What Are 3GPP 5G Phase 1 and 2 and What Comes After

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Abstract. This paper describes the ongoing standardization of the new 5G system and the planned next steps in the 3rd Generation Partnership Project (3GPP) groups. Starting with an overview of how 3GPP works, what is meant with 5G Phase 1 and 2 and a clear timeline for ongoing and planned activities are provided. Finally an interesting innovation vector for beyond 5G systems, i.e. dynamic (in time) spectrum management, is briefly mentioned.

Keywords: 3GPP · 5G · Beyond 5G · Dynamic spectrum management · Standardization · Funded research projects

1 Introduction

The continuous development, generation after generation [1], of the telecommunication system allows mobile users to benefit from new services and applications almost with a yearly cadence. Starting with the second half of 2019, the first commercial deployments of the latest generation of the cellular communication system, known as the 5th generation (5G), are being rolled out in several countries.

The new 5G system aims at two main targets: First, to be a game changer in the way mobile users can experience nomadic communications, by introducing brand new technologies and functionalities that on the one hand can enhance several system key performance indicators (KPI), and on the other hand manage to relax some system constraints. Second, to provide for the first time in a unique framework a real synergy and a seamless integration of the legacy systems with the so called '5G verticals', i.e. domains and businesses different from the telecommunication domain, like Automotive and more in general Intelligent Transport Systems (ITS), E-health, or Industrial Internet of Thing (IIoT).

In order to fulfil its set targets, 5G has been defined along three main so called 'usage scenarios' (also known as 5G 'use cases'), which, as shown in Fig. 1, are supposed to cluster, along three main innovation vectors, similar requirements and constraints, among the numerous new ones coming out of the long list of 5G expected improvements. Such usage scenarios, which are detailed and broadly discussed in [2–4], have been jointly defined by both the research community and the industry as:

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- enhanced Mobile BroadBand (eMBB),
- Ultra Reliable and Low-Latency Communications (URLLC),
- massive Machine Type Communications (mMTC).

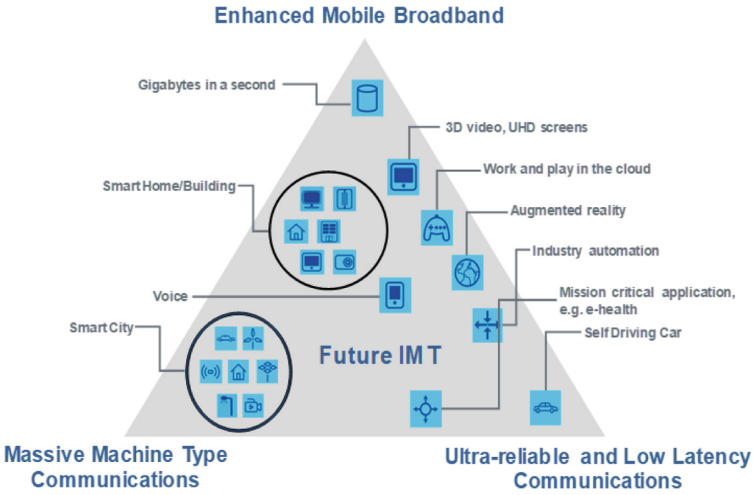

Fig. 1. 5G usage scenarios (Source: Recommendation of ITU-R M.2083-0 [4]).

In a nutshell, ***eMBB*** is supposed to take care of data hungry applications and how they can exchange from and to terminals a huge amount of data per second. For instance, mmWave access is considered a new enabling technology under this usage scenario. ***URLLC*** covers a variety of use cases, like Mission critical services, E-Health and Autonomous driving, where reliability and low latency are both equally important. Finally, ***mMTC*** covers a broad spectrum of IoT-related services and applications, usually concerning a huge number of small or cheap devices communicating a tiny or small amount of data. mMTC is usually relevant for the different Smart-x paradigms (with x = city, grid, etc.).

Following the very recent launch of 5G commercial services, which finally allow mobile users to experience the new services and applications based on the 5G system, it is now a timely move to provide, thanks to this paper, an updated insight on the current status and planned work of the 3rd Generation Partnership Project (3GPP) [5], i.e. the most relevant standard for the 5G system definition.

