FANTASTIC-5G: Novel, flexible air interface for enabling efficient multi-service coexistence for 5G below 6 GHz

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***Abstract*—The advent of a new generation of wireless cellular communication networks (5G) is currently being discussed both in research and standardization, while 4G is continuously evolving. Within the overall 5GPPP framework, FANTASTIC-5G is the project dealing with the design of the multi-service air interface for below 6 GHz. Ultimate target of the project is to allow the system to adapt to any means arising from diverse service requirements and device capabilities, various deployment and environment settings and mobility levels. Additionally, the ambition of the project is to have an impact to standardization. Therefore, we focus on technologies being relevant for standardization instead of proprietary elements. This paper provides some insights on the project itself and on the concepts being worked on.**

Keywords—5G; air interface; waveforms; PHY; MAC; RRM; frame design; D2D; massive access; broad-/multicast; MIMO; advanced receivers; NOMA

I. INTRODUCTION

5G is mainly about two ambitions:

1. Finding a response to the strong growth of requested data rates both per connection and overall (evolutionary effect)

2. and enhancing the business model of operators by widening the pool of services (revolutionary target).

So, 5G will have to cope with a high degree of heterogeneity in terms of: (a) services (mobile broadband, massive machine and mission critical communications, broadcast/multicast services and vehicular communications); (b) device classes (low-end sensors to high-end tablets); (c) deployment types (macro and small cells); (d) environments (low-density to ultra-dense urban); (e) mobility levels (static to high-speed transport).

Consequently, diverse and often contradicting Key Performance Indicators need to be supported, such as high capacity/user-rates, low latency, high reliability, ubiquitous coverage, high mobility, massive number of devices, low cost/energy consumption. 4G is not designed to meet such a high degree of heterogeneity efficiently. Moreover, having multiple radio access technologies for multi-service support below 6GHz will be too costly and inefficient. With having a single multi-service air interface (AI) we have the following advantages:

- Less carriers to be active in parallel.
- More efficient use of the active carrier(s) through use case multiplexing and resource sharing.
- Economy of scale through the possibility of sharing functions in the provision of different use cases.
- Forward compatibility for upcoming use cases is assured (future proofness). Future use cases might deviate from the settings of specialized air interfaces.
- Specific devices (e.g. smart phones, cars) may comprise different use cases benefiting from a single harmonized air interface (e.g. eMBB for streaming, MMC for instant messaging, MCC for mobile gaming).

FANTASTIC-5G (Flexible Air iNTerfAce for Scalable service delivery wiThin wIreless Communication networks of the 5th Generation - 5G PPP project dealing with the air interface below 6 GHz) will develop a flexible and scalable multi-service air interface (ambition 2) with ubiquitous coverage and high capacity (ambition 1) where and when needed. The new air interface is targeted to be highly efficient in terms of energy and resource consumption as well as to be future proof, allowing sustainable delivery of wireless services far beyond 2020.

Ultimate target is to allow the system to adapt to the anticipated heterogeneity, the pursued properties are: flexibility, scalability, versatility, efficiency, future-proofness [1]. To this end, we will develop the technical AI components (e.g. flexible waveform and frame design, scalable multiple access procedures, adaptive retransmission schemes, enhanced multi-antenna schemes with/without cooperation, advanced multi-user detection, interference coordination, support for ultra-dense cell layouts, multi-cell radio resource management, device-to-device) and integrate them into an overall AI framework where adaptation to the above described sources of heterogeneity will be accomplished. Our work will also comprise intense validation and system level simulations.

