Latest Considerations on the 5G RAN Design from the 5G PPP Project METIS-II

Patrick Marsch[1], Icaro Da Silva[2], Ömer Bulakci[3], Milos Tesanovic[4], Salah Eddine El Ayoubi[5] and Mikko Säily[1]

[1]Nokia Bell Labs; [2]Ericsson Research; [3]Huawei ERC; [4]Samsung Electronics; [5]Orange

Objectives and Partners

METIS II

Special focus on pre-standardization

1 Develop the overall 5G radio access network design

2 Provide the 5G collaboration framework within 5G-PPP for a common evaluation of 5G radio access network concepts

3 Prepare concerted action towards regulatory and standardization bodies

19 Partners:

- Operators: NTT Docomo, Orange, Deutsche Telekom, Telefonica, Telecom Italia
- Vendors: Ericsson, Nokia, Huawei, Alcatel-Lucent, Samsung, Intel
- Academia (in Europe): KTH, Uni Pol. Valencia, Uni Kaiserslautern
- SMEs: iDate, Janmedia
- Non-European partners: NYU, Winlab, ITRI

Project coordinator: Olav Queseth, Ericsson

Technical manager: Patrick Marsch, Nokia

RAN Design Focus and Project Scope

METIS-II will provide a complete 5G RAN design according to “technology readiness level 2”, especially focusing on the integration of

- multiple services (eMBB, mMTC and URLLC),
- and various bands (0-100 GHz)

WP 1 – Scenarios, Use Cases, Techno-economic assessment

WP 2 – Overall RAN Design and Performance

WP 6 – Asynchr. Control Functions
(Initial access, RRC, mobility etc.)

WP 5 – Synchronous Control Functions
(RLC, MAC design, RRM etc.)

WP 4 – Air Interface and User Plane Design
(air interface harmonization, integration etc.)

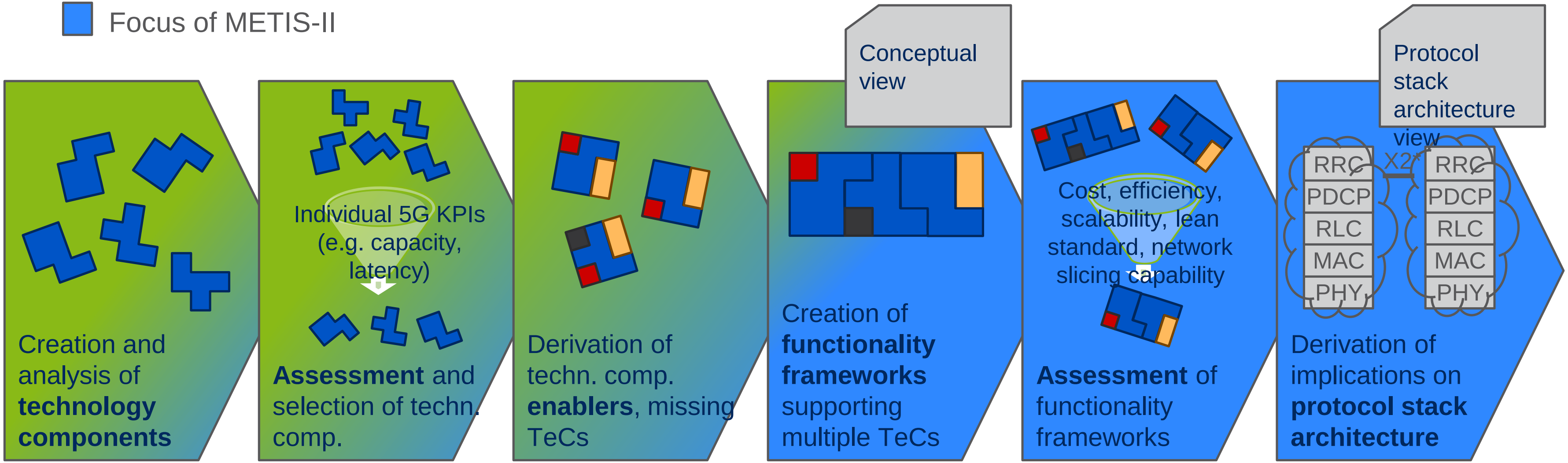
WP 3 – Spectrum
(e.g. spectrum requirements etc.)

WP 7 – Dissemination
(e.g. evaluation & visualization platform)

RAN Design Methodology

Already done in previous projects, e.g. METIS-I, 5GNOW, or taken from other 5G-PPP projects

Focus of METIS-II



Timeline and Key Output so far

2015 | 2016 | 2017 | 2018

5G SI | Rel. 15 WI

METIS-II (2015.07-2017.06)

January 2016:
D 1.1: Scenarios, Requirements

Feb 2016:
Demo at MWC

April 2016:
D 4.1: Air Interface Landscape, UP Design

May 2016:
D 3.1: Spectrum scenarios, requirements > 6 GHz
D 5.1: Synchr. Ctrl. Func., Resource Mgmt.

