5G & mobile network developments

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1 Issue 1: Are there any additional demand drivers supporting 5G network deployment in Australia not identified in this paper?

The occasional paper covers only the demand for mobile services strictly related to *Enhanced Mobile Broadband* (up to 10Gb/s peak per link) which is only one of the drivers for next generation mobile networks. 5G is especially needed for ***Mission Critical Machine Communications*** (1ms latency and 100% reliability), and ***Massive Machine Communications*** (100bn connections) [1]-[8]. 5G technologies will efficiently enable new secure, dependable, ultra-reliable, and delay-critical services to everyone and everything, such as cognitive objects and cyber physical systems (CPSs).

A ***full immersive experience*** and ***anything as a service*** are the primary drivers for a global adoption and market uptake of new technology components, beyond today's client– server model, where the network has been reduced to a mere pipe of bits. For instance, to this end, a full parallax holography rendering, over a "retina display" with more than 100 degree vision (multiple views), with soundfield audio reproduction for a spatial sound experience, would require up to 1Gb/s. Anything or everything service (XaaS) refers to those services—beyond the current software platform and infrastructure (SPI) model (software as a service, platform as a service, and infrastructure as a service) of cloud computing—such as data as a service (DaaS), security as a service (SaaS), knowledge as a service (KaaS), machine as a service (MaaS), robot as a service (RaaS), Network Slice as a Service (NSaaS) and so forth, that could be delivered over the 5G infrastructure without the need to own hardware, software, or the cognitive objects themselves [5].

The network will become the nervous system of the true digital society, digital economy, and silver economy [5]-[8]. The advanced 5G network infrastructure will be a key asset to support the Australian societal transformation, leading to the fourth industrial revolution and impacting multiple sectors. As a result of this transformation, vertical industries will have capabilities to trigger the development of new products and services. Identifying key vertical sectors' requirements, anticipating relevant trends early and mapping them into the 5G design is a fundamental element for the 5G success in Australia. Examples of innovative digital use cases from the most important vertical sectors are [1]:

- ***Factories of The Future***;
- ***Automotive***;
- ***Healthcare***;
- ***Energy***;
- ***Media & Entertainment***;

An inclusive analysis of the corresponding requirements shows that *latency* (below 5ms), *reliability* and *density* (up to 100 devices/m^2), along with tight constraints on territory and/or population *coverage*, are the most important performance targets 5G needs to achieve for supporting all possible services of the five investigated sectors.

A comprehensive analysis and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe was presented in [2]. The document discusses the most important emerging use case were consensus has been achieved, 5G capabilities and a qualitative analysis of impact and benefits of 5G to vertical sectors and environments. In the report, special focus was placed on Automotive, Healthcare, Transport, and Utilities with policy and regulatory considerations, also relevant for the Australian market. The 5G socio-economic analysis provides an overview of the output and employment effect of the €56.6 billion 5G investment in the EU28 Member States. The report highlights that 5G investment will lead to 'trickle-down' or multiplier effects with a value **€425.5 billion**. These effects are likely to create **7.184 million jobs** in EU28 Member States. These figures may be used to calculate the potential output and jobs creation in Australia.

Furthermore, the *global ageing* is one of the greatest transformations of our time and the *Silver Dollar*, defined as the public and consumer expenditure related to population ageing and specific needs of the people over 50, is becoming the 3rd largest economy in the world, i.e. US$7 trillion per year, with private spending power of the elderly generation reaching $15 trillion by 2020, globally. The latest progresses on key 5G enabling technologies to help older persons live better, independently, whilst reducing cost and effort of long-term care were presented in [7]. Among other things, authors described the main stakeholders and actions taken in Europe, particularly relevant for the Australian needs, to address the ageing population problem, and discussed the most important usage scenarios, new business models and the crucial 5G capabilities and related enabling technologies for ***Active and Healthy Ageing (AHA)***, namely: Sensing, Reasoning, Interacting, Acting and Networking, using the 5G advanced infrastructure, which is expected to become the new lifeblood of the Silver Economy.

2 Issue 2: Are there any additional significant enablers or major inhibitors to 5G network deployment in Australia that are not identified in this paper?

