GRANDMETRIC

NETWORK & WIRELESS... STAY CONNECTED.

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

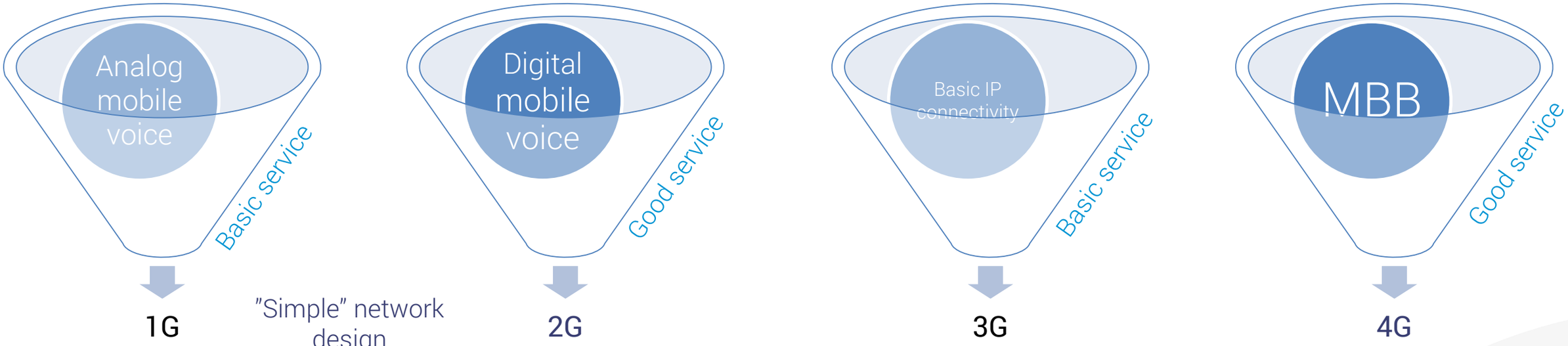
Marcin **Dryjanski**

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**



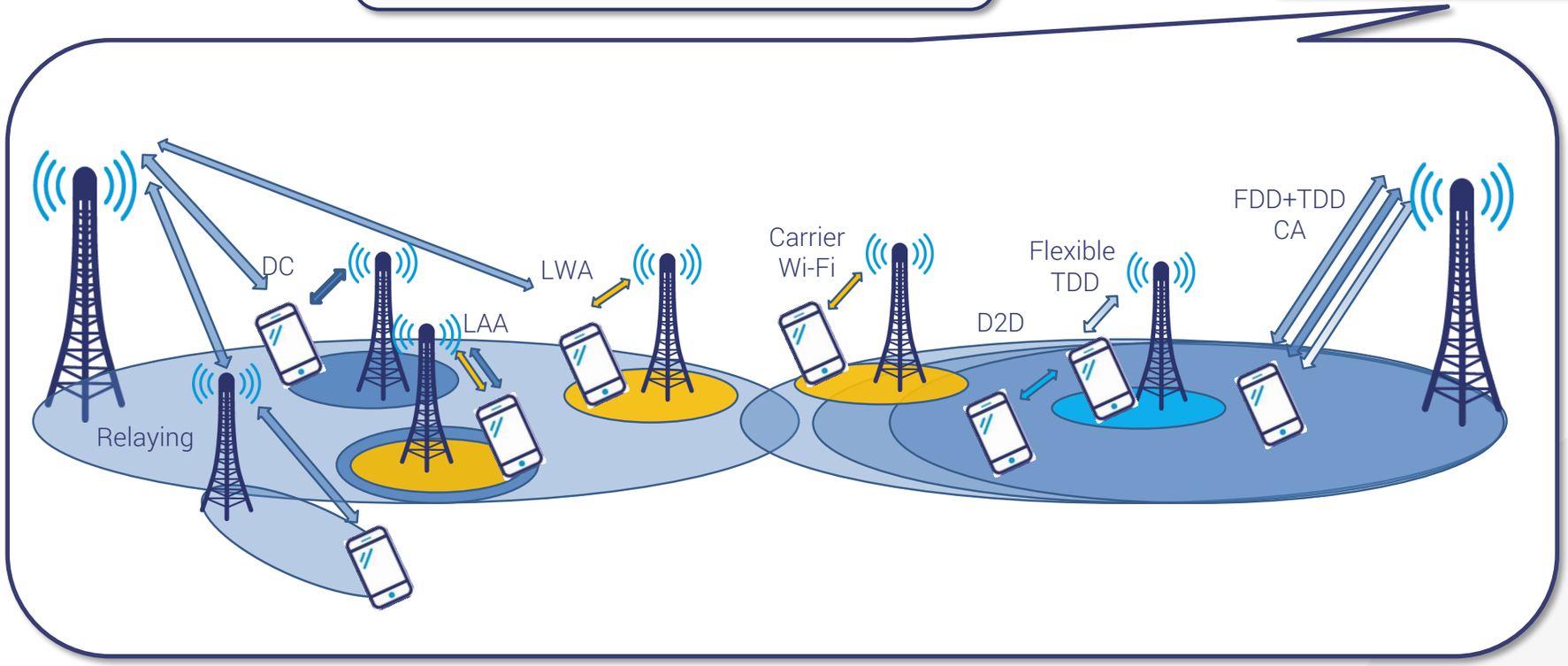
LTE Complexity

Features Evolution – **HetNet**

Need for more capacity

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

Heterogeneous Network



Ref.: Szydelko M., Dryjanski M. "Spectrum Toolbox Survey: Evolution Towards 5G", CrownCom 2016

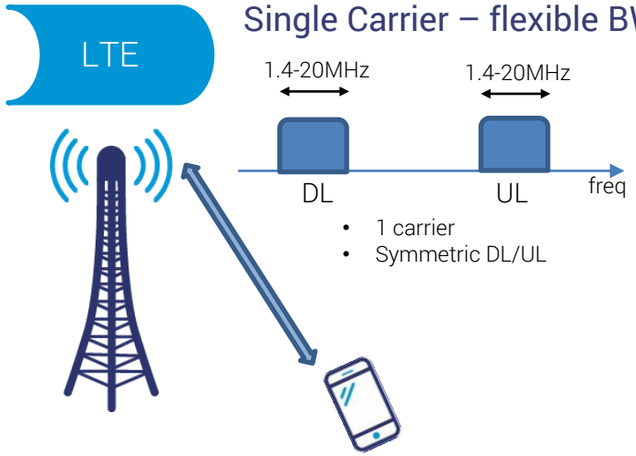
Spectrum Toolbox

- Frequency bands
- Spectrum aggregation
- Duplexing schemes
- Spectrum licensing and sharing schemes
- Spectrum refarming