January 2016:
D 2.1: Performance Evaluation Framework

March 2016:
White Paper: 5G RAN Arch. and Func. Design

June 2016:
D 6.1: Synch. Ctrl. Func.
D 2.2: Draft RAN Design

Use Cases and their Harmonization across 5G PPP Projects

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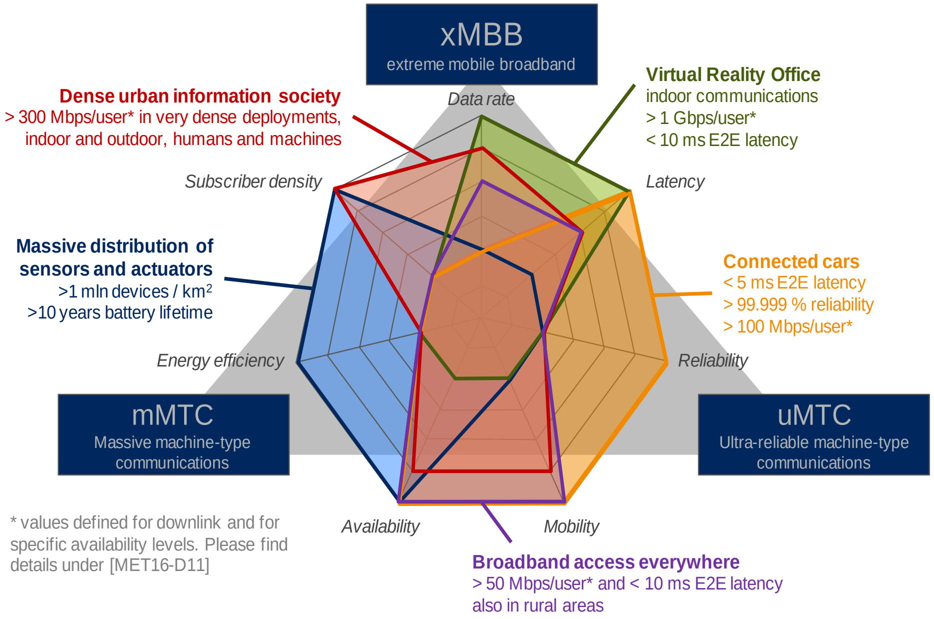
5G Use Cases in METIS-II

Use Case Set

- METIS-I
- ITU-R
- 3GPP
- NGMN
- Other EU projects

METIS-II Use Case

- Dense urban information society
- Virtual reality office
- Broadband access everywhere
- Massive distribution of sensors and actuators
- Connected cars



* values defined for downlink and for specific availability levels. Please find details under [MET16-D11]

With these five use cases, all three generic services (xMBB, uMTC, mMTC) are being addressed.

5G PPP Use Case Harmonization

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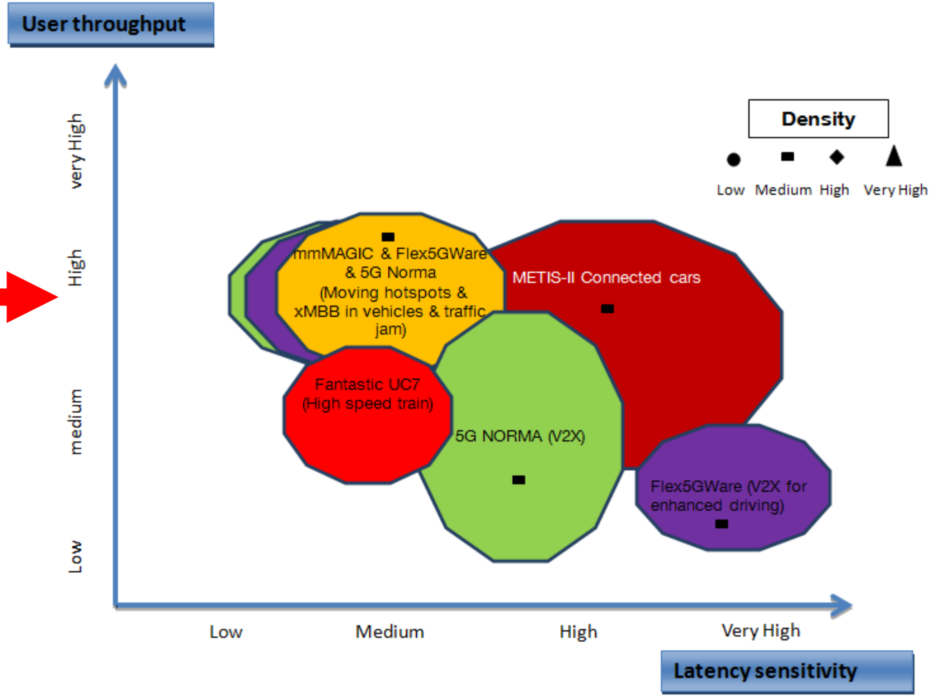
- We worked with other 5G PPP projects towards the harmonization of use cases
- 5 groups of use cases, covering all requirements of vertical industries:

- **Dense urban**
- **Broadband (50+Mbps) everywhere**
- **Connected vehicles**
- **Future smart offices**
- **Low bandwidth IoT**
- **Tactile internet / automation**



Key 5G Architectural and Functional Design Paradigms of METIS-II

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METIS-II Key 5G Architecture Paradigms

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5G RAN – a Harmonized and Integrated Landscape of AIVs	Lean and Future-Proof Design of the 5G RAN	A Logical CN/RAN Split with evolved Interfaces	Moving Functionality from Core Network to RAN: Mobility and Paging in 5G
RAN Protocol Stack Considerations	Functionality on a Faster Time Scale: Agile Traffic Steering and Resource Mgmt	RAN Enablers for Network Slicing	Physical Architecture and Possible Function Splits

