Towards a flexible harmonised 5G air interface with multi-service, multi-connectivity support

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Talk overview

› Background: the ‘why’
  – Air interface (AI) flexibility required to support the multiple and diverse services envisaged for 5G

› Technical challenges and key concepts: the ‘what’
  – A critical SotA assessment of where we are, and where we need to go

› Concepts of harmonisation and aggregation: the ‘how’
  – METIS-II approach: achieving compromise between specialized optimization for specific services and the goal to only have one AI supporting multiple services

› 5G AI component candidates
  – Current snapshot of METIS-II proposals under discussion

› Initial observation on harmonisation possibilities

› Key takeaways
Road to 5G

› In addition to meeting more ambitious KPIs than 4G is able to meet today, 5G will need to natively offer multi-connectivity, support for a wide range of frequencies, and multi-service support

› mMTC, uMTC and xMBB* have different (and often diverging) requirements

› Evolutions of 4G AIs may meet some of the KPIs of these individual 5G services, but not the key 5G requirement to natively integrate multi-service support

* Massive Machine-Type Communications – mMTC, Ultra-reliable Machine-Type Communications – uMTC, and Extreme Mobile Broadband – xMBB
LTE evolution v. 5G requirements

› LTE is not well suited for MTC traffic comprising short data packets and transmitted in quick bursts
  – 3GPP has initiated activities (LTE-M) to improve 4G with respect to the support of MTC

› For new applications requiring lower latencies (in many cases 1ms or lower) static LTE structures designed for MBB are not well suited
  – Examples include industrial control and traffic safety and efficiency (Vehicular-to-Everything/V2X use cases)

› Latency is further bounded by consecutive retransmissions based on HARQ process
LTE evolution v. 5G requirements (cont’d)

› 5G needs to facilitate the use of alternative connection types such as Device to Device (D2D)
  – 3GPP has initiated activities to improve 4G with respect to the support of D2D

› Especially for MTC, energy efficiency based on LTE is comparatively poor – low efficiency of active mode

› 5G should also support sensors or other low cost devices
Our AI design principles

› Flexibility by design: 5G AI needs to be adaptable and flexible
› 5G AI should be forward-compatible
› 5G AI should offer easy interworking with evolution of LTE
› Design of 5G AI should be lean, minimizing signalling overhead and unnecessary transmissions
› 5G AI design should take into account the latest information on bands available to mobile; in all likelihood 5G systems will operate across a wide range of mm-wave and cm-wave frequencies
› 5G AI design should take into account terminal complexity as well as network/infrastructure complexity
› 5G AI design should enable APIs to higher layers so as to facilitate the implementation of network slicing
Key AI concepts

› AI comprises the entire protocol stack that is common in the communicating nodes
  – 5G AI is the complete Radio Access Network (RAN) protocol stack (i.e. PHY/MAC/RLC/PDCP/RRC or 5G equivalents) and all related functionalities

› A 5G AI variant (AIV) is the RAN protocol stack and all related functionalities as described above covering a subset of services, bands, cell types

› 5G AI can, hence, be defined as the integration of multiple AIVs
Key AI concepts (cont’d)

› a) individual AIV
› b) the RLC layer over the two PHY/MAC variants harmonised, but not aggregated
› c) aggregated RLC and MAC

the key focus of our work is to determine whether multiple lower layer variants (e.g. PHY, or PHY / MAC variants) could use identical higher protocol stack layers
Further details and assumptions

- Suitable extent of harmonization and integration is to be researched in METIS-II
- METIS-II takes orientation in 3GPP protocol stack, but does not exclude changes
- METIS-II aims to understand how Network Slicing shall be reflected in RAN design
Why harmonise?