Features Evolution – Spectrum Aggregation

LTE

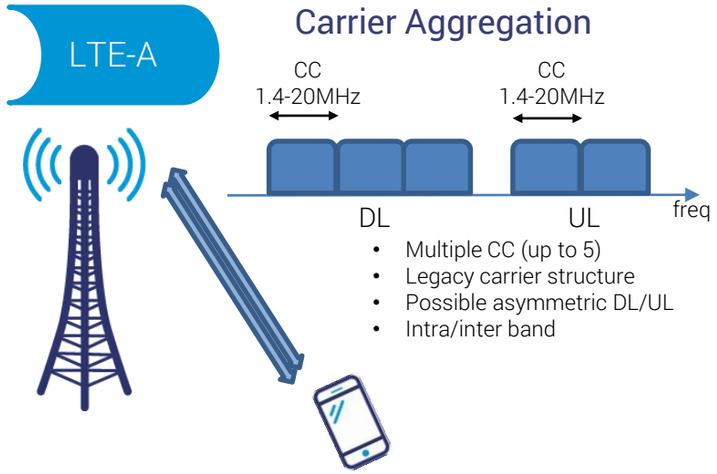
Single Carrier – flexible BW



- 1 carrier
- Symmetric DL/UL

LTE-A

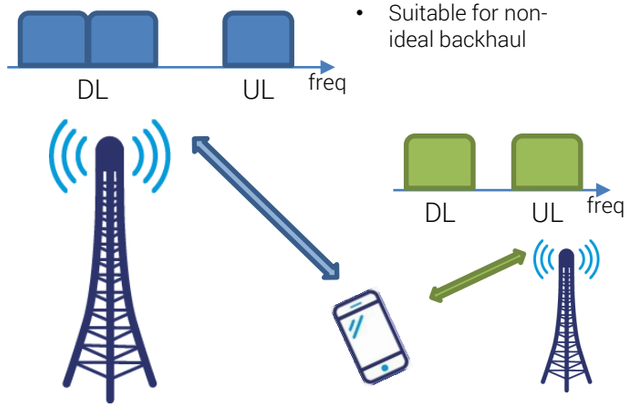
Carrier Aggregation



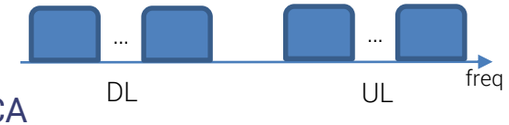
- Multiple CC (up to 5)
- Legacy carrier structure
- Possible asymmetric DL/UL
- Intra/inter band

Dual Connectivity

- Suitable for non-ideal backhaul



LTE-A Pro

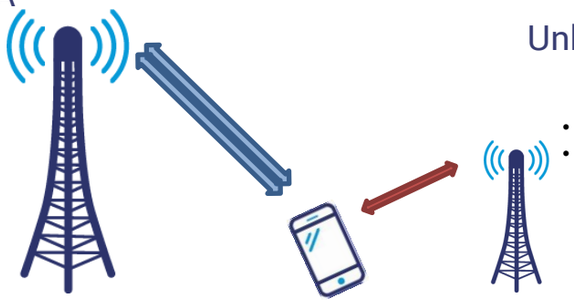


Massive CA

- Up to 32 CC
- SDL

Unlicensed spectrum usage

- LTE-WiFi tight aggregation
- Unlicensed LTE



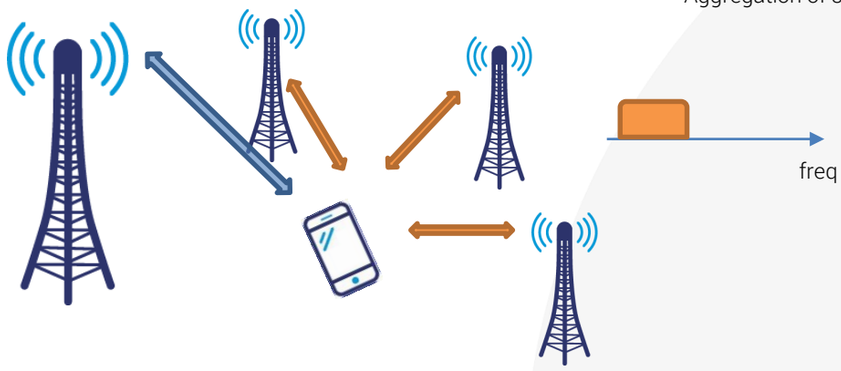
"5G"

DC & Multi-RAT DC

- NR + LTE DC
- Make-before-break

Non-backwards compatible carrier

- Flexible numerology & lean carrier
- Aggregation of sub-6GHz and mmW



Ref.: Szydelko M., Dryjanski M. "Spectrum Toolbox Survey: Evolution Towards 5G", CrownCom 2016

Features Evolution – Spectrum Toolbox

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

Ref.: Szydelko M., Dryjanski M. "Spectrum Toolbox Survey: Evolution Towards 5G", CrownCom 2016

Features Evolution – **Pros & Cons (Examples)**

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

Ref.: M. Szydelko, M. Dryjanski, “Spectrum Toolbox Survey: Evolution Towards 5G”, EAI Endorsed Transactions on Cognitive Communications, Vol. 3, Issue 10

