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Essential Components and Core Features of the Smart5Grid Platform *for implementing the 5G perspective*

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Smart5Grid

Demonstration of **5G** solutions for **SMART** energy **GRID**s of the future

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Summary

Content overview

- *The Smart5Grid Project & related Use Cases*
- *Smart5Grid's Architectural Approach*
- *Smart Energy Grids*
- *Cloud native context*
- *Multi-access Edge Computing*
- *Smart5Grid NetApp concept*
- *Concluding Remarks*

Smart5Grid in brief

- European Call: H2020-ICT-2018-2
- Grant Agreement (GA) No.: 101016912
- Topic: ICT-41-2020
- Duration: 36 months *(January 2021 – December 2023)*
- Overall budget (requested grant) of ~6 Million Euro
- Consortium members: 24 main partners *(from 7 EU member states)*
- Project Coordinator: ENEL (IT)

Beneficiaries:

Smart5Grid in brief – Partners

Smart5Grid

The Smart5Grid ecosystem:

Coordinator
enel

TELCOs
WINDTRE
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NET IS SAT

SMEs
EIGHTBELLS Independent Research & Consultancy
INFOLYSiS
SC
NBYCOMP NearbyComputing
axon logic
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ATHONET
SETECHCO
SIDROCO
ENTRA ENERGY
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nosia - SEÑALIZACIÓN INDUSTRIAL - EQUIPAMIENTO PARA LA INDUSTRIA
STAM MASTERING EXCELLENCE

Tech Companies
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Universities/Research institutions
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HELLENIC REPUBLIC National and Kapodistrian University of Athens EST. 1837
University of Cyprus
KOIOS

DSOs
e-distribuzione
e-distribución

(Linked third-parties of Enel GI&N)

TSOs
ECO ΕΑΔ
αδμηε

The Smart5Grid Project _(1)

Fundamental Aims:

- Promotion of innovation for the energy vertical sector, by providing an open 5G-enabled experimentation platform, *customized to support the smart grid vision*.
- Realization of a 5G-based experimental facility for integration, testing and validation of both existing and new 5G services as well as of NetApps from third parties *(i.e., SMEs, developers, engineers, not being members of the project consortium)*.
- Provision of an open access NetApp repository, *offering support and assistance to third parties through a clear and trustworthy experimentation roadmap, with the opportunity to accelerate their growth in the high impact industry of the energy vertical.*
- Validation, *both at technical and business level*, of the opportunities offered by 5G technology to the energy vertical, *demonstrated in four meaningful use cases (UCs) being relevant to real scenarios of use.*

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The Smart5Grid Project _(2)

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Challenges:

- Smart5Grid implicates for new challenges to communication networks, requiring a flexible & orchestrated network, slicing options and millisecond-level latency.
- Power distribution companies need new tools to monitor/operate the distribution network and to maintain/increase reliability and Quality of Service (QoS), if they wish to transform today's power distribution grids into "evolved" smart grids, enabling efficient, fast and secure operation

- Smart5Grid identifies several high-level requirements for the communication network, allowing the establishment of innovative and high performance smart grids:
  - *Very high device density* for connecting thousands of energy metering and power electronic devices, in one location.
  - *Very high bandwidth* to allow massive data flows from multiple devices simultaneously, making available remote maintenance and substation monitoring.
  - *Ultra-low latency* for fault detection, network isolation and operation of recovery devices within one power cycle (i.e. 20ms for the 50Hz frequency used in electric current).

The Smart5Grid Project _(3)

Smart5Grid

Detailed objectives:

Objective #1: Specifying the critical architectural and technological enhancements from previous 5G-PPP Phases needed to fully enable an open experimental platform for the Energy vertical.

Objective #2: Design, deployment, operation and evaluation –in real world conditions– of the baseline system architecture and of related interfaces for the provisioning of an integrated, open, cooperative, and fully featured 5G network platform, customised for smart energy distribution grids.

