5G & FUTURE NET

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Introduction

The European Commission has been a very early supporter of 5G with visionary research sponsored already in 2012 [Ref 1]. At the Mobile World Congress 2013, Commissioner Kroes challenged the industry to come up with a structuring European approach for 5G R&D. This has led to the setup of the European 5G Public Private Partnership (5G PPP). The 5G PPP is implemented under the Horizon 2020 programme with about 700 M€ of public support over the 2014-20120 time frame, with a private sector contribution expected to match that amount by a factor of at least 5. Altogether, this represents the largest 5G R&D initiative in the world.

Piggybacking on these intense technological efforts, and taking stock of fast international developments, Commissioner Oettinger at the MWC 2016 urged the Euro-

pean industry to develop a 5G deployment roadmap. This has led to the 5G Action Plan (5G AP) presented by the Commission on 14 September 2016.
The European Commission considers that the emergence of 5G in Europe will be a strategic asset to support the digital transformation of the industry and of the economy and both the 5G PPP and the 5G AP testify of this bold ambition.

5G, R&D and Vision

Through a set of 19 core projects under Horizon 2020, the 5G PPP has been instrumental in researching and evaluating multiple technologies related to the main 5G scenarios contemplated by industry, namely i) the "enhanced Mobile Broadband (eMBB) scenario targeting carrier data rates larger than 10 Gb/s whilst the most sophisticated version of LTE (LTE-A-PRO) will reach about 3,2 Gb/s with spectrum aggregation; ii) the massive M2M telecommunication scenario (mMTC) targeting connectivity of millions of devices per km² whilst current scenarios are in the order of thousands of devices/km²; iii) the Ultra reliable Low Latency Communications (URLLC) scenarios, targeting latencies in the order of 1ms, whilst current LTE versions exhibit in the order of 10 ms or more latency figures.

These scenarios are in line with the socio economic evolutions driving the telecom and the wider ICT sector. Broadband access has become the norm and the advent of ever more feature rich content located in remote clouds coupled with ever more powerful end user devices like tablets and smartphones call for very high capacity and speed networks. The advent of the Internet of things, with massive deployment of connected objects in cities or in dense location areas calls for new approaches to efficiently address huge collections of devices with minimum power consumption whilst the advent of very low latency systems opens the door to new mission critical applications where response time is of the essence, such as in factories environments, healthcare, or automated driving.
The 5G PPP has also developed a European 5G vision, where vertical use cases are leading 5G developments. This was outlined in a White Paper [Ref] released at the Mobile World Congress 2016. This paper describes a European approach with 5G seen as a more holistic and radical network transformation to serve vertical industries, with connectivity solutions tailored "ad-hoc" to the specific digital business case of diverse industries (e.g. automotive, health care, smart factories, energy, media). In this case, the role of connectivity shifts from a "cost factor" to an intrinsic asset of a full digital product or service. This strategy relies on the development of cross sectors ecosystems, in addition to providing short term super high rate access, It is directly in line with the wider policy ambitions of "Digitisation of the European Industry" (DEI) [Ref].

Within this perspective, 5G has two main aspects:

First an evolutionary aspect, where 5G brings more of the same". That means that through the normal stream of technology evolution, 5G will allow the same applications as we have today, but with much better performances. Faster Internet access, faster video downloads, better access in crowded places are typical examples. Users may not see a new category of applications, but they will enjoy a much better quality of experience. This is what may be seen as the "evolutionary" 5G path, extending beyond the current 4G capabilities.
Second, 5G is expected to make possible, new classes of application and business models that are not possible with today existing technologies. This may be seen as the revolutionary aspect of 5G. Applications with very low latency and extreme reliability, will become possible whilst they may be limited today. Telesurgery, critical communication for energy grids where reactions time needs to be very short in case of failure, robotic application in factories, connected cars with instant reactivity between automated cars are application that may be unleashed by 5G. And this will in turn create new business models and ecosystems whose advent may be limited with existing technologies.

New Business Models

Telecom operators are currently facing several challenges with flat revenues, decreasing ARPU's and open questions with respect to business model evolution, multi-stakeholder coordination, alignment of incentives, regulation and competition [1]. The evolution of business models integrating in win-win partnerships the requirements of multiple vertical industries offer opportunities to NSP's that 5G is being designed to satisfy. The major challenge is to deliver the needed level of service to a vertical (SSLA: Service and Security Level Agreement), while keeping a sufficient control of its own and whole infrastructure.
Changes are induced in the relationships between different actors of the value chain. Service requirements from different vertical industries may be aggregated from different 5G infrastructure providers, in view of satisfying pre-established end to end service level agreements. This is a completely new paradigm compared to earlier network systems. It directly expands the service portfolio marketable by network operators towards flexible and "tailor made" service provision to vertical markets and B2B operations. Stakeholders from vertical industries such as automotive, energy, factories, health, media, public transportation aeronautics and other sectors, can take the role of SPs providing services directly to end-customers on top of the infrastructure and connectivity services of infrastructure providers. These opportunities are conditioned by the ability of 5G technologies to provide the targeted performance levels of vertical stakeholders and allow the creation of this new dynamic ecosystem around 5G networks.