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, unlincensed, satellite…

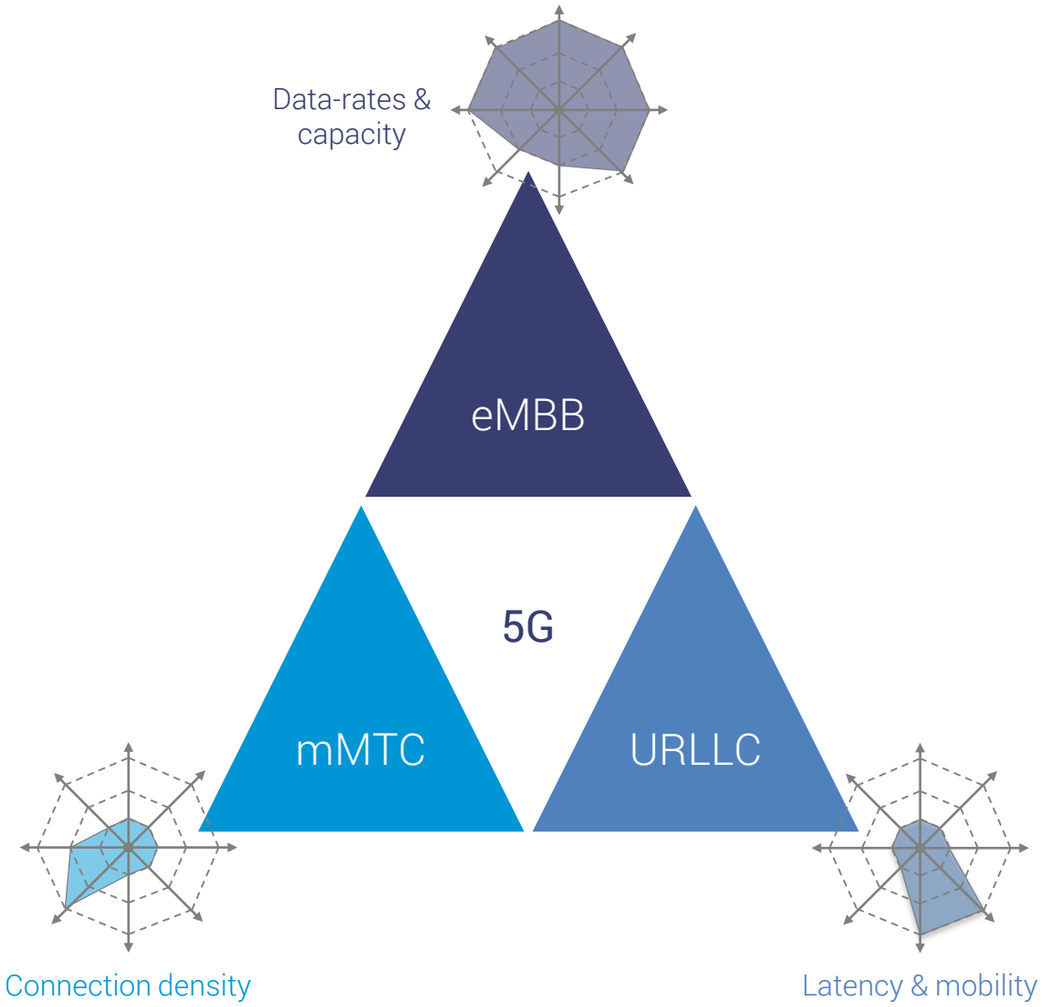
3GPP Release 16
5G phase 2

Freeze: Q1 2020*
(basis for submission to ITU-R)

5G NSA Freeze
Dec 2017

* ASN1 - 3 months later

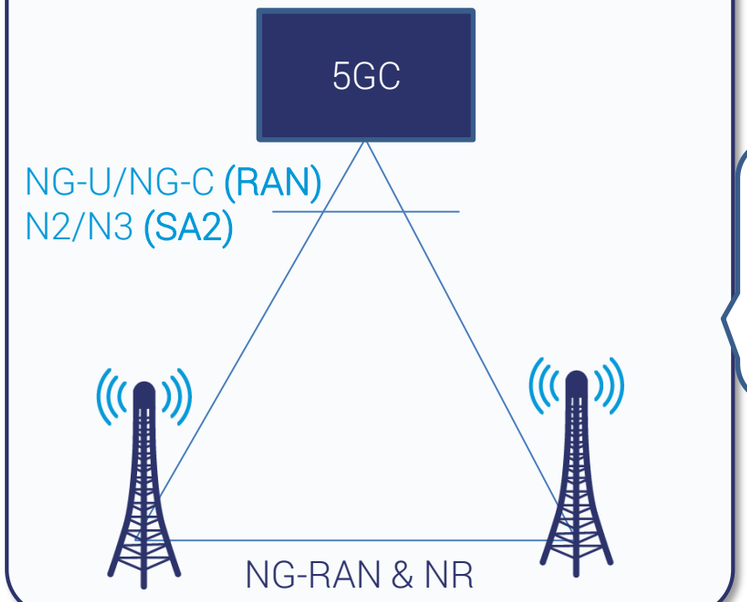
5G Standards – **Service Mix & Technologies**



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

5G Standards – **Complexity of the System**

Naming - Architecture



Compared to:
EUTRAN
EUTRA
EPC
EPS

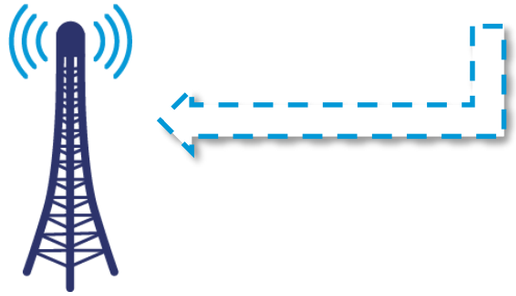
Dual connectivity options

EN-DC	E-UTRA-NR Dual Connectivity
MR-DC	Multi-RAT Dual Connectivity
NE-DC	NR-E-UTRA Dual Connectivity
NGEN-DC	NG-RAN E-UTRA-NR Dual Connectivity

L1 parameters

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**)