Objective #3: Development of an open NetApp repository. In conjunction with the 5G network facility, the Open Service Repository will have access to network resources and it will be used to develop and accommodate NetApps, providing rapid access and execution environment to developers, third parties, and SMEs from the energy vertical sector.

Objective #4: Development of high-performance NetApps for the support of ambitious Smart5Grid energy-oriented use cases.

Objective #5: Provision of a Validation and Verification (V&V) experimentation framework for NetApp automatic testing, certification and, integration.

Objective #6: Realisation of four advanced 5G real-life demonstrations over a wide set of energy related use cases. *Performance exhibition will be conformant to 5G-PPP KPIs.*

Objective #7: Conduction of a market analysis and establishment of new business models. Detailed techno-economic analysis and road mapping towards exploitation and commercialisation by industry partners and SMEs are also of high priority for the project.

Objective #8: Maximisation of Smart5Grid impact to the realisation of the 5G vision by establishing close liaison and synergies with 5G-PPP Phase-2 and -3 projects and the 5G-PPP. Pursuing of extensive dissemination and communication activities and assessing the perceived impact from the stakeholders and the wider community.

The Smart5Grid Project _(4)

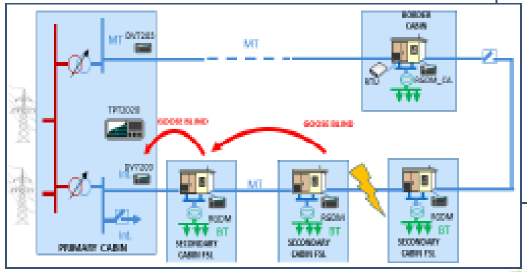
Use Cases:

The Smart5Grid Open 5G platform is demonstrated upon four real-life environments in the south-eastern Europe.

The respective use cases "target" the entire energy service chain

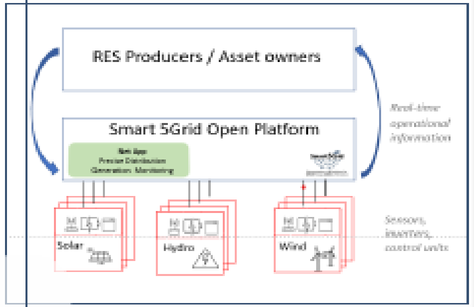
- *from green power generation and coordinated cross-border transmissions system operation*
- *to power distribution.*

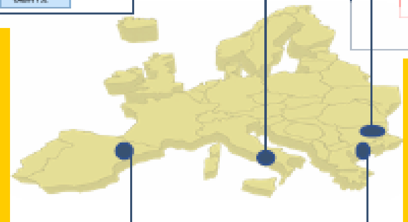
Italian Pilot — (DSO-Operations) Automatic power distribution grid fault detection



This pilot will test in real life environment the use of 5G infrastructure and a dedicated monitoring NetApp for facilitating the debugging process of an advanced grid-fault detection and self-healing system in Olbia Region, Italy.

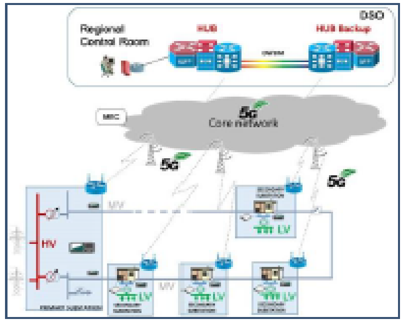
Bulgarian Pilot — Millisecond level precision distributed generation monitoring





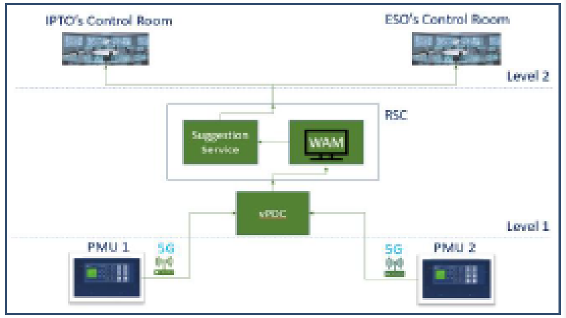
This pilot will test a use-case specific NetApp with the role to allow the electricity producers owning renewable generation assets to use fast, real-time cloud-based tools to monitor plant performance and production parameters for optimal operation and maintenance of the plants and for grid integration facilitation.