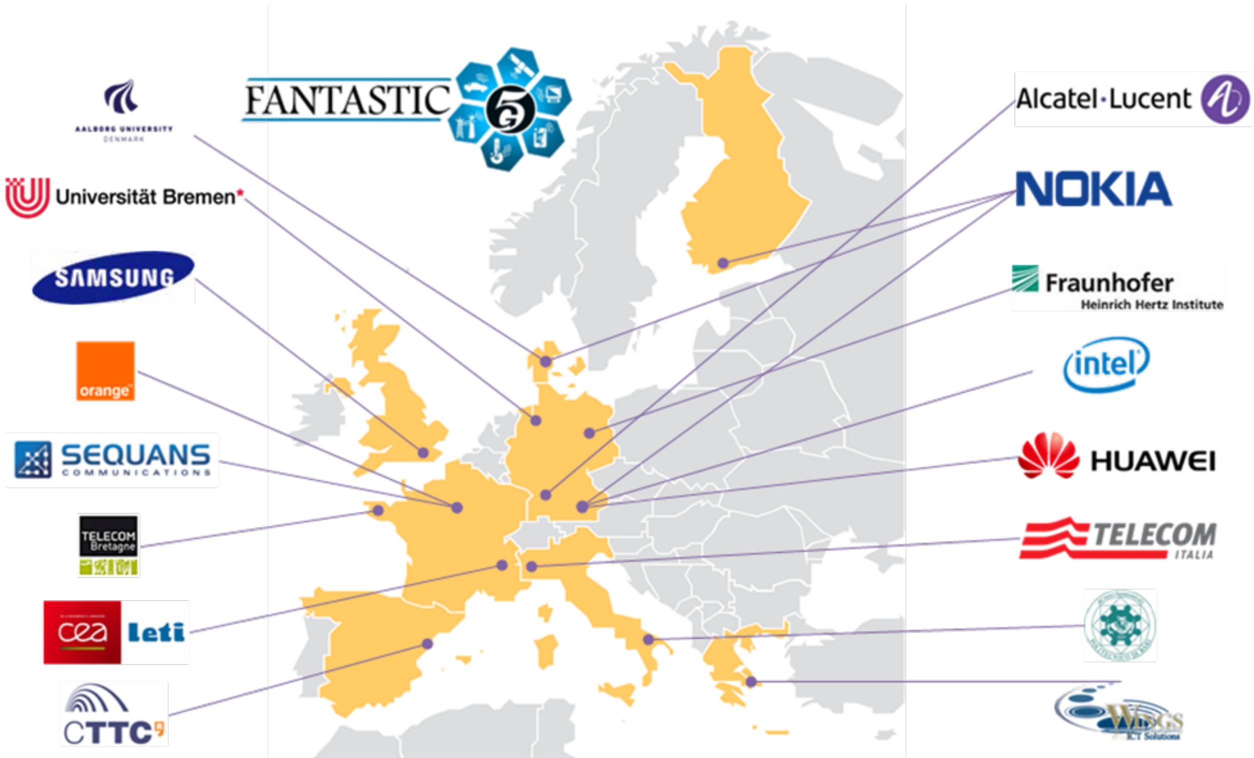

Fig. 1. Partners of FANTASTIC-5G.

In a nutshell the objectives of the project are:

1. To develop a flexible and scalable multi-service air interface
2. with ubiquitous coverage and high capacity where and when needed
3. being highly efficient in terms of energy and resource consumption
4. being future proof and allowing for sustainable delivery of wireless services far beyond 2020.
5. To evaluate and validate the developed concepts
6. and build up consensus on reasonable options for the standardization of 5G.

The paper is structured as follows: the next section provides some insights on organizational aspects of the project. Subsequent sections are describing the projects technical work related to Requirements, Integration, Evaluation, Link Design, and Network Design followed by a description of the planned proof of concepts. The paper ends with an outlook on special scenarios and a conclusion.

II. The Project

The project has started July 1. 2015 and has a duration of two years. It is part of the overall 5GPPP framework and is thus strongly connected to other project dealing with other aspects of 5G (e.g. architecture, mmW transmissions).

Fig. 1 depicts the partners of the project. Overall the consortium has a good balance between industry and academia. The participation of multiple vendors (Nokia, Alcatel-Lucent, Huawei), equipment manufacturers (Intel, Samsung, Sequans) and operators (Orange, Telecom Italia) highlights the ambition and capability of having an impact to standardization.

III. Requirements, Integration, Evaluation

A. *Use case selection*

The development and evaluation of the FANTASTIC-5G air interface is carried out on the basis of the following seven use cases [2].

- UC1: 50 Mbps everywhere
- UC2: High speed train
- UC3: Sensor networks
- UC4: Tactile Internet
- UC5: Automatic traffic control / driving
- UC6: Broadcast like services: Local, Regional, National
- UC7: Dense Urban Society below 6GHz

This selection was made with the aim of providing a good representative set of 5G use cases, while keeping the number of use cases (and thus the overhead) at a reasonable level. The following selection process has been adopted. Firstly, it was decided to base the analysis on the 60 use cases that are described in the state-of-art references (NGMN [3], 3GPP [4] and METIS I+II [5]). Then, a set of selection rules was applied to filter out redundant use cases. Examples of these include those use cases that are already covered by others, or that are irrelevant for frequencies below 6GHz. The complete procedure is described in [2].

Each use case is representative of one or more of the following *core services* defined by FANTASTIC-5G:

- Mobile Broadband (MBB)
- Massive Machine Communication (MMC)
- Mission Critical Communication (MCC)
- Broadcast/Multicast Services (BMS)
- Vehicle-to-Vehicle/Infrastructure Communication (V2X)

To be more specific the 7 use cases aim at the following aspects:

UC1 aims at providing MBB services for rural and sub-urban areas. One of the main challenges of this use case is the provision of coverage, in combination with medium-size data rates that are suitable for mobile internet applications.

UC2 addresses the combined challenge of providing MBB services with high speed.

UC3 aims at massive access of low-cost, low-energy devices and sensors, with short messages and low data rates.

UC4 addresses the challenge of MCC (ultra-reliable, ultra-low latency) in combination with medium-size data rates.

UC5 also addresses MCC, but the focus is more on V2X. This use case is representative of a number of possible applications related to so-called Intelligent Transportation Systems (ITS). An example is Road Hazard Warning (RHW), which aims to reduce road collisions by sending drivers warning messages.

UC6 is a special instance of an MBB service, in which the same messages is broadcast to a group of users, thereby allowing for a resource-friendly distribution of information and content.

UC7 aims at MBB in urban areas. This use case represents the capacity challenge, for dense areas that are well-equipped with network infrastructure, potentially massive MIMO and small cell sizes.