The Overall 5G Air Interface

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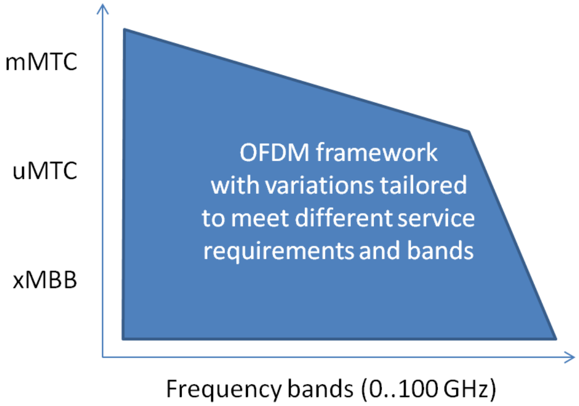
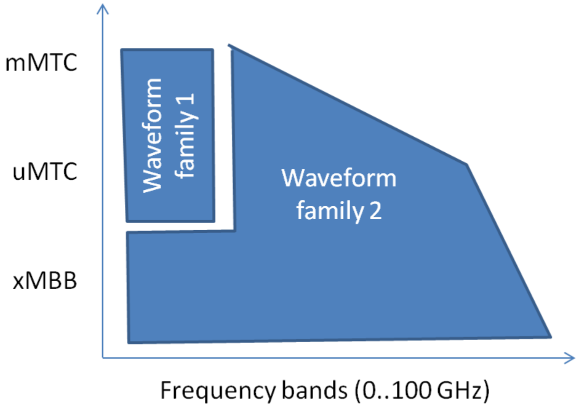
METIS-II envisions that 5G uses a wide range of frequency bands (0-100 GHz), ideally using dedicated and contiguous spectrum

METIS-II envisions the 5G air interface (AI) to be composed of multiple air interface variants (AIVs), including LTE-A evolution and novel AIVs, e.g. tailored to certain frequencies and bands

It is seen essential to strive for a **large extent of harmonization** among AIVs for different bands and services, for reduced complexity, a lean standard, and efficient AIV integration options

It is not concluded whether the overall AI will be based on a single- or multi-waveform approach





5G RAN – a Harmonized and Integrated Landscape of AIVs

Service Tailored Network Functions

There is consensus on the fact that different services in 5G will need tailored network functions in 5G (see examples on right).

It is likely that this can be achieved through parameterization or (de-) selection of generic network functions

	Static Temperature Sensor (mMTC)	Video Streaming (xMBB)	Smart Grid (uMTC)
RRC	HO measurements omitted	State handling optim. for reduced RAN/CN signaling	State handling optim. for reduced state change latency
PDCP	Potential omitting of ciphering and header compression	default	Potential omitting of ciphering and header compression
RLC	Unacknowledged mode only	default	Acknowledged mode only
MAC	H-ARQ optimized for coverage	default	H-ARQ omitted for low-latency, RACH prioritization
PHY	Coding optimized for coverage, energy efficiency	Coding optimized for very large payloads	Coding optimized for short payloads, low latency

5G RAN – a Harmonized and Integrated Landscape of AIVs

AIV Integration

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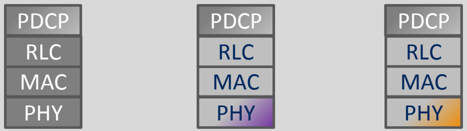
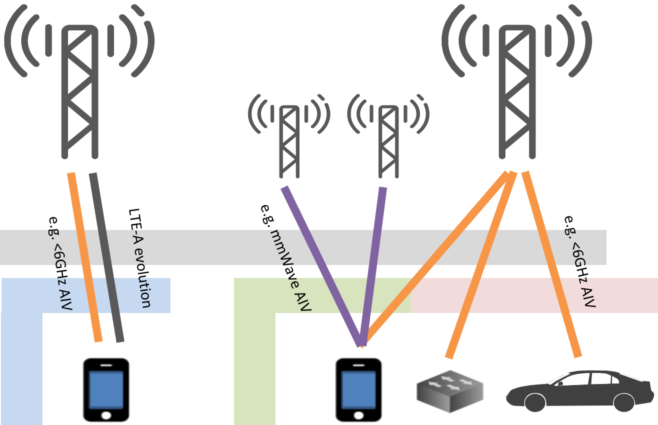
Harmonization



LTE-A evo. e.g. mmWave AIV e.g. <6GHz AIV

- Between LTE-A evo. and novel 5G AIVs, harmonization benefits have to be weighed against legacy constraints imposed towards novel AIVs
- Among novel 5G AIVs, maximum harmonization should be aimed for, but it is not sure whether full harmonization for all bands and services is possible

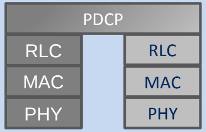


Service Multiplexing

- All novel protocol stack layers and related functions introduced in 5G should natively support service multiplexing for xMBB, mMTC, uMTC*

* Though some bands and related AIVs may be predestined for a subset of services (e.g. mmWave mainly for xMBB)

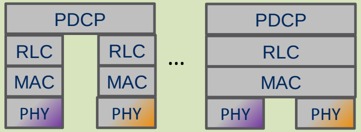
Integration among LTE-A evolution and novel AIVs



LTE-A evo. Novel 5G AIV, e.g. mmWave AIV

- RAN level integration should be supported
- PDCP is seen as a viable UP aggregation layer, though also MAC layer is investigated
- Cases with single and dual RRC protocol instances above PDCP investigated (e.g. one for LTE-A evo. one for novel 5G AIV)