Spanish Pilot — (DSO- Safety) Remote inspection of automatically delimited working areas at distribution level



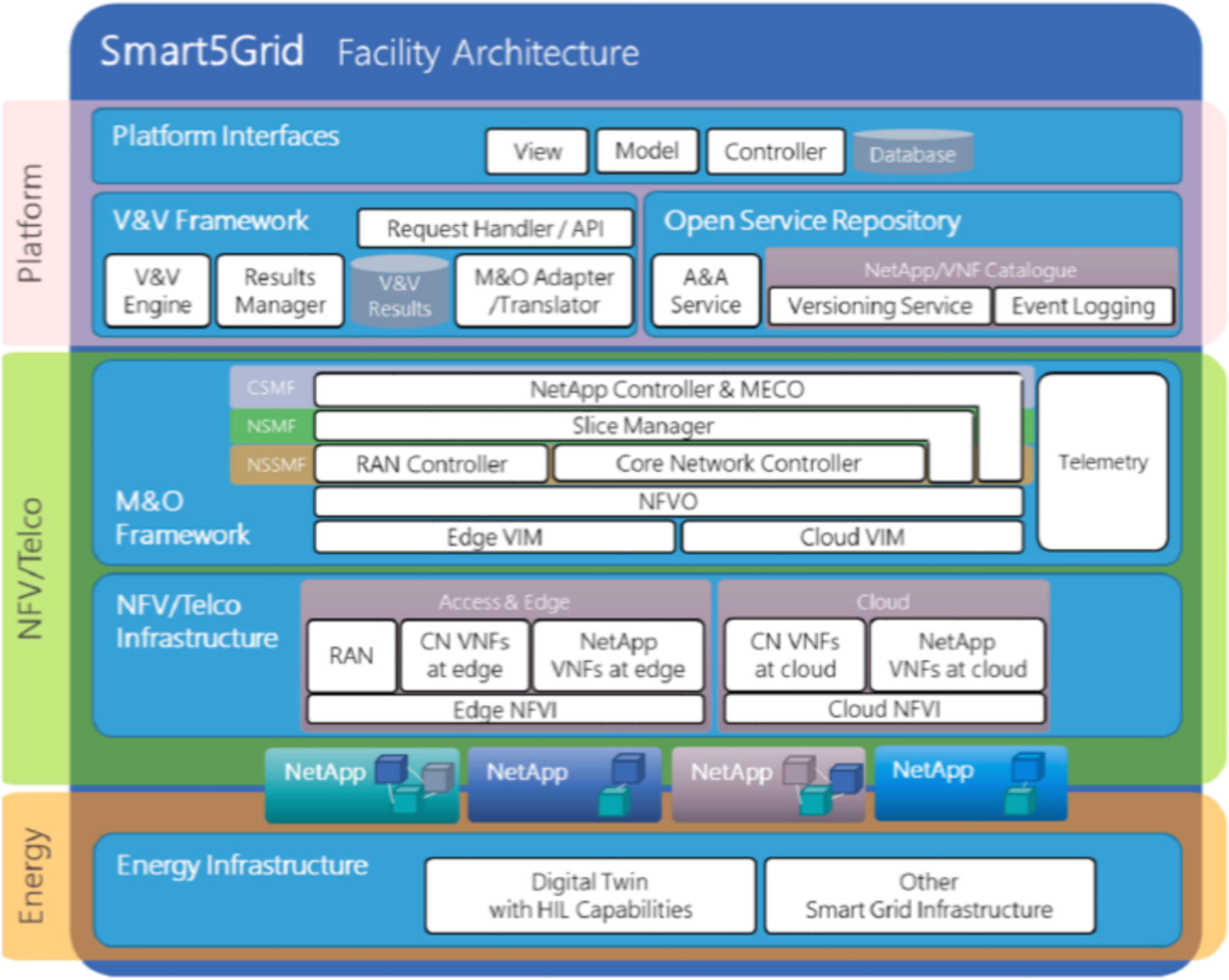
This pilot will test a suite of safety monitoring NetApps which exploit user-plain function at the edge, end-to-end latency below 100ms on top of high localization precision.

