NRG-5: Synergies to Improve the 5G Ecosystem

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***Abstract*— The 5G PPP project NRG-5 aims at enabling the deployment, operation and management of new 5G communication infrastructure, targeting the energy vertical (in the context of the Smart Energy-as-a-Service), providing security, resilience and high availability mechanisms, and validating the approach via smart energy use cases. One key concept arising from NRG-5 is that it tries to adopt and extend relevant concepts and designs from other H2020 and 5G PPP projects, when appropriate for the design and implementation of its architecture. In this paper, we consider specific H2020 projects in order to explore the potential synergies and to improve the global 5G ecosystem. Initially, the paper provides a brief introduction to the approach followed by NRG-5. Then, the paper identifies the synergies with the solutions coming from other projects, making the link with 5GCity and 5G ESSENCE.**

Keywords—5G, H2020, 5GCity, 5G ESSENCE, NRG-5, Vertical markets, Energy, Media.

I. Introduction

5G is more than just the linear evolution of current mobile telecommunication standards. Its ambitious goal is to cover all types of communications. Among other advances, it is expected that 5G will provide:

- A new flexible radio interface or interfaces to meet the challenging performance requirements;
- The integration of currently existing and evolved radio access technologies into a coherent end to end system (e.g. 3GPPP LTE and NR, IEEE 802.11 Wi-Fi, mmWave, satellite);
- The support for a broad range of vertical industry segments both in terms of technical capabilities, business and deployment models; the focus on verticals like energy, media, manufacturing, healthcare and automotive aims at developing new applications, markets and businesses.

Regarding the last point, 5G technology enables new applications, implying many challenges and a profound transformation for both fixed and mobile networks. Compared to the previous generations of wireless communication technologies, including the 4G, the driver for developing the 5G has shifted away from simply providing an increased mobile broadband capacity to end-users. 5G is thus expected to handle a variety of scenarios with very different specificities and is intended primarily to become a “facilitator” for a variety of services required by several heterogeneous industrial sectors, such as utilities, healthcare, media and transport. More generally, the 5G conception will shape this new generation of solutions; for this reason, the overall design needs to be supported by the experiences and the requirements coming from the different vertical contexts.

At the same time, the “Energy” context is witnessing a historic change: a “cross-industry” transformation is happening based on the evolution of the wireless concept. Connectivity is expected to enable the development of new functionalities, revolutionizing the ways of defining services in this domain.

The NRG-5 project aims to show how much this energy vertical industry can benefit from the advent of 5G, both from the technical and the business standpoints. NRG-5 takes also a comprehensive and unified approach within other selected verticals, by taking advantage of the complementarity of the contributions coming from the other projects developed under the European 5G PPP program. Building such an ecosystem allows sharing the knowledge first, and then the technical components to be used for deployment, resulting into a fruitful cross-fertilization of the projects results.

As an example of the benefits of the envisioned approach, synergies among several projects that run in parallel, such as NRG-5 [2], 5GCity [3], 5G ESSENCE [4] are presented in this paper. They will offer the possibility for each project to capitalize on a common catalogue of Virtual Network Functions (VNFs) available to the different verticals in order to create new solutions, improving as well the interoperability among different systems.

The rest of paper is organized as follow: Section II presents the technical requirements of the energy industry taken as representative example of vertical. Section III presents NRG-5 and selected sister projects. Section IV extracts the possible synergies among the different projects and their added-value impact on the 5G ecosystem. Finally, Section V concludes the paper summarizing the synergies that have been developed among these projects.

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II. TECHNICAL REQUIREMENTS FOR THE ENERGY VERTICAL

From a technical point of view, the energy vertical industry has very specific requirements that have to be matched by the supporting communication solutions. This means that, as of today, communication solutions developed for the energy market have been mostly tailor-made, with a reduced set of functionalities and presenting strong assumptions on the underlying network topology.

One of the baseline requirements for this type of application is low latency. In particular, it is expected by using a new generation communication solution (5G) to reach a reduced latency (between 1 and 10 ms) and a shorter transmission-time interval (e.g., sub- 1ms of TTI) so to enable real-time mechanisms for smart grid operations characterized by massive Machine-Type Communication (mMTC). mMTC represents a key paradigm for 5G: concepts like device-to-device (D2D) relaying for coverage extension, data and computation offloading, and latency reduction are very useful for smart grid applications. The usage of many antenna elements (Massive MIMO) can guarantee better link reliability and extended coverage. Also, very accurate time synchronization, provided by the mobile communication infrastructure (in particular, 5G including satellite based solutions) offers an important element in this framework.

In this context, the NRG-5 approach started from the analysis of the strict requirements for the smart energy vertical [7], building an architecture capable of meeting those requirements [8]. The NRG-5 project cooperates to facilitate consensus building on the 5G architecture proposed by 5G PPP, and to improve the opportunities offered in the energy vertical to address the critical challenge for electricity Smart grids to optimize Distribution System Operators (DSO) and other selected use cases.

