Bending the Boundaries: METIS Research towards a Flexible 5G PHY

Malte Schellmann and Ömer Bulakci *

Huawei ERC, Munich, Germany

***Abstract*—Scenarios envisaged for mobile and wireless communication systems beyond 2020 suggest a multitude of different applications and services being provided simultaneously, where each one imposes its particular demands and requirements on the system. To appropriately respond to these diverse requirements while ensuring an efficient usage of available spectrum and system resources, the air interface of 5G system should be capable of providing much more flexibility compared to today's systems. A brief overview on METIS radio link technologies enabling this flexibility is given in this article.**

FUTURE radio communication systems are expected to provide a huge variety of different services, posing highly diverse requirements on the system design. While the types and number of simultaneously requested services of human-driven communications may continue to increase steadily, a multitude of machine-type devices will access the network additionally, acting as agents for a large variety of new services, which may, for example, support facility operations, public safety features, tracking of goods, and monitoring current conditions in local areas. These machine-type devices may themselves come with highly diverse requirements, encompassing low-cost battery-powered sensors as well as power-plugged complex controllers. Moreover, the particular demand in traffic for the different services mentioned may vary significantly over the day, not only depending on varying user densities. Therefore, the traffic situation – and, thus, the service distribution - is expected to be dynamically changing. In this scenario, we thus conclude to encounter at anytime a colorful mix of services with substantially different requirements, ranging from low-cost narrow-band sensor applications to broad-band multimedia. Fifth generation (5G) mobile and wireless communication system must guarantee the coexistence of all these services while ensuring an efficient use of the scarcely available spectrum resources.

The European METIS project [1] elaborated on a set of scenarios foreseen for the information society beyond 2020, which the 5G mobile and wireless communication system should be able to address by providing novel and efficient solutions [2]. In the light of these scenarios and the diversity of use cases, it seems to be common understanding that an air interface providing a "one-fits-all" solution will no longer be the favorable choice. Instead, the air interface for the future mobile radio system should become more flexible, providing different solutions for particular use cases and applications under a common umbrella framework [3]. In what follows, we briefly describe some of the enabling technology components from METIS radio link research for a flexible air interface design for 5G, which allow responding appropriately to the individual demands of each service. Detailed descriptions of these technology components can be found in [4], while results from their initial assessment are provided in [5].

A. Unified air interface design for dense deployments

Given that a broad range of frequencies may be used in ultra-dense networks (UDN), flexibility is brought to the system by an air interface with a scalable frame structure, which allows to adapt framing times and symbol durations to the signal conditions specific for the utilized bands. A unified base band design based on a harmonized PHY layer numerology facilitates a low-cost implementation of this concept. The research herein covers dynamic partitioning of Uplink/Downlink periods in Time Division Duplex (TDD) mode to account for the highly asymmetric traffic expected in UDN.

B. Air interface for moving networks

High mobility requirements raised in the context of vehicular based communications (V2x) are addressed by solutions aiming to improve the reliability and the quality of transmission at high vehicular speeds. One essential objective is to improve the robustness of mobile communication links and enable services with strict reliability requirements, such as road traffic applications for improved safety or for traffic efficiency. Tailored solutions for channel estimation and channel prediction addressing highly time variant channels are provided, as well as a framework for ultra-reliable communications (URC).

C. Filtered and filter bank based multi-carrier

For the PHY layer, a particular challenge is the efficient support of a broad range of data rates going from low-rate sensor applications up to ultra-high rate multi-media services. New waveforms using pulse shapes with good energy localization in frequency domain are considered promising enablers, as they allow partitioning the spectrum into independent bands which may be individually configured according to the needs of a service. Besides providing excellent capabilities for the coexistence of services in the same band, these waveforms allow efficient spectrum sharing, in particular for the access to fragmented bands. Moreover, high robustness

* The authors have provided an overview of METIS radio link research on behalf of all partners in METIS Work Package 2.

against Doppler distortions and synchronization errors can be achieved.

D. *Non- and quasi-orthogonal multiple access allowing spectrum overload*

The new scenarios will also yield the introduction of new classes of devices and services, which should be efficiently supported by appropriate multiple access: Non-orthogonal and quasi-orthogonal multiple access schemes relax the requirement of the number of users to be served simultaneously being bound to the set of orthogonal resources. Instead of orthogonal resource allocation, the concept allows for a spectrum overloading with only smooth performance degradation. This comes at the price of higher complexity, since successive interference cancellation and multi-user detection at the receiver is needed.

E. *Contention-based massive access*

Medium access control (MAC) approaches for contention- or reservation-based access allow for the efficient access of a massive number of machine-type devices with low overhead. Depending on the application requirements, users may either transmit whenever they have data by using a random access channel, or reserve resources with efficient access reservation. A promising technique in random access to resolve potential collision with low signalling is a combination of coded random access and compressive sensing multi-user detection, which exploits the sporadic access of machine-type nodes.

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