Slicing and Orchestration in Service-Oriented 5G Networks

Navid Nikaein
Associate Professor - Eurecom
Coordinator of Mosaic-5G Initiative

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Connected, Controlled, and Flexible

Digital Society

Value Creation
Consistent experience
Sustainable business model

5G Promises
Evolution to Internet of Skills

Source: Dohler
Communication-Oriented

Today’s 4G is designed for a limited number of UCs

- Throughput-optimized
- Fixed
- Rigid

Is 4G enough?
Mindful about

3GPPP facts and figures

514 Companies from 45 Countries
50,000 delegate days per year
40,000 meeting documents per year
1,200 specifications per Release
10,000 change requests per year

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Turn physical infrastructure into multiple logical networks, one per service instance: **One-Network, Many-Service**

**NOT** a one-size fits all architecture, **NOT** a Dedicated Network

Service-oriented 5G
Different aspects of network slicing have been already prototyped/demonstrated based on Opensource and commercials platforms

Industry is currently providing network slicing by means of
(a) Local/dedicated services enabled by MEC platforms
(b) Dedicated core networks and 3GPP RAN sharing

Next steps : **SO-CN** and **SO-RAN**

**From R&D to Reality**
5G technology enablers

- Software Defined Networking
- Fog Computing
- Edge Computing
- SDN/NFV Orchestration
- Network Function Virtualization
- Cloudification Virtualization
- Contextual Networking
- Heterogeneous Networking
- Self Organization Networking
- Ultra dense network
- Advanced MIMO
- Carrier Aggregation of discontinuous bands
- Advanced waveforms
- Flexible and high capacity backhaul
- Millimeter Wave
- Single channel full duplexing
- More Flexible Spectrum
- New Spectrum Allocations
Network Slicing Concept

Flexible & Customizable logical networks tailored to each use-cases/verticals

Service-oriented 5G
Slicing Technology Enablers

- Softwarization
- Virtualization
- Disaggregation

Multi-service multi-tenant network

Service-oriented 5G
Why will it happen?

Extreme network flexibility and elasticity
Network Slicing evolves the value-chain of telecom industry

Decoupling of Players, but the reality might be different

Service-oriented 5G
3GPP Role Model (3GPPPP 28.801)

E.g.: End user, Small & Medium Enterprise, Large enterprise, Vertical, Other CSP, etc.
<table>
<thead>
<tr>
<th>Feature</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downlink waveform</td>
<td>CDMA</td>
<td>OFDM</td>
<td>OFDM, SCFDMA</td>
</tr>
<tr>
<td>Uplink waveform</td>
<td>CDMA</td>
<td>SCFDMA</td>
<td>OFDMA, SCFDMA</td>
</tr>
<tr>
<td>Channel coding</td>
<td>Turbo</td>
<td>Turbo</td>
<td>LDPC (data) / Polar (L1 contr.)</td>
</tr>
<tr>
<td>Beamforming</td>
<td>No</td>
<td>Only data</td>
<td>Full support</td>
</tr>
<tr>
<td>Spectrum</td>
<td>0.8 – 2.1 GHz</td>
<td>0.4 – 6 GHz</td>
<td>0.4 – 90 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5 MHz</td>
<td>1.4 – 20 MHz</td>
<td>Up to 100 MHz (400 MHz for &gt;6 GHz)</td>
</tr>
<tr>
<td>Network slicing</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>QoS</td>
<td>Bearer based</td>
<td>Bearer based</td>
<td>Flow based</td>
</tr>
<tr>
<td>Small packet support</td>
<td>No</td>
<td>No</td>
<td>Connectionless</td>
</tr>
<tr>
<td>In-built cloud support</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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**Service-oriented 5G**
3 Tier RAN Node

CU0 \(\to\) DU[0-n] \(\to\) RRU[0-m]

Functions Split

CP - UP split

Service-Oriented CN

service catalog and discovery

Slice selection function

CP - UP split
Dedicated or Shared Functions?

- Safety/autonomous driving service
- URLLC (Ultra Reliable Low Latency)
- Infotainment/video streaming
- eMBB (Mobile Broadband)
- Maintenance/statistics
- mIoT, low throughput

- URLLC Slice
- eMBBB Slice
- Default Slice
- mIoT Slice

- UDM
- NSSF
- NRF
- PCF
Network Slicing

Dedicated or Shared?

RAN Sharing
(e.g. [NVS – IEEE/ACM TON 2012])

Efficient and adaptive use of radio resources

Functional isolation

Inefficient use of radio resources

Full Isolation
(e.g. [FLARE – JIP 2017])
Multiplexing Gain

Dedicated or Shared?
Shared Resources?
Dedicated Resources?
Automation-Orchestration
LifeCycle Management (Encapsulate Operations)

Interplay among control, management, and orchestration subsystems
LifeCycle Management
(Encapsulate operation)

→ installation
→ configuration
→ connections
→ upgrades and updates
→ scale-out and scale-back
→ health checks
→ operational actions
→ benchmarks

https://jujucharms.com/q/oai

Automation-Orchestration
Phase Change of Modern Software

Free software is becoming expensive!