Integration among novel AIVs

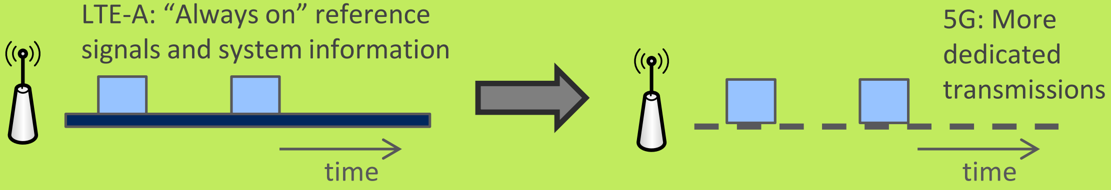


(for instance considering aggregation between mmWave and <6GHz AIV)

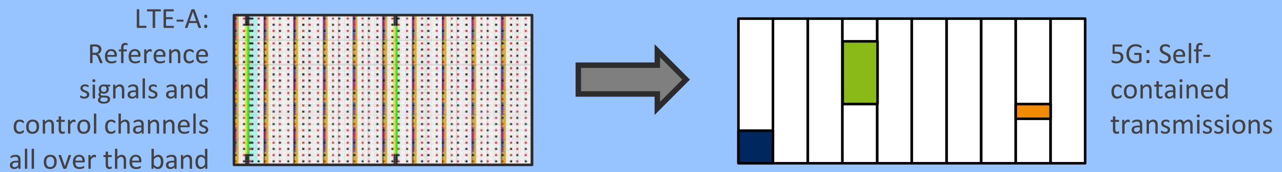
- User plane aggregation could 1take place on PDCP, RLC or MAC level
- Single RRC protocol instance envisioned above PDCP, RRC diversity, fast control plane switching etc. investigated

Lean- and Future-Proof 5G RAN Design

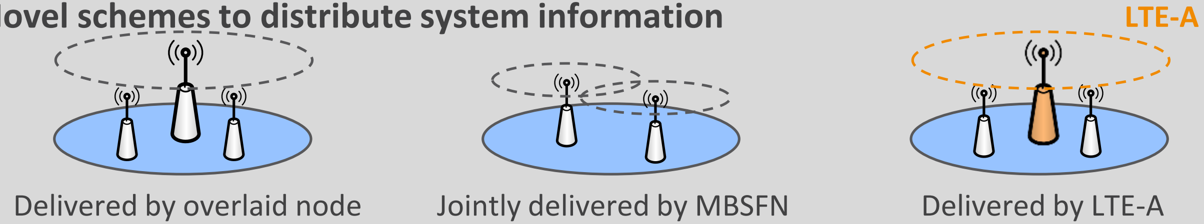
a) Avoid constant and traffic-independent transmission of common signals



b) Self-contained transmissions

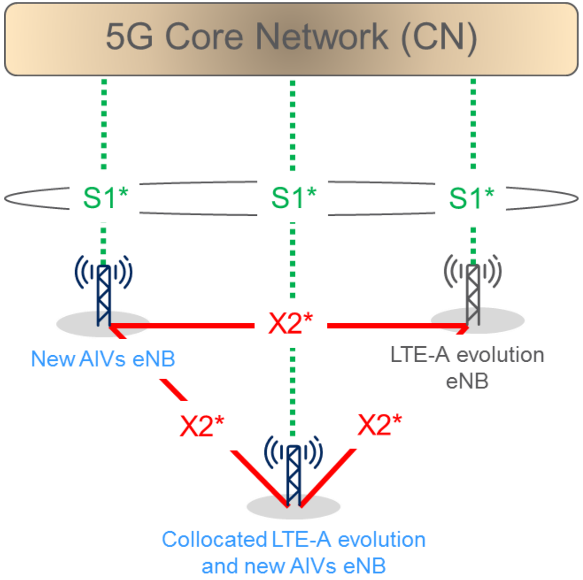


c) Novel schemes to distribute system information



Numerical evaluation needed to determine trade-offs between energy-efficiency and mobility performance

A Logical CN/RAN Split with Evolved Interfaces



A logical CN/RAN split is assumed with the benefits that it:

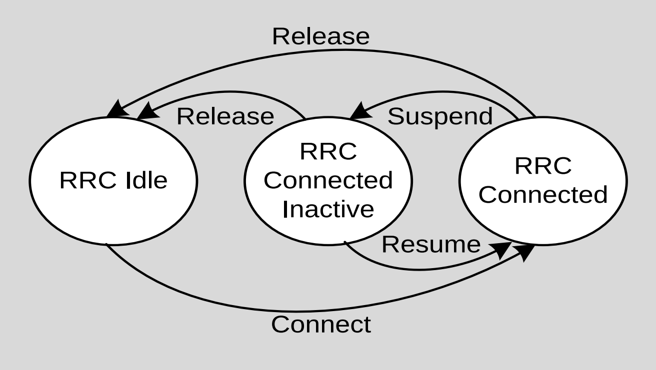
- Allows for an independent evolution of RAN and CN functionality in order to speed up introduction of new technology;
- Facilitates mobility since some CN functions (CP and / or UP) can be kept (anchored) when UEs move to a new RAN node;
- Allows cross-layer optimizations when the functions are co-deployed
- Facilitates multi-vendor CN / RAN interoperability.

