Beyond-5G Radio Interface:
Some considerations from the 5G-PPP projects

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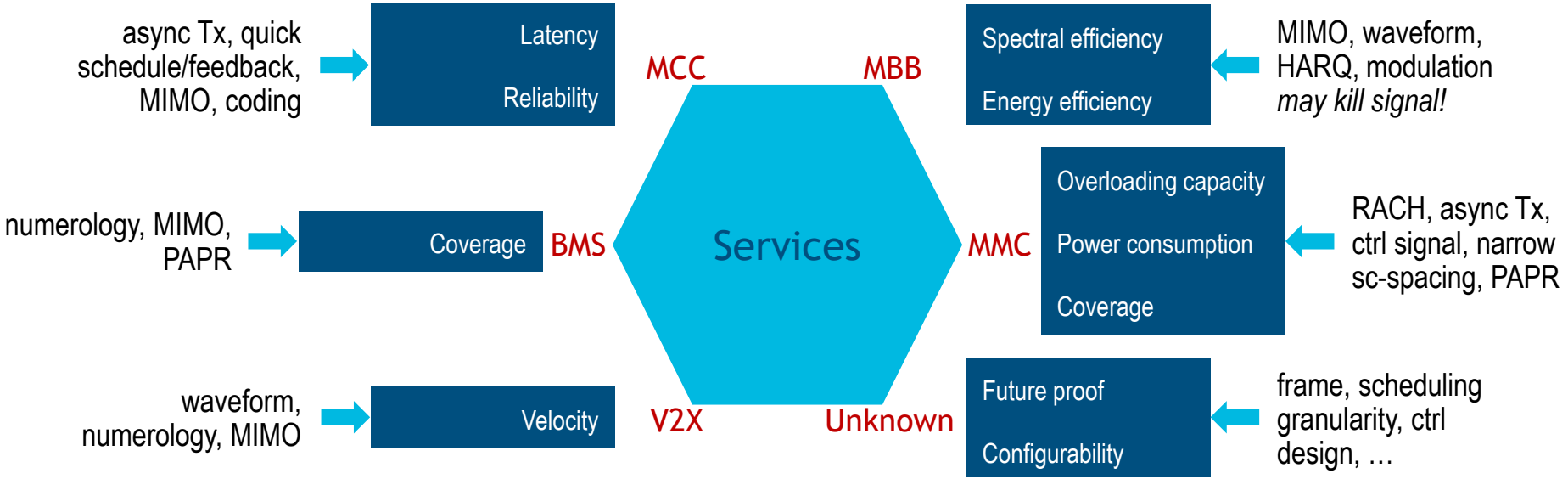
Outline

- Overview on technologies which are partly investigated within past and ongoing EU 5G-PPP projects (e.g. FANTASTIC-5G, ONE5G)
- FANTASTIC-5G: Technology development and contribution to 3GPP NR
- ONE5G: Technology development and impact on 3GPP NR and advanced 5G
- Future radio interface and some challenges
- Discussion