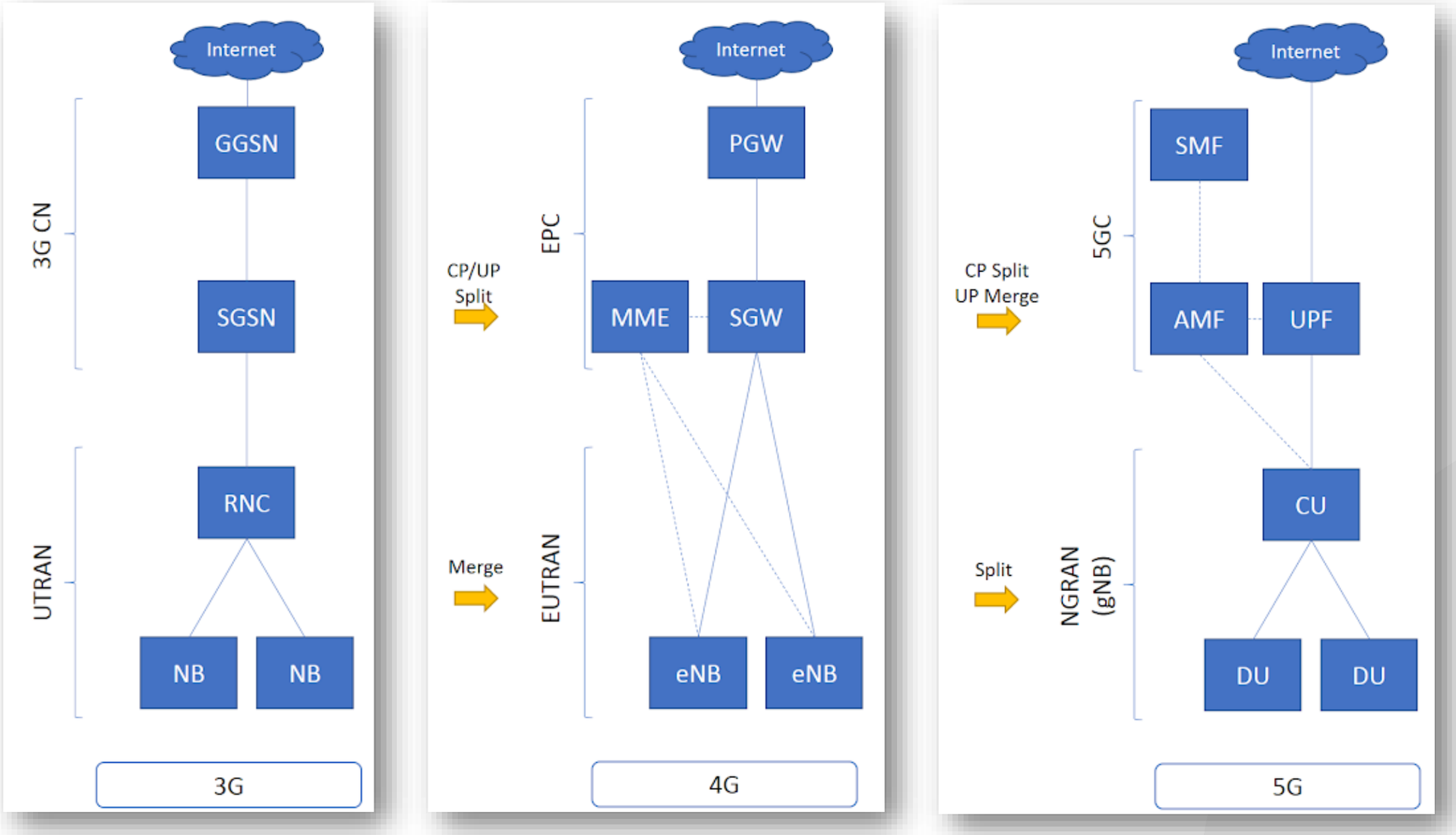
5G Standards – How Do We Call This One?



BS (Base Station)	BTS (Base Transceiver Station)	NB (NodeB)	eNB (evolved NodeB)	gNB (next generation NodeB) but also: en-gNB ng-eNB gNB-DU lls-gNB-DU ...
1G	2G	3G	4G	5G

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

5G Architecture – An Evolution?



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…?

China National News

National news service for People's Republic of China

China starts research into 6G technology

ANI - Sunday 11th March, 2018

Beijing [China], Mar 11 (ANI): The Chinese Minister for Industry and Information Technology Miao Wei has announced the beginning of research into the next-generation of mobile communications networks, 6G.

According to the Sputnik, Wei said the start of the research was closely tied to the constant broadening and development of the "Internet of Things."

UNIVERSITY OF OULU

HOW TO APPLY STUDYING RESEARCH COOPERATION

6Genesis

After being a leader in Finland's telecommunications research for more than two decades, University of Oulu has started **Academy of Finland's Flagship programme** 6Genesis. The programme will provide intelligent digital applications and will develop the fundamental 6G competence needed for smart societies.

Mobile Networks Design Approaches

Current Landscape – RRM Complexity

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

Ref. https://www.grandmetric.com/2015/10/30/hetnet-design-challenges/ (M. Dryjanski, M. Szydelko)

A large Radio Resource Management challenge of Multi-RAT/HetNet!

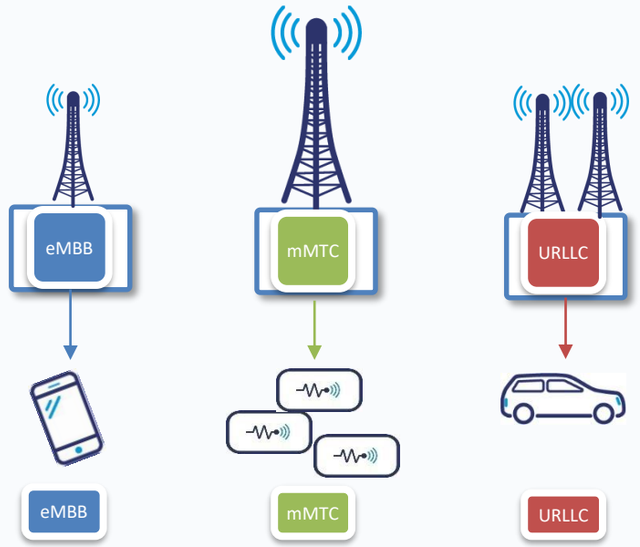
Design Approaches – **Technology vs Purpose**

- 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

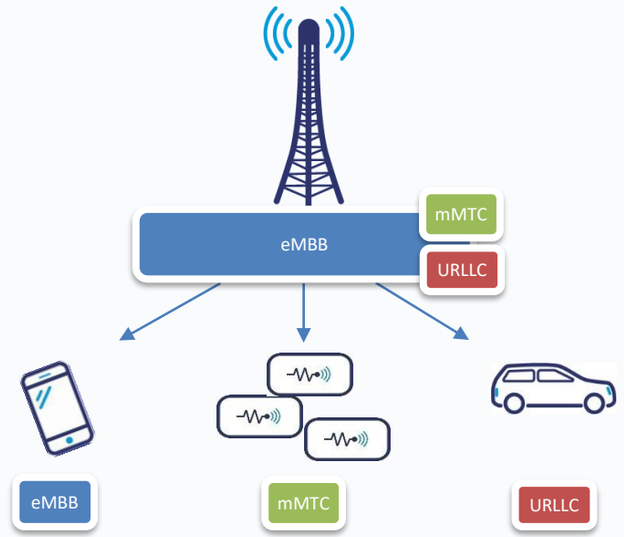
5G is a set of very diverse applications / requirements