The rest of the paper is organized as follows: Sect. 2 surveys some key works that provide background on why the 5G system is needed and hints at some promising enabling technologies for 5G and beyond 5G (B5G) systems. Section 3 explains how the 3GPP standardization groups work and describes what the content of the so called 5G Phase 1 and Phase 2 is. Section 4 provides an overview of what comes after 5G Phase 2, and hints at a new topic for B5G systems, which was recently proposed to the European Telecommunications Standards Institute (ETSI) [6] work. Section 5 gives a

glimpse of what could be the content of the 3GPP work in the timeframe 2022–2023. Finally, Sect. 6 concludes the paper.

2 5G Background and Some Key Seminal Works

Several papers have provided in the last few years interesting overviews on the potential impact of newly defined technologies for the forthcoming 5G era. Several of those works are the outcome of international collaborative research projects, funded by the European Union or other international institutional agencies, under the 'Framework Programme 8' (also called 'FP8' or 'Horizon 2020'), which started in 2013 and is going to be completed in 2020. This paper therefore takes some main outcome of those projects, but not only, to provide a short overview of main 5G aspects and related work, planned in the 3GPP standardization body. Some of the touched-upon outcomes of those projects will be instrumental to build the foundation for the new technology enablers that will characterize the successor of FP8, i.e., the forthcoming new research programme FP9, at the moment tentatively also called 'Horizon Europe', which will run in the time window 2020–2027.

Concerning works on the 5G usage scenarios, regarding the impact of the 5G ***eMBB***-related technologies in the society, authors in [7], from the *5G-CHAMPION* project, elaborate on the benefits brought to the Winter Olympic games held in Korea in 2018, and authors in [8], from the *5G-MiEdge* project, on the potential impact on the 2020 Summer Olympic games in Japan. Regarding the ***URLLC*** usage scenario, authors in [9] elaborate on how merging together different technologies like Wi-Fi and SDN can help in reducing the communication latency, so to more effectively steer a robot from remote, whereas authors in [10] provide an overview of several different interesting aspects of URLLC services and applications. Regarding the ***mMTC*** usage scenario authors in [11, 12] detail constraints and aspects of effective 5G mMTC deployments.

In addition to the 5G usage scenarios, several other papers focus on the so called enabling technologies, i.e. newly developed means that will allow the 5G system to fulfill its system KPIS and reach its ambitious goals. Among others, one of the most promising new 5G enabler is ***millimeter waves (mmWave) access and backhaul*** enhancements: authors in [13, 14], from the *MiWaves* project, elaborate on what could be impactful contributions in standards regarding a smooth introduction of mmWave access and backhaul, up to 70 GHz bands. Authors in [15], from the *mmMAGIC* project, move even further and broadly elaborate on different aspects of newly proposed technologies, mainly at the lower layer of access networks, up to the 100 GHz bands. Specifically on the backhaul topic, an interesting overview of key Radio Resource Management (RRM) aspects are discussed in [16].

Another vector of innovation, very important for an effective 5G deployment, is the ***usage of new spectrum bands***, or ***the more enhanced usage of existing spectrum bands***. Interesting works in frequencies below 6 GHz are described in [17], from the *ADEL* project, on extending the concept of Licensed Spectrum Access (LSA) with time dynamicity, and even further in [18], from the *SPEED-5G* project, with the introduction of the extended dynamic spectrum allocation (eDSA) concept. For bands in the mmWave domain a disruptive approach is sketched in [19] from the *5GENESIS* project, and for

a more forward looking perspective for B5G on THz bands, a very recent survey is presented by authors in [20].

The ***integration among wireless and optical networks*** is a very appealing target of future networks, as discussed in [21, 22] from the EU-Brazil co-funded project *FUTEBOL*, and very recently in [23] regarding its positive impact on the backhaul topology optimization.

The ***integration between terrestrial and satellite networks***, as discussed in [24, 25] is a topic gaining more and more traction in 3GPP. That stems from the fact that real ubiquitous and disaster-resilient communications will be more and more looked for in the years to come, and a seamless integration of the satellite link coverage, also in remote areas, together with the features and performance of terrestrial networks can offer a valuable solution to ease the always more numerous natural disasters caused by the warming up of the average air temperature on earth.