Some key 5G RAN design requirements are relevant or expected to be relevant to the NRG-5 project activities:

- It should be able to scale to extremes in terms of throughput, device and connection numbers;
- It should support the Network Slicing vision;
- It should be energy efficient by enabling sleeping modes and flexible deployments (where not all the nodes need to send system control signals);
- It should be designed to operate in a wide spectrum range with a diverse range of characteristics such as bandwidths and propagation conditions;
- It should integrate LTE-A evolution and novel 5G radio technology on RAN level;
- It should integrate fronthaul and backhaul traffic supporting both eMBB and URLLC traffic;
- It should be designed taking into account an SDN/NFV-based control infrastructure to enable applications also in the case of multi-tenant networks and network slicing.

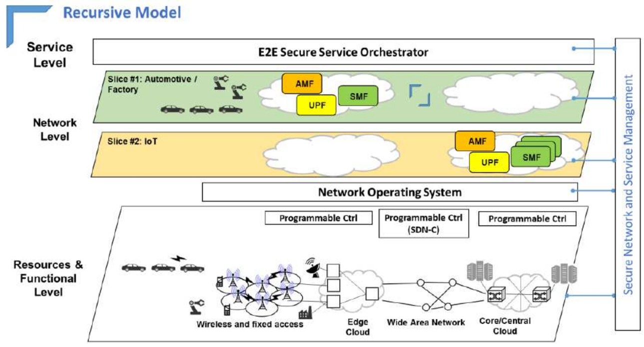

Figure 1– 5G Architecture of 5G PPP Architecture Group [1].

III. NRG-5 AND ITS SISTER PROJECTS

In the cases of other 5G PPP projects the approach is similar and focused in the creation of a synergy with experimental contexts: in particular, besides the NRG-5 project that deploys a novel 5GPPP-compliant software framework, based on xMEC specifically tailored to the Energy domain (smart grid and the associated innovative business models), in our analysis we take into account the following two projects, 5GCity [3] and 5G ESSENCE [4].

A. NRG-5

Besides the already mentioned RAN aspects, several other architectural elements of 5G networks play a key role in NRG-5 [2] such as: 1) the placement of network intelligence at the network edge via Network Functions Virtualization (NFV) and Edge Cloud Computing capabilities; 2) the consolidation of the multi-tenancy model, allowing several operators/service providers to engage in new sharing models of both access capacity and edge computing capabilities; 3) the creation and allocation of the logical network slices to allow use cases flexibly and efficiently in a multi-operator environment.

NRG-5 decided early on to follow the 5G PPP architecture, depicted in Figure 1, adding to it several domain specific functionalities. By following this approach NRG-5 is capable of supporting the innovations added by other projects under the same 5G PPP umbrella. One example is network slicing that will be made possible by using the solution available from other projects (e.g., Slicenet [5]), while Open Source Mano (OSM, [6]) is selected as the orchestration platform. NRG-5 makes use of an *extended Mobile Edge Computing* (xMEC) concept and some tailored NFV:

- Define an xMEC software stack for fast and optimal deployment of generic and utility-centric VNFs;
- Build on mMTC communications through the development of generic- and utility-centric VNFs;
- Realize an extended 5G ETSI-compliant MANO framework integrating analytics in the OSS/MANO layers addressing smart energy applications requirements.

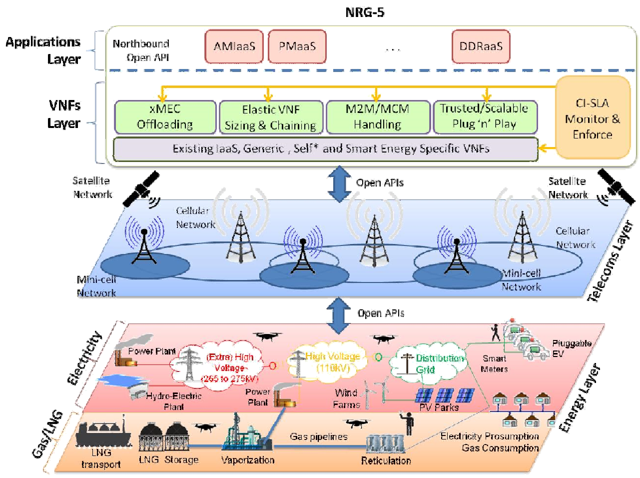

Figure 2 – NRG-5 high-level architecture.

Offloading of heavy computational functions via the xMEC, using of elastic VNF sizing and chaining, MTC, Machine-Cloud-Machine (MCM) communications, and trusted Plug and Play functionalities are the main building block employed to design the architecture compliant with the requirements coming from the Energy vertical. The high-level design of the NRG-5 approach is represented in Figure 2 and discussed in the related document [8].

