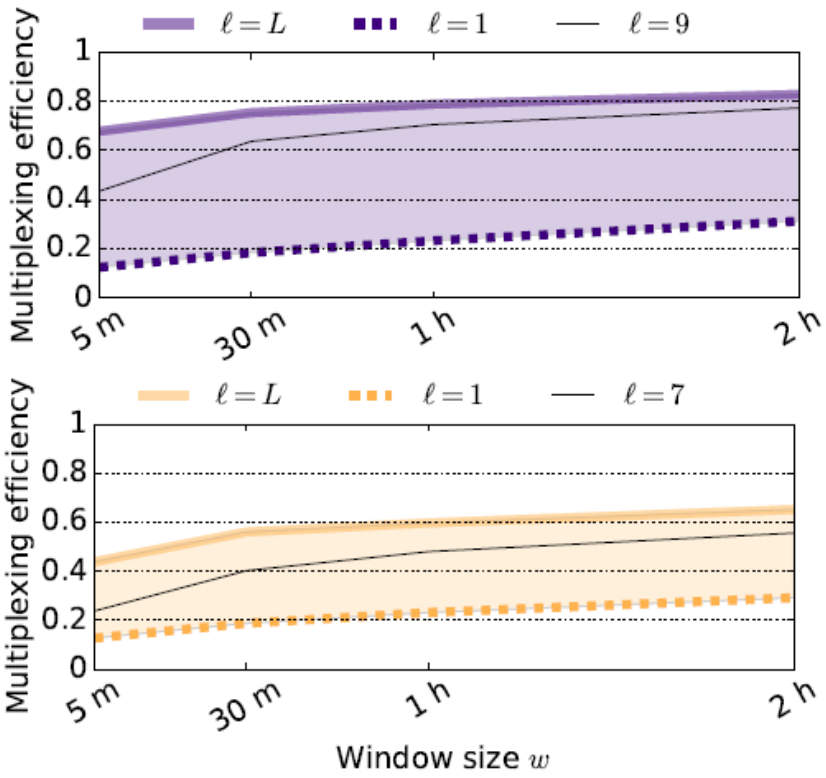
Right-Sizing Network Slices – Overbooking Potential

Large City





Medium-size City

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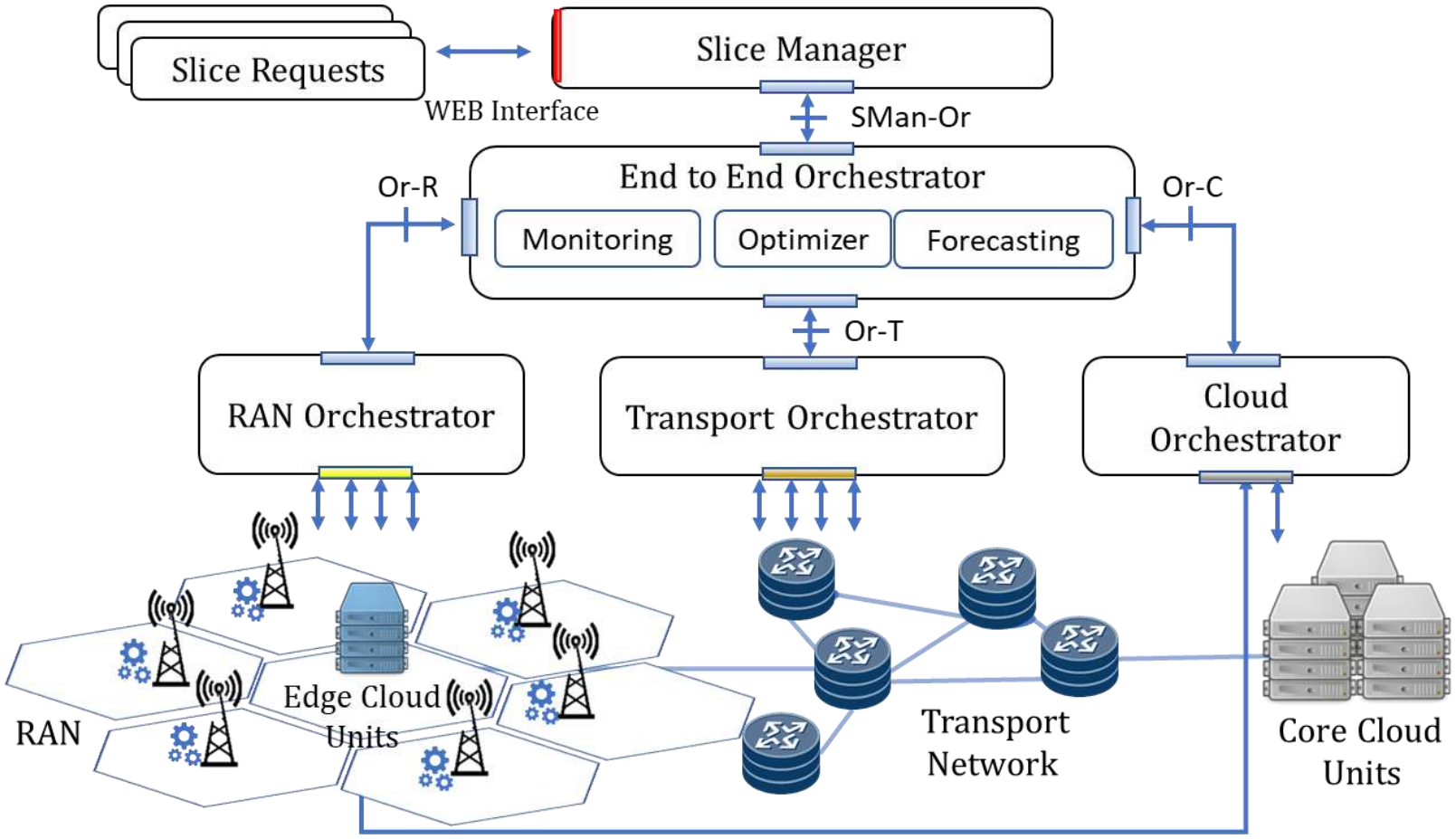
OVNES: OVerbooking NEtwork Slices (Network Slice Broker)