Automation-Orchestration
Network Abstractions and CP-Apps Ecosystems

Cloud & NFV

Application

Open Data APIs

MEC

App SDK
Control APPs
Slice / App Orchestration

SDN

Platform SDK
Control plane Services
Platform Orchestration

Network

Data-Plane Service
Data-driven Network Control
Network Slicing brings network flexibility and resource elasticity

(1) Open up the interfaces with the help of SDN
(2) Customized control Apps for monitoring, reconfigurability, and programmability

But, modern networks are too complex to be controlled and optimized by means of rule-based Alg.

Why do we need to evolve 5G?
Flexibility to generalize and comprehend: Never seen Z before, but it is similar to X, so do Y, but adjust as needed

Scale to automate control and management to meet the required QoS/QoE

Dynamicity to constantly adapt and anticipate for different workloads and use cases

Abstraction and multi-layering to combine sources with different semantics
What is Data-driven Control?

**MONITOR**
Right now, what is the avg throughput of user/cell? resource utilization of user/cell? contention faced by user/cell?

**FORECAST**
In the next 1s, what will be the: avg throughput of user/cell? resource utilization of user/cell? contention faced by user/cell?

**PREDICT IMPACT**
In the next 1s, what if: handover users? admit/reject new users? increase/decrease tx power?

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Network actions
- handover user
- admit/reject user
- inc/dec tx power

Network state
- cell: bandwidth, #users, demand etc.
- user: serving cell, link quality etc.

Network effects
- throughput
- resource utilization
- contention

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ML models to manage network and resources
(a) Comply better with slice SLAs
(b) Maximizes the revenue of physical network operators
(c) Robust against runtime issues

Pipelining by means of “Reason-Predict-Control”

Why Data-driven Network Control?
Need to predict the user and network performances in time and space with many unknown and/or dynamic variables.

(1) Realtime control and coordination across cells
(2) Network Intelligence
Video Streaming Use-Case Revisited

Objective:
- maximize video quality
- minimize stall time
- Maintain service continuity

Policy:
- maintain SLA (e.g. minimum average throughput)

Data:
- Link quality
- sustainable TCP throughput

Control (beyond just ABR, joint UE and BS):
1. Adapt the video bit rate through video optimizer
2.1 Add/provision a new BS through SMA+ORCH
2.2 increase the BW of the current BS (SMA)
3. Interference coordination through RRM
4. Update frequency and power through SMA

No buffer freezes
Smoother bitrate adjustment
Proactive Control Scheme

- Knowledge Base (continuously updated)
  - Monitor
  - State
  - Control
  - Reason

- Policies
  - Intent
  - SLA

- Prediction
  - Future State
  - Future Effect
  - Future Impact

- Information Flow:
  - Raw Info
  - Query
  - Logs
  - Changes
  - Statistics
Example of QoE With PCS
Example of QoE With PCS
Example of QoE With PCS
Example of QoE With PCS
Characterizing the Data

- Availability
- Accountability
- Trustworthiness
- Structured
- Semi-structured
- Unstructured
- Exabytes
- Transactional
- Records, files
- Velocity
- Volume
- Variety
- Veracity
- Realtime
- Batch
- Streaming
- Posts
- Transactional
- Records, files
- Exabytes
- Availability
- Accountability
- Trustworthiness
- Velocity
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- Veracity
- Posts
- Realtime
- Batch
- Streaming
Conclusion
Fusion of Computing, Information and Cellular technologies

(a) 5G and beyond is not only New Radio and verticals, it is also an evolution in General-Purpose computing for wireless networks.

(b) More and more software technologies (NFV, SDN, MEC) and Data (mining, analytics) jointly with radio signal processing.

Conclusion
Network slicing is an on-going research with several challenges

Isolation, Sharing, Customization

Satisfy requirements of slice owner and operator/infra. provider

Conclusion
Data-driven network control is difficult

Reason-Predict-Control is a generic framework

Prediction performance is limited by the available computing resources

Conclusion
Open Questions

(1) Can we predict user QoS/QoE per application in realtime?

(2) Can we learn network-user-application dependencies across various network domains?

(3) Can we automatically learn the right control to apply?
Personal Info:
Email: navid.nikaein@eurecom.fr
Website: http://www.eurecom.fr/~nikaeinn/
Linkedin: https://www.linkedin.com/in/navidnikaein
Tel: +33.(0)4.93.00.82.11

Mosaic-5G.io :
Mail : contact@mosaic-5g.io
Website : http://mosaic-5g.io
Linkedin: https://www.linkedin.com/in/in/mosaic-5g
Twitter: @mosaic5g