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

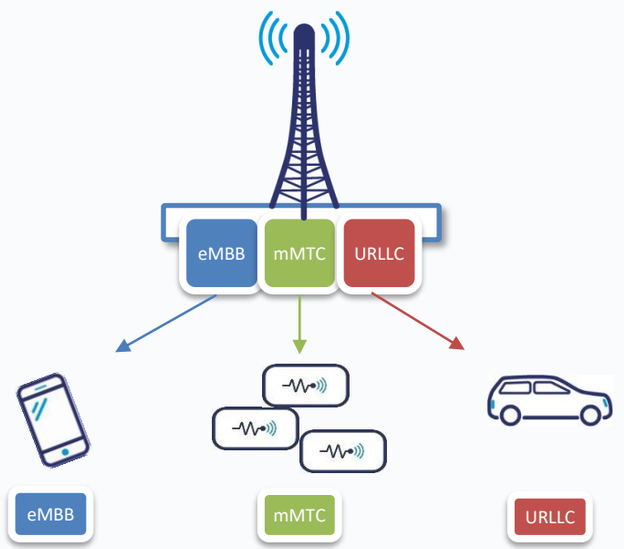
5G is all about IP services (one „use case")



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.

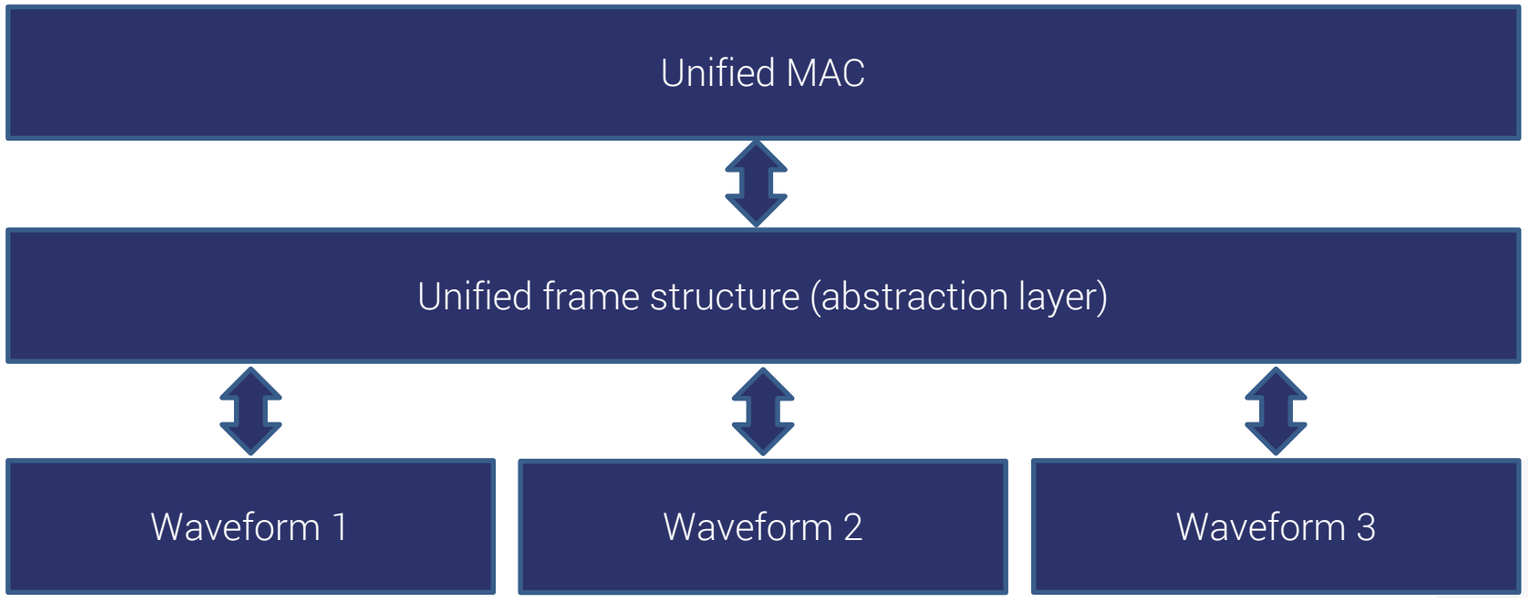
Design Approaches – **Observations**

- 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 difficuilt 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 requriements in advance and design with flexiblity, forward compatibility, and easy "pluginability" is the way to go!

Unified and Hierarchical Framework

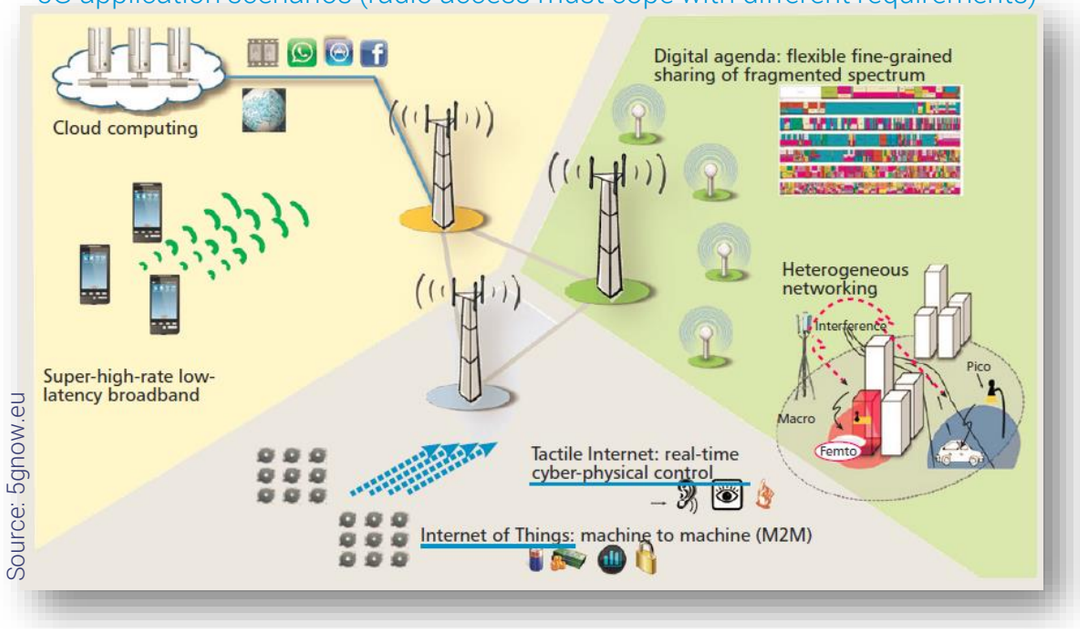
Unified & Hierarchical – **Framework Usage Example**