Finally, an important field of activities is the integration of cellular technologies with the 5G verticals, like ***IIoT*** or ***Automotive and the more general ITS***. Among the huge existing literature on those topics, it may be worth mentioning, regarding IIoT, the work in [26], where authors provide a recent overview of applications and advances on 5G and B5G mobile technologies in that domain. Regarding the Automotive and the ITS domains, particularly interesting is the work in [27], where authors deliver a comprehensive survey on the standardization status and the open issues of the broader vehicular communication topic.

3 3GPP 5G Phase 1 and Phase 2

In this section we provide a short description of the way 3GPP bodies works, and then summarize what is the meant with and what is the content of '5G Phase 1' and '5G Phase 2'.

3.1 3GPP Working Procedures

3GPP organizes its work splitting the topics to be standardized in numerous parallel activities and in a hierarchical manner. The focus area of communication systems is organized in three high level groups, called ***Technical Specification Groups (TSG)***, which are:

- Radio Access Network (RAN).
- Service and System Aspects (SA).
- Core Network and Terminals (CT).

Each TSG is made of a different number of so called TSG Working Groups (WG), i.e., six each in RAN and SA, four in CT. The number of WGs can increase or decrease with the time, thus adapting in a dynamical way to the changes of the ecosystem, so to be always capable of coping with the raise of new needs or technologies. A WG can be closed if its focus area is considered completed, a new one can be opened if a new topic deserves a major effort and a focused activity spanning more years.

Each one of those WGs organize independently (in different times and locations) meetings with a specific cadence, during which a consensus-based decision mechanism is used to define the kind of and the content of the newly discussed features, and changes, corrections or amendments of the already existing ones. The participants to the 3GPP work usually physically meet each quarter co-locating the attendees of the three TSG in the same place, and on an almost monthly cadence for the work of the several WGs. Some WGs may decide, on special occasions, e.g. when cross-WGs decisions are to be taken, or when the expertise of different teams need to converge to solve a difficult technical issue, to co-locate their meetings as well.

When a new feature or functionality is to be added to the standards, the WGs operate in a 3-steps cycle of activities called *Stage 1 - Stage 2 - Stage 3*, each one partially overlapping in time with the others and feeding the next one in the row with its outcome:

- *Stage 1*: first use cases and scenarios for the new services and applications are introduced, together with related (new) requirements on the system architecture.
- *Stage 2*: Then changes are proposed to the different part of the lower (in the ISO/OSI layer sense) communication system architectural blocks, protocols and messages. If needed new architectural blocks can be proposed to take into account new needed functionalities.
- *Stage 3:* Finally, also the upper layers of the protocol stacks, together with the related new communication protocols and messages, are enhanced in order to fulfil the new services in the enhanced system architecture.

There is also a fourth short stage called '*ASN.1*', however we do not have enough room in this paper to enter in too many details.

During the work of each stage a set of documents is produced, each one of them usually focusing on a new single feature to be added to the system. Depending on their content and scope, they are called be ***Feasibility Study (FS)***, ***Technical Report (TR)***, or ***Technical Specification (TS)***, which is the most important one as it contains normative text, i.e. a description of a functionality or a feature that is to be literally fulfilled, if compliancy with 3GPP standards is looked for when a new device is commercially launched into the market.

The full-fledged implementation of a new feature therefore is obtained through the overall outcome of a cycle (Stage 1 to Stage 3), as shown in Fig. 2. When a feature is particularly complex, or when it implies a huge re-work of the existing standards, it is usually split in smaller activities called ***Work Items (WI)***, which are the smallest pieces of work that can be independently tracked and discussed at WG level.

A set of parallel activities on different features, and spanning a defined time window, is the so-called ***Release-x (Rel-x)***, which is composed of a set of new or enhanced architectural blocks, protocols, functionalities, and messages, to be added to the previously existing system, where '*x*' is a progressive number that distinguishes among old and new generations.