B. System Integration

Based on the selected use cases and requirements, FANTASTIC-5G is developing an overall air interface framework. To this end, we identify the most relevant enabling technologies (e.g. new waveforms, D2D, enhanced MIMO, multi-cell cooperation, flexible spectrum usage...) and assess their relevance for achieving the requirements of each use case. This will result in a high-level description, including main functional blocks with interfaces, and an analysis of how they are embedded in an overall 5G system architecture. This will be done for each of the 5 core services MBB, MMC, MCC, BMS, and V2X

This high-level framework will be the focal point for the integration of solutions provided by the technical work packages. One main outcome of this task will be to answer the question to which degree the co-existence of diverse 5G services can be realized by a single air interface including different settings/configurations or component selections within a single RAT. The integration and selection process will be supported by system level simulations.

To this end, FANTASTIC-5G adopts a 3-staged plan:

1. We perform dedicated research activities on service-specific (air interface) components, e.g. channel coding, waveform design, etc. At this point, the project focuses on technical solutions that are optimized with respect to certain core services.
2. We collect the components and integrate them into a service-specific air interface solution (including waveform, frame, control signaling, coding, modulation, procedures, retransmission schemes, MIMO etc.). This integration will be done using the high-level air interface framework.
3. A sensitivity analysis will be carried out by all core services, to see how we will adapt the different designs so that they conform to more than one service. In this way, we will see the limits of the degrees of flexibility of the service-specific solutions. The goal is a single air interface solution which is able to adapt itself to the requirements of more than one service.

C. Evaluation

The selected scenarios and use cases are defining the environment models and KPI targets. Technology components (procedures) being developed during the project and indicating promising performance gains are to be implemented via certain system features (i.e. dedicated building blocks within the simulator realizing a given functionality of the technology component). The developed system-level simulators have the ability to model and simulate the use cases by taking into account environment models (e.g., traffic, mobility, radio conditions, considered network topologies etc.); system features (e.g., usage of spectrum in frequency bands below 6GHz, dense network deployments, impact of modulation, coding, MIMO etc.) and results/analysis.

Regarding environment models the impact of traffic, mobility and radio conditions are taken into account in the system-level simulators. Specifically, it is possible to generate in the simulators 1000x more traffic (compared to previous years), usage of massive number of devices, ultra-dense infrastructures, D2D communications, high mobility etc. Certain components will be developed that control the configuration of network topology, traffic distribution to cells, distribution of cells and users in space, traffic distribution in space and time, etc. Compliance with benchmarks and 3GPP standards (release 12 plus selected relevant features from release 13 is the reference) will be sought in order to ensure valid simulations.

Regarding system features the usage of spectrum in frequency bands below 6GHz is taken into account and suitable abstractions of PHY and MAC layers in order to define system behavior models and to limit the computational complexity of simulations will be taken into consideration.

IV. Link Design

The link design covers several technical components such as modulation and coding, waveform, frame and control channel structure, physical layer procedure, etc. Given the diverse and mutually conflicting requirements of 5G, the link design is based on two general questions and their corresponding sub-questions:

1. How can new features/services being added in later releases without heavy constraints and without bothering legacy devices.
2. What is the best balance between flexibility and fixed preconfiguration?

Due to the wide scope of 5G services, as well as the important objective of enabling future proofness, the 5G design shall possess high degree of flexibility from the very beginning. To relax the burden of backwards compatibility, the system has to be designed with a minimum amount of fixed and predefined elements. For highest flexibility the only static/predefined element is the initial access channel (IAC). Every subsequent item should be open for configuration between a device and the network according to the actual needs, thereby relying on a given set of options. This way new features and services may be implemented at later releases without affecting legacy devices. In addition, the second question challenges the current mobile system where a mostly fixed (or non-self-adaptive) configuration is applied. Such concept cannot support multi-service 5G in an efficient way, since it can provide merely a compromise in addressing the needs of all envisaged services. So, the technology components being developed require flexible adaptation capabilities.

The sub-questions, driving our technical investigations are relevant for connecting the link design to the particularities of the 5G services. Following questions are raised as examples:

1. How to address high reliability and low latency for short package transmissions?
2. How to maintain a guaranteed QoS at high speed with severe Doppler impact?
3. How to manage massive access efficiently?
4. How to design the system for future proofness?
5. How to integrate all relevant functionalities into one system?

The so-called *holistic* solution investigated in this project is such a self-adaptive solution that provides answers to all above questions. The approach is to start with a service-specific investigation on technical components, e.g. waveform, modulation and coding schemes, PHY layer procedures. In a second step, system integration connects the single components. Control signaling will apply a mixture of broadcast and unicast (aka user-specific) modes keeping the former to a minimum. In the following we provide some more details on the most importan technical components.

A: Service-specific waveform design

Multi-carrier waveforms with filtering functionalities are considered key enablers for a service-specific PHY design, as they allow for individual configurations of sub-bands in terms of their PHY parameters according to the requirements of a service. The candidates proposed and analyzed within the project can be categorized into subcarrier-wise filtered multicarrier (e.g. FBMC with QAM/OQAM signaling [6]) and subband-wise filtered multicarrier (e.g. UF-OFDM/F-OFDM [7]/[8]).