OVNES Architecture – Control Plane



Control plane

- Hierarchically designed for guaranteeing more scalability

- Orchestration at any layer of the stack
- Each DO provides abstraction
- Underlying controllers feed (abstracted) monitoring data to parent orchestrator

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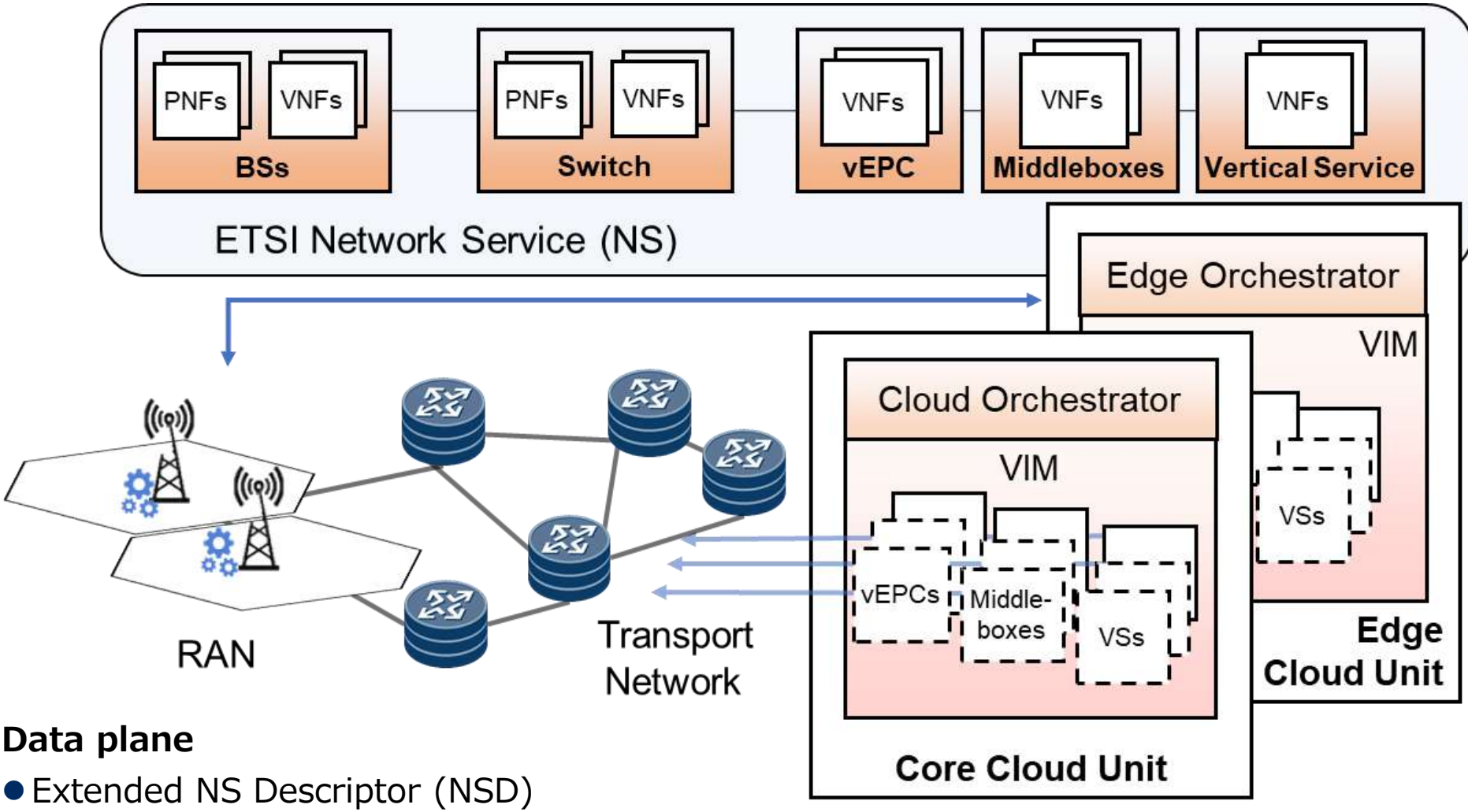
OVNES Architecture – Data Plane