A Release is '*frozen*' when no new feature can be added to it, only essential corrections to the standards are allowed; that happens usually with roughly a yearly cadence. A Release can be '*closed*', when it no longer is maintained, and no changes or amendments are allowed any more. Finally, it is worth mentioning that TR and TS, once

created, can evolve and be enhanced through several Releases, each one of them adding new functionalities to the specific feature in focus in that TR or TS.

Technical discussions happen primarily during WGs meetings, where new documents, amendments, enhancements and new features are discussed and agreed-upon within the different partners participating to the work, thus creating so called 'normative documents', i.e., the mentioned above ***TS***. Overall alignment, resolution of controversial cases, and assessment of the compliancy with the working procedures of 3GPP of the work produced by WGs is usually the scope of the TSG meetings.

The following two subsections explain what the content of the first specifications on 5G are, what is already finalized and what are the still ongoing activities on the 5G system definition.

3.2 Release 15 (5G Phase 1)

3GPP bodies started to work on the definition of the 5G system with Rel-15 in 2016. Figure 2 shows a timeline of Rel-15 and Rel-16 work, where the x axis is a time axis based on the increasing number of the TSG meeting, taking place on average each three months. The first set of 5G features is composed of several TSs, which were completed under Rel-15, and that is what is called '***5G Phase 1***'.

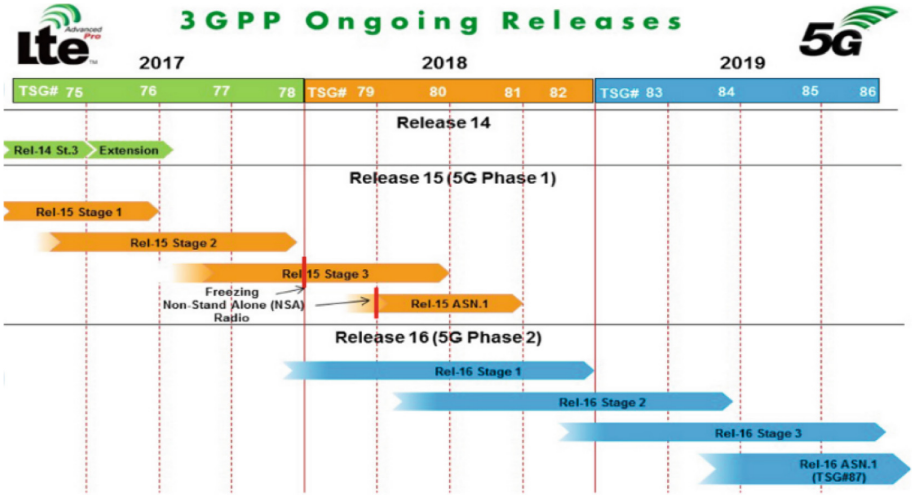

Fig. 2. Phase 1 and Phase 2 timeline (Source: 3GPP website).

Rel-15 mainly focused on eMBB services and worked on building the basic blocks of the new 5G system, describing the new 5G system access part, also called New Radio (5G NR) and the new 5G core network (5GC). Other new concepts have been introduced, like network slicing and virtualization mechanisms, a functional interworking with legacy (2G, 3G, 4G/LTE) cellular system and other wireless technologies (Wi-Fi).

Several proposals were made and discussed on the new 5G architecture, however only two so-called 'operations modes' were defined in Rel-15, i.e. the *Standalone mode*

(SA) and the *Non-Standalone (NSA) mode*. The former assumes an independent operation of the 5G NR with the 5GC, whereas the latter assumes that an existing LTE network, on top of which the new 5G network overlaps, provides the control plane for the 5G network to operate. The NSA work was prioritized as the 3GPP participant companies, as well as the overall ecosystem, identified that one as the mode which would create most added value; its new use cases and scenarios focus on features and services that are supposed to have a smoother and more successful market launch.

In a nutshell, the main new features of Rel-15 are the introduction of the new 5G NR access, and the first enhancements to the whole communication network in order to take more into account the requirements of the so-called 5G verticals, i.e. sectors of the industry that so far have not been seamlessly integrated with the mobile network, or of which only a partial support for their requirements was taken into consideration in previous 3GPP releases. Among the numerous 5G vertical one can mention Media and entertainment, ITS, IIoT, or the different paradigms that look towards the future evolution of our society called Smart-City, Smart-Grid, Smart-x, ….