FBMC uses prototype filters with steep power roll-off in frequency domain for pulse shaping the subcarrier signals. A steep roll-off can be realized by allowing the time domain representation of the pulse to expand over the length of the symbol interval T, resulting in overlapping pulses if several FBMC symbols are transmitted successively in time. An orthogonal (or bi-orthogonal) pulse design ensures that the overlapping pulses can be (near to) perfectly reconstructed without creating any mutual interference. For achieving maximum spectral efficiency, OQAM signaling has been proposed. In this case, no guard bands or guard intervals are required, yielding the time-frequency grid to satisfy $TF = 1$ (with F being the subcarrier spacing). However, the orthogonality in OQAM is constrained to the real signal field, which prevents direct transfer of some algorithms developed for OFDM and thus requires a redesign of some signal processing procedures. If $TF > 1$ is chosen, though, translating to an oversampled system with excessive signal samples (represented either by a CP-like guard interval or by frequency guards), QAM signaling based on complex field orthogonality can be established, enabling the direct use of any scheme developed for OFDM systems [9].

The options applying subband-wise filtering (UF-OFDM and F-OFDM), on the other hand, employ FIR filtering after the classical OFDM modulation which conceptually ensures a close similarity (in fact actual implementations can apply the filtering functionality before the transformation to time domain). In some realizations filtering is only applied at the transmitter side (though it is not confined to this). The filters can be optimized according to selected KPIs, e.g. spectrum confinement, inband distortion, etc. The main differences between these two variants are the degree of spectral and temporal confinement.

In addition, a concept allowing the concurrent support of different waveforms following different service needs in a frequency multiplexed manner is proposed in the project under the name of FC-OFDM [10].

B: service-specific PHY procedures

In order to ensure a reasonable signaling overhead for 5G supporting multiple services concurrently, notably the MBB service and MMC service with massive access, flexibility is required also for the respective PHY layer procedures (e.g. random access, synchronization). While some PHY layer concepts may be shared, others need to be tailored to specific requirements of the respective service.

With 5G, MBB transmissions may be controlled by the basestation scheduler as it is done within 4G. However, for MMC transmissions (typically being sporadic and constituting less information bits as e.g. MBB transmissions) we have to rethink this paradigm as it would translate into severe control overheads and quickly drained device batteries. There are multiple proposals for redesigning the access procedure for MMC. One example is contention-based access applying either 1-stage or 2-stage transmission formats.

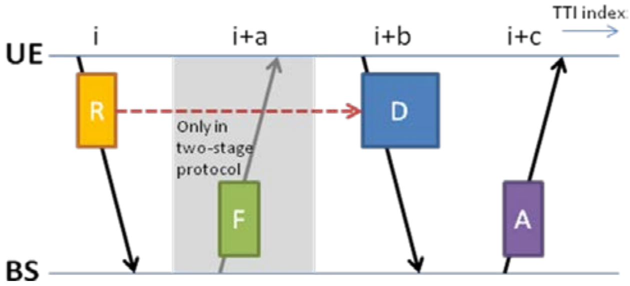

Fig. 3: Abstract view of 1-stage and 2-stage protocols.

The former follows the principle of slotted ALOHA (i.e. the device directly transmits its data – D in Fig. 3 - in conjunction with a respective preamble – R in Fig. 3 - specifying the used resources) while the second allows the basestation to somewhat control the transmissions (i.e. the device having data to transmit initiates a service request in the form of a UL preamble). The basestation receiving this request then indicates this reception in conjunction with a respective message – F in Fig. 3 - structuring the subsequent UL transmission – there are myriads of options for doing this, the interested reader is referred to existing and upcoming deliverables of the project and to [11]. The advantage of the 1-stage protocol is a very lean control effort and a very quick completion of the transmission at the cost of a higher collision probability and thus a reduced throughput. The 2-stage protocol requires more control and takes longer until completion, however, is more resource efficient. With applying multi-user detection both variants can be improved.

Based on the waveforms being introduced in section IV.A, asynchronous data transmission can be supported, facilitating multi-user UL data transmission that does not need any timing advance (TA). Coupling this waveform with an SDMA multiple access scheme relying on multiple antennas at the BS, a grant-free transmission can be enabled, where users simply transmit their signals on randomly chosen resources. Given that the users' channel signatures can be properly estimated (by using unique preamble signals as in LTE UL or unique pilots patterns as in LTE DL coupled with the data packet), potential collisions of multi-user signals can be conveniently resolved at the multi-antenna BS by making use of MIMO-MMSE detection schemes. With this grant-free and TA-free uplink access, a single-shot signal transmission for short package messages can be enabled.

C: flexible frame design

The frame is the key element for aggregating user-specific transmission modes into one holistic solution. In this project, we allow fractions of the frame to be configured differently to be able to support different link and service characteristics with highest efficiency. Reconfigurations may be done dynamically following changes in the traffic demands of the different service types.

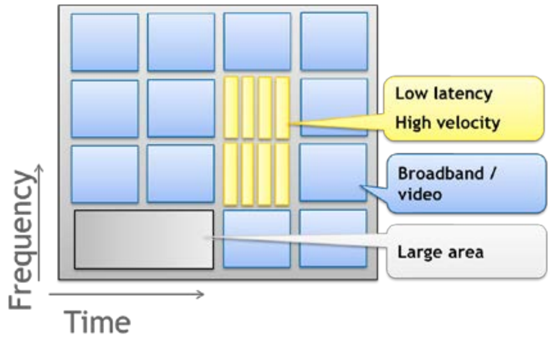

Fig. 4 Frame design allowing for transmissions being optimized towards various aspects.