Economic opportunities

From a market perspective, it is predicted that 5G revenues may reach US$250 billion in 2025 with North America, Asia-Pacific, and Western Europe being the top markets [2], with critical and massive Machine to Machine communications potentially generating high revenues in addition to enhanced Mobile Broadband services. A study carried out for the Commission indicates that yearly the benefits of 5G introduction over 4 industrial sectors may reach €113 billion per annum will arise from the introduction of 5G capabilities. In year 2025 it is expected that €62.5 billion will arise from first order benefits in the four key industrial sectors examined in the study [3] (automotive, healthcare, transport, utilities).
Lead industry actors also predict that 5G will already represent more than 150 million connections in 2021 [4] globally, more than the current LTE subscriptions in Europe (147 million).
Other available studies [Ref IHS] taking a longer term approach also indicate that 5G will contribute to a $12 Trillion output in 2035, i.e. about 4,5% of the global economic output, the contributed output in the ICT sector being of $ 1,4 trillion (11%). These figures have been established using models based on observation of the economic impacts deriving from the introduction of earlier generations of network technologies.

Technological approach

The implementation of the 5G PPP vision addresses a wide ranging set of technologies. The Commission has recognised the need to move towards the "Gigabit society" [Ref]. This can be supported by wireless technologies, taking as a target the ITU objectives [ref] of moving beyond 10 Gb/s on the radio access. Carrier aggregation has eventually some limitations, considering the growing complexity of devices integrating several bands and the fact that multi band combinations may come at a loss of 20% of spectrum efficiency. This

has prompted industry to consider the use of higher frequency bands at mmwave frequency ranges, where large chunks of contiguous spectrum is available. Over the last two years, several industrial trials have demonstrated the capability of higher frequency bands, (e.g. 15, 28, 73 Ghz) to support data rates above 10 Gb/s either in fixed or mobility conditions.

On the other hand, the realisation of 5G capabilities go much beyond the availability of a new high speed radio interface. Multiple technologies are called upon to support:

- a flexible radio access network that allows operators to manage an heterogeneous set of access technologies and to optimise the access according to the required service capabilities and to manage multiple radio accesses as a seamless access continuum across multiple frequency bands ranging from UHF to mmwave;
- a large range of deployment scenarios, including a variety of static or moving nodes, with much denser deployment of access points, integrated backhaul/fronthaul operations, and optimised locations of Centralised Units (CU) and Distributed Units (DU) in the context of C-RAN implementations;
- very low latency services, with optimisation at several levels, e.g. at air interface level with MAC design enabling fast access and low TTI, and at architectural level using Mobile Edge Computing and in network caching techniques;
- massive connectivity services, with redesign of access protocols enabling to drastically reduce the signalling load over the air interface, whose overhead tend to grow very fast as large amounts of devices with small bursty traffic try to access a resource pool;
- high performance in high mobility scenarios, with control of Doppler effects at higher frequency ranges and optimisation of handover overhead in high density deployments.

The above issues may be considered as a non-exhaustive set of issues where 5G R&D is today concentrating. A White Paper presented by the 5G PPP in the context of the MWC 2017 [Ref] details the contribution of European R&D to these issues.

Beyond these "classical" aspects mostly related to Radio Access Network architectures and technologies, the full transformative value of 5G will however require the adoption of NFV and SDN technologies at large scale to support a redesigned core network. This is required to make 5G a holistic orchestration platform that integrates networking, computing and storage resources into one programmable and unified infrastructure. It supports the vision that requires a flexible multi-tenant architecture where computing resources are distributed within the network including sites of the vertical industry stakeholders, within the base stations, in edge clouds at central offices, in regional and central clouds, and managed by different stakeholders.