Greek-Bulgarian Pilot — Real-time wide area monitoring



This pilot will test in real life environment the 5G infrastructure and chain network virtualization functions under a Monitoring NetApp which ensures a virtual PDC role.

Smart5Grid – Architectural Approach _(1)



A&A: Authentication & Authorization
API: Application Programming Interface
CN: Core Network
CSMF: Communication Service Management Function
HIL: Hardware-In-the-Loop
M&O: Management & Orchestration
MECO: Multi-access Edge Computing Orchestrator
NFV: Network Fuction Virtualization
NFVO: NFV Orchestrator
NFVI: NFV Infrastructure
NSMF: Network Slice Management Function
NSSMF: Network Slice Subnet Management Function
RAN: Radio Access Network
V&V: Verfication & Validation
VIM: Virtual Infrastructure Manager
VNF: Virtual Network Function

Smart5Grid – Architectural Approach _(2)

Smart5Grid

In the present work we assess relevance of the proposed Smart5Grid architecture to

- *Smart Grids (SGs);*
- *the cloud native paradigm, and;*
- *the impact of Multi-access Edge Computing (MEC) in 5G networks.*

Each one is assessed as of its relevance to the state of the Smart5Grid platform design and/or implementation.

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Smart Energy Grids _(1)

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Challenges for the Energy Sector

- *Deeper and faster decarbonisation is changing the energy world and creates new requirements both on the supply side and on the demand side. The electric grids, which are essentially massive interconnected physical networks, are the infrastructure backbone for energy supply and use of today.*

- *The energy infrastructure needs to be enhanced and digitalized, to cope with the deployment of renewable sources, increased decentralization, electrification of end-user and active customers, so that to ensure energy network stability, security, and resilience.*

- *Electricity generated from renewable sources is predominantly variable in nature: Thus, grids will be required to manage power flows more promptly and efficiently and to support the integration of less predictable energy production, while maintaining the quality of supply.*

- *For the support of the deployment of Renewable Energy Sources (RESs), smart grids will deliver substantial benefits in terms of resource-efficient economic growth, global and local pollution reduction.*

Smart Energy Grids _(2)

Challenges for the Grids

- *Grid interoperability with distributed resources is one of the fundamental pillars of modern grids' development.*
- *The shifting from demand and supply patterns towards more decentralized generation (connected at medium and low voltage grids) raises the need to properly manage congestions and multidirectional energy flows.*
- *Connecting customers equipped with smart meters to the distribution system will allow their active participation to the energy market through the provision of flexibility services (e.g. via a "demand response" approach).*
- *Energy consumption patterns are also changing, due to the growth of new forms of energy demand in building, transport and industry sectors, with a high variability and high-power rating.*
- *The smart integration of electricity with final uses will significantly decrease both greenhouse gas emissions and energy demand, to deliver equivalent services with less energy input and resources.*

- *In this multi-challenging framework, energy system operators need to be empowered with more advanced instruments to provide reliable electricity supply and quality of service (QoS) in the increasing challenging energy system.*
- *The goal is to allow the grid system to work as efficiently as possible, minimizing operating costs and environmental impacts while maximizing system stability and security.*