It is important to mention that currently available commercial networks that run 5G services offer only a subset of all the defined 5G Phase 1 features. More will be deployed in the forthcoming quarters in an incremental manner. That is always the case when a new technology is launched, as it has to be ensured that first a smooth integration with the legacy system is possible, and then that the newly proposed services and applications are economically viable; indeed all of the above takes time.

3.3 Release 16 (5G Phase 2)

Rel-16, fulfilling the time-scheduled indicated in early 2016 as shown in Fig. 1, started at the end of 2017, its Stage-2 and Stage-3 definition is currently in full swing and principally ***takes care of the other two usage scenarios, i.e. mMTC and URLLC***.

The content of the new features and functionalities introduced by Rel-16, considered an evolution of the 5G system defined in 5G Phase 1, is what is called '***5G Phase 2***',

In general terms Rel-16 can be split in two sets of main activities or features, i.e. *Efficiency Items*, listed in Fig. 3, and *Expansion Items*, listed in Fig. 4. The former are a mix of system improvements and enhancements on different domains (positioning, MIMO, dual connectivity, etc.), which can be seen as an evolution of the previous releases and aim at overall improving the core 5G system functionalities, as defined by the 5G Phase 1. The latter aim at providing functions to serve (and better interact with) 5G verticals, like Automotive (in the 3GPP flavor of interaction between vehicles and the environment called Vehicle-to-everything (V2X)) and IIoT, as well as at handling other features like URLLC and unlicensed spectrum operations, which were not yet taken into consideration in the first set of features composing 5G Phase 1.

In both figures lighter coloured lines indicate set of features that got lower priority when compared to others of the same Release. Finally, it is worth mentioning that there are numerous other features under work that cannot be easily mapped on the listed items shown in both figures. However, The intention of this paper is not to provide a comprehensive report of the activities per release, rather to summarize and briefly elaborate on the main activities that drive the work of 3GPP WGs.

Looking at the content of Fig. 3, one can notice from the names that much attention is given to enhance the status quo, and to reduce the impact of the new introduced functionalities on the legacy system, specifically regarding the interference issues that might arise in using adjacent spectrum bands between 5G NR and legacy access.

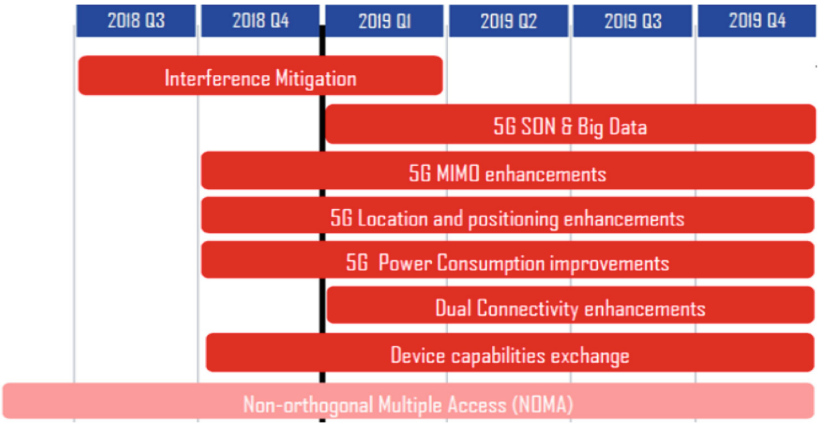

Fig. 3. 3GPP Release 16 Efficiency Items (Source: 3GPP website).

Looking instead at the content of Fig. 4, one can notice that a more disruptive approach is used on introducing new features, mainly targeting the mentioned above new interaction with 5G verticals, and with introducing the support for 5G NR to operate in unlicensed bands, a rather promising new feature for industrial deployments willing to operate by their own a cellular network (e.g. a vast industrial production environment).

