Joint Expert Group and Vision Group Workshop
Bologna, March 16th 2016

LABORATORIO DELLE ARTI, Auditorium room.
Organizers: Arturo Azcorra, Jean-Sebastien Bedo

Rapporteurs: Jaime García-Reinoso, Alexandro Stavdas, Alessandro Vanelli-Coralli ,and Roberto Verdone

Summary

The Expert Group together with the Vision Group of the NetWorld 2020 European Technology Platform for communication networks and services held a joint workshop in Bologna last March. More than 80 researchers and professionals on the area of telecommunications attended the workshop, promoting a lively and intense debate in 5G and beyond technologies.

As originally scheduled, 18 contributions were presented in the workshop, divided in four different sessions: experimentation with verticals, virtualized network and services, radio networks and optical networks. These contributions tackled several relevant topics like D2D (device-to-device) communications, C-RAN, satellite communications in 5G, distribution of audiovisual media services, WDM, UAV/RPA in 5G, VLC, V2X (vehicle to everything), softwarization, EPC virtualization, etc. Furthermore, one more contribution was presented in the verbal presentations slot. The main result of the workshop is the certainty that there are several outstanding proposals, envisaged to improve current networks beyond 5G.

Apart of the presentations, attendants enhanced the contributions with their questions and appropriate comments, which promoted an intense and fruitful debate. All presentations are now public in the Expert Advisory Group webpage, and it is possible to download all of them by following the links available in the agenda.

Agenda

9:00 Welcome and Introduction

Welcome by Expert Group Chair and Vision Group Chair, Arturo Azcorra, IMDEA Networks and Univ. Carlos III, Expert Group Chair*, and* Jean-Sébastien Bedo, Orange, Vision Group Chair
Inaugural address by Werner Mohr, Head of Research Alliances - Technology and Innovation, Nokia

9:30 Experimentation with verticals, Chair: Roberto Verdone

5G - Using UAVs for Better Connectivity, Roberto Verdone, University of Bologna
Audiovisual media services in the 5G environment, Darko Ratkaj, EBU
5G Playground – a flexible 5G environment tailored for the verticals, Ilie Daniel Gheorghe Pop, NGNI – Fraunhofer FOKUS Institute

Integrating verticals with the 5G communications network for E2E experimentation, Raul Muñoz, CTTC
Complementary Mobile Operator Business Models to Facilitate Fast Emergence of Digitized Society, Matti Latva-aho, University of Oulu

11:15 Virtualised Network and Services, Chair: Jaime García-Reinoso

Intent Based Networking, Pedro Aranda, Telefonica I+D
Lightweight EPC Virtualization for Mobile Network Operators, Felipe Gil, AtlanTIC
Standing on the shoulders of Softwarisation, Jaime Garcia-Reinoso, University Carlos III of Madrid
Network softwarization, network management and energy efficiency: friends or foes?, Franco Davoli, University of Genoa

13:15 Radio Networks, Chair: Alessandro Vanelli-Coralli

Wireless ultra-reliable low-latency device-to-device communication, Thomas Zemen, Austrian Institute of Technology
V2X Communications: The Killer Application of Millimeter Wave, Nuria González-Prelcic, University of Vigo
On the integration of terrestrial and satellite systems in future 5G networks: a waveform perspective, Alessandro Vanelli-Coralli, University of Bologna
Self-Organising and Programmable Virtual Cloud Radio Access Network for 5G and Beyond, Hamed Al-Raweshidy, Brunel University London
Signal Processing Challenges for Communications beyond 5G, Giuseppe Caire, TU Berlin
Beyond 5G: Toward the Terabit Wireless Era, Emilio Calvanese, CEA-LETI

15:15 Optical Networks, Chair: Alexandro Stavdas

Next Generation Fixed-Wireless Converged Access Networks, Alexandro Stavdas, University of Peloponnese
Guaranteed Service Packet-Based WDM co-hauling, Carla Raffaelli, University of Bologna
Second thoughts on common home objects: Lamps and home gateways, Ioannis Neokosmidis, INCITES

16:00 Discussion and Wrap-up, Chairs: Arturo Azcorra, Jean-Sébastien Bedo

Verbal presentations of key ideas not in the main program
Expert Group Workplan and related actions
Workshop closure

Workshop Operations

The call for contributions was announced to the EC community through the 5GPPP expert group lists, with a short period of time to submit proposals. Even so, we received 27 contributions with an excellent quality. Because of the time constraints for a one-day workshop, some of the received contributions could not be accepted for the programmed sessions, and only 18 were included as main contributions. This decision

was made based on complementarity, to include a widespread number of topics. In order to include all submitted contributions, a special session called "*Verbal presentations of key ideas not in the main program"* was incorporated in the agenda.

