Why “one-size-fits-all” approach does not work anymore?

Crowncom 2019, Poznan, 11.06.2019

Marcin Dryjanski
Talk Outline

- History of Wireless Systems
- LTE Complexity
- 5G Complexity
- Mobile Networks Design Approaches
- Unified and Hierarchical Framework
- Conclusions & Summary
History of Wireless Systems
Mobile Wireless Systems – Evolution

1G
- Analog mobile voice
- Basic service
- "Simple" network design

2G
- Digital mobile voice
- Good service

3G
- Basic IP connectivity
- Basic service

4G
- MBB
- Good service

5G
- eMBB
- mMTC
- URLLC
- (Basic) service mix
- Complex network design
  (NR, NB-IoT, LTE, Wi-Fi, Satellite, ...)

5G
- eURLLC
- emMTC
- feMBB
- ??
Features Evolution – HetNet

- Unlicensed spectrum usage
- New spectrum bands
- Novel spectrum sharing methods
- New spectrum access methods

Heterogeneous Network

Need for more capacity

- Unlicensed spectrum usage
- New spectrum bands
- Novel spectrum sharing methods
- New spectrum access methods

Spectrum Toolbox

- Frequency bands
- Spectrum aggregation
- Duplexing schemes
- Spectrum licensing and sharing schemes
- Spectrum refarming
Features Evolution – Spectrum Aggregation

**LTE**
- Single Carrier – flexible BW
  - 1.4-20MHz
  - DL/UL
  - 1 carrier
  - Symmetric DL/UL

**LTE-A**
- Carrier Aggregation
  - CC 1.4-20MHz
  - DL/UL
  - Multiple CC (up to 5)
  - Legacy carrier structure
  - Possible asymmetric DL/UL
  - Intra/inter band

**LTE Pro**
- Massive CA
  - Up to 32 CC
  - SDL
- Unlicensed spectrum usage
  - LTE-WiFi tight aggregation
  - Unlicensed LTE