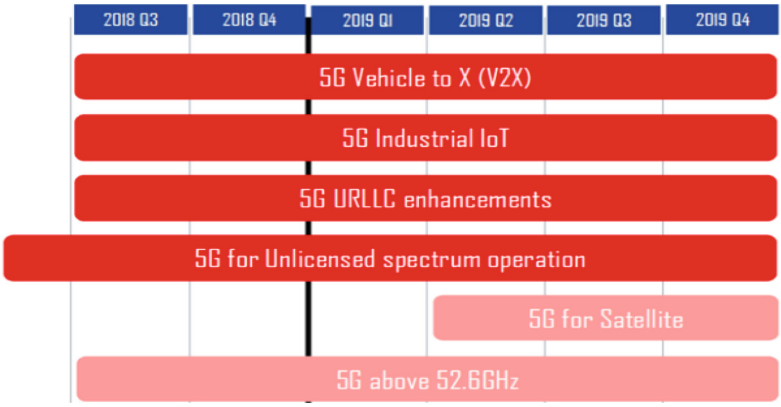

Fig. 4. 3GPP Release 16 Expansion Items (Source: 3GPP Website).

It is worth noting that a smoother interworking with satellite networks and work needed to operate on mmWave bands above 52.6 GHz have been given lower priority

compared to the other items. That might stem from the fact that the telecommunication community is waiting to analyze the outcome of the work done during the World Radiocommunication Conference (WRC-19), expected to be finished by the end of November 2019. The WRC is driven by the International Telecommunication Union (ITU) council and governs the usage of both terrestrial and satellite networks, including the allocation of new spectrum bands, e.g. in the lower mmWave range, for worldwide deployment. Therefore, decision taken there will have an impact on both satellite-terrestrial interworking and on the usage of mmWave access.

The same lower priority in the 3GPP work applies also to the introduction of more disruptive technologies like the Non-orthogonal Multiple Access (NOMA), a promising approach to improve the spectral efficiency while taming the interference experienced at receiver side [28].

In conclusion, what composes the Phase 1 and the Phase 2 of the 5G system is very well defined, part is being commercially launched starting with June 2019, part will be in an incremental manner commercialized in the forthcoming quarters.

4 Beyond 5G Phase 1 and Phase 2: Release 17

As Rel-16 is getting close to its completion, work has already started in defining the content of Rel-17, as sketched in Fig. 5.

Fig. 5. 3GPP Release 17 timeline (Source: 3GPP website).

During 2019 a long list of candidate features for Rel-17 has been drafted, 15 from the RAN groups and 29 from the SA groups, summing up to 44 entries, too many for the planned duration of Rel-17. It was therefore decided that a prioritization exercise will take place in the December 2019 plenary TSG meeting, and those entries that will not make it in Rel-17 will be shifted into Rel-18. It is important to stress that the list of Rel-17 features is now 'closed', i.e. no new items can be added to it. The latest news on Rel-17 is that during the November SA1 WG meeting, the Stage-1 of Rel-17 has been completed, and first discussions have just started on Rel-18 topics.

In the following, the list of features under discussion are reported, to give an idea of where in 2020 the focus of the 3GPP WGs will concentrate on.

The following SA features seem to have a common agreed-upon relevance and will therefore be treated within Rel-17 [29]:

- 5G system enhancement for Advanced Interactive Services,
- Architectural enhancements for 5G multicast-broadcast services,
- Architecture enhancements for 3GPP support of advanced V2X services - Phase 2,
- Enablers for Network Automation for 5G-Phase 2,
- Enhanced support of Industrial IoT,
- Enhanced support on Non-Public Networks,
- Enhancement of Network Slicing Phase 2,
- Enhancement of support for Edge Computing in 5GC,
- Integration of satellite in 5G systems,
- Support for Multi-USIM devices,
- System enhancement for Proximity based Services in 5G.

There is no shared agreement on the importance of the following SA entries, which will therefore be good candidate to be included in Rel-17 work during the December TSG meeting:

- Enhancement of support for 5G LAN-type services,
- Enhancement to the 5GC location services - Phase 2,
- Extended Access Traffic Steering, Switch and Splitting support in the 5G system architecture,
- Multimedia Priority Services (MPS) Phase 2,
- Study on enhancement of support for 5G wireless and wireline convergence,
- Supporting Unmanned Aerial Systems Connectivity, Identification, and Tracking,
- UPF enhancement for control and SBA.