Following the 5G-PPP Architecture proposal, NRG-5 architecture is considered as a number of VNFs offering Infrastructure as a Service (IaaS), Self* (self-discovery, self-configuration, self-healing) functions and smart energy specific VNFs. The positioning and sizing of the VNFs together with the fundamental infrastructure functions (e.g. network slicing offered by other 5G projects) enable the NRG-5 Smart Energy deployment.

The VFNs developed in the NRG-5 project can be grouped in 3 main categories, the General Core VNFs, the General Applications VNFs and the Smart Energy Specific VNFs, as described in the following:

Group 1 - the General Core VNFs are required to enable the distributed self-* capabilities and enhance the communication capabilities of the otherwise limited smart energy devices (e.g., an electric meter):

- vTSD: virtual Terminals Self-Discovery;
- vSON: virtual Self-Organizing Networks;
- vMCM: virtual Machine-Cloud-Machine;
- vMME: virtual Mobility Management Entity;
- vBCP: virtual Blockchains Processing;
- vAAA: virtual Authentication, Authorization, Accounting.

Group 2 – the General Applications VNFs are required to enable the seamless integration of fleets of drones for predictive maintenance use cases:

- vMPA: virtual Media Processing & Analysis;
- vDFC: virtual Drone Flight Control.

Group 3 – the Smart Energy Specific VNFs are required to interface with specific physical components of the energy distribution network:

- vPMU: virtual Phasor Measurement Unit;
- vESR: virtual Electricity Substation & Rerouting;
- vRES: virtual Renewable Energy Sources;
- vDES: virtual Distributed Energy Storage.

B. Sister project: 5GCity

5GCity will develop deploy and demonstrate, in operational conditions, a distributed cloud and radio platform for municipalities and infrastructure. 5GCity's main goal is to build and deploy a common, multi-tenant, open platform that extends the centralized cloud model to the extreme edge of the network. 5GCity aims to deploy and test the benefits of 5G technologies by adding *neutral hosting* functionalities in the design, deployment, and development of a distributed cloud and radio platform. The *neutral hosting* model consists in managing a network infrastructure to host (without imposing technical and economic constraints) any entity that uses it to provide its services to its end users. According to this model, the infrastructure owner develops the network and offers network capacity slices to the various 5G service providers, as Telecom operators, Over-the-Top (OTT), Industries or Public Administrations.

Similarly to NRG-5, the proposed architecture is the result of the integration between NFV, Software Defined Networking (SDN) and multi-access MEC on distributed cloud and radio platform. A forward looking synergy between 5GCity and NRG-5 is expected to evaluate closely how the 5GCity approach, allowing the owners of the infrastructure to monetize their investment, may be applied not only to media service providers deploying collaborative and innovative applications, but also to energy providers delivering new "user centric" solutions to their residential and industrial clients.

C. Sister project: 5G ESSENCE

On the other hand, 5G ESSENCE is the continuation of the previous H2020 SESAME project a reference for new 5G architectural solutions to deal with virtualization, network softwarization, cognitive network management [9]. 5G ESSENCE's main aim is to build and deploy an open platform that extends the network model to support new revenue streams and business models, dealing with a wide range of service and applications. In particular, the proposed architecture is enabling the integration of other vertical industries merging the Small Cells featuring the LTE/5G network and the NFV environment.

The main concept of 5G ESSENCE is dedicated to the implementation of the Cloud-Enabled Small Cells (CESCs) to deliver edge cloud computing in a multi-service ecosystem; the envisaged architecture of 5G ESSENCE enriches the possibility to manage and control the CESCs to improve other main architectural blocks useful also in the vertical context as the energy one. 5G ESSENCE offers a tiered architecture with the first distributed tier for providing low latency services and a second centralized tier for providing high processing power for computing-intensive network applications.

Similarly to NRG-5, the virtualization techniques considered in the 5G ESSENCE architecture allows bringing mobile core functions closer to the mobile edge, thus enabling deploying the services in a more effective way in proximity to final users as indicated in the 5G PPP 5G Architecture White Paper [1]. For this reason, an interesting synergy between 5GESSENCE and NRG-5 is to evaluate closely how to use a common infrastructure based on different virtualized networks, specialized for each service, in particular for the energy context, overcoming the inefficiencies of current dedicated hardware deployments.

IV. Impact Creation for the Whole 5G Ecosystem

Starting from the introduced elements, we explore in detail what can be achieved by exploiting the existing synergies among the projects under analysis for the whole 5G ecosystem.