› Similar problems are already addressed in current systems like LTE/LTE-A

› The concept of dual connectivity (DC) currently enables to combine radio resources from at least two different network nodes of same or different existing RATs
  – Unlike 3GPP who are limited to co-ordination of different RATs, in our work we have the freedom to integrate the benefits of individual RATs into a harmonized AI
Why harmonise? (cont’d)

› Another related functionality already implemented between GSM, UMTS and LTE is the inter-RAT handover, which basically switches between different AIs depending on their suitability and availability
  – Inability to guarantee an agreed QoS
  – Causes potentially significant delay

› Hence a solution relying on a common protocol layer as envisaged by the harmonization approach in METIS-II can be a response to 5G requirements, without relying on a new network element
Benefits of harmonisation

› Better utilization of available resources due to the flexibility even in short time scales, e.g.,
  – Multiple services being provided using the same frequency
  – Potential of utilizing multiple bands for the same service in a very flexible manner
› Reduced complexity in the access nodes and the end devices, as less functionalities may need to be implemented
› Lower delay in case of switching between air interface variants, as this can happen on a rather low protocol layer
› Less standardization and implementation effort, as less functionalities have to be specified and tested, and
› Simpler upgrading of an existing system by implementing additional air interface variants
**Types of harmonisation**

- a) Separated stacks;
- b) Harmonized PDCP, RLC and MAC;
- c) Aggregation by using a single instance of PDCP, RLC and MAC; and
- d) Usage of different RLC but with harmonized MAC
What to harmonise?

› METIS-II has selected a number of promising AI variants, based on the examination of the underlying technologies

› These AIVs help meet one or more 5G KPIs, and conform to one or more 5G AI design principles presented earlier

› On the topic of selected AIV candidates, it should finally be noted that other 5G-PPP projects may design new AIVs not captured by our current survey
  – METIS-II continues to liaise with these other projects
<table>
<thead>
<tr>
<th>Name</th>
<th>Motivation</th>
<th>Waveform details</th>
<th>Frame structure</th>
<th>Main features</th>
<th>Frequency bands</th>
<th>Other PHY details</th>
</tr>
</thead>
<tbody>
<tr>
<td>OQAM/ FBMC</td>
<td>Low OOB emissions, flexible sub-band configurations, better spectral efficiency, higher robustness to time/freq. distortions</td>
<td>Filtering per subcarrier, time/freq. localized filter design, no Cyclic Prefix (CP), QAM: real-field orthogonality</td>
<td>Scalable frame design, enabling service-specific adaptations. QAM poses constraints</td>
<td>Supports async. transmission; efficient spectrum sharing</td>
<td>Original design for &lt;6 GHz. Applicability for above 6 GHz.</td>
<td>Due to OQAM modulation, adaptations are necessary for some MIMO schemes.</td>
</tr>
<tr>
<td>QAM/ FBMC</td>
<td>Low OOB emissions, flexible sub-band configurations, better spectral efficiency, OFDM compatible</td>
<td>Separate filters for even- and odd-numbered sub-carrier symbols, no CP, QAM: complex-field orthogonality</td>
<td>Supports multiple numerology sets</td>
<td>Supports async. FDMA transm., efficient spectrum sharing</td>
<td>Original design for &lt;6 GHz. Applicability for above 6 GHz.</td>
<td>All MIMO schemes supported. QAM modul., LDPC coding preferred over turbo.</td>
</tr>
<tr>
<td>P-OFDM (pulse shaped OFDM)</td>
<td>Low OOB emissions, flexible sub-band configurations, higher robustness to time/freq. distortions, OFDM compatible</td>
<td>Filtering per subcarrier, time/freq. localized filter design, QAM: complex-field orthogonality</td>
<td>Scalable frame design, enabling service-specific adaptations</td>
<td>Supports async. transmission, efficient spectrum sharing, robust to phase noise</td>
<td>Original design for &lt;6 GHz. Applicability for above 6 GHz.</td>
<td>All MIMO schemes supported. Modul. &amp; coding like in LTE</td>
</tr>
<tr>
<td>F-OFDM / UF-OFDM based user-centric multi-service air interface</td>
<td>Low OOB emissions, flexible sub-band configurations, OFDM compatible</td>
<td>Filtering per sub-band (aggregation of M subcarriers) with steep roll-off</td>
<td>Scalable frame design, enabling service-specific adaptations</td>
<td>Supports async. FDMA transm., efficient spectrum sharing</td>
<td>Original design for &lt;6 GHz. Applicability for above 6 GHz.</td>
<td>All MIMO schemes supported. Modul. &amp; coding like in LTE</td>
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## Selected AIVs (cont’d)

