5G INTERCONNECT AND ROAMING

How can we make network slicing and edge computing work across networks?

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FIVE GENERATIONS MOBILE COMMUNICATION

1G
- 1980s
- Analog voice
- 100 kbps

2G
- 1990s
- 1 Mbps

3G
- 2000s
- 10 Mbps

4G
- 2010s
- 1 Gbps

5G
- 2020s
- 1 Gbps

INTRODUCTION
5G AIMS TO PROVIDE TAILORED CONNECTIVITY TO A VARIETY OF APPLICATION AREAS

5G networks subdivided into virtual networks each optimised for one business case

(source: GSMA, 2017)
IN THIS PRESENTATION

- 5G builds on several new technology ingredients for providing tailored connectivity, computing and storage to digital society domains
  - Slicing
  - Edge computing
- The new technologies make 5G more powerful and flexible than 4G but also introduce new interconnect and roaming challenges
  - Network slices provided by different operators
  - Edge computing provided by different operators or service providers
- The growth of the 5G ecosystem depends on adequate interoperability to achieve network effects
  - This has worked well in 2G, 3G and 4G
  - How can we make it work for network slicing and edge computing in 5G?
SLICING GIVES SEPARATED VIRTUAL NETWORKS ON TOP OF ONE PHYSICAL NETWORK INFRASTRUCTURE
EDGE COMPUTING IS AIMED AT APPLICATIONS REQUIRING LOW-LATENCY NETWORKED COMPUTE
EXAMPLE USE CASE FOR 5G: CONNECTED AND AUTOMATED MOBILITY (CAM)

- Low latency, depending on application
- High reliability of connectivity

5G TECHNOLOGY INGREDIENTS AND USE CASES
EXAMPLE IMPLEMENTATION OF CONNECTED AND AUTOMATED MOBILITY IN A SINGLE 5G NETWORK

5G TECHNOLOGY INGREDIENTS AND USE CASES
SERVICES DEPLOYED OVER 5G NEED TO COMPLY WITH THE EU NET NEUTRALITY RULES

(HOW ABOUT NET NEUTRALITY?)
IN PRACTICE, CAM SERVICES WILL NEED TO WORK ACROSS **MULTIPLE** 5G NETWORKS
x-Border corridors

Greece – Turkey

The Greece – Turkey cross-border corridor is located in the South-Eastern borders of Europe.

Spain – Portugal

The Spain-Portugal cross-border corridor connects the cities of Vigo and Porto.

(source: www.5g-mobix.com)
5G INTEROPERABILITY CHALLENGES: (1) HORIZONTAL

THERE IS A NEED TO INTERCONNECT SLICES ON TOP OF INTERCONNECTION OF NETWORKS (1)
There is a need for interconnection of slices on top of interconnection of networks (2).

Table 5.15.2.2-1 - Standardised SST values

<table>
<thead>
<tr>
<th>Slice/Service type</th>
<th>SST value</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>eMBB</td>
<td>1</td>
<td>Slice suitable for the handling of 5G enhanced Mobile Broadband.</td>
</tr>
<tr>
<td>URLLC</td>
<td>2</td>
<td>Slice suitable for the handling of ultra-reliable low latency</td>
</tr>
<tr>
<td>MIoT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3GPP TS23.501

Figure 2: Standardised and private NESTs

From Vertical Industry Requirements to Network Slice Characteristics, GSMA

S-NESTs to be hosted and maintained by GSMA

P-NESTs to be hosted and maintained by operators

NOTE: The support for vertical industry requirements
VERTICAL INTEROPERABILITY CAN BE AN ALTERNATIVE FOR HORIZONTAL INTERCONNECT (1)
Both VR and AR are disruptive forms of immersive multimedia that, combined with operator edge cloud and 5G connectivity, will transform the cost structures of the enterprise and entertainment fields,” commented Alex Sinclair, Chief Technology Officer, GSMA. “Mobile operators will play a key role in its development, but without a common approach and industry-wide collaboration we risk fragmenting the market from the beginning. ...”
Strong network effects in mobile networking are achieved through interoperability
- For individual users and verticals/sectors
- Value for network providers and investors

5G interop

• Across slices carrying various applications
• Across vertical users and sectors
• Across classical operator networks and local “non-operator” networks

4G interop

• Across countries
• For voice and Internet data
• Across network providers of different sizes

THE GROWTH OF THE 5G ECOSYSTEM DEPENDS ON OLD AND NEW TYPES OF INTEROPERABILITY
OBSERVATIONS ON WAY FORWARD TO 5G INTEROP
(1) 5G TECHNOLOGY MEETS BUSINESS MODELS

New: vertical interfaces that support applications over 5G for verticals

Network effects: European operator groups, midsize operators, IPX providers
OBSERVATIONS ON WAY FORWARD TO 5G INTEROP

(2) TIMING IS AN IMPORTANT FACTOR

Let’s focus on deploying 5G infrastructure and sector services now and look at interop later vs Let’s plan ahead to avoid fragmentation and benefit from network effects early on

Interop may slow down innovation

5G interop is more complex than 4G interop
WRAP UP

5G interop

4G interop

- Across countries
- For voice and Internet data
- Across network providers of different sizes

- Across slices carrying various applications
- Across vertical users and sectors
- Across classical operator networks and local “non-operator” networks

How?

When?