**“5G”**
- DC & Multi-RAT DC
  - NR + LTE DC
  - Make-before-break

**Dual Connectivity**
- Suitable for non-ideal backhaul

**Non-backwards compatible carrier**
- Flexible numerology & lean carrier
- Aggregation of sub-6GHz and mmW

# Features Evolution – Spectrum Toolbox

<table>
<thead>
<tr>
<th>3GPP Release</th>
<th>Toolbox Element</th>
<th>LTE: Rel-8, 9</th>
<th>LTE-Advanced: Rel-10, 11, 12</th>
<th>LTE-Advanced Pro: Rel-13,14</th>
<th>5G Phase I: Rel-15</th>
<th>5G Phase II: Rel-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency bands [GHz]</td>
<td>Single Carrier (1.4-20MHz), symmetric DL/UL</td>
<td>0.7, 0.8, 1.8, 2.1, 2.3-2.4, 2.5-2.6GHz</td>
<td>0.45 (Brazil), Digital Dividend, 1.5, 3.4-3.8GHz</td>
<td>5GHz ISM; WRC-15 bands</td>
<td>New bands below 6GHz for 5G RAT; mmW: 6-100GHz; WRC-15/19 bands</td>
<td></td>
</tr>
<tr>
<td>Spectrum aggregation</td>
<td>Dual Connectivity, CA variants: -up to 5CC, FDD and/or TDD -intra-/ inter-band, (non)-continuous, -Co-located, RRH -asymmetric DL/UL</td>
<td>Massive CA (32CC), LAA (5GHz), LWA, eLWA, SDL for CA: 2.3-2.4GHz</td>
<td>Multi-Connectivity with asymmetric DL/UL, SDL for CA: 700MHz, 2.5-2.6GHz, NR-LTE DC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrum licensing schemes</td>
<td>Licensed spectrum only</td>
<td>Licensed, Carrier Wi-Fi</td>
<td>Licensed, Unlicensed, DL, LAA, LWA, LSA, eLWA</td>
<td>Co-existence of: LSA, exclusive licensed, shared license-exempt spectrum, enhanced LAA (DL+UL), CBRS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duplexing schemes</td>
<td>Separate FDD, TDD</td>
<td>FDD and TDD (CA-based), eIMTA</td>
<td>FDD Flexible Duplex</td>
<td>Flexible TDD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharing schemes (network, spectrum)</td>
<td>Static schemes (MOCN, MORAN)</td>
<td>Static schemes (MOCN, MORAN)</td>
<td>RSE, LSA</td>
<td>LSA, Cognitive Radio (CR), Slicing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrum refarming</td>
<td>Static</td>
<td>Static</td>
<td>Dynamic, DSA, MRAT Joint Coordination</td>
<td>Fully dynamic, opportunistic, CR</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# Features Evolution – Pros & Cons (Examples)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Advantages and opportunities</th>
<th>Disadvantages and challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carrier Aggregation</strong></td>
<td>• Improves user throughput and cell capacity</td>
<td>• Not possible to aggregate spectrum in non-ideal backhaul RRH deployments</td>
</tr>
<tr>
<td></td>
<td>• Possibility to aggregate different spectrum bands</td>
<td>• Scheduler complexity (CA and non-CA users)</td>
</tr>
<tr>
<td></td>
<td>• Extension beyond single carrier allocation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• MAC layer management</td>
<td></td>
</tr>
<tr>
<td><strong>Massive Carrier Aggregation</strong></td>
<td>• Enables to acquire multitude of bands and BWs to increase capacity and mix licensed with unlicensed bands</td>
<td>• Complex management</td>
</tr>
<tr>
<td></td>
<td>• Complex management</td>
<td>• Complexity of RF chains</td>
</tr>
<tr>
<td></td>
<td>• Complexity of RF chains</td>
<td>• UE support as a limiting factor</td>
</tr>
<tr>
<td><strong>Supplemental Downlink</strong></td>
<td>• Possibility to adapt aggregated capacity to the required DL/UL demand</td>
<td>• Feature limited by the available SDL-specific bands</td>
</tr>
<tr>
<td></td>
<td>• Aggregation and management on MAC</td>
<td>• CA-based operation only</td>
</tr>
<tr>
<td><strong>Dual Connectivity</strong></td>
<td>• Adds spectrum aggregation opportunity for non-ideal backhaul inter-site</td>
<td>• Not possible to allocate resources on MAC level</td>
</tr>
<tr>
<td></td>
<td>• Possible to combine with CA</td>
<td>• May have problems at anchor cell boundary due to both Macro and SC change</td>
</tr>
<tr>
<td></td>
<td>• Enables extension to aggregate multi-RAT aggregation on PDCP level</td>
<td>• Requires additional scheduler</td>
</tr>
</tbody>
</table>
Features Evolution – An "Evolved" LTE

- IoT: NB-IoT, LTE-M
- Licensing: LTE-U, LAA, MuLTEfire, LSA, CBRS
- More resources: Massive CA, DC
- WiFi access: LWA, RCLWI, LWIP
- Resource allocation flexibility: eIMTA, short TTI
- Direct connectivity: V2X, D2D, ProSe
- ...
Features Evolution – Not Really Successful(?)*

- MBMS/eMBMS
- WiMAX
- LTE-U
- Small cells (so far)
- LWA
- CoMP
- Relaying

* Personal opinion
5G Complexity
5G Standards – Roadmap

Defining requirements

3GPP Release 14
initial 5G studies
Freeze: Q1 2017*

Most immediate needs, eMBB, initial
URLLC, freq < 52.6GHz

3GPP Release 15
5G phase 1
Freeze: Q1 2019*

All ITU-Requirements, URLLC, mMTC, V2X,
unlicensed, satellite...

3GPP Release 16
5G phase 2
Freeze: Q1 2020*
(basis for submission to ITU-R)

5G NSA Freeze
Dec 2017

* ASN1 - 3 months later

Most immediate needs, eMBB, initial
URLLC, freq < 52.6GHz

All ITU-Requirements, URLLC, mMTC, V2X,
unlicensed, satellite...

5G NSA Freeze
Dec 2017

* ASN1 - 3 months later
5G Standards – Service Mix & Technologies

- eMBB
- mMTC
- URLLC

- mmWave, MMIMO
- Flexible numerology
- CP/UP split, Slicing, CRAN
- Unlicensed, Satellite access
- D2D, V2X
- LTE & NR integration options
- SON, SDN, NFV

Data-rates & capacity
Connection density
Latency & mobility
Few weeks before freezing 5G NSA, RAN1 sent RAN2 ~600 L1 parameters to cover within RRC spec.