A common CN/RAN interface for LTE-A and novel AIVs is seen beneficial because:

- It makes it possible to very quickly establish Dual Connectivity for a UE first connected to a single RAT since there is no need to perform any extra CN/RAN signaling or NAS signaling when adding the second RAT
- It makes it possible to have a common evolution of LTE and novel AIVs where new CN features will benefit both RATs at the same time.
- It simplifies the UE implementation since a single NAS layer is needed for both LTE and NR, hence avoiding a dual protocol stack at the UE.
- It simplifies the RAN / CN interaction since a single connection is used. This gives clear advantages when handling mobility and state transitions

Moving Functionality from CN to RAN

RAN-based Mobility through new RRC State



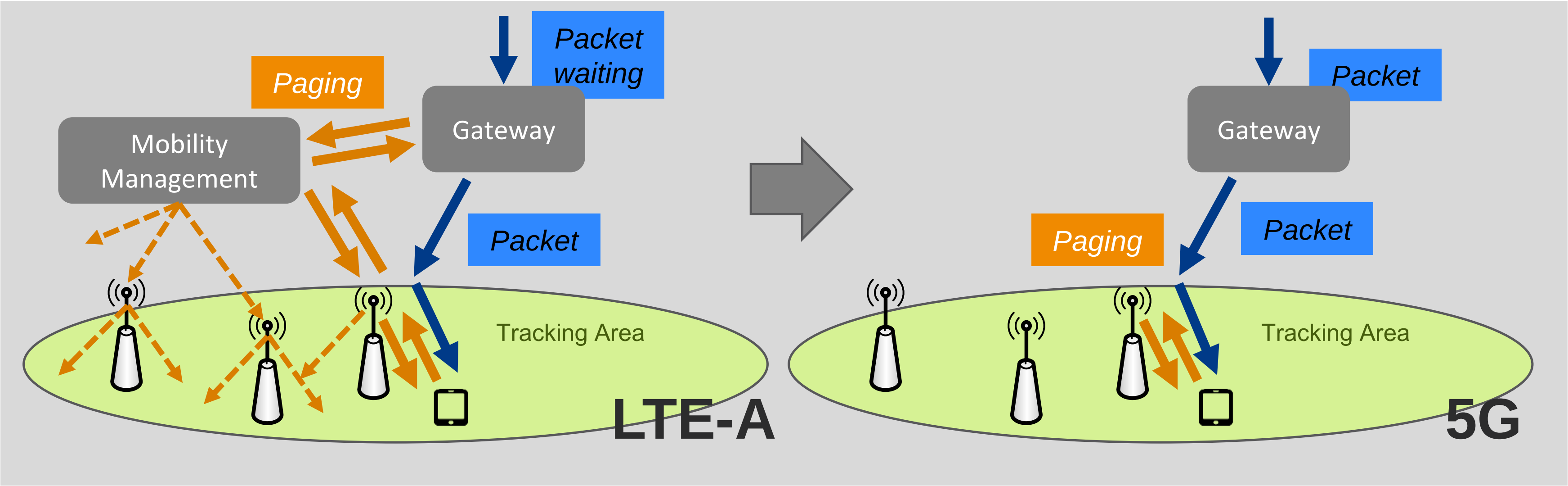
A new "connected_inactive" state is envisioned, with intra-RAN mobility for devices in this state, and service-specific DTX/DRX. **This essentially means that a large extent of mobility is handled within the RAN (also cross-AIV), without core network involvement.**

	4G (Transition from idle to connected)	5G (Trans. from conn. inactive to connected)	Gain
Signaling overhead	13x RRC messages* 8x S1AP msgs** * if the CN has kept some context information ** if the CN has kept some context information	2x RRC msgs Network signaling related to context fetching* * Though this may be negligible if UE returns to same area	At least 70% signaling reduction
Control Plane Latency	RA delay + 3.5x radio RTT + S1 RTT	RA delay + radio RTT	Reduction by 2x radio RTT + S1 RTT

Moving Functionality from CN to RAN

RAN-based Paging

The new RRC state also allows a hierarchical form of paging, where the device location is known to the CN on TA-level, but to the RAN on cell-level. Again this embodies a shift of functionality from CN to RAN level



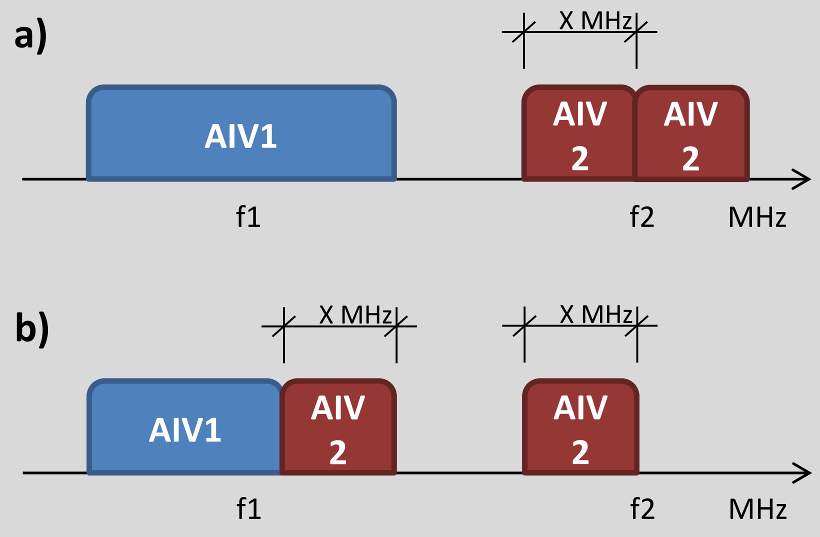
RAN Protocol Stack Considerations

Key changes as opposed to legacy standards foreseen by METIS-II

RRC	• support exclusive beam-based measurements and reporting mechanisms • new ways to distribute and encode system information • new RRC state
PDCP	• compression and decompression may be more strongly tailored to different services • data-recovery procedure will need to be defined for both multi-connectivity among LTE-A evolution and novel 5G radio, as well as among multiple novel AIVs
RLC	• combination of ARQ and HARQ should be further studied. With improved HARQ reliability, ARQ may in some use cases be omitted. • Concatenation and segmentation may be moved to MAC (so that remaining RLC functions are asynchronous, allowing a clearer function split between asynchronous and synchronous)
MAC	• new set of transport formats needed to be defined, possibly with a new transport format selection procedure • improved UL granting signaling to enable greater granularity and control of logical channels • synchronous RLC functionalities such as concatenation and segmentation may be placed here