The final goal is to merge newly deployed solutions as well as the technical outcomes of different 5G PPP projects (in this case NRG5, 5G ESSENCE, and 5GCity) to create a new digital economy based on a ubiquitous network that will connect people, things, and services. Vertical business use cases, specifically designed for the future 5G context are expected to have strong economic and social impacts; those will be tested not only from a technical point of view but also from the business approach considering all the components of the new chain of value.

In general terms, the 5G system architecture, the specific use cases for the pilot demonstrators and the related requirements will be enriched by the contribution coming from the different vertical contexts and the related projects. Other benefits will arise from a common definition of the communication endpoints, the main workflows connecting the different entities of the systems, resulting in the functional decomposition and the detailed specification of the architecture components and application programming interfaces (APIs). For instance, the synergies that have been identified among the three projects discussed in this paper will provide a more complete definition and specification of the compatibility between multiple use cases and architecture.

Also, the technology selection phase and the market watch (assessment of potential behavior of end users) in the landscape of the different context as the neutral hosting model based on CESCs, the distributed edge cloud environment, and the cutting edge services offered combined with the need of media and energy verticals will be underlined using this holistic approach. As already mentioned, one of the most tangible advantage will concern the ways in which the VNF components are provided to different projects. By setting up a common VNF catalogue as a central repository for the development of each project, it is possible to mutualize the efforts, enhance the effectiveness of each project by reducing the time necessary to deploy new services, and optimize the usage of the requested resources. This obviously must be backed by an effective platform that guarantees the following capabilities:

- Design and development of effective VNF deployment and relocation frameworks taking care of portability, respecting the mobility of devices and the requirement of the service;
- Perform elastic and efficient scaling of deployed VNFs;
- Create new services using the 5G features;
- Design and implement an SLA monitoring mechanisms able to cover the needs of the specific vertical context.

5G will accelerate the introduction of new solution to reach the excellence in different markets: a particular focus is on the technologies and solutions to enable the «next generation services» in different context. Taking a business perspective, 5G is expected to support completely new models which can transform the technical innovations into business by allowing potentially new models of ownership, operation, maintenance, and as well usage. According to this approach, it remains to explore how to evolve from the traditional Telco approach (that intercepts a very low value in the Value Chain) to a new one based on *disruptive* technologies and partnerships. It is needed to analyze the sustainability of new solutions from technical and economic perspectives to have a complete vision of all opportunities. An example of this *disruption* is the Network Slicing & MEC as a service model, where the network coverage will be both *service*- and *device*- driven.

Network infrastructure sharing is a fundamental element capable of unlocking the commercial take up of dense 5G wireless networks. It is expected to overcome the current model that proposes the deployment of many overlapping access networks by exploring new models able to deal with different requirements in such dense environments. For instance, it is important to consider also for the smart energy vertical the possibility to deliver different type of services following the model suggested by 5G ESSENCE and 5GCity in which the provisioning of an end to end network and cloud infrastructure slices over the same physical infrastructure, able to fulfill vertical-specific requirements as well as mobile broadband services in a highly flexible and scalable platform.

The cooperation among these different projects can offer a promising solution for the given challenges faced by infrastructure providers and vertical like energy, media and the Mission critical applications for public safety ones of the most important contexts in the “Gigabit Society” to ensure access to online activities for individuals and businesses under conditions of fair competition, consumer and data protection, removing geo-blocking and copyright issues, as indicated in the European Digital Single Market strategy.

The combination of the different use cases, architectural approaches, and technical solutions will provide better modern vision: the aim of the different project is to evaluate the capability of the 5G network of supporting innovative services with reference to suitably designed Key Performance Indicators (KPIs), and to evaluate the opportunities offered by these services considering fundamental aspects as:

- Better access for consumers and businesses to digital goods and services;
- Creating the right conditions for digital networks and innovative services;
- Maximizing the growth potential of the digital economy;
- Reducing the cost to deploy the new expected services.

In summary, the projects under analysis will promote the development and the adoption of 5G by establishing and maintaining open interaction with ICT and non-ICT organizations, also called vertical sectors. Besides the information sharing regarding 5G technology and opportunities among project members is compliant to national and international targets related to 5G.

The synergy is expected to push an integrated model to enrich the 5G ecosystem for innovation and to deal with the requirements coming from the "Gigabit Society".

V. Conclusion

The project NRG-5 aims to guarantee optimal communications of the smart energy grid, which is believed to be one of the most complex, heterogeneous and gigantic machine ever made in human history, deploying, by operating and managing existing and new 5G communications techniques and energy infrastructures (in the context of the Smart Energy-as-a-Service) easier, safer, more secure and resilient from an operational and financial point of view.

Through interactions with 5GCity, 5G ESSENCE, and other projects in the 5G-PPP program, as well with the 5G-IA, the NRG-5 project aims at defining and specifying some vertical additional use cases focusing on utilities domain.

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