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Smart Energy Grids _(3)

Smart5Grid

Benefits of use:

- *Smart grids accomplish the required optimization of energy networks by using digital and advanced technologies.*
- *Smart grids are necessary for the integration of growing amounts of variable RESs (like solar and wind power), and of new loads (such as energy storage and charging of electric vehicles), while maintaining stability and efficiency of the system.*
- *Smart grids enable the utilization of flexibilities that are currently available or that will become available in the future, to "better match" needs on the grid with respect to generation and demand.*

- *The Smart5Grid platform is appropriately structured to support the energy transition, by providing the needed digital layer to ensure the availability of the communication infrastructure, whenever is needed.*

Smart Energy Grids _(4)

Smart5Grid

Support for higher functionalities:

With respect to power transmission and distribution networks, Smart Grids integrate interconnected and geographically wide distributed components, both hardware and software, both on the demand and on the supply side, and "pool" their resources to create higher functionalities such as:

- **Advanced metering and monitoring,** for close to real-time (RT) transmitting and receiving data for information, monitoring & control purpose on what goes on the energy network, in order to acquire/provide feedback for the grid operation and enable consumers to better manage consumptions.
- **Active network management**, for the operational optimization through predictive maintenance, energy network remote reconfiguration and recovery schemes activation in almost real time.
- **Flexibility services,** from Distributed Energy Resources (DERs) such as distributed generation, energy storage assets and demand side response, leveraging on end-user's flexibility. (DER is a small-scale unit of power generation that operates locally and is connected to a larger power grid at the distribution level. DERs can include solar panels, small natural gas-fueled generators, electric vehicles, and controllable loads, such as HVAC (Heating, Ventilation and Air Conditioning) systems and electric water heaters).
- **Smart charging services,** such as vehicle-to-grid (V2G) or vehicle-to-home (V2H) solutions (for battery electric and plug-in hybrid vehicles) and additional growth of electrification grade (i.e.: heating and cooling), increasing RESs grid hosting capability.
  V2G is a technology that enables energy to be pushed back to the power grid from the battery of an electric car.
  A V2H system enables customers to store home generated renewable energy in their leaf battery or fill their battery when energy tariffs are low/free.

Smart Energy Grids _(5)

Smart5Grid

Smart5Grid's responses:

- For the case of *advanced monitoring,* an innovative cross-border frequency monitoring system will be implemented to support the regional Transmission System Operators (TSOs) to provide the system stability in the Greek-Bulgarian demo (*as discussed in the context of the respective use case 4, UC#4*).
- In the Spanish demo (*as examined in the specific framework of use case 2, UC#2*), an innovative *safety system* for people working in high-voltage power stations will also be implemented and tested, *since electricity still represents a danger for workers if not properly approached, keeping the due physical distance from the live parts.*
- The most advanced *active grid management system*, *developed by Enel Distribuzione Italia (EDI)*, will be supported by a NetApp to provide RT communication monitoring, preparing the ground for further implementation of edge-based computing (*as examined in the specific framework of use case 1, UC#1*).
- The real-time monitoring and control of DERs compose the basis for the provision of *flexibility services* to the energy system operators.

- ***Smart5Grid is structured to effectively support most of the above functionalities, by offering dedicated services not only for the energy system operators, but also for DERs providers and aggregators.***

The Cloud Native Context _(1)

General Approach

- Within the Smart5Grid framework, *a core aim is to embrace and adopt, where possible, the cloud native paradigm.*

- *The concept of cloud native, in a simple way, can be defined as related to applications that are born in the cloud – as opposed to applications that are born and raised on-premises.*

The Cloud Native Context _(2)

Characteristics of Cloud-native applications:

- *They often need to operate at global scale:* While a simple website can be accessed anywhere given that Internet is not blocked, **the concept of "global" implies that the application's data