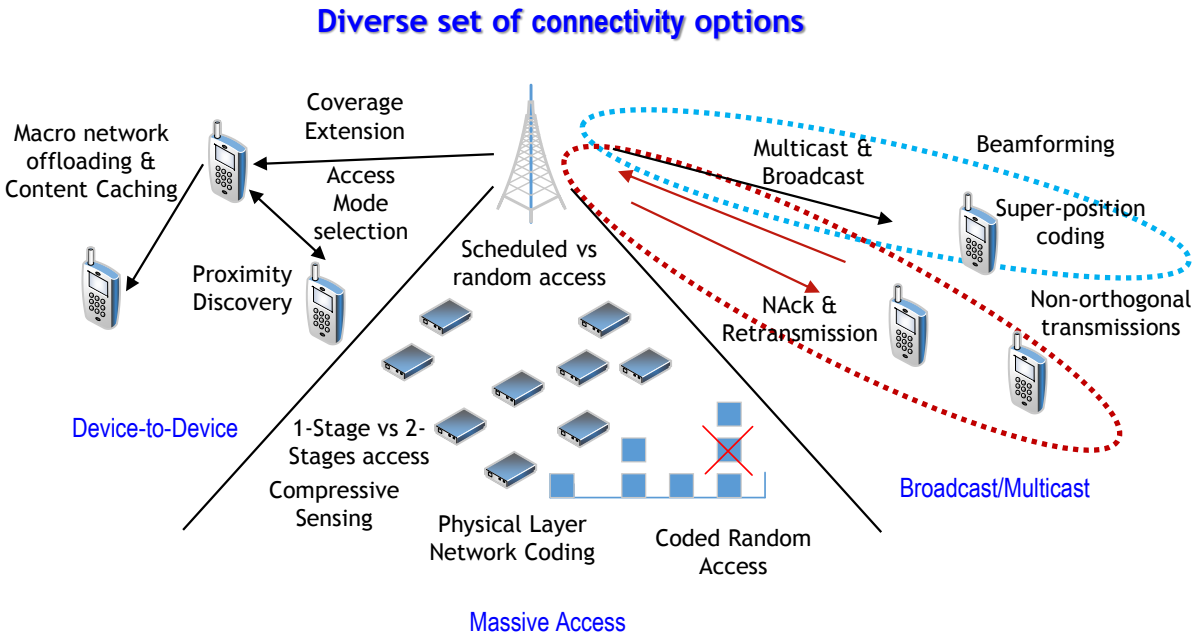
FANTASTIC-5G: Link design



FANTASTIC-5G: *Flexible Air iNTerfAce for Scalable service delivery wiThin wIreless Communication networks of the 5th Generation*

FANTASTIC-5G: Network design

- Multi-node connectivity
- Mobility enhancements
- Multi-service scheduling
- Service classification
- Massive access MTC solutions
- Broadcast/multicast
- Network-based ICIC
- System-level mMIMO integration
- Advanced receivers
- …



FANTASTIC-5G: Some technologies/work adopted in 3GPP NR

- Specification transparent filtering or windowing design, e.g. filtered/windowed OFDM.
- DFT-s-OFDM and CP-OFDM based waveforms are supported for UL.
- 15KHz based power of 2 scaling subcarrier spacing.
- Different numerologies mux in the same carrier bandwidth in the form of confined resource block group.
- Configurable frame structure.
- Configurable HARQ timing.
- Multi-bit HARQ feedback.
- Three state RRC machinery.
- Enhanced mobility with reduced interruption times.
- Dynamic scheduling with different TTI sizes, punctured scheduling, etc.
- mMIMO with GoB (grid of beams) and enhanced CSI acquisition.
- ...

ONE5G: Overview

- The European-funded 5GPPP project ONE5G tackles the design of advanced air-interface technologies and optimizations from an end-to-end (E2E) perspective for 5G, beyond the first standard release (3GPP Rel. 15).
  - 14 partners, 8 M€ and 2 years (5G PPP Phase 2).
  - PM: F. Schaich (Nokia), TM: M.-H. Hamon (Orange).
- The project aims at researching advanced link enhancements beyond Rel. 15, moving 5G to "5G advanced", incl. optimizations for both the network operator and the E2E user-experienced performance.

- ONE5G will upgrade the first version of 5G to be more comprehensive:
  - Address all services (eMBB, URLLC, mMTC), incl. verticals.
  - In various environments, from dense urban (megacity) to large underserved areas.

***ONE5G**: E2E-aware Optimizations and advancements for the Network Edge of 5G New Radio*

ONE5G

ONE5G: Multi-service access solution

- **Goals:** Propose enhancements to meet the new requirements set by URLLC and mMTC services and develop access schemes to facilitate multi-service operation.
- **Reliable signalling**
  - New URLLC schemes (e.g. sidelink assisted HARQ, reliability-enhancing frame design/RRM).
  - Control signaling overhead optimization for short packets.
  - User scheduling and RRM for URLLC services.
  - Secure access schemes for URLLC and mMTC - exploit the inherent retransmission procedure associated with random access to encode information and enable security.
- **Non-orthogonal multiple access (NOMA) and code design**
  - Non-orthogonal cooperative wireless communication with limited feedback.
  - NOMA without cooperation: Design enhanced random access protocols, allowing user collisions which can be resolved with advanced receivers.
  - Signal shaping for MIMO channels, esp. for backhauling applications.
  - Massive access schemes that jointly consider the code and space domain, esp. for co-located users.
  - Implementation aspects and receiver complexity reduction.