As shown in Fig. 4 we target to have coexistence of a diverse set of configurations being optimized to e.g. low latency, high velocity (Doppler), conventional broadband traffic, coverage extension and BMS services (large area services). These configurations may e.g. vary in terms of waveform characteristics (applied filter, subcarrier spacing), TTI length and further frame design elements such as pilot density and resource partitioning.

V. NETWORK DESIGN

A. Basic RRM concept:

Allocation of radio transmission resources is one of the most essential RRM management tasks. This includes allocation of radio resources for scheduled unicast transmissions between network infrastructure base stations and UEs, scheduled multicast and broadcast transmissions, D2D, as well as resources for non-scheduled uplink access (also known as uplink contention based access following the 1-stage and 2-stage protocols being described earlier). The allocation of radio resources for different types of transmissions are by default assumed to be network controlled and to be conducted for each individual cell. A separate downlink and uplink shared channel is assumed for each cell. The shared channel is assumed to offer an orthogonal time-frequency resource grid for multiplexing users within the cell. It is well-known from communication theory that there are fundamental trade-offs between capacity, latency, reliability, and coverage [12]. From a system design point of view, this tells us that we should not optimize the air interface according to a given extreme case - e.g. low latency for any transmission, even if not required - as this will incur a loss in capacity (spectral efficiency), and vice versa. Instead, a flexible system design that allows optimizing each link in coherence with its service requirements is desirable.

Our hypothesis is that efficient scheduling of the considered services requires the support for scheduling formats with different transmission time intervals (TTIs). As a few examples, users with tight latency constraints (e.g. MCC) require short TTIs, while MMC users scheduled on a narrow bandwidth are most efficiently served with longer TTIs. Moreover, users with MBB traffic could also benefit from variable TTI sizes to efficiently adapt to various conditions. As an example of the former, during the initial MBB data transmission session, the end-user experienced performance is primarily determined by the RTT due to the slow start TCP procedure (i.e. TCP flow control). Therefore, it would be advantageous to first perform scheduling of the MBB TCP users with short TTIs, followed by using longer TTI sizes when reaching steady state operation. An example with flexible time-frequency multiplexing of users on a shared channel with different effective TTI sizes is shown in Fig. 5 and in [13].

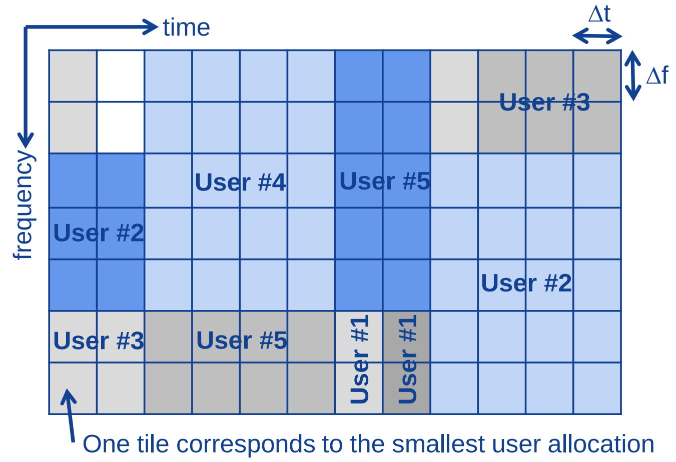

Fig. 5: Flexible time-frequency multiplexing of users with different TTI sizes.

B. *Advanced Connectivity Options:*

Advanced connectivity options, beyond the traditional cellular unicast connections between the cellular devices and the cellular infrastructure, will bring forth the flexibility to support a plethora of new application requirements in 5G networks. The advanced connectivity options considered in FANTASTIC-5G are the following: (a) direct Device-to-Device (D2D), (b) massive access, and (c) broadcast/multicast communications.