Data plane

- Extended NS Descriptor (NSD)
- Objects of the descriptor could be abstracted depending on the orchestrator actions

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OVNES: Inside the End-to-end Orchestrator

Admission Control – Resource Reservation (AC-RR)

- Yield-management concept to maximize the overall revenues while limiting the risk of violating Service Level Agreements (SLAs)
- Joint problem: select slices that can be admitted (based on the available capacity and current revenues) as well as reserve resources on different domains
- *Bender Decomposition* approach to mathematically decouple the two problems
- Heuristics proposed to boil down the complexity while showing near-optimal results

Risk of resource deficit if we allocate Depends on forecast!!

Whether slice τ is accepted or not

$$\min_{\boldsymbol{x}\in\{0,1\}^{\mathcal{S}},\boldsymbol{z}\in\mathbb{R}_{+}^{\mathcal{S}}} \sum_{\tau\in\mathcal{T}} \sum_{\substack{p\in\mathcal{P}_{b,c} \\ \forall b\in\mathcal{B},c\in\mathcal{C}}} \overbrace{K_\tau f(z_{\tau,p})x_{\tau,p}}^{\text{Estimated penalty}} - \overbrace{R_\tau x_{\tau,p}}^{\text{Reward}}$$

$z_{\tau,p}$

Penalty associated to resource deficit

Reward associated to slice τ

s.t.

$$\text{capacity constraints} \quad (1)$$

$$\text{system constraints} \quad (2)$$

$$\text{coupled constraints} \quad (3)$$

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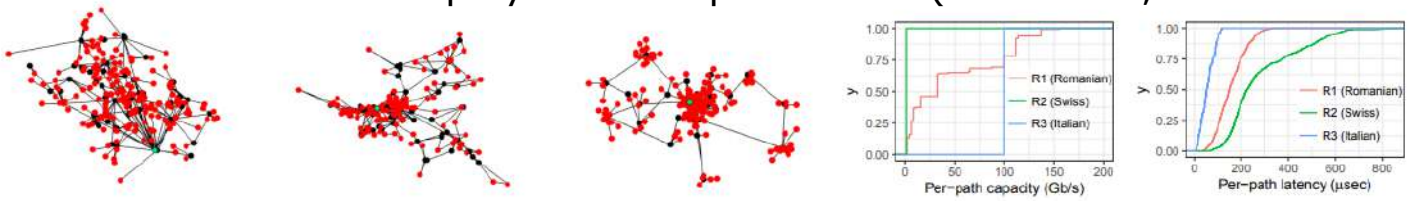
Overbooking Network Slices – Large-scale Simulations