And finally, the SA features that will be most probably shifted to Rel-18 are:

- Application awareness Interworking between LTE and NR,
- Cellular IoT enhancement for the 5G system,
- Enhancement of 5G UE policy,
- Service-based support for SMS in 5GC,
- Smarter User Plane,
- Support for minimization of service interruption,
- Supporting Flexible Local Area Data Network,
- System architecture for next generation real time communication services,
- Usage of User Identifiers in the 5G system.

For completeness, also the features planned to be discussed by the RAN groups are listed here below.

- Coverage enhancements,
- Generic enhancements to NR-U,
- Integrated Access ad Backhaul enhancements,
- MIMO enhancements,
- Multi SIM operation,
- NB-IoT and eMTC enhancements,

- NR above 52.6 GHz (incl 60 GHz unlicensed),
- NR for Non Terrestrial Networks,
- NR light,
- NR Multicast broadcast,
- Positioning enhancements,
- Power saving enhancements,
- RAN data collection enhancements,
- Sidelink enhancements,
- Small data transfer optimization.

In summary, even if the work has not started on the definition of the Pahse 2 and Phase 3 of Rel-17 features, we already know the content of the 5G system in the 2021/2022 timeframe, i.e. the dates by when Rel-17 systems will be commercially launched. This is important information, as knowing how standards work, people have the possibility to understand when and how the 5G system will be deployed, and which features are expected in which year. Such information is very relevant to both academia and industry to plan future activities, and push at the right time their innovative ideas, patents, or products into standards.

5 Beyond 5G or 5G Long Term Evolution? Release 18

According to a recent document discussed during the September plenary meeting [29], the real work on defining the Rel-18 content is supposed to start at the beginning of 2020 (Stage 1 work). However, we already know that some of the items listed above will not make it in Rel-17 and are therefore the best candidates to be among the features composing what will be called Rel-18, or at least a part of it.

Will the content of Rel-18 still be called '5G Phase X' or will it get a more appealing name, like for instance the rumored '5G Long-Term-Evolution', a name that has been used by the European Union for some of the text of its recent calls for new funded projects that target a long-term vision of 5G capabilities? We can only speculate on such topics, and we will know the answer probably in the next couple of quarters.

Even if the list of features that will be shifted out of Rel-17 into Rel-18 is already rather long, there are several other interesting new topics that could be taken into consideration for Rel-18 work. For instance, the feature of adding a ***dynamic (in time) spectrum management*** to the RRM functionalities. That is one of the innovation vectors that the 5GENESIS project [19] aims at pushing into the ecosystem. The proposal is to extend the work done in the finalized EU-funded research projects ADEL [30] and SPEED-5G [301], aiming at extending the 5G system architecture with logical blocks, functionalities, and messages that would make possible to allocate spectrum (disregarding if using Wi-Fi, 5G NR, or legacy cellular access) in a timely dynamical manner, say on minutes base. Several benefits can be mentioned if such a feature would be implemented, e.g., a much more granular and effective utilization of all the access technologies that surround a mobile phone, with the consequence of a much more energy-efficient operation of telecommunication networks. Moreover, having the possibility to allocate spectrum chunks with minute-granularity would increase of an important factor the capability

of making the best usage of all the available spectrum for access, disregarding of the underlying access technology, thus allowing for an overall increased spectral efficiency.

To that end the 5GENESIS project has already started to provide contributions to a standards body, i.e., ETSI Technical Committee Reconfigurable Radio System Work Group 1 (TC RRS WG1) [32, 33] so to engage with the ecosystem and prepare the discussions and the contributions for potentially impacting also the 3GPP bodies, ideally within the Rel-18 timeframe.

6 Conclusion

This paper provides an overview of the current status in 3GPP bodies of features and usage scenarios of 5G systems. International collaborative research projects and 5G Verticals are taken as examples of the new features and services that 5G can bring as added values for the final mobile phone users. After explaining what 3GPP 5G Phase 1 and 2 are, we have elaborated on what comes after, i.e., Rel-17, also providing for all the 5G releases a timeline of the planned work. Finally a glimpse of an interesting new item to be discussed in Rel-18 is provided, as part of the ongoing and future work of the 5GENESIS research project.

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