The occasional paper covers only a part of the significant enablers and inhibitors to 5G network deployment in Australia. Additional inputs may be taken from the most important 5G initiatives ongoing globally, especially the 5G Private Public Partnership (5G-PPP) in Europe. The 5G-PPP is within the EU Horizon 2020—The EU framework Programme for Research and Innovation—under one of the most important EU industrial leadership challenges: ICT Advanced 5G network infrastructure. Within this research and innovation framework, the European Commission, under the approval of the European Parliament, has committed **€700mn** of public funds over six years (2015–2021). The investment of the Private Party (e.g., industry, small and medium enterprises (SMEs) and research institutes) is expected to be two to ten times higher than the public funds. Bilateral and multilateral Joint Declaration (JD) and Memorandum of Understanding (MoU) have been already signed between the corresponding public and private parties in EU, China, Japan, Korea and USA, looking at an international cooperation on relevant 5G themes, such as vision (global understanding), joint research actions, global standardization, spectrum requirements, and Internet of Things (IoT).

Australia is currently not on the global map, and one possible goal would be to bring Australia on the same level playing field [9]. Initial contacts between the European Commission (Public Party in EU) and 5G Infrastructure Association (Private Party in EU) and Australian representatives were established at MWC2016 in Barcelona.

In the following, we report some relevant information on technical and operational characteristics of 5G systems and 5G evolutions through advances in technology and spectral efficient techniques, and their deployment. More insights into the presented future technical aspects of 5G, and ongoing and upcoming projects in Europe, may be found in [10] and [11], respectively.

The network architecture, air interface and spectrum usage evolution from 4G to 4.5G and 5G may be summarized as follows:

- **4G (3GPP LTE R12 and older releases)** is characterized by two network domains: Evolved Packet Core network (EPC) and a Long Term Evolution radio access network (LTE), with utilization of large blocks of spectrum below 6GHz and up to 5 carrier aggregation (CA).

- **4.5G (3GPP LTE R13 and later releases)** supports new features, such as: LTE-WLAN Aggregation (LWA); Licensed Assisted Access to Unlicensed spectrum at 5GHz (LAA or LTE-U); LTE Carrier Aggregation enhancements (eCA); Beam Forming / Full-Dimension (MIMO); Low Latency LTE; Multi-User transmission; LTE-M enhancements FDD; Narrowband IoT (NB-IoT); Enhancements to R12 Proximity Services (ProSe) for Device to Device (D2D) communication. (LTE D2D framework expansion to Vehicle to Anything (V2X) applications, with initial priority on V2V safety applications, is a target for Release 14.)

- **5G (IMT for 2020 and beyond)** will be characterized by a new flexible (plastic) architecture that supports network slicing (multi-tenant business model), a new configurable air interface and multiple access schemes, exploiting much larger blocks of spectrum also at higher complementary frequencies (above 6GHz) with wider carrier aggregation in the range from “cellular band” up to “visible light”.

Key enabling wireless technologies can be divided into two categories, depending on the type of filtering at sub-carrier or sub-band level, respectively:

- Filter bank multi-carrier modulation (FBMC) with QAM/Offset OQAM (OQAM) signaling; pulse shaped OFDM (P-OFDM); and flexibly configured OFDM (FC-OFDM).
- Universal-filtered OFDM (UF-OFDM) and filtered OFDM (F-OFDM), which can be based on both CP-OFDM and zero-postfix OFDM (ZP-OFDM).

The choice of either one of the two variants depends on the required degree of spectral and temporal confinement.

The spectral efficiency of 5G systems may be further improved by advanced modulation and coding schemes, and multiple access techniques. For instance, non-orthogonal multiple access (NOMA) allows multiple users to share time and frequency resources in the same spatial layer via power domain or code domain multiplexing, including multiple access with low-density spreading (LDS), sparse code multiple access (SCMA), multi-user shared access (MUSA), and so forth. Other multiple access methods such as pattern division multiple access (PDMA), interleave division multiple access (IDMA) and bit division multiplexing (BDM) may be also possible.

Software-Defined Networking (SDN), network functions virtualization (NFV), and mobile edge computing (MEC) are among the most important emerging technologies for configuring flexibly network nodes, as well as optimally processing and improving the operational efficiency of network. In 5G, the shift in paradigm is about moving from a functional architecture based on logical boxes and related interfaces, which in practice correspond to specific physical network elements and interface cards using dedicated hardware, to a **service and software defined architecture** composed by logical functions (network and service applications) installed on purpose, to support multi-tenant business models and related carrier grade services, end to end. The flexible and malleable (plastic) architecture consists of selected applications and links mapped onto **virtual network slices** embedded separately and in isolation within a single physical infrastructure (network elements and data centers). An end to end network slice is an instantiation of tailored system architecture over a software-defined or physical infrastructure, composed by a set of interconnected logical access and core network functions in the control, data and management planes, to provide the diverse services in the intended usage scenarios.