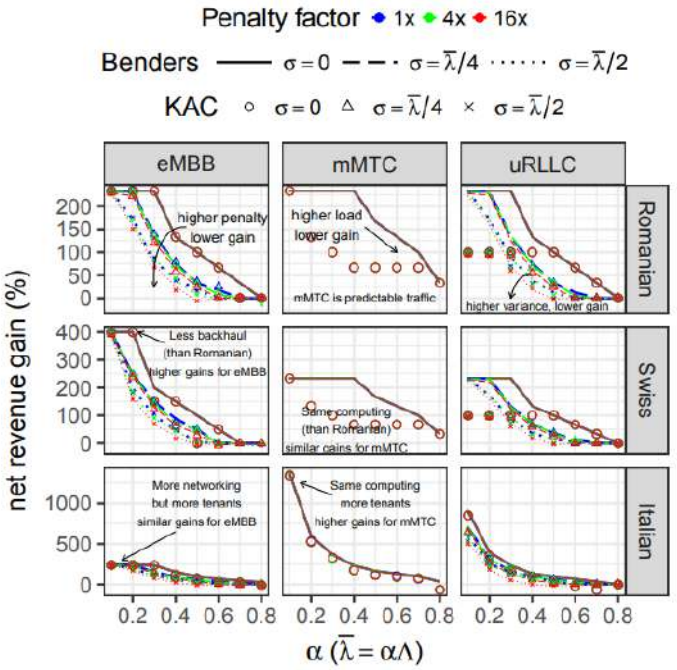
Overbooking brings significant gains

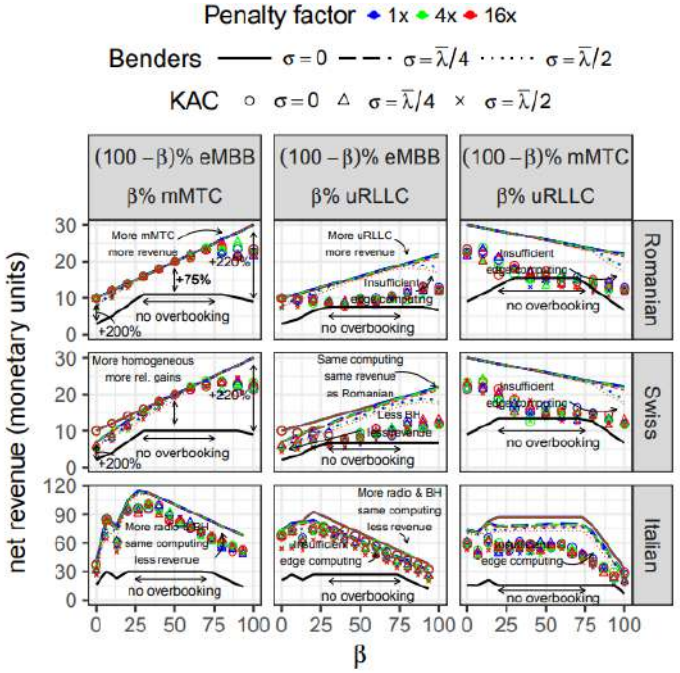
- Different realistic network deployments implemented (Romanian, Swiss and Italian)



(a) Romanian topology (N1). (b) Swiss topology (N2). (c) Italian topology (N3). (d) Path Capacity Distribution (e) Path Delay Distribution

- Our heuristic (*KAC*) exhibits near-optimal results (*Benders)*
- Mixed setups provide insights on how different slice types can be properly combined





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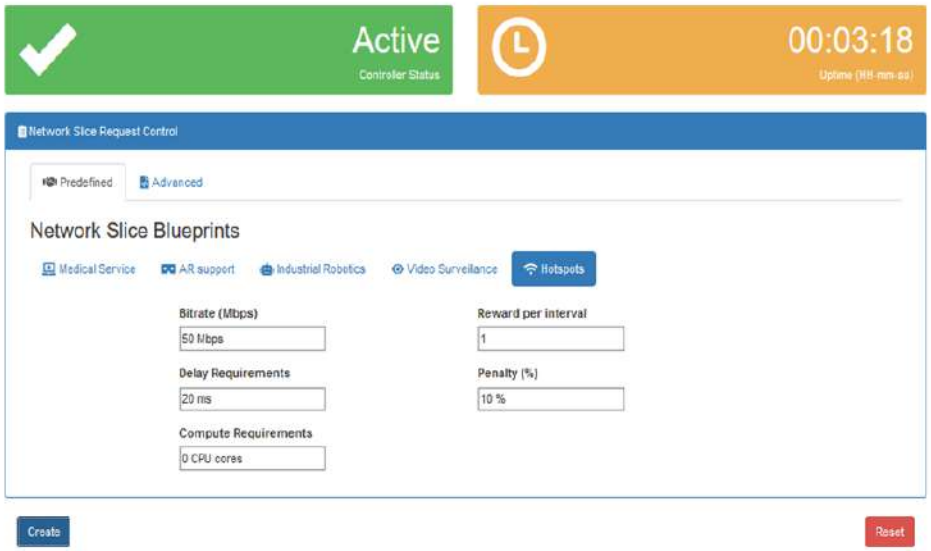
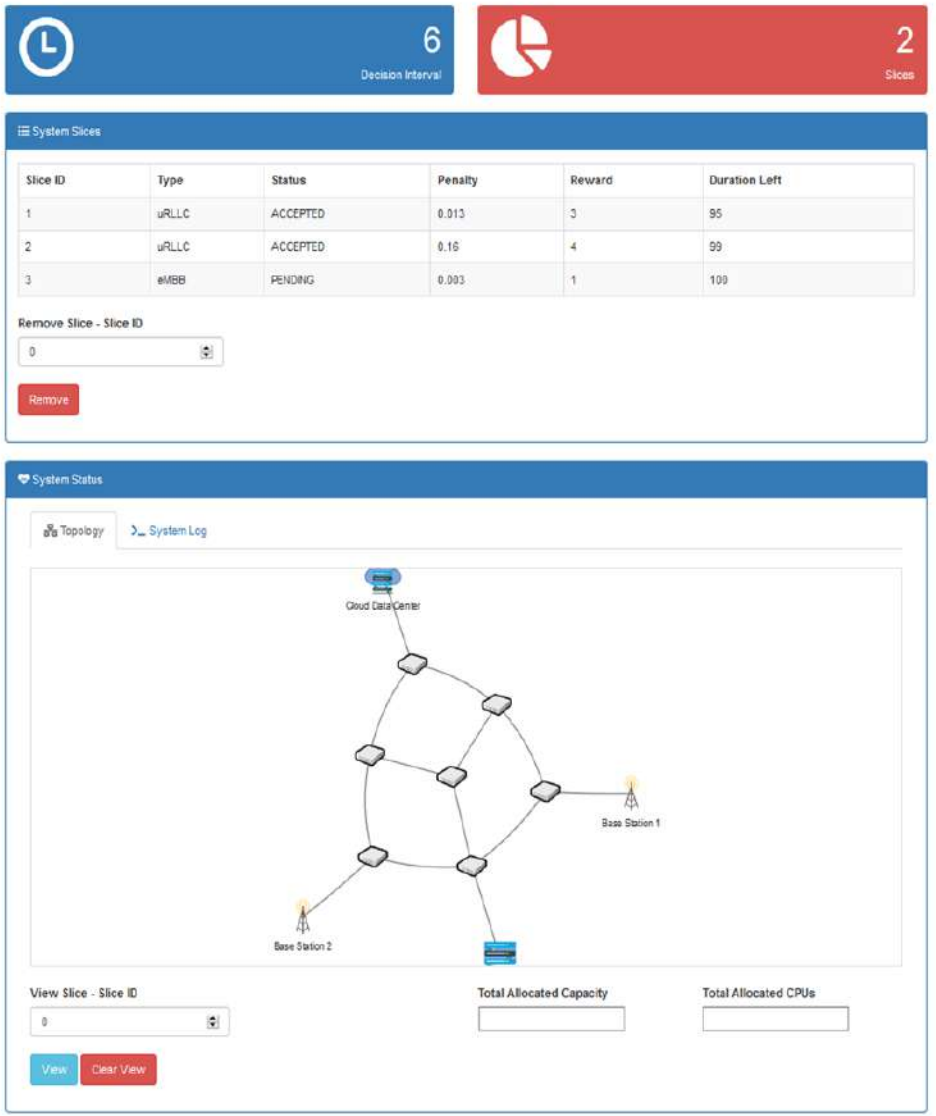
Single 5G Mobile Platform for *Multiple* Verticals
OVNES Network Slice Broker

