Overbooking 5G Networks

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Overbooking 5G Networks

Connected Society

- Virtualization
- SDN/NFV

Verticals Reqs
- Rate
- Latency
- CPU
- Storage

# Devices

1990 → 2025

2G 3G 4G 5G
Overbooking 5G Networks

VerticaIs  Reqs  5G Network

Forecast  Utilization

Overbooked  5G Network

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Overbooking 5G Networks – Industry Verticals Needs

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

Complete understanding of the NW situation

Analysis of necessary information/features, and feature deployment

Automatic creation of configuration change sequence

② Analyze collected data

① Collect data from networks and services

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?
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

Large City

Medium-size City

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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 – Multiplexing Potential

Large City

Medium-size City
OVNES: OVerbooking NEtwork Slices
**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
**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

Monitoring

- Decision epochs are divided into multiple monitoring samples
- sFlow to collect transport samples
- OpenStack Ceilometer/Gnocchi to collect computing/storage monitoring data
- A proprietary protocol to gather signal quality samples
- InfluxDB to store time-series data and a MySQL database to save additional control plane information, e.g., current state of each slice

Forecasting

- Machine-learning algorithms to learn and predict the future traffic behaviors
- Three-smoothing function, such as Holt-Winters to improve the accuracy
- Feedback loop to automatically adjust the prediction intervals (trade-off between aggressive/conservative vs potentially more revenues/less revenues)
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

\[
\begin{align*}
\min_{x \in \{0,1\}^S, z \in \mathbb{R}_+^S} & \quad \sum_{\tau \in T} \sum_{p \in \mathcal{P}_b, c} \sum_{\forall b \in \mathcal{B}, c \in \mathcal{C}} K_{\tau} f(z_{\tau,p}) x_{\tau,p} - R_{\tau} x_{\tau,p} \\
\text{s.t.} & \quad \text{capacity constraints} \\
& \quad \text{system constraints} \\
& \quad \text{coupled constraints}
\end{align*}
\]

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

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

Penalty associated to resource deficit

Reward associated to slice \( \tau \)

(1)

(2)

(3)
Overbooking Network Slices – Large-scale Simulations

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
OVNES: Proof-of-concept
OVNES: Proof-of-concept

Monitoring Dashboard

- User-friendly interface to continuously monitor
  - Allocated resources per domain and slice
  - Number of accepted tenants
Overbooking Network Slices – PoC Results

RAN

Transport

Edge/Core

No overbooking

Our approach

No overbooking

Our approach

No overbooking

Our approach

No overbooking

Our approach

Resource reservation

Resource capacity

Tenant load

Resource reservation

Resource capacity

Resource reservation

Resource capacity

CPU load (cores)

Time of day

Time of day

Time of day

Time of day

BS 0

BS 1

Network share (Mb/s)

Link 0

Link 1

uRLLC1

mMTC1

eMBB1

eMBB3

uRLLC2

mMTC2

eMBB2

eMBB3

uRLLC1

mMTC1

eMBB1

eMBB3

uRLLC2

mMTC2

eMBB2

eMBB3

uRLLC1

mMTC1

eMBB1

eMBB3

uRLLC2

mMTC2

eMBB2

eMBB3
OVNES Benefits from Forecasting

- Net revenue per BS of our approach (with Forecasting) significantly outperforms the legacy (trivial) solution
- (Consistent) gains may vary depending on the day-time load
5G Transformer Project

5G Mobile Transport Platform for Verticals

- Vertical MANOs
- (Federated) Network Slicing

Verticals

- Automotive: Chrysler Fiat
- E-Health: SAMUR (Emergency)
- Media: ATOS (Olympics)

Operators

- Telefonica
- Orange

Vendors

- NEC
- Ericsson
- Nokia
Acknowledgements – Further Details

Related Publications

- J. Salvat et al. “Overbooking Network Slices through Yield-driven End-to-End Orchestration,” ACM CONEXT 2018
- C. Marquez et al. “How should I slice my network? A multi-service empirical evaluation of resource sharing efficiency”, ACM MOBICOM 2018
- P. Caballero et al. “Network Slicing for Guaranteed Rate Services: Admission Control and Resource Allocation Games” IEEE Transactions on Wireless Communications 2018
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