ONE5G: Massive MIMO enablers towards practical implementation

- **Goals:** Develop advanced CSI acquisition techniques for massive MIMO with minimum complexity, and integrate hardware constraints into the design of transmission schemes.
- **Massive MIMO enabling technologies**
  - Interference coordination, scheduling, and precoding with cylindrical arrays.
  - Beyond uniform rectangular and cylindrical array formats to optimize spatial diversity and multiplexing.
  - New beamforming schemes for new services, network functionalities and coverage enhancement (e.g. MIMO multicasting for V2X, wireless backhaul beamforming in sub 6GHz, etc).
  - Low complexity Hybrid beamforming, hybrid beamforming for MU-MIMO.
- **Advanced pilot and feedback design for mMIMO**
  - Enhanced channel estimation and feedback with reduced signaling overhead and improved accuracy.
  - Joint UL/DL channel estimation and MIMO detection.
  - Advanced pilot contamination mitigation techniques exploiting the inherent channel structures.
  - Covariance based clustering schemes in FDD mode to reduce feedback (and scheduling) complexity.

ONE5G: Advanced link management

- **Goals:** Develop innovative multi-nodes schemes to improve the scalability and interference mitigation capabilities of heterogeneous links (macro, micro, D2D,…).
- **Advanced node collaboration and link state prediction**
  - Prediction and control of network link states for C-RAN via compressed sensing.
  - Enhanced new coordination schemes with low-overhead signaling for dense multi-node cooperation and interference management.
  - Signaling schemes for co-existence of D2D and cellular mMIMO in TDD mode.
- **Cell-less design**
  - Interference management and distributed learning in cell-less systems.
  - Cell-less design in multi-service network: Functional split of C-RAN functionalities among RRHs and BBU pools.
  - Multicast beamforming in cell-less systems.
  - Non-linear beamforming based on machine learning.

Future radio interface and some challenges

- Network capacities for simple point-to-point and point-to-multipoint MIMO channels are known. Less is known on multipoint-to-multipoint capacity → **5G systems are far from making full use of the possibilities** offered by an advanced distributed multipoint radio interface.
- Future radio technologies will target various frequency bands, licensed and unlicensed spectrum, different service types (eMBB, URLLC, mMTC, ...), different types of devices (high/low power, high/low computational complexity, …), etc.
- **Some Challenges**
  - Develop flexible cross-layer networking schemes and advanced collaboration strategies to support the heterogeneous technologies and services.
  - Integrate diverse components such as D2D and multicasting in coordinated mMIMO systems, taking into account interference and mobility.
  - Improved integration of hardware impairments in the modeling of mMIMO arrays to better predict performance and possible limitations.
  - Integration of full-duplex systems.

Discussion

- 3GPP NR is progressing with eMBB (Phase 1), URLLC (Phase 2), mMTC, etc. Many 5G candidate technologies not yet adopted. They may be utilized for Beyond-5G.
- mMIMO mainly regarded as an enabler for eMBB, it can be used for further applications, e.g.
  - Positioning by exploiting the increased spatial resolution of massive MIMO.
  - Physical layer security by using the increased degrees of freedom and beamforming capabilities.
- Network coding for physical and higher layers.
- Further advanced fundamental technologies for modulation, coding, synchronization, MIMO, ...
- Cognition, context awareness, caching, cell edge computing, etc.
- Machine learning, artificial intelligence, neural networks, etc.
  - Advances in hardware and increased computational power may make their use in cellular networks realistic.
  - Applicable (e.g. for B5G) to communication and control, RRM, network coordination, channel prediction, etc.
- Future applications & services: Vertical industries, IoT (large/small scale, mega/nano scale, …), etc.

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Thanks!

Questions?