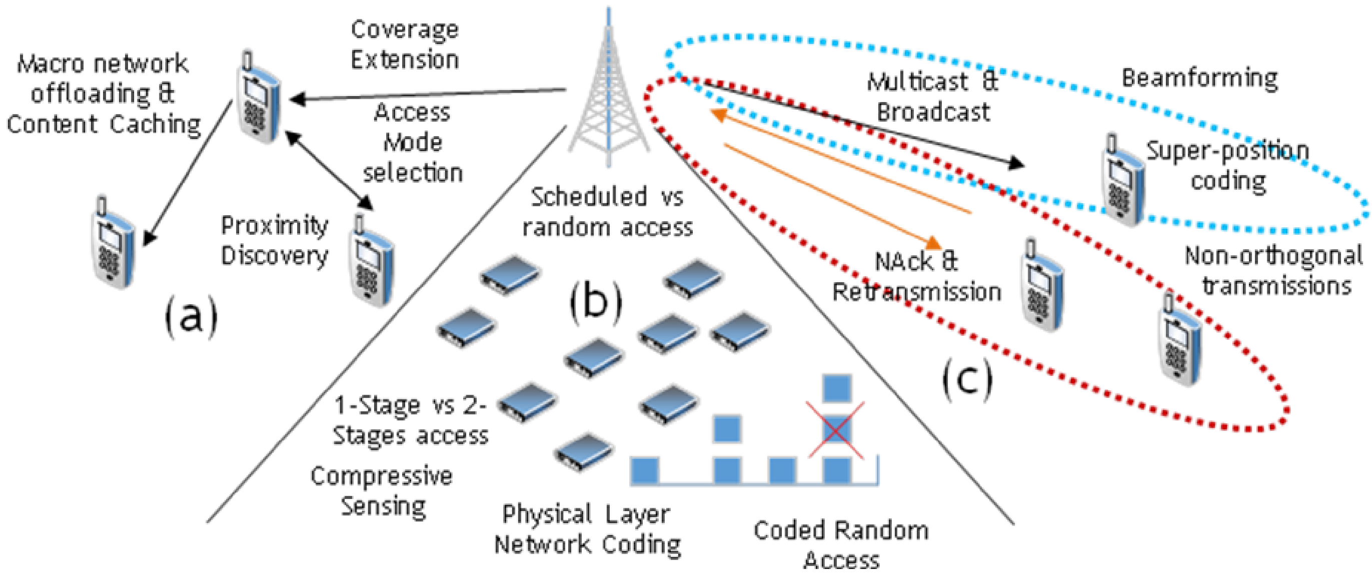

Fig. 6 Advanced connectivity options.

In (a), the availability of network support, in terms of signaling and resource management, enables resource efficient and reliable D2D (e.g. [14]) proximity discovery and direct communication, the core components of D2D. Namely, in traditional ad-hoc networking scenarios, such as traffic safety in vehicular communications, the use of network supported D2D can bring communication reliability guarantees not possible with non-network supported schemes. Another aspect of D2D connectivity is that it can be used to improve overall cellular network performance, enabling the cellular traffic to be offloaded via localized content caching and distribution. D2D scenarios, in particular distribution of cached content, introduces additional connectivity between devices and network nodes, which allows the application of wireless (physical-layer) network coding techniques, which has been shown to improve network performance significantly.

In (b) the goal is to enable the access of a massive number of devices (e.g. [15]), predominantly machine type devices, to the cellular network infrastructure. This access type is not handled efficiently by current cellular networks, due to the massive number of devices and the associated signaling overhead. The efforts are focused on leveraging (non-) contention access protocols based on random access. Several physical and medium access layer techniques are explored, including: one stage, two-stages access protocols (see earlier) and; application decoding and belief propagation and compressive sensing based multiuser detection to detect active users and resolve packet collisions (coded slotted ALOHA), and overload resolution techniques. Beyond machine-type devices, another scenario investigated is related to enhanced MIMO for serving areas with very high user density (e.g. hotspots). This scenario calls for new uplink and downlink communication protocols adapted to a massive access from users in a single or multiple cell setting.

In (c) new broadcast/multicast techniques are explored beyond of what it currently available. Namely on the use of multi-antenna transmitters, with focus on precoding and on feedback requirements, as well as multi-level coding (MLC) and non-binary coding schemes. Another aspect explored is the introduction of an acknowledgment protocol, which enables unicast retransmissions to devices unable to decode the transmissions in the original broadcast.

C. *Spectral efficiency enablers:*

The high data rates expected to be supported by 5G require the exploration of all possible ways to use spectrum efficiently. In this course, two possible ways to enhance spectral efficiency are studied. First option is to apply advanced receivers. This is related to the reception capability/complexity of the respective node. The second option is to rely on Multiple Input Multiple Output (MIMO). This is related to the use of multiple antennas at the transmitter and receiver in order to increase the data rate or the signal robustness.

Advanced receivers are needed in order to successfully exploit the potential of complex transmission techniques including those that support more than one stream. MIMO techniques are not the only case where advanced receivers are needed. For example, in the case of Non Orthogonal Multiple Access (NOMA) Interference cancellation at the receiver is needed in order to fully exploit the potential of multiple access. Other forms of advanced receivers can be used to improve the spectral efficiency both in downlink and in uplink. Different use cases may require different levels of receiver complexity ranging from a Maximum Likelihood receiver to linear low complexity receivers. In the case of MMC, for example, the receiver complexity needs to be very low in order to be a viable solution for this kind of small devices with long battery life requirements.

MIMO techniques provide another powerful method to increase spectral efficiency by transmitting multiple independent/redundant streams. MIMO technique can be used either to increase the data rate using spatial multiplexing or increase the signal robustness. MIMO techniques may require cooperation between different base stations/relays or be used without cooperation. The complexity of the techniques and the receivers increases with the number of antennas at the transmitter/receiver and the number of cooperating nodes. FANTASTIC-5G explores the use of a very high number of antennas as well - known as massive MIMO - going beyond LTE full dimension MIMO. This opens up a whole range of research aspects to solve problems faced, when trying to exploit the potential of a large number of streams and associated pilots and receiver. Other aspects that need to be addressed include the channel state feedback and the signaling overhead for a proper use of MIMO. The challenge addressed in the project is to integrate these techniques into a common framework enabling the support of different use cases and facilitates adaptive mode switching between different transmission/reception techniques.