Unified & Hierarchical– 5GNOW Example

5GNOW Use Cases and Requirements

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



Source: 5gnow.eu

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

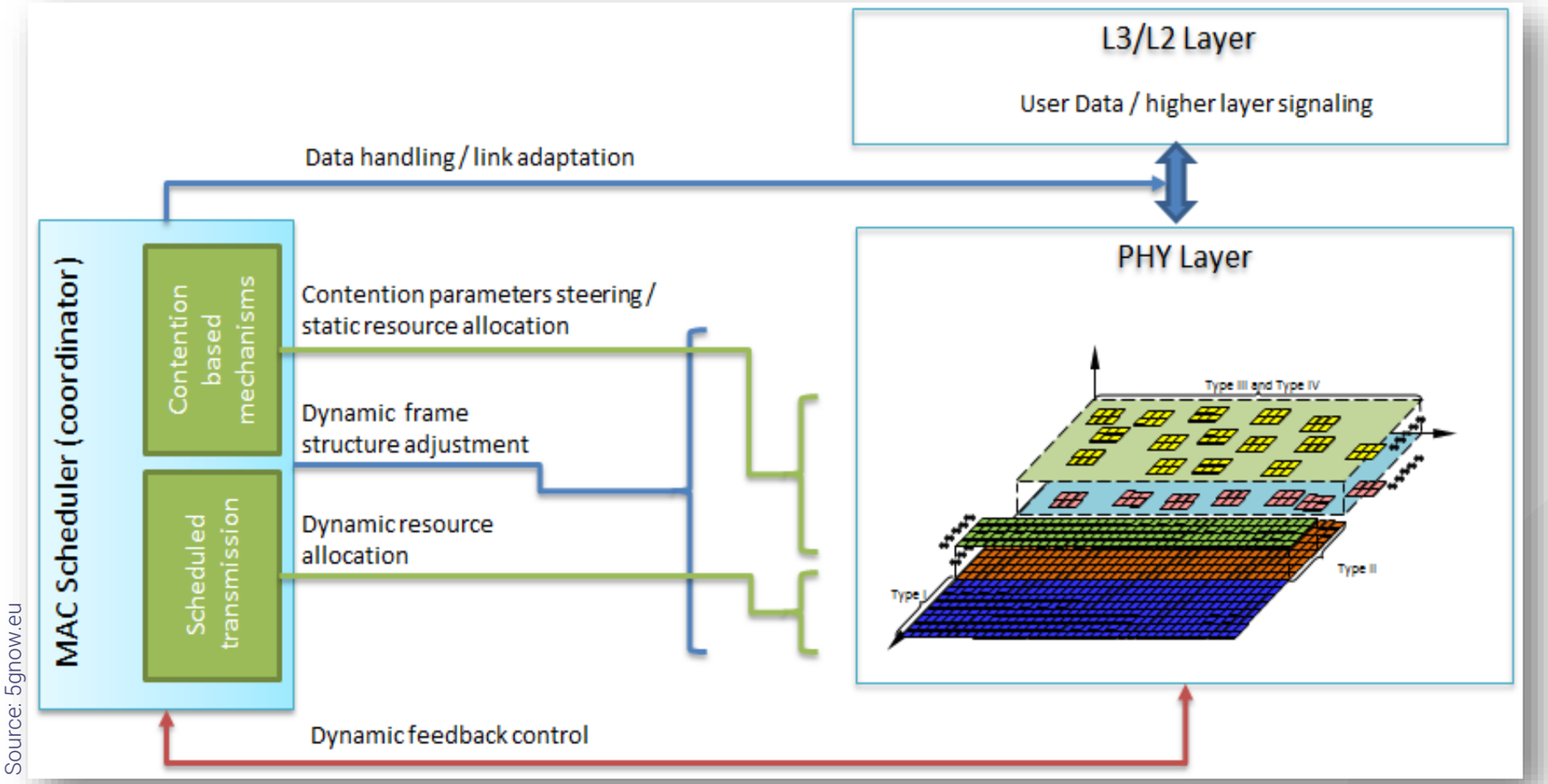
Unified & Hierarchical– **5GNOW Example**

Making a long story short...

- 5G is capturing a lot of use cases, but it's difficuilt to incorporate everything in a single design, and whenever a new use case comes, it needs to be captured somehow.
- You could theoreticaly 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?