(Compared to ~80 L1 parameters for LTE Rel-8)
5G Standards – How Do We Call This One?

What we can end up with: even-further-enhanced lower-layer-split next-generation-NodeB distributed-unit (efe-lls-gNB-DU)
5G Complexity – Observations

- Aspects making 5G more complex than previous systems:
  - bigger scope of use cases to be covered by 5G,
  - new technologies to be brought under the 5G umbrella,
  - comparing to the baseline LTE.

- Lot of addons that LTE has been equipped with along seven 3GPP releases: NB-IoT, eMTC, LAA, LWA, DC, V2X, D2D, CA, CoMP, FD-MIMO, LSA, CBRS, short TTI, ... - made it an "LTE Frankenstein".

- 5G should bring those features natively with forward compatibility and flexibility as design principles, which:
  - makes 5G really complex,
  - requires time until 5G gets matured to release its full potential.
Beyond 5G – Shall We?

Will 5G become an umbrella with a set of technologies (NR + LTE + NB-IoT + …) where new features are added over time?

Or do we need nextG’s...?
Mobile Networks Design Approaches
## Current Landscape – RRM Complexity

<table>
<thead>
<tr>
<th>RAN Management</th>
<th>Multi-RAT</th>
<th>HetNet</th>
<th>Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC RRM (LA/PC/Scheduling)</td>
<td>GSM/GPRS</td>
<td>DAS</td>
<td>CA</td>
</tr>
<tr>
<td>Traffic Steering</td>
<td>UMTS/HSPA</td>
<td>Pico, Femto, Small Cell</td>
<td>CA scheduling/CC selection</td>
</tr>
<tr>
<td>SON (ESM, CCO, MLB, MRO)</td>
<td>LTE/LTE-A/LTE-A Pro</td>
<td>Wi-Fi offloading</td>
<td>TDD + FDD</td>
</tr>
<tr>
<td>OSS/OAM</td>
<td>Wi-Fi</td>
<td>Dual Connectivity</td>
<td>LAA/LSA</td>
</tr>
<tr>
<td>Multi-RAT RRM</td>
<td>5G NR (low band + mmWave)</td>
<td>Massive MIMO</td>
<td>Cognitive Radio/SDR</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td></td>
<td></td>
<td>Supplemental DL/UL</td>
</tr>
</tbody>
</table>

A large Radio Resource Management challenge of Multi-RAT/HetNet!
Design Approaches – Technology vs Purpose

- Short range vs Local area vs Wide area, e.g. in IoT space:
  - Bluetooth, BLE (smartwatch, mouse, pointer) vs
  - Wi-Fi, zigbee (Internet access, energy management, home monitoring) vs
  - LTE, NB-IoT/Lora (e.g. Outdoor Internet access, smart city)

- Indoor vs Outdoor, e.g. Wi-Fi vs Cellular for Internet access

- High speed vs low speed (content vs sensing), e.g. LTE vs NB-IoT, WiFi vs zigbee

- Adaptive vs Fixed, e.g. dynamic content sharing vs predefined periodic updates

- Local vs global, e.g. handled by gateways vs directly communicating to network
Design Approaches – Three Designs

Approach 1: Fragmented solutions for individual use cases
- 5G is a set of very diverse applications / requirements
- Due to fragmentation of the supporting technologies – need to design separate systems to realize requirements (like IoT landscape)

Approach 2: “One-size-fits-all” / One design
- 5G is all about IP services (one “use case”)
- Evolving of the existing systems with add-on features to realize particular need (like LTE)

Approach 3: Hybrid and optimized set of tailored designs with unified management
- Diverse requirements jointly managed
- Natively unified and hierarchical approach to the design of the system.
Design Approaches – Observations

- There are diverse requirements and diverse services
- There are technologies supporting different services tailored to them
- We will never know all the services in advance
- There are different approaches suited for different purposes (e.g. radio waveforms for periodic transmission vs high burst vs low mobility vs high mobility)
- Designing a system that is suitable for everything at once is difficult and hard to manage (e.g. same radio interface for local IoT and for high speed outdoor Internet access)

An assumption that we will NOT know all the requirements in advance and design with flexibility, forward compatibility, and easy “pluginability” is the way to go!
Unified and Hierarchical Framework
Unified & Hierarchical – Framework Usage Example