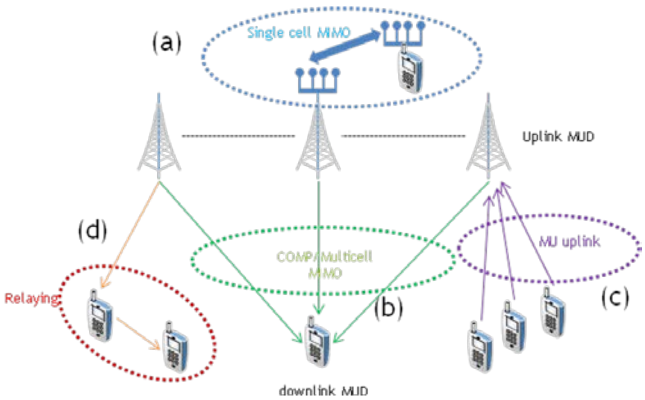

Figure 7 Spectral efficiency enablers.

VI. Proof-of-Concepts

The proof-of-concepts (PoC) target to implement key technical components developed within FANTASTIC-5G. The demonstration aims at validating the feasibility and the superiority of the different components of the foreseen 5G air interface.

The planned PoCs in FANTASTIC-5G can be generally classified into three main categories:

- post-OFDM waveform prototyping,
- coexistence aspects evaluation
- software defined radio (SDR) based demonstration for broadcast and multicast transmission.

In the following, we will provide a brief description of the planned PoCs.

Taking into account that Post-OFDM waveforms are foreseen as key enablers to several 5G scenarios as it enhances system robustness to different types of impairments, the post-OFDM prototyping addresses the building of PoCs for the algorithms evolved in FANTASTIC-5G to tackle the open issues like synchronization, channel estimation, equalization, efficient MIMO support and pulse shape adaptation. To that end, the development of FBMC, FBMC-MIMO, FC-OFDM, and UF-OFDM transceivers is intended from algorithm simplification and optimization to on-board validation and demonstration. The transceivers will be tested in both vehicular and MMC scenarios.

In addition settings with asynchronous uplink transmissions and in high-velocity contexts using FBMC for grant-free low latency transmission will be demonstrated. Moreover, different post-OFDM waveforms will be evaluated jointly and compared using hardware-in-the-loop approaches and/or transmissions over wireless channel emulator.

Coexistence aspects will be evaluated. The developed waveforms in FANTASTIC-5G as well as the standard waveforms will be overlaid and evaluated.

Broadcast and multicast transmissions are expected to have high importance in 5G networks as it reduces drastically the network load by delivering the same content to a group of end users. The techniques being developed in the project to enable multicast transmissions to different multicast groups by the use of MIMO techniques but, at the same time, provide a common broadcast layer to all users will be demonstrated using a SDR platform.

Fig. 8 summarizes the planned PoC demonstrations in FANTASTIC-5G. A wide range of developed techniques in the project will be demonstrated and compared with the state of the art to illustrate the unique features of FANTASTIC-5G solutions.