In **5G-PPP Phase I** (**2015-16**, EU Public funds **€128mn**), 19 co-funded projects have been retained from the 83 proposals received by the EC in response to the first call of H2020. The comprehensive project portfolio covers radio access network architecture and technologies, convergence beyond last mile, network management (including quality and security aspects), and virtualization and software networks.

In **5G-PPP Phase II** (**2017-18**, EU Public funds **€148mn**), research and innovation projects will address wireless access and radio network architecture/technologies, high capacity elastic - optical networks, software networks, ubiquitous 5G access leveraging optical technologies, and flexible network applications.

In **5G-PPP Phase III** (**2018-20** EU Public funds **€420mn**), research and innovation actions will target show cases and large scale trials in Europe, with a tight collaboration between keys stakeholders (industry, verticals, SME and academics), and especially leveraging results and capabilities of previous projects. The target is to have the first commercial roll-out of 5G systems in Europe.

3 Issue 3: Are there additional regulatory issues around 5G network deployment, relevant to the ACMA's responsibilities that are not discussed in this paper?

Within each of the five identified key components of an internet-enabled economy, existing and new regulatory arrangements that may further enable the development of mobile networks should be also considered for [5]-[10]:

- Infrastructure: **wireless/wireline for back-/fronthauling**; **flexible spectrum usage (allocation/licensing) schemes** for maximal exploitation of new spectrum below 6GHz (primary for coverage and mobility) and above 6GHz (complementary for capacity), following the two main global resolutions of WRC15.
- Devices: **cognitive objects** such as service robots, cars, drones, cyber physical systems, and so forth, beyond smart phones. **Dependability of devices** – in terms of reliability, maintainability and maintenance support performance of devices that have to operate in human-inhabited environments.
- Services/apps: **network applications**, **anything as a service**, beyond cloud computing models, and **managed services**, where 3rd parties could accelerate the development/deployment of integrated offerings by managing the whole value chain on a fee-per-service basis. **Security** and **dependability** of services/apps.
- Digital information/digital content: **sound-field** and **light-field capturing/rendering**, **holographic displaying**.
- Users interacting with each of these elements: evolution of social networks including **communities of cognitive objects (artificial intellingence) and humans**.

In addition to what discussed in the paper, other actions by the regulator, to support the development of current 4G and upcoming 5G mobile network, should focus on **support for 5G global standards (e.g. ITU-R and 3GPP)** to ensure all requirements from Australian consumers and especially from Australian vertical sectors (mining, agriculture, energy, care/health and transportation) are incorporated in the standards, so that 5G will be the platform of choice to support an industrial and economical transformation at national level.

In Europe, and globally, vertical sectors acknowledge the strong need for high performing and innovative communication networks and call for policies that would promote and reward such an investment [1]. Yet, new regulatory arrangements need to make sure that **operating an ICT network remains profitable** enough to finance continuous network upgrades and thus match demand for speed and capacity at national level. This latter point is a crucial condition for the large scale deployment of 5G and the foundation for an IoT economy. In Australia, carriers should be in the position to invest in network capacity and improvements with the assurance that they can offer specialized services – in particular IoT services, such as Tele-care and Tele-health, smart cities and connected cars – that are based e.g. on specific commercial agreements and Quality-of-Service levels. The lead for network investment needs to be stimulated by a reviewed regulatory framework in a way that reduces sector-specific ex-ante regulation and ensures a level playing field across market players in the digital value chain [1].

Ultimately, appropriate regulations need to be created and put in place **without constraining innovation**: there will be always needs for space in the regulatory environment that allow new players to enter markets with disruptive solutions and new offerings.

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David Soldani received a M.Sc. degree with maximum score and “cum laude approbatur” in Electronic Engineering from the University of Florence, Italy, in 1994; and a D.Sc. degree in technology with distinction from Aalto University, Finland, in 2006. In 2014, he was appointed Visiting Professor at the University of Surrey, UK. He is one of the top experts in multi-disciplinary, transformative frontier research.

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