AI-based Overbooking of Network Slices





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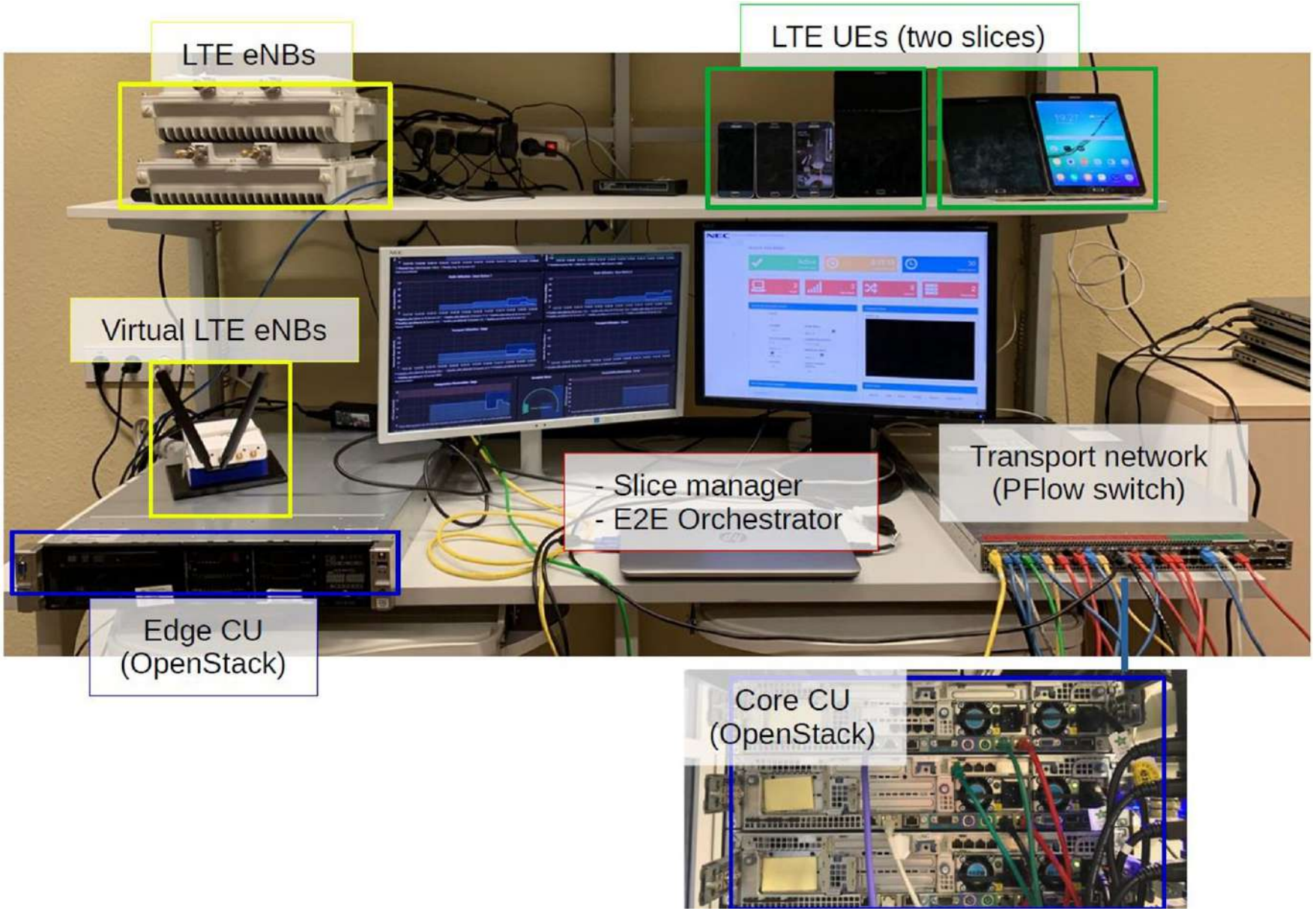
Single 5G Mobile Platform for *Multiple* Verticals