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<td>CP-OFDM for xMBB in mm-wave bands</td>
<td>Support mm-wave transmission &amp; adaptive beamforming for hotspots targeting high data rates and short E2E delay</td>
<td>CP-OFDM for ease of implementation and backward compatibility with LTE/LTE-A</td>
<td>Follows the LTE resource grid, frame length &amp; symbol duration significantly shortened</td>
<td>Beam scheduling</td>
<td>Above 6GHz with focus on mm-wave.</td>
<td>Both short and long CP supported; QAM modul. &amp; LDPC (preferred over turbo), MIMO support</td>
</tr>
<tr>
<td>CP-OFDM for Cell-edge/Energy Efficient Application</td>
<td>Increasing cell-edge rate, reducing PAPR</td>
<td>FQAM based on OFDM (other WF also possible)</td>
<td>Follows the LTE resource grid</td>
<td>Tailored for cell edge users and energy constrained services</td>
<td>Mainly for below 6GHz.</td>
<td>QAM &amp; LDPC (preferred over turbo), MIMO support</td>
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<td>Harmonized OFDM enhancements</td>
<td>Harmonized CP-OFDM with scalable numerology for different operating frequencies, low OOB emissions</td>
<td>CP-OFDM for DL/UL/D2D, SC-FDMA for UL, zero-tail SC-FDMA and OFDM for D2D, F-OFDM optionally</td>
<td>Support for flexible TDD with scalable and flexible numerology, dynamic TTI sizes, short subframes (~0.2 ms)</td>
<td>Multiple numerology sets for scaling in time &amp; freq., multiplexing of different services using flexible spectrum sharing</td>
<td>Both above &amp; below 6GHz; Multiple carrier frequencies with target bandwidths of 5 MHz to 2 GHz</td>
<td>LTE-like modul. up to 256 QAM; new DL &amp; UL control channels embedded within a subframe, MIMO support</td>
</tr>
<tr>
<td>Communication with Relaxed Synchronism (CRS)</td>
<td>D2D with relaxed synchronism requirements and MTC with low power budget</td>
<td>FBMC, UFMC or F-OFDM</td>
<td>Any frame structure with a low quantity of sync. signals</td>
<td>Tailored for D2D and MTC with high data rate</td>
<td>Any, scalable bandwidth</td>
<td>MCS-agnostic, MIMO support</td>
</tr>
<tr>
<td>Communication with Non-Coherent Reception (CNCR)</td>
<td>Pilot signal overhead can be drastically reduced for non-coherent reception</td>
<td>Any WF that provides negligible ISI</td>
<td>Any frame structure with a low quantity of pilot signals</td>
<td>Tailored for V2V and massive MIMO in high-mobility scenarios</td>
<td>Any, scalable bandwidth</td>
<td>Modulation: DUSTM and Grassmannian constellations, MIMO support</td>
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Initial observations

- The co-existence of different waveforms (e.g. OFDM / FBMC based solutions) in the same band is a key element of many AIV proposals under consideration.
- It is further noted that in some cases certain aspects of proposed AIVs could work with both OFDM and FBMC based solutions.
- Implementation complexity / performance trade-offs play an important role in proposal selection and will be made further challenging by the desire to harmonize functionalities.
- Not all AIVs are applicable for all bands of interest to METIS-II, as shown in the “Frequency band” column in the Table above.
- Widespread use of QAM is noted, except in certain very special cases (CRS and CNCR).
- Use of LTE-like resource grid is noted but with heterogeneous numerology.
Role of LTE evolution in 5G

› LTE-A and its evolution is likely to play a pivotal role in the overall 5G system

› The exact mechanics of integration of LTE-A evolution into the overall 5G system are an important research topic in METIS-II

› Among LTE-A evolution and novel 5G AIVs, user plane aggregation on PDCP level is initially investigated
Key takeaways

› We elaborated our 5G AI design principles
› Based on these we introduced concepts of harmonisation and aggregation
› We then selected a set of AIVs which meet some or many of the 5G KPIs and which follow our design principles
› We then additionally presented initial observations on the harmonisation possibilities of these AIVs
› In future work we will address the following:
  – which forms of AI aggregation are foreseen for 5G, and
  – on which protocol level novel AIs should ideally be integrated among each other and with legacy technologies such as LTE-A and its evolution
Thank You
http://www.metis2020.com