Let's focus on deploying 5G infrastructure and sector services now and look at interop later

Let's plan ahead to avoid fragmentation and benefit from network effects early on

Interop may slow down innovation

5G interop is more complex than 4G interop
THANK YOU FOR YOUR ATTENTION

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SEVERAL TOPICS IN THE DETAILED COMPLIANCE ANALYSIS ARE FURTHER DEVELOPED BY BEREC

1. Multiple IASs with different traffic management settings in one network
2. QoS differentiation within IAS
3. Local access to the internet
4. Public and private services and associated networks
5. Objective need for optimisation in SpS
6. Impact of SpS on IASs
7. SpS and connections to the internet
8. Connectivity to limited number of internet end points
9. Access control
The topics encountered in our further analysis are of varying complexity.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Key points identified in analysis</th>
<th>Relative regulatory complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple IAs with different traffic management settings</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>• Interpretation of sender and receiver in Art 3.3 of the Regulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Note: assumption needed in remainder of analysis - it is allowed to have multiple IAs with different traffic management settings for a given end user</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. QoS differentiation within IAS</td>
<td></td>
<td>medium to high</td>
</tr>
<tr>
<td>• Applications with multiple different traffic flows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Transparency through 5QI values or other methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Dependency of ISP on other entities for assignment of traffic flows to traffic categories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Duration of QoS differentiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Local access to the internet</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>• (potentially:) IP interconnection of local networks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Public and private services and associated networks</td>
<td></td>
<td>low to medium</td>
</tr>
<tr>
<td>• Size and scope of predetermined group of end users in private service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Objective need for optimisation in SpS</td>
<td></td>
<td>high, except if SpS requirements are clearly much stricter than achievable over IAS.</td>
</tr>
<tr>
<td>• Determination of IAS for benchmark in case of multiple IAS offers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Variation of IAS performance between geographical regions and operators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Services comprising multiple traffic flows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Impact of SpS on IAs</td>
<td></td>
<td>high</td>
</tr>
<tr>
<td>• Multiple IAs affected by one SpS, within and outside the slice used for the SpS.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Isolation of the effect of the SpS on IAS from other effects occurring in mobile network at the same time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Complexity of network and capacity management in mobile network with many services and applications in general</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. SpS and connections to the internet</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>• Connectivity to internet from SpS through separate IAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Connectivity between different legs between end user device and internet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Connectivity to limited number of internet end points</td>
<td></td>
<td>medium</td>
</tr>
<tr>
<td>• Evaluation whether sub-internet service is acceptable for providing connectivity in specific situations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Access control</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>(no issues if use is restricted to network congestion in emergency situations)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5G CAN USE A WIDE VARIETY OF FREQUENCIES

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>600MHz (2x35MHz)</th>
<th>700MHz (2x30 MHz)</th>
<th>700MHz (2x30 MHz)</th>
<th>700MHz (2x30 MHz)</th>
<th>New 5G band</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1GHz</td>
<td>3.55-3.7 GHz</td>
<td>3.4-3.8 GHz</td>
<td>3.6-3.8GHz</td>
<td>3.6-4.2GHz</td>
<td></td>
</tr>
<tr>
<td>3GHz</td>
<td>3.55-3.7 GHz</td>
<td>3.4-3.8 GHz</td>
<td>3.6-3.8GHz</td>
<td>3.6-4.2GHz</td>
<td>Licensed</td>
</tr>
<tr>
<td>4GHz</td>
<td>3.55-3.7 GHz</td>
<td>3.4-3.8 GHz</td>
<td>3.6-3.8GHz</td>
<td>3.6-4.2GHz</td>
<td>Existing band</td>
</tr>
<tr>
<td>5GHz</td>
<td>3.55-3.7 GHz</td>
<td>3.4-3.8 GHz</td>
<td>3.6-3.8GHz</td>
<td>3.6-4.2GHz</td>
<td>Unlicensed/shared</td>
</tr>
<tr>
<td>24-28GHz</td>
<td>24.25-24.5GHz</td>
<td>24.75-25.25GHz</td>
<td>27.5-28.35GHz</td>
<td>27.5-28.35GHz</td>
<td></td>
</tr>
<tr>
<td>37-40GHz</td>
<td>37.5-37.6GHz</td>
<td>37.96-38.2GHz</td>
<td>40.7-41.0GHz</td>
<td>40.7-41.0GHz</td>
<td></td>
</tr>
<tr>
<td>64-71GHz</td>
<td>64-71GHz</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Global snapshot of 5G spectrum bands allocated or targeted

Source: Qualcomm
SOME OF THE 5G BANDS WILL BECOME AVAILABLE FOR LOCAL NETWORKS

The Chamber has ruled as follows:

Of the whole band at 3400 MHz – 3800 MHz, the Chamber will provide the spectrum from 3400 MHz to 3700 MHz (and therefore the majority of the 3.6 GHz band) for nationwide assignments. It will thus be possible to provide adequate spectrum for nationwide operators to realise their business models. This will ensure that the spectrum for nationwide assignments will be able to be used in full from 3400 MHz to 3700 MHz – and thus up to the upper edge at 3700 MHz. The future nationwide assignment holder will, therefore, not have to observe a guard band between the adjacent applications above 3700 MHz. Rather, the local and regional assignment holders will have to comply with a potential guard band with regard to the adjacent national usage.

It will nevertheless also be possible to provide adequate spectrum in the band at 3700 MHz – 3800 MHz for small and medium-sized enterprises to realise local and regional business models.

Vanaf die datum is de 3,5 GHz-band in principe in zijn geheel beschikbaar.
Agentschap Telecom beveelt aan om de band van 3700 – 3800 MHz op lokaal niveau te blijven uitgeven, zodat ook na afloop van de huidige vergunningen blijvend in de lokale behoeften van bestaande vergunninghouders kan worden voorzien.
5G WILL BRING MULTIPLICITY AND VARIATION IN NETWORKS AND “OPERATORS”

Technical preconditions and enablers (in addition to 5G tech):
- Spectrum
- Mobile network codes

Consequences for ecosystem:
- Many options and scenarios
- More participants and roles

How can end-to-end quality be guaranteed?