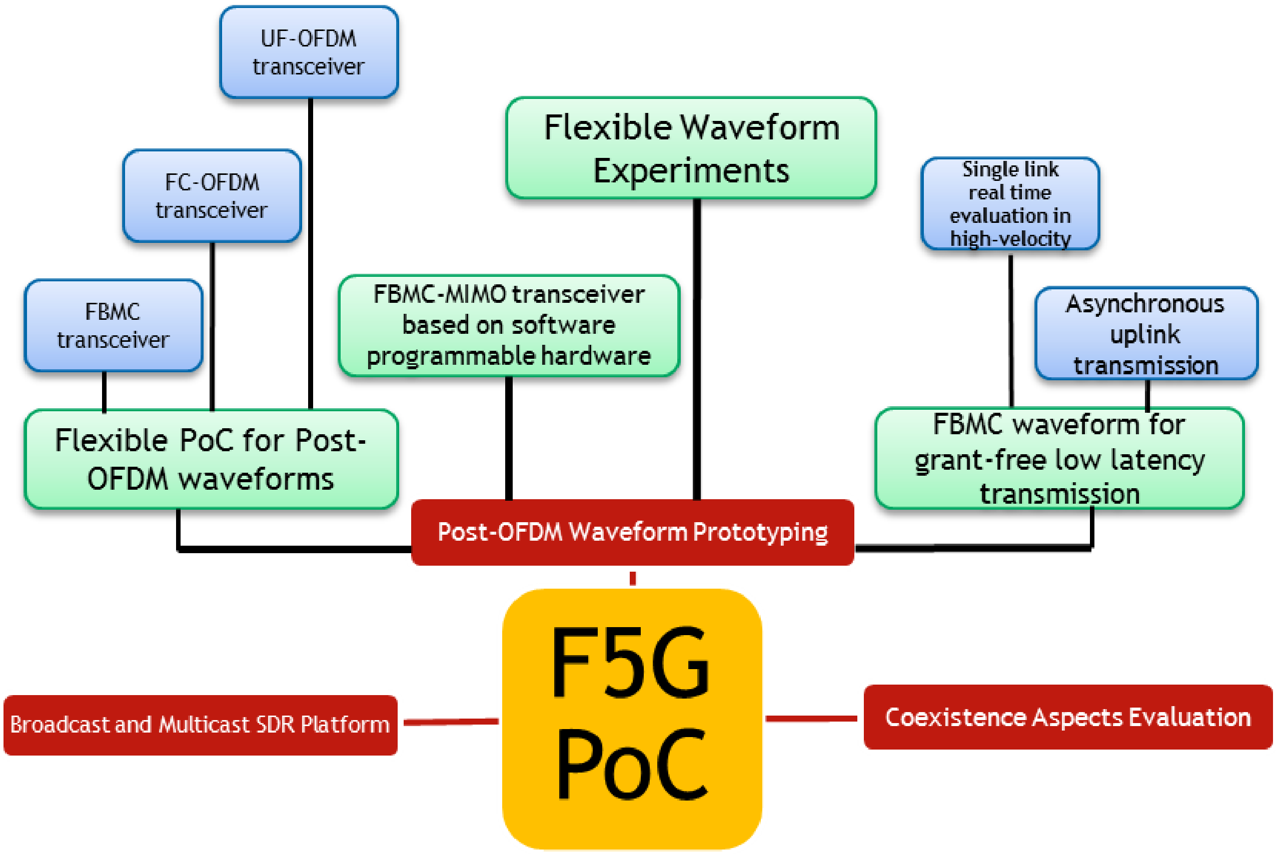

Fig. 8 Proof-of-concepts of FANTASTIC-5G

VII. Application to Special Scenarios

The flexible multi-service air interface of FANTASTIC-5G can also be adapted to *special* (or *extreme*) scenarios/use cases that are not within the scope of the project, i.e. not being reflected by the 5 core services and the 7 selected use cases described above. Typical examples are (1) Satellite Communications (SatCom), (2) wireless connectivity in low ARPU (Average Revenue Per User) areas, (3) industry 4.0, and (4) emergency cases (resilience).

These scenarios impose extreme conditions to the AI. As the target of FANTASTIC-5G is to have the AI highly flexible, with minimum possible predefined characteristics, it is possible to configure the air interface towards these extreme directions.

More specifically,

(1) SatCom may present a good candidate for wireless backhaul solutions (for ex. the link from the base station to the vehicle relay in UC2). The round-trip-time is longer (13-240 ms), so we are at the other extreme of the "low latency" axis. The protocol messaging (for ex. PDCP) as well as retransmissions have to be adjusted. The satellite channel can be more severe in terms of non-linear distortions, PAPR and delay spread. So FANTASTIC-5G proposals on waveforms, PAPR reduction and flexible frame structure could be adapted to present solutions for the SatComm channel.
(2) For the low ARPU areas, the main target is to have an *ultra low-cost network*. This is done by keeping only the essential functionalities through a "basic" (and less costly) configuration/connectivity. The most costly part of the RAN is the passive infrastructure, so maximizing the ISD (Inter-Site Distance) reduces the cost considerably. High ISD has impacts on the delay spread, so the air interface should support long delay spreads (the issue is more on coverage than capacity). Here again, FANTASTIC-5G's proposals on waveforms and flexible frame structure can be adapted to provide solutions for this long delay spread.
(3) As for industry 4.0, it represents the very extreme case of MCC. We can push our flexible air interface to the extreme case of very low latency and very high reliability (extremely small TTIs, D2D with very close proximity, very strong FEC, extremely fine grained localization capability through flexible frame structure and adaptive antennas, precise energy focusing through active antennas). To achieve very high reliabilities, a high degree of diversity is needed. In industry 4.0, we have to strongly rely on antenna diversity as time diversity does not work due to the latency constraints and frequency diversity suffers from the very short delay spreads.
(4) Emergency mode (resilience) is an indispensable option to have connectivity if (parts of) the network breaks down (natural disaster, attack etc.). The system has to fall back to (non-network controlled) D2D and may also use BMS features (e.g. to broadcast relevant info about rescue plans).

VIII. Dissemination Efforts

The dissemination activities aim at inter-project concertation, scientific publications, workshops, training activities, industry booths, as well as promoting concepts and results produced by the project through the website http://www.fantastic5g.eu from the outset of the project. FANTASTIC-5G will complement this with strong presence in social media through its Twitter account @fantastic5g and its LinkedIn group with currently 465 members! FANTASTIC-5G has issued first official widespread press release and made its first report on 5G requirements and scenarios publicly available. Eventually, FANTASTIC-5G strongly interacts with the EU 5G-PPP initiative through joint workshops and initiatives. Moreover, FANTASTIC-5G has started its own international workshop series within the IEEE VTC spring series, and recently launched already the 2ed call for papers towards VTC Spring 2016 in Nanjing (China), see http://workshop2016.fantastic5g.com.

IX. Conclusion

In this paper we have provided insights on the project FANTASTIC-5G itself and on the concepts the project is working on. The target is to strongly influence the development of 5G on aspects related to the air interface. Ultimately, we see 5G to require a much higher degree of adaptability/flexibility than 4G offers. While the latter is close to optimal for transmitting high data rate services (MBB), it is not able to follow the currently arising diversification of services (e.g. MCC, MMC) potentially benefitting from getting access to a cellular network. Therefore, the project will develop and analyze promising technology components for efficient multi-service support. We will evaluate these components in the light of the different service characteristics and propose optimized configurations. Means to allow different services to coexist on the same carrier will be investigated. Key elements for achieving this vision are waveform and frame design, dedicated PHY procedures, flexible radio resource management (RRM), advanced connectivity options (D2D, massive machine access and broad-/multicast) and techniques to maximize spectral efficiency. Additionally, the project will identify, design and analyse means to significantly increase the offered capacity.

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