OVNES Network Slice Broker



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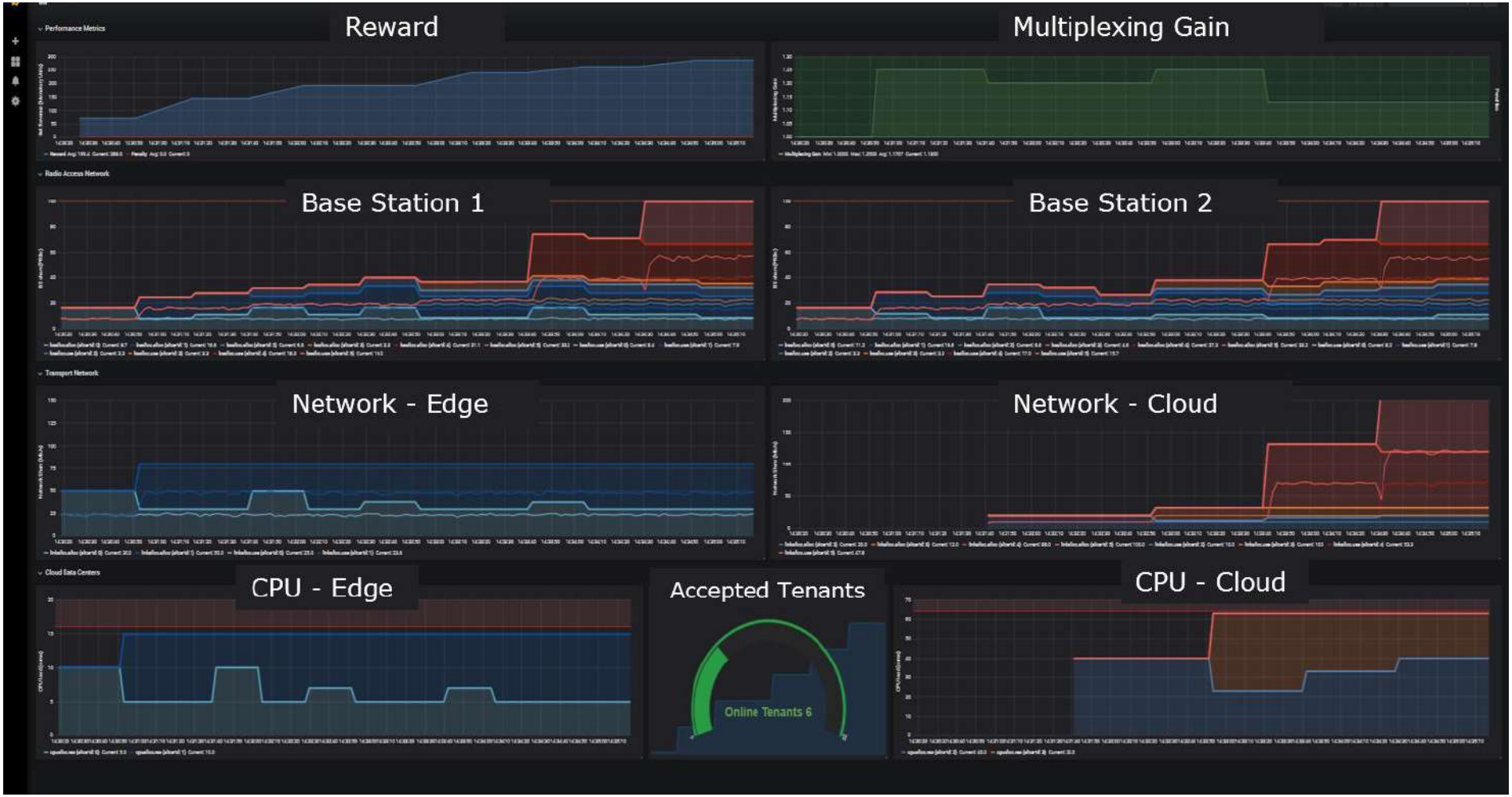
Single 5G Mobile Platform for *Multiple* Verticals