The full realisation of 5G hence calls for a next generation Core Network architecture based on SDN/NFV paradigms to address an Access Agnostic Converged Core Network, enabling next generation services regardless of access network and integrating next generation devices. It feature fully flexible, programmable separate Control and Data planes, unified connectivity, security, mobility and routing [5] management, as well as a unified physical infrastructure and corresponding abstractions (virtual resources, functions, etc.) control and orchestration. Eventually, it may require a Network Operating System to manage and orchestrate a unified access to computing, storage, memory and networking resources across wired networks, wireless (cellular and satellite, access and fronthaul/backhaul) networks, which requires the identification of abstractions of primitives, functions and corresponding states, in the control and data planes for a unified connection, security, mobility and routing management. These aspects are currently subject of intensive research work worldwide. The 5G PPP has released an Architecture White Paper addressing these issues [Ref Arch WP]

Towards Trials and Deployment

Whilst a "full capability" 5G system is still in the research domain, several operators have announced 5G early deployments for customer trials already in 2017, taking advantage of the relative maturity of new access technologies at mmwave frequencies with capability to move access rate level up by one order of magnitude. This is primarily the case in the US, where eMBB applications are contemplated as priority deployment, and pushed by Verizon and AT&T. South Korea has also an aggressive deployment plan with 5G showcasing planned for the Pyun Cheong winter Olympic games in 2018. These early 5G versions target primarily Fixed Wireless Access at 28 GHz, as a solution to rapidly provide very high rate access capabilities as an alternative to fiber access. Mobile application scenarios target high speed trains in the first place, with a 28 GHz demonstrator being built along the rail tracks between Seoul Airport and the location of the Olympic games.

These deployments have been largely facilitated by the availability of the required spectrum. In the US notably, the publication of the "Spectrum Frontier" rulemaking in July 2014, laying down a set of applicable 5G frequency bands together with their conditions of use has been a decisive factor to initiate industry initiatives and investments.

In Europe, the Commission considers that 5G is a strategic infrastructure and that we should avoid to replicate with 5G the uncoordinated and late deployment that prevailed for 4G deployment. From that perspective, it is considered that it is now time to define an ambitious deployment plan of 5G, with a coordinated European approach. These considerations have led the Commission to present the "5G Action Plan" on 14 September 2016, together with a consistent "connectivity package" [Ref] including the proposal for a revised regula-

tory package, a Communication of the "Gigabit Society" with proposals to move towards availability of access in the GB/s range by 2025, and an initiative aiming at supporting WiFi availability in public places (WiFi4EU).
The 5G Action plan draws on the pro investments measures of the proposed new regulatory package to facilitate early deployment in Europe. It builds on the "5G manifesto" developed by industry [Ref] in the context of the 5G industrial Roundtable put in place by Commissioner Oettinger early 2016 to prepare a common industrial roadmap for 5G deployment in Europe. Main target objectives of the 5G Action Plan include:

- introduction of early trials in Europe in 2018;
- deployment in 2020, with at least one "5G city" in every Member State;
- availability of 5G along main transport paths in 2025;
- coordinated approach by Member States towards 5G deployment, with 5G deployment issues addressed in the National Broadband Plans of the Member States;
- identification of pioneer frequency bands and availability for early trials and commercial introduction in 2020;
- support to development of "holistic" standards (not eMBB limited);
- availability of a venture fund to catalyse a 5G ecosystem of smaller players.

From a Commission perspective, it is key that European industry moves forward to deploy and trial 5G capabilities in Europe in view of staying a credible actor in this global race. To convince vertical sectors and stimulate investments, new business discovery requires demonstrators and large scale 5G trials also with vertical sectors, beyond industry-customer trials. Member States role is crucial, considering the public nature of key verticals (mobility, health, energy...) whose cross border operations will require from Member States better coordination of spectrum allocations.
The 5G PPP phase 2 (operations starting mid 2017) expands significantly the stakeholder base of 5G PPP phase 1, launched in 2015, focused on 5G core technologies. Phase 2 already includes early trials and proof of concepts for key verticals like automotive, media, healthcare. These projects will initiate concrete 5G demonstrations with key verticals in Europe already in 2017 in line with the 5G Action Plan. The 5G PPP phase 3, currently under definition and covering the 2018-20 time frame, will support large scale demonstration and trials with a support of about € 400 million from the European Horizon 2020 R87 programma.
In response to the 5G Action plan, the industry also announced at the last Mobile World Congress the preparation of a coordinated approach towards a European trial roadmap [Ref]. This roadmap is expected to be presented at the 3rd 5G Global event taking place in Japan on 24 and 25 May [ref]. In that context, the declaration of under state secretary Giacomelli at the second 5G Global event in Rome last November [Ref] announcing 5G pilots in 3 Italian cities to be started in 2017 is a very welcome support to the Commission strategy.