Functionality on a Faster Time Scale

Dynamic AIV Reconfiguration



SDN-enabled
dynamic reconfiguration of AIVs

It is envisioned that software-defined networking approaches enable a fast reconfiguration (on the order of hours) of air interface variants depending on traffic and service needs, new services rolled out etc. Such reconfiguration would include

- Activation of new AIVs, with the specific chaining of network functions needed
- Change in key parameters of AIVs, such as bandwidth, numerology etc.

Functionality on a Faster Time Scale

Agile Traffic Steering and Resource Management (1)

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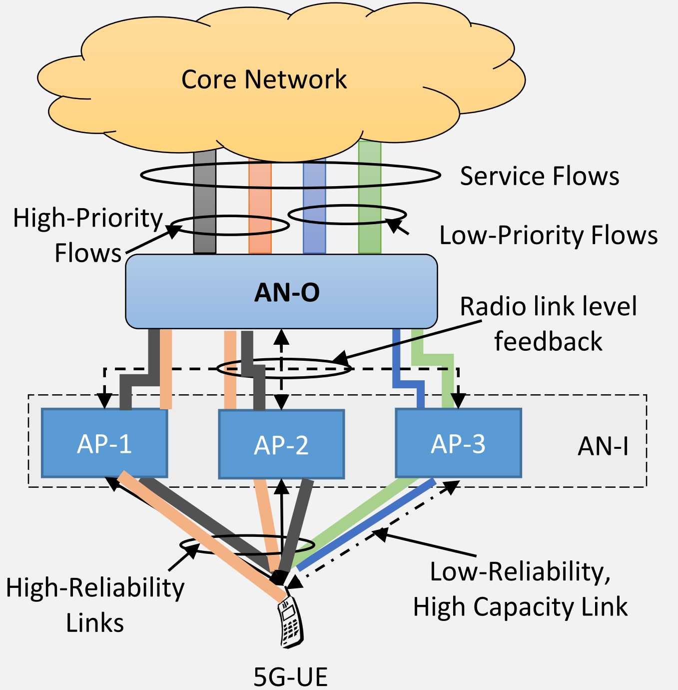
- In legacy systems, traffic steering usually takes place on RRC level, i.e. through handover → In 5G, this is expected to happen on a much lower level in protocol stack and on faster time scale
- In particular, METIS-II envisions the usage of a hierarchical traffic steering and resource management, with an AIV-agnostic outer layer (AN-O) receiving fast feedback from AIV-specific inner layers (AN-I)

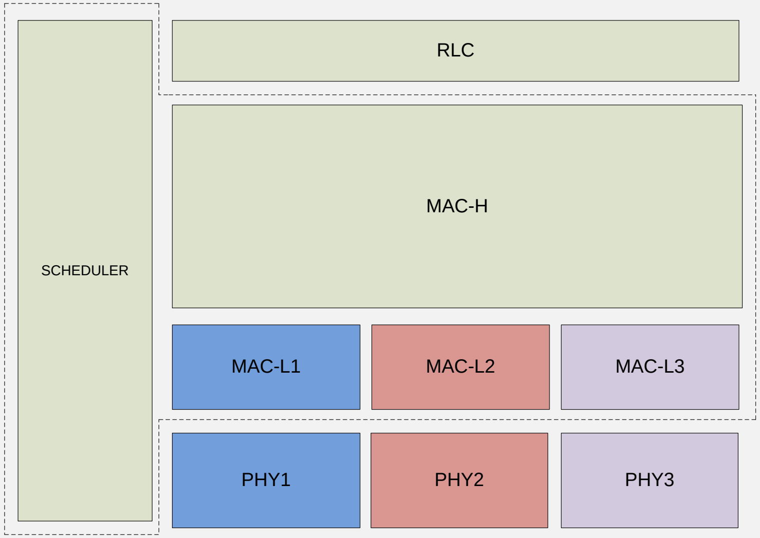


Agile Traffic Steering and Resource Mgmt

Functionality on a Faster Time Scale

Agile Traffic Steering and Resource Management (2)

- Different practical realizations are thinkable, depending on the backhaul/fronthaul architecture and related function split
- One option could be to have a common upper MAC with AIV-agnostic functions (logical channel prioritization, (de-)multiplexing of logical channels, queue management etc.), and individual AIV-specific lower MAC instances (e.g. containing H-ARQ etc.)
- The potential implication on standardization is under discussion



Agile Traffic Steering and Resource Mgmt

RAN Support for Network Slicing

It is foreseen that network slices will be used to form logical E2E networks for particular business constellations

The 5G RAN should
- be slice-aware
- Offer means for slice isolation and protection
- Provide means for efficient resource reuse