Unified MAC

Unified frame structure (abstraction layer)

Waveform 1
Waveform 2
Waveform 3
Unified & Hierarchical – 5GNOW Example

5GNOW Use Cases and Requirements

5G application scenarios (radio access must cope with different requirements)

Future radio access:
- Flexible
- Scalable
- Reliable
- Robust
- Content aware

5GNOW Solutions

5GNOW PHY
Non-orthogonal waveforms
- FBMC
- GFDM
- UFMC
- BFDM

5GNOW PHY-to-MAC I/F
Mixture of synchronous and asynchronous traffic
- Unified Frame Structure

5GNOW MAC
Hybrid and hierarchical
- Unified MAC

Source: 5gnow.eu
Unified & Hierarchical – 5GNOW Example

Making a long story short...

- 5G is capturing a lot of use cases, but it’s difficult to incorporate everything in a single design, and whenever a new use case comes, it needs to be captured somehow.

- You could theoretically fit all the waveform designs to support all use cases.

- BUT:
  - let’s do the opposite instead: let’s assume we don’t know the use cases and then design a system to capture them with this assumption,

- why not to design an optimized mechanism covering a certain use case and encapsulate it within a big machine, but avoid rebuilding the whole thing?
Unified & Hierarchical – 5GNOW Example

5GNOW Unified MAC Interfacing with Unified Frame Structure
Unified & Hierarchical – Framework Usage Example

Unified traffic steering

Abstraction layer

LTE RAT

NR RAT

Wi-Fi RAT
Unified & Hierarchical – UTS Example

Unified Traffic Steering Framework

New aspects can be incorporated in a straightforward manner:
- Load metrics
- Available features
- Available RATs/layers
- Available strategies
- Available procedures

© IEEE 2016
Unified & Hierarchical – Framework Usage Example

Unified data storage/acquisition

Abstraction layer

Traffic map
RSRP map
RAT accessibility map
Unified & Hierarchical – RSM Example

Recursive Radio Service Map Architecture

Same maps could support different features:
- Low level RRM (scheduling)
- Upper level RRM (TS)
- SON (MLB)
- Orchestration (Network layers)
Unified & Hierarchical – Elasticstack Example

- An example from IT systems – *elasticstack* – monitoring & analytics system

- Architecture:
  - Visualisation – Kibana
  - Search engine/big data - Elasticsearch (ES)
  - Ingest nodes – logstash/beats

- An abstraction layer inbetween ingest nodes and database, enabling to use ES for various monitoring applications with the approach: provide the proper communication of your ingest module with the ES through the API

- You don’t need to rebuild the whole system when adding new feature – you adapt your plugin to the elasticsearch through API

- Additional notes:
  - *Kibana* can also run on top of a different database (e.g. Prometeus), dedicated for IoT metrics
  - *Elasticsearch* is more for logs search and processing – can also work with IoT metrics, but less efficient, thus integration can be done on a different level

Have integration possibility on many levels, to decide where to integrate / where things fit optimally!
Conclusions and Summary
Putting it Altogether – Beyond 5G

NextGs should be:

- Flexible, programmable, software-defined and cloud-enabled network...
- ... highly heterogeneous, using multi-connectivity and multi-RAT concepts...
- ... combined with various spectrum licensing and management schemes, utilizing wide range of bands (from below 1GHz to up to and beyond 100GHz)...
- ... optimized and tailored to specific-services and multi-tenant enabled...
- ... with unified and hybrid management...
- ... fully automated and self-learning.

It all comes down to – where to put the abstraction
Let’s talk:
IoT, SD-WAN, Wireless, Proptech.
The information contained herein is the property of Grandmetric and is provided solely on condition that it will not be disclosed, directly or indirectly to a third party, nor used for any purpose other than that for which it was specifically prepared.

ETSI is the copyright holder of LTE, LTE-Advanced and LTE Advanced Pro and 5G Logos. LTE is a trade mark of ETSI. Grandmetric is authorized to use the LTE, LTE-Advanced, LTE-Advanced Pro and 5G logos and the acronym LTE.

All information that will be discussed is provided “as is” and Grandmetric gives no guarantee or warranty that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and liability.

©2019 Grandmetric sp. z o.o. All Rights Reserved.

Note: The referenced figures’ copyrights remain under the responsibility of their respective owners.