OVNES Network Slice Broker



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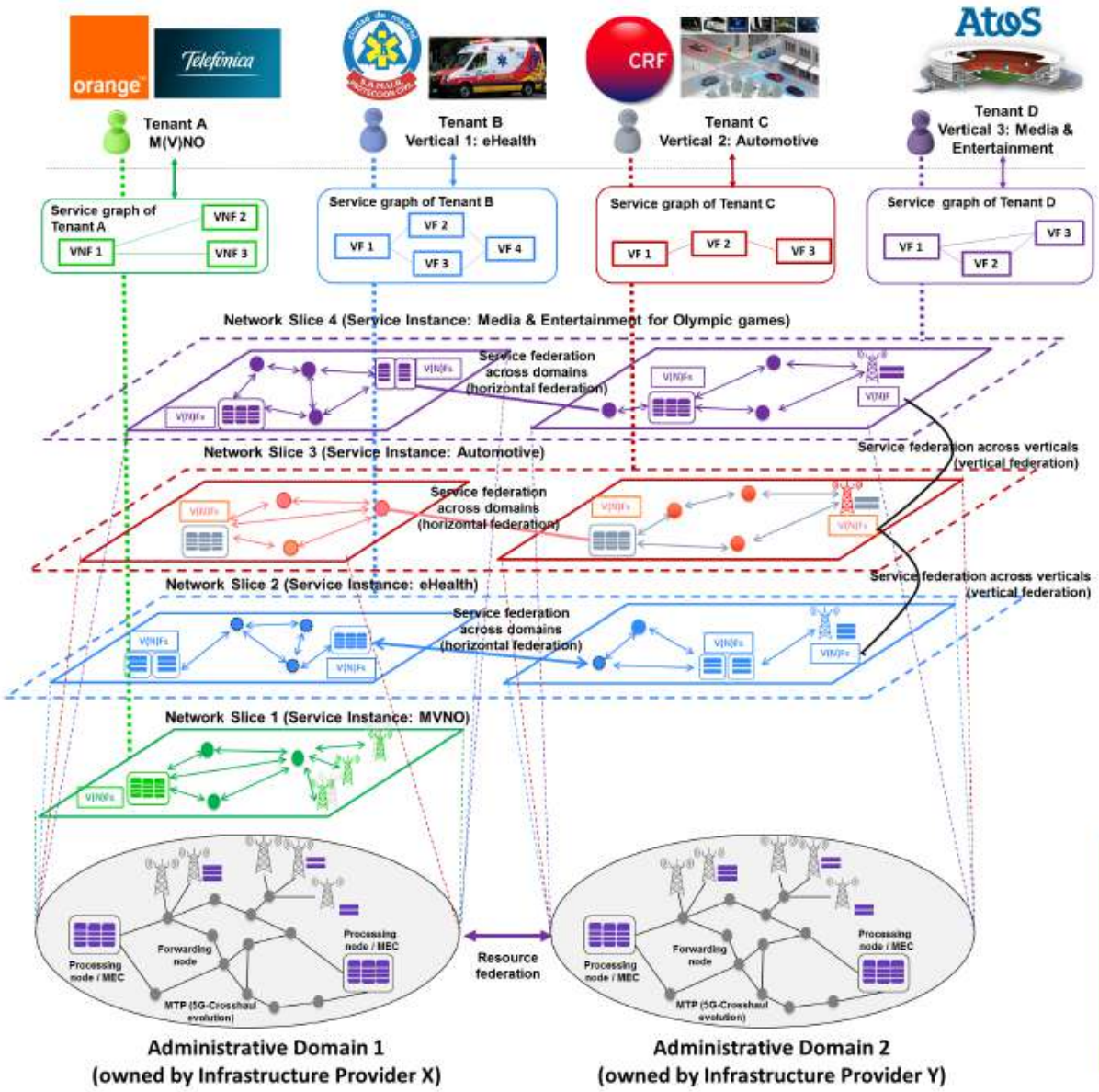
What's Next?