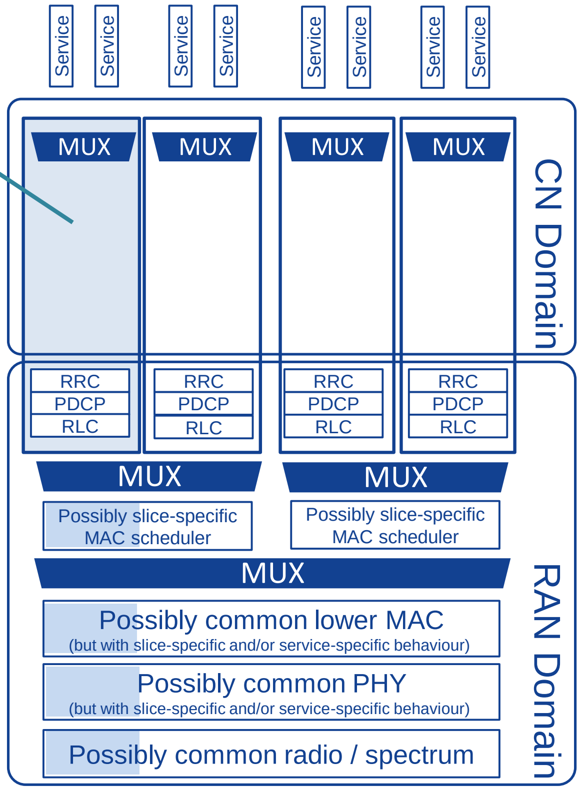
Key questions are yet the assignment of devices to slices and multi-slice connectivity.

Example network slice (E2E logical network)

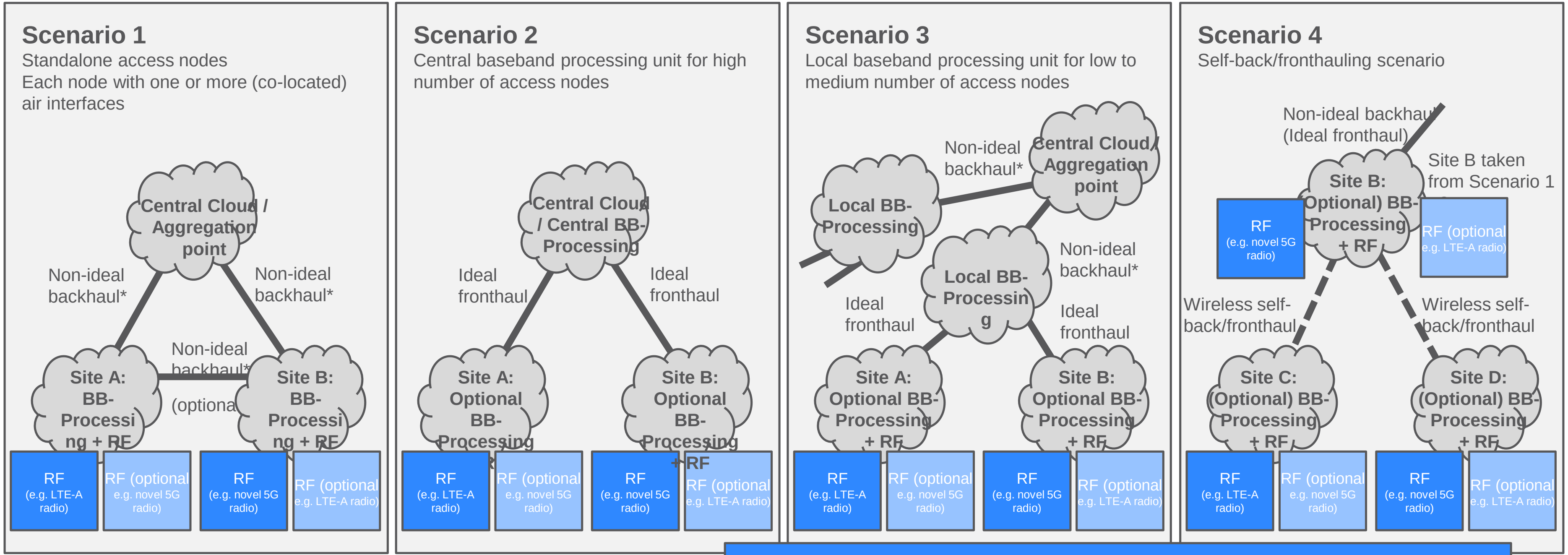
Completely independent realization of network slices in the core network

Likely individual logical protocol instances for different services, highly tailored to these. Possibly slice-specific processing of services

Likely multiple slices and the services therein multiplexed into common instances for lower MAC, PHY, and sharing the same radio. Note that MAC or PHY functions may still be highly slice- or service tailored