Workshop Lessons

The following is a summary of all contributions presented in the workshop, including some comments from the attendants.

Session 1 – Experimentation with verticals
The session included five contributions.

Roberto Verdone, representing the University of Bologna and the startup IDESIO, discussed the possible role of small Unmanned Aerial Vehicles (UAVs), also known as "drones", in 5G. It was postulated that in the near future regulations might allow certified operators to fly over cities with UAVs equipped with multi-radio ports connected to the 5G base stations. According to this scenario, benefits in terms of coverage, capacity and network flexibility were mentioned. A discussion was held at the end of the presentation, with some of the workshop attendees that claimed this scenario as worth being investigated further.

Darko Ratkaj, representing the European Broadcasting Union, stressed the relevance of future requirements of AudioVisual (AV) services, including high throughput, low latencies and jitter. It was emphasized that further research is required to better identify and exploit synergies between 5G infrastructure and broadcasting networks. The role of AV services in 5G was highlighted.

Ilie Daniel Gheorghe-Pop, representing NGNI-Fraunhofer, presented the "5G playground" available at his institution, which includes a number of toolkits that are highly reconfigurable and customizable. The requirements of verticals such automotive, industry and localization services, were emphasized.

The following speech was given by Raul Muñoz, representing CTTC. CTTC owns a large test-bed facility including both radio access and core network elements, developed in the past years in the context of several EC projects. The importance of End-to-End perspectives was discussed.

Finally, Matti Latva-aho, from CWC – University of Oulu, described the experimental facilities available at the University of Oulu, set up in cooperation with industries and a number of other Finnish institutions. Moreover, the presentation introduced the concept of micro local operators, i.e. operators owing locally 5G infrastructure that can help the MNOs in service provisioning. The business models of these micro local operators was discussed, against the usual model of MNOs. Especially ofr indoor coverage, it was claimed that the role of micro local operators would be extremely useful. The Finnish 5G trial environment is willing to prove that new stakeholder roles can be proposed for 5G network development.

Session 2 – Virtualised Network and Services

The second session started with the contribution presented by Pedro Aranda, focused on Intent Based Networking, where an "intent" can be defined as the "desire" of the programmer/manager of a given network. Opposite as a list of instructions to configure a network, the intent expresses what the manager of the network wants. The contribution tackles the challenges of the northbound interface (NBI), considering intent based networking as a possible solution for this protocol. Currently, different SDN controllers have different approaches to incorporate intent based networking, so convergence is key. On the other hand, CogNet is building a network management solution based on machine learning, essentially based on a Machine Learning Cluster (MLC) and two data flows, where the input is measurement and monitoring and the output is a set of policies.

Felipe Gil introduced an approach where, instead of a full virtual Evolved Packet Core (EPC) solution, a lightweight implementation of EPC was fulfilled by using containers (Docker containers in this work). In NFV, it is crucial to achieve a near-to-baremetal performance, so different solutions are considered nowadays to reach such values: paravirtualization, hardware-assisted virtualization, containers, etc. In containers, the host operating system is used for the isolated environment, increasing the performance of overall system. The future work will defined/extend an orchestration framework to support infrastructure sharing among operators, completely automate the deployment and setup of the EPC, offer support for cloud enviroments, etc.

Softwarization is a hot topic nowadays, and Jaime Garcia-Reinoso introduced a couple of examples using specialized software on general hardware. More specifically, this contribution is centred on virtualization on cheap, low-power consumption and small resource-constrained devices. This type of devices has several benefits, because, for example, it is possible to deploy them on remotely piloted aircrafts or drones. Such deployments could help to fulfil some KPIs of 5G as, for example, more connected devices or even the reduction of service deployment time with a low CapEx and OpEx. On the other hand, virtualization on resource-constrained devices is challenging, so it still requires more research. The second contribution is entitled content-based connection, where user equipment are guided to establish connections with base stations near caches storing the requested content.