5G-Transformer users
Mobile (Virtual) Network Operators
Vertical Industries

Vertical Slicer (VS)
Logical entry point for verticals to support the creation and management of their transport slices in a short time-scale

Service Orchestrator (SO)
Federation of transport networking and computing resources from multiple domains and allocation to slices

Mobile Transport and Computing Platform for Verticals (MTP)
Underlying unified transport stratum for integrated fronthaul and backhaul networks

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5G-CARMEN
5G for Cooperative, Connected and Automated Cars

Objectives

- Improve mobility for people and goods; Validate CCAM use cases (business, technical)
- Leverage 5G technology enablers, incl. 5GNR, MEC, C-V2X, E2E network slicing, accurate positioning and timing, predictive QoS
- Federation & Multi-Tenancy – openness to MVNO, OTT providers, service providers

Pilot

- **Covers >600km**
- **Across 3 countries**
- **~80k vehicles per day (Italy, Austria, Germany)**

Consortium

- 11 partners from Industry
  - **BMW, Chrysler Fiat**
  - **Autostrada**
  - **Deutsche Telekom, T-Mobile, Telecom Italia**
  - **NEC, Nokia, Qualcomm, …**

Funding

- **~20 Million**

https://create-net.fbk.eu/en/news/detail/5g-carmen/
https://magazine.fbk.eu/en/news/5g-carmen-a-digital-corridor-for-the-mobility-of-the-future/

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Further Details – Related Work

- *"vrAIn: A Deep Learning Approach Tailoring Computing and Radio Resources in Virtualized RANs"*, **ACM MOBICOM 2019**
- *"A Utility-Driven Multi-Queue Admission Control Solution for Network Slicing."*, **IEEE INFOCOM 2019**
- *"DeepCog: Cognitive Network Management in Sliced 5G Networks with Deep Learning"*, **IEEE INFOCOM 2019**
- *"STORNS: Stochastic Radio Access Network Slicing",* **IEEE ICC 2019 - Best Paper ward**
- *"RL-NSB: Reinforcement Learning-based 5G Network Slice Broker",* **IEEE Transactions on Networking 2019**
- *"A Machine Learning approach to 5G Infrastructure Market optimization"*, **IEEE Transactions on Mobile Computing 2019**
- "Network slicing games: Enabling customization in multi-tenant mobile networks", **IEEE Transactions on Networking 2019**
- *"Resource Sharing Efficiency in Network Slicing"*, **IEEE Transactions on Network and Service Management (TNSM), 2019**
- *"How should I slice my network? A multi-service empirical evaluation of resource sharing efficiency"*, **ACM MOBICOM 2018**
- "*Overbooking Network Slices through Yield-driven End-to-End Orchestration*," **ACM CONEXT 2018**
- *"Network Slicing for Guaranteed Rate Services: Admission Control and Resource Allocation Games"* , **IEEE Trans Wir Com 2018**
- *"Joint Optimization of Edge Computing Architectures and Radio Access Networks.",* **IEEE Journal on Selected Areas Com 2018**
- *"WizHaul: On the Centralization Degree of Cloud RAN Next Generation Fronthaul".* **IEEE Transactions on Mobile Comp 2018**
- "CARES: Computation-Aware Scheduling in Virtualized Radio Access Networks". **IEEE Transactions on Wireless Comms 2018**
- "z-TORCH: An Automated NFV Orchestration and Monitoring Solution", **IEEE Transactions on Network and Serv Mng 2018**
- "*Mobile Traffic Forecasting for Maximizing 5G Network resource Utilization*", **IEEE INFOCOM 2017**
- "*Optimising 5G infrastructure markets: The Business of Network Slicing*", **IEEE INFOCOM 2017**
- *"Network slicing games: Enabling customization in multi-tenant networks",* **IEEE INFOCOM 2017**
- *"Multi-Tenant Radio Access Network Slicing: Statistical Multiplexing of Spatial Loads"*, **IEEE Transactions on Networking 2017**
- *"A capacity broker architecture and framework for multi-tenant support in LTE-A networks"*, **IEEE ICC 2016**
- "*From Network Sharing to Multi-tenancy: The 5G Network Slice Broker*", **IEEE Communications Magazine, 2016**
- *"RMSC: A Cell Slicing Controller for Virtualized Multi-Tenant Mobile Networks"*, **IEEE VTC Spring 2015**
- *"Radio access network virtualization for future mobile carrier networks"*, **IEEE Communications Magazine 2013**

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Thank you for your attention

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No 761536. Responsibility for the information and views set out in this document lies entirely with the authors