AI-based Overbooking of 5G Networks

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Overbooking 5G Networks

Connected Society

# Devices

1990 2025

2G 3G 4G 5G

Virtualization

SDN/NFV

Verticals

Rate

Latency

CPU

Storage

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Orchestrating a brighter world
Overbooking 5G Networks

Verticals | Reqs | 5G Network | Forecast Utilization | Overbooked 5G Network
---|---|---|---|---
Car | Ship | Factory | Hospital | Bank

Rate | Latency | CPU | Storage

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Overbooking 5G Networks – Industry Verticals Needs

FACTORIES OF THE FUTURE
- Time-critical process control
- Non-time-critical factory automation
- Remote control
- Inter/Intra-enterprise communication
- Connected goods

ENERGY
- Grid access
- Grid backbone
- Grid backbone

AUTOMOTIVE
- Automated driving
- Share my view
- Bird's eye view
- Digitalization of Transport and Logistics
- Information society on the road

MEDIA & ENTERTAINMENT
- Ultra High Fidelity media
- On-Demand Live Event Experience
- User/Machine Generated Content
- Innovative and Integrated Media
- Collaborative Media Production
- Collaborative Gaming

e-HEALTH
- Assets and interventions management in hospital
- Robotics
- Remote monitoring
- Smarter medication

FACTORIES
- Time-critical process control
- Non-time-critical factory automation
- Remote control
- Inter/Intra-enterprise communication
- Connected goods

Source: 5GPPP
Overbooking 5G Networks – Network Slice Broker

OVNES: OVerbooking NEtwork Slices

Network Slice Broker

Requirements of Network and service
OSS/BSS

End-to-end orchestrator

1. Collect data from networks and services
2. Analyze collected data
3. Act according to analysis results

Public emergency network
Ultra low delay/highly reliable network
High speed/broadband network
Large-scale connection network

Variety of virtualization layers to meet service requirements

Multi vendor, Multi domain Network
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
Right-Sizing Network Slices – A Data-driven Study

Grouping of Traffic by 38 Service Types
Right-Sizing Network Slices – Slicing Types

\[ \ell = 1 \quad \ell = 2 \quad \ell = 3 \quad \ell = L \]

Slice \( a \)
Slice \( b \)
Right-Sizing Network Slices – Overbooking Potential

Large City

Medium-size City

Guaranteed time fraction $f$

Window size $w$
OVNES: OVerbooking NEetwork Slices (Network Slice Broker)
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
OVNES Architecture – Data Plane

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

\[
\min_{x \in \{0,1\}^S, z \in \mathbb{R}_+^S} \sum_{\tau \in \mathcal{T}} \sum_{p \in \mathcal{P}_{b,c}} \sum_{\forall b \in \mathcal{B}, c \in \mathcal{C}} K_{\tau} f(z_{\tau,p}) x_{\tau,p} - R_{\tau} x_{\tau,p}
\]

s.t.
- capacity constraints
- system constraints
- coupled constraints

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

Estimated penalty

Whether slice \( \tau \) is accepted or not

Reward associated to slice \( \tau \)

Penalty associated to resource deficit

(1)
(2)
(3)
Overbooking brings significant gains

- Different realistic network deployments implemented (Romanian, Swiss and Italian)
- Our heuristic (KAC) exhibits near-optimal results (Benders)
- Mixed setups provide insights on how different slice types can be properly combined
Single 5G Mobile Platform for Multiple Verticals
OVNES Network Slice Broker

AI-based Overbooking of Network Slices

<table>
<thead>
<tr>
<th>Network Slice Request Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predefined</td>
</tr>
<tr>
<td>Advanced</td>
</tr>
</tbody>
</table>

Network Slice Blueprints

- Medical Service
- AR/VR support
- Industrial Robotics
- Video Surveillance

<table>
<thead>
<tr>
<th>Slice ID</th>
<th>Type</th>
<th>Status</th>
<th>Penalty (%)</th>
<th>Reward</th>
<th>Duration Left</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>uRLLC</td>
<td>ACCEPTED</td>
<td>0.313</td>
<td>3</td>
<td>95</td>
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<tr>
<td>2</td>
<td>uRLLC</td>
<td>ACCEPTED</td>
<td>0.15</td>
<td>4</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>mIoT</td>
<td>RESERVING</td>
<td>0.303</td>
<td>1</td>
<td>100</td>
</tr>
</tbody>
</table>

Remove Slice - Slice ID

- 0

System Status

- Topology
- System Log

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MOBILE WORLD CONGRESS

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

- Slice manager
- E2E Orchestrator

LTE eNBs
Virtual LTE eNBs
LTE UEs (two slices)
Transport network (PFlow switch)

Edge CU (OpenStack)
Core CU (OpenStack)
Single 5G Mobile Platform for Multiple Verticals
OVNES Network Slice Broker

![Graphs and charts showing performance metrics for different components of a 5G network platform.]
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
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

Further Details – Related Work

- “A Utility-Driven Multi-Queue Admission Control Solution for Network Slicing.”, IEEE INFOCOM 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
- “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
- “Radio access network virtualization for future mobile carrier networks”, IEEE Communications Magazine 2013
Thank you for your attention

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