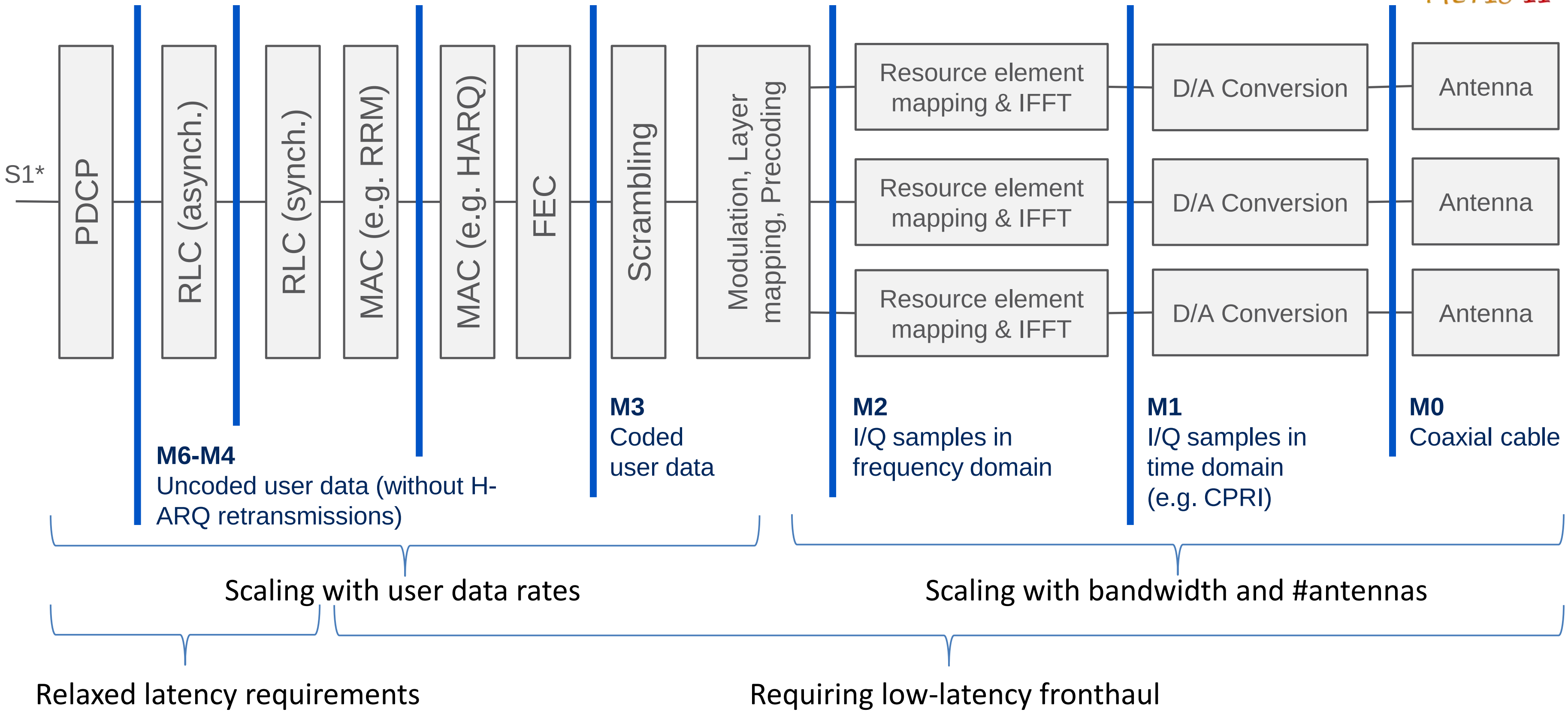
Deployment Scenarios Considered



In METIS-II, all 5G concepts/frameworks developed are evaluated w.r.t. their suitability for the stated four physical network architectures

Physical Architecture

Possible Function Splits



Outlook

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Planned further METIS-II Output

2016	2017	2018

METIS-II (2015.07-2017.06)

October 2016:
R 1.2: Tecno-Econ. Assessment

February 2017:
D2.3 Performance eval.

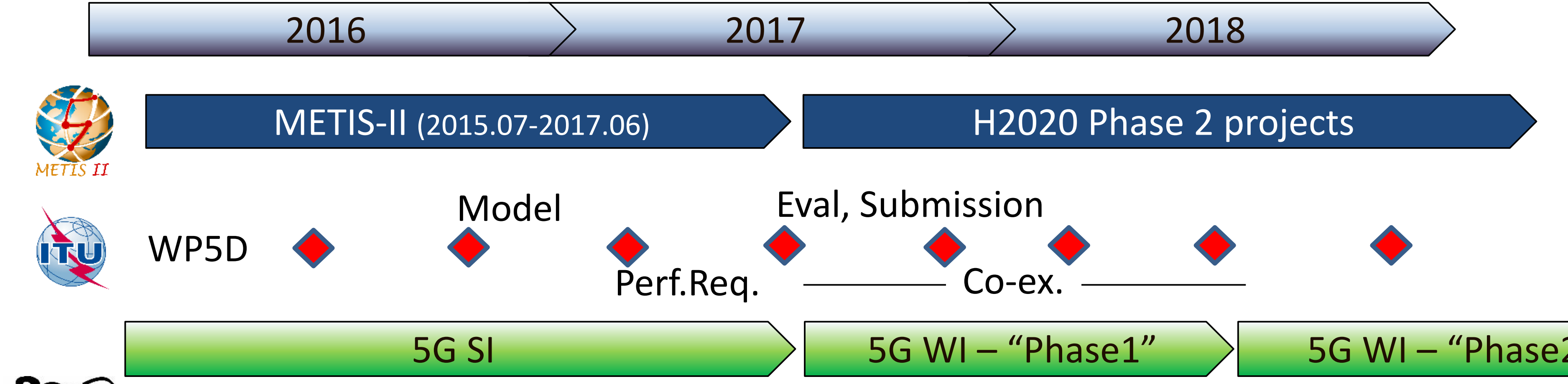
April 2017:
D 1.2: Techno Economics.
D 4.2: Air interf. And UP des.
D6.2 Async control functions

October 2016:
R 2.3: Prel Perf. Evaluation

March 2017:
D 5.2 Sync. Control functions

June 2017:
D 3.2: Spectrum Roadmap
D 2.4: RAN Design

METIS-II w.r.t. 3GPP Work



"All use cases"
Physical layer, protocol architecture and procedures
RAN-CN interface and functional split
Slicing
Qos, SON, D2D (sidelink), Relay

Forward compatible

Interworking LTE, non-3GPP
Licensed and licence assisted

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Thank You

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