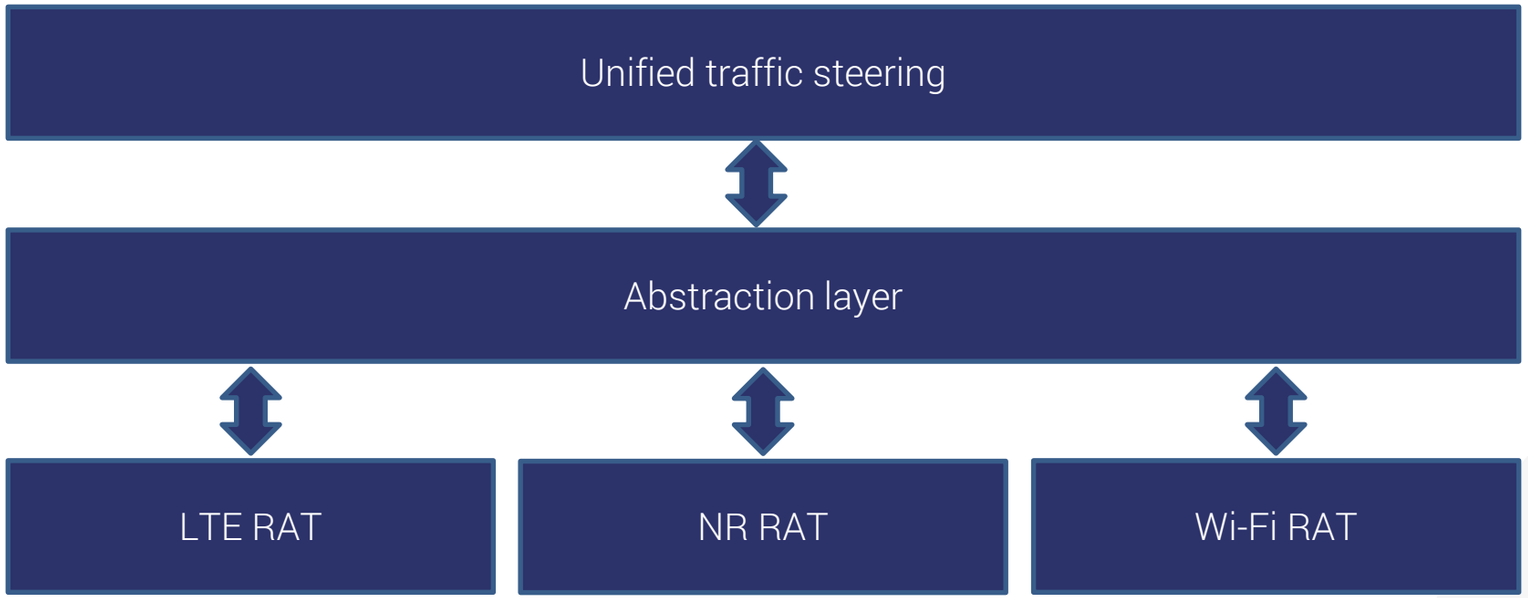
Unified & Hierarchical– 5GNOW Example

5GNOW Unified MAC Interfacing with Unified Frame Structure



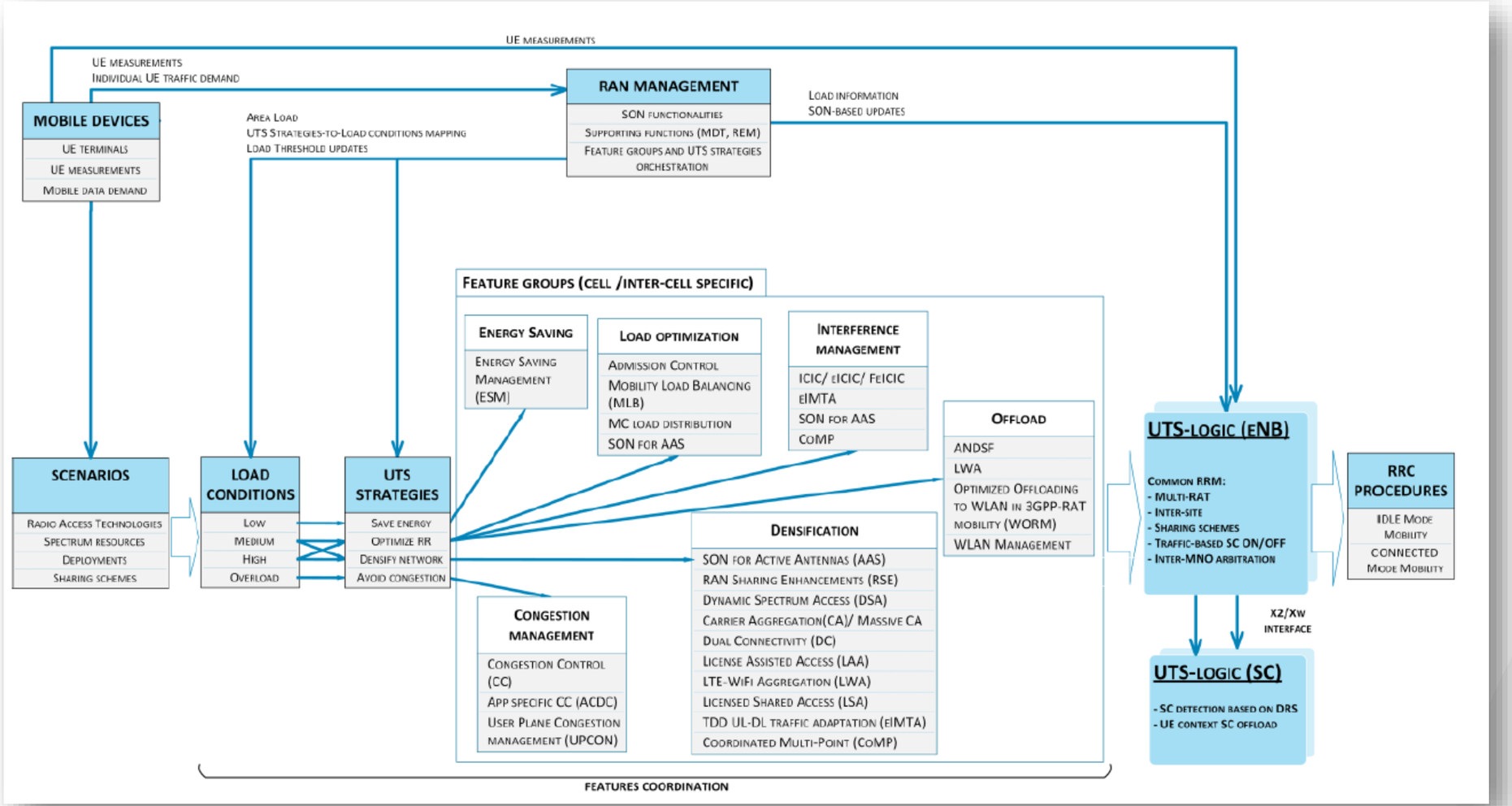
Source: 5gnow.eu

Unified & Hierarchical – **Framework Usage Example**



Unified & Hierarchical– UTS Example

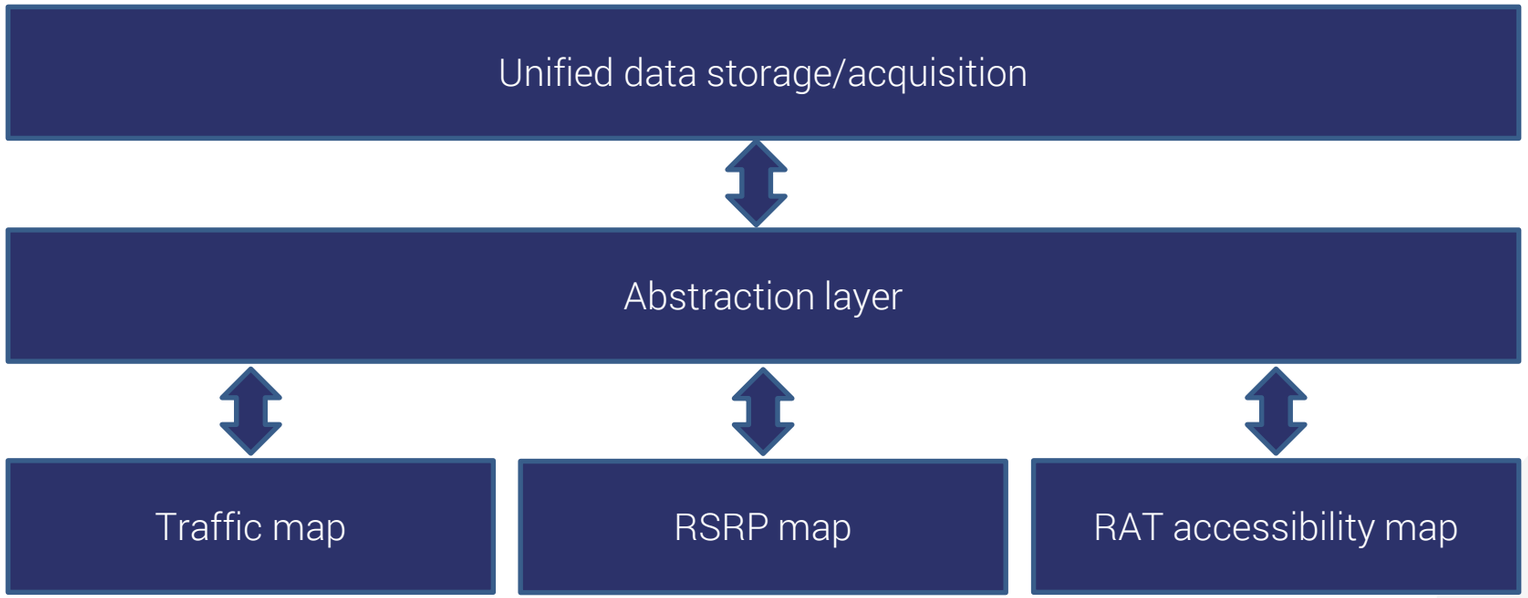
Unified Traffic Steering Framework



New aspects can be incorporated in a straigth-forward manner:

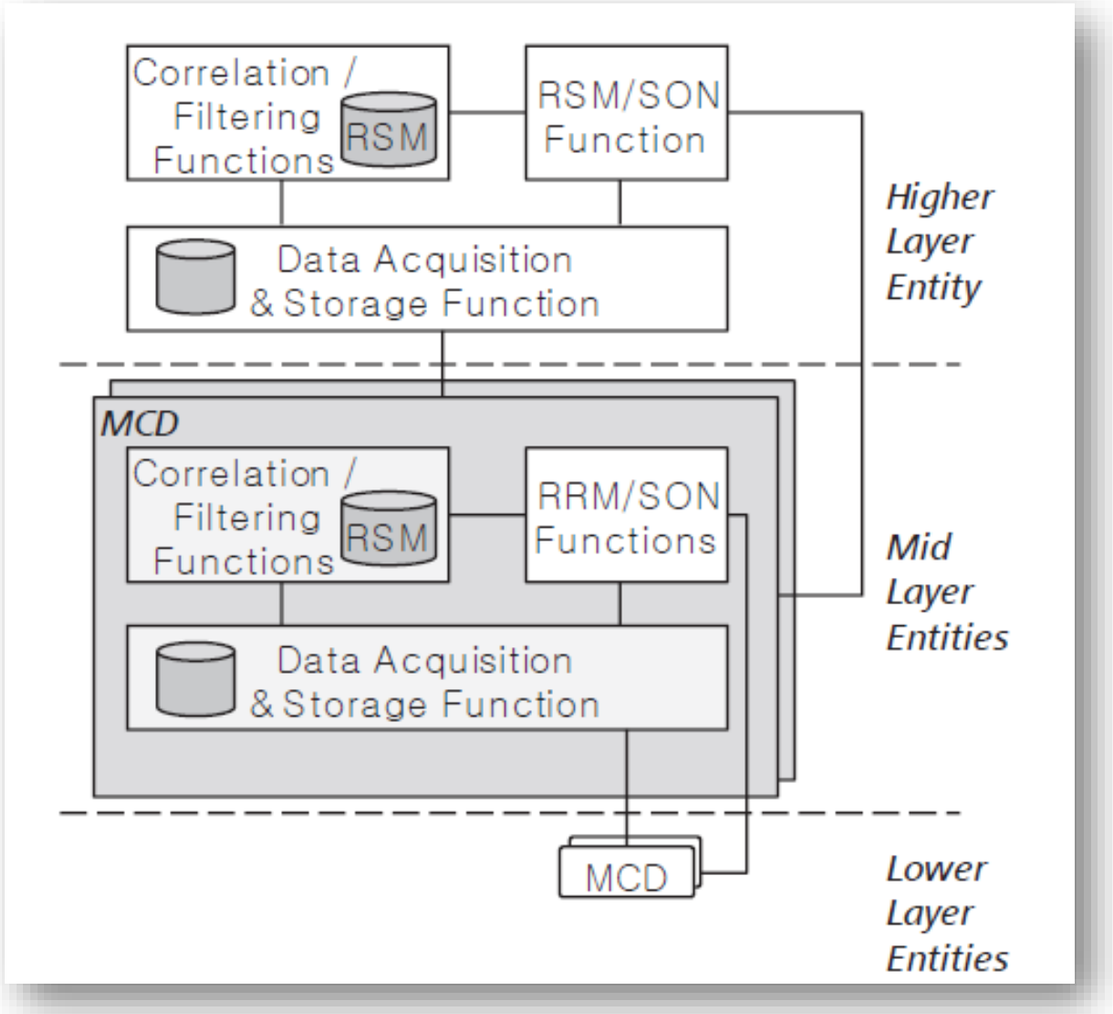
- Load metrics
- Available features
- Available RATs/layers
- Available strategies
- Available procedures

Unified & Hierarchical – **Framework Usage Example**



Unified & Hierarchical– RSM Example

Recursive Radio Service Map Architecture

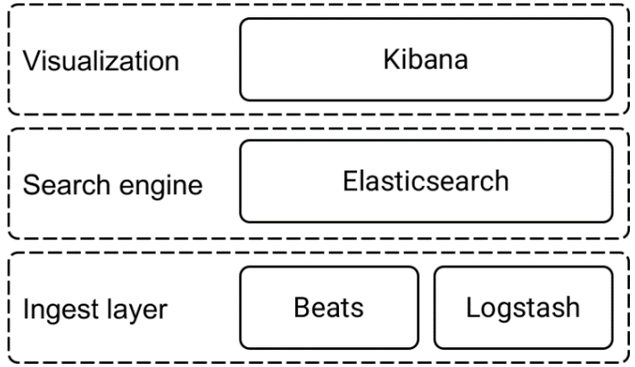


Same maps could support different features:

- 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 posibility 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.

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