In the last contribution of this session, Franco Davoli presented the challenges of network softwarization in terms of energy consumption. On the one hand, very specialized networking ASICs provide greatly enhanced performance/power (in the order or 1Gbps/W) but minimum flexibility, while with general CPUs, virtual network functions have reduced performance/power. The contribution suggests different ways to tackle these issues, like standing on the services provided by the network management. Furthermore, and based on this network management, the contribution proposes to use cloud offloading too, based on service applications on top of SDN controllers.

Session 3 – Radio Networks

The Radio Networks session started with a presentation by Thomas Zemen, Austrian Institute of Technology, on Wireless ultra-reliable low-latency device-to-device communication. The presentation highlighted how Ultra reliable low-latency device-to-device (D2D) communications are strongly demanded in vertical markets such as industry 4.0 or intelligent transportation systems (ITS) with applications such as: a) replacement of cable connections to mobile actuators or sensor in industrial cyber physical system (CPS), and b) provisioning of redundant sensor information (radar, optical, etc.) for autonomous vehicles to achieve a level of safety that is significantly higher than that of today's road traffic. In both cases harsh radio propagation environments lead to non-stationary fading processes that have a strong impact on the reliability and latency provided by the wireless communication link. Hence, the following research areas have been identified as strategic to be addressed for 5G systems in order to *minimize latency, ensure robust and stable operation in a dynamic wireless network*: i. measurement, modelling, and emulation of multi-node communication channels in the targeted 5G frequency bands; ii. low-latency physical layer modulation formats for low packet error rates at short packet lengths, e.g., exploiting wireless diversity mechanisms; iii. geometry-based system-level test methodologies; iv. software-defined-radio (SDR) test-bed implementations; v. protocols for low-latency operation in 5G.

In the second presentation, V2X Communications: The Killer Application of Millimeter Wave**,** Nuria González-Prelcic, University of Vigo, emphasised that for the expanding and evolving V2X market, 5G mmWave seems to be the natural companion. The V2X market paradigm is fast evolving from the “connected vehicle”, estimate to generate 1.5GByte/month of mobile data in 2017, to the “autonomous vehicle”, estimated to generate up to 1TByte/driving-hour of data. In such a context, Prof. Gonzalez-Prelic made a case for the 5G mmWave waveform as it is already developed, it will be operated in dedicated spectrum and will be supported by lower frequencies as back-up. In this context, specific research research areas to be addressed to fully empower 5G mmWave for V2X applications were identified as the following: i. measurements and modelling of propagation channels for the V2X scenario; ii. development of specific signal processing techniques for a communication system integrated and enhanced by the radar and sensor information; iii. design and adaptation of the physical layer to the peculiarities of the V2X scenarios.

The third presentation, given by Alessandro Vanelli-Coralli, University of Bologna, was focused on the role of satellite communication systems in the 5G Architecture. By analysing the requirements posed to the future 5G networks, considering satellite communications characteristics, and illustrating the extremely interesting capacity, flexibility, and global coverage that nowadays satellite communication systems such high throughput geostationary satellites or low orbit mega-constellations can offer, the presentation highlighted potential roles of SatComs in the next 5G Architecture. The following research areas were identified as fundamental to be addressed: i. design of integrated satellite terrestrial network management, control techniques and hierarchical backhauling architecture; ii. study of the compatibility and of the required adaptations of the radio interface (waveform, framing structure, etc.), and related

impairments countermeasure, developed for terrestrial scenarios to satellite systems; iii. development of suitable channel and interference management models; iv. study and demonstration of the feasibility of efficient integration of Satellite and Terrestrial networks.

Next presentation was given by Hamed Al-Raweshidy, Brunel University London, on Self-Organising and Programmable Virtual Cloud Radio Access Network for 5G and Beyond**.** The rationale and motivation of the presentation were that to overcome the high traffic demand, C-RAN should be re-designed to enhance its capability to manage the overall network by dynamically scaling the network services with respect to particular service classes. Therefore, the proposed paradigm of a Self-Organising and Programmable Virtual Cloud RAN has the following objectives: a) designing an algorithm for cell differentiation and optimization based on CQI and the network load to increase network performance; b) model an adaptive inter-cell interference co-ordination during cell differentiation to provide smart resource allocation; c) design a reconfigurable front-haul using Open Flow switches, low-latency cascaded fibre-wireless link, 3D-MIMO and millimetre-wave; d) developing NFV for SDN network architecture, which are SDN BBU pool, local cloud pool, orchestra pool and gateway pool. In this context, the following key challenges were identified: i. selecting the proper KPIs to achieve the Guaranteed QoS and QoE; ii. dynamic cell differentiation and BBU-RRH mapping for thousand-fold capacity increase; iii. millimetre wave delivery over 3D-MIMO using different polarisation antennae; iv. combination of the mobile protocol with SDN protocol with a testbed implementation.