Connected and Automated Driving (CAD) aspects

As part of the 5G for verticals vision, CAD is an important use case. The creation in July 2016, with Commission support, of the "European Alliance between Telecom & Automotive" (EATA) to promote CAD deployment has led to a pre-deployment cross-border project being prepared for testing CAD in real-world settings and with the direct support of the Member States involved. 5G is a core technology to be tested in the context of connected cars. The Alliance targets CEF Transport funding in the context of hybrid systems. Plans are being developed to trial 5G cellular technology in cross border CAD corridors, which is essential to support the broader context of mobility attracting also private investors beyond public investments contemplated for safety related services.
At the last Mobile Worl Congress, the EATA signed a MoU with the 5G Automotive Alliance (5G AA) to jointly study deployment scenarios and co-existence/complementarity of a portfolio of technologies including 802.11.P, cellular V2X developed as an LTE evolution and 5G. This is considered crucial to best identify the business models and corresponding infrastructure scenarios in the context of public private partnerships.

Spectrum and Standards

Early availability of spectrum is to enable 5G deployment in Europe. The identification of 5G spectrum above 24 GHz (i.e. in the millimeter wave range) is framed by the ITU preparatory process, which has identified a number of candidate bands between 24.25 and 86 GHz to be studied until the next World Radiocommunication Conference in 2019 (WRC-19).
Whilst the 28 GHz band was not part of the bands to study by the last WRC, several nations (US, South Korea, Japan) have decided to already allocate this band for early 5G introduction, in view of driving the international spectrum policy agenda. Amongst the other heavyweight ITU members, China is pushing for the 26 GHz band.
In the European context, the RSPG concluded in its Opinion on 5G Spectrum, adopted in November 2016 and supported by the European industry, that there was a need to pick a set of pioneer bands for early 5G trials and pilots, in order to ensure appropriate early commercial deployment in 2020. The 26 GHz band is one of these pioneer bands, together with the 700 MHz and 3.6 GHz bands. It was deemed essential for obtaining the very high data speeds targeted by 5G, thanks to the considerably larger bandwidth it can offer compared to the lower spectrum bands. Its compatibility for the use by 5G is to be studied swiftly by the CEPT, as tasked in the EC Mandate on 5G spectrum that was adopted by the RSC in December 2016. These positive developments should support the ambitious deployment objectives of the 5G AP.
Similarly, global standards are needed to support the ambitious use cases that are targeted by 5G. The recent 3G PP meeting of TSG RAN and SA that took place in Dubrovnik from the 6 to the 10 of March have allowed significant progress on this issue. The meeting has decided to start a new Work Item (WI) under release 15 aiming at the standardisation of the New Radio (NR) of 5G.
It indicates that:
The work item should specify the NR functionalities for enhanced mobile broadband (eMBB) and ultra-reliable low-latency-communication (URLLC) as defined in [TR38.913]. The NR under this work item should consider frequency ranges up to 52.6 GHz. The NR functionalities shall be forward compatible and allow for smooth introduction of additional technology components and support for new use cases. Backward compatibility of the NR to LTE is not required.
Several connectivity options as defined in TR38.801 and corresponding to either non standalone or standalone options are considered for this normative work. However, the agreed schedule indicate that:

a) Complete Stage-3 Layer 1 and Layer 2 user plane specifications common to all supported architecture options to be finalised until December 2017. It takes into consideration the fact that for some aspects, Layer 1 and Layer 2 user plane specifications are different between single connectivity and Dual Connectivity options.
b) Complete Stage-3 specifications on eMBB including support of low latency for E-UTRA-NR DC via EPC where the E-UTRA is the master to be finalised until December 2017.
c) Complete all the core specifications for the other supported architecture options until June 2018.

a) and b) above indicate that the early drop that will be finalised by December 2017 is related to the non standlone option, i.e. NR operated through a classical EPC. Standalone options operated by an NG Core network are delayed by 6 months.
The decision reached at that meeting may be considered as satisfactory from a European perspective. On the one hand, it allows the fast movers to quickly progress towards early eMBB implementations of 5G compatible with a 3G PP standard, at least from the lower layers per-

spectives. On the other hand, it does not exclude other use cases, as the URLLC option is clearly indicated as part of the priority of the normative work.

In addition, a number of Release 15 Study Items have been decided by the meeting, paving the way towards further evolutions of the standards for other use cases such as V2X, NOMA access, non terrestrial networks..From that perspective, it will be key to ensure that future 5G PPP work clearly contribute to the evolutions of the more complete version of the standard expected to be available by 2019.

Conclusion

The European Commission has identified 5G as a key infrastructure in the context of the wider policy objectives aiming at a modernised digital industry and economy. Bold support has been provided to industry through structure and targeted research programme and through policy initiatives aiming at accelerating the availability of 5G in Europe. Moving towards early trials is of the essence and the framework conditions to make it happen (availability of technology, frequency bands, standards, regulation) are rapidly developing. It is now up to the industry to seize the opportunities and to develop ambitious plans to make Europe a lead market of the 5G era ■

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