In Signal Processing Challenges for Communications beyond 5G, Giuseppe Caire, representative of the EURASIP Special Area Team Signal Processing for Communications, collected a list of topics indicated by the members of the EURASIP SAT SPC group as promising and challenging research directions over the next 3-5 years time-horizon, beyond what is considered as “mainstream” 5G. The proposed rationale of the presentation was that the 5G research in the framework of EU-funded activities had been directed and framed into the various 5GPPPs projects, which had a strong applied R&D flavour and were clearly aimed to define the convergence towards a first round standardization, the EURASIP SAT SPC would therefore like to attract attention on the following open-ended, academic-oriented, challenging, and fundamental research topics**,** more properly adapted to a thriving scientific community that represents a major strength and a main asset for the sake of EU leadership in Information Technology: i. processing of side-information for improving network performance; ii. Satellite networks as part of beyond 5G; iii. quantum-Assisted Design of Wireless Systems; iv. Network-Assisted Self-Driving Objects; v. inferential networks; vi. hybrid visible light communications and radio networks; vii. networked signal processing and wireless fronthaul/backhaul; viii. open-source tools for radio network innovation.

The final presentation, given by Emilio Calvanese was entitled Beyond 5G: Toward the Terabit Wireless Era**.** The talk highlighted that, as it happened for the definition of the 5G system, future generation of wireless network will address higher and higher spectrum bandwidth in order to meet the ever increasing request of data rate. The

presentation argued that next generation wireless systems will have to provide peak data rate in the order to terabit/s, well above the requested peak data rate targeted by the 5G requirements. According to the presentation conclusions, research for systems beyond 5G system shall therefore address challenges posed by the use of spectrum frequency above 90 GHz and in the range of 100-300 GHz.

Session 4 – Optical Networks
The forth session of the workshop was dedicated to Optical Networks. This session had three presentations.

The first presentation made from Alexandros Stavdas that elaborated a novel network architecture providing a common, shared platform for a number of heterogeneous networks like: IoT and/or M2M local area networks, mobile front/backhauling systems, residential users, business users. The converging point would be located close to the end-user and because of this really low-cost and low power consumption terminals may be deployed. Moreover, micro-Datacentre (µ-DC) infrastructure can be collocated to jointly provide networking, local processing and storage resources.

Carla Raffaelli made the case of a converged optical-wireless transport to support x-haul services. Coarse and Dense WDM systems are powerful tools providing they are suitably exploited based on enhanced Ethernet transport. In this framework, the required extensions to Ethernet switching in order to implement statistical multiplexing while supporting QoS-related performance requirements were introduced and discussed.

In the final presentation, Ioannis Neokosmidis discussed the applications of visible-light communication systems in the framework of 5G. These systems can be deployed in both indoor and outdoor cases. These systems can be virtualized to instantiate a real multi-play device (multi-users, multiservices, multi-terminals, multi- locations. This platform may also combine VLC with other 5G- related technologies.

Discussion and Conclusions

In the last session one more contribution was presented in the special slot for “Verbal presentations”. Tommy Svensson, from Chalmers University of Technology, explained his contribution about moving network nodes and communication links between vehicles and between mobile devices of other traffic participants.
Finally, Jean-Sébastien Bedo and Arturo Azcorra presented the expert group workplan with the roadmap for phase 3 preparation. This includes a questionnaire on phase 3 activities where participants can provide their view about upcoming projects. Related with this roadmap, the expert group and vision group chairs announced the elaboration of the Strategy Research and Innovation Agenda (SRIA), which will be a very impactful document, cornerstone of Networld2020 and of the next work programme. Participants can contribute to the SRIA by sending their contributions to the chairs of the sessions of this workshop, who will select the most outstanding ones in order to produce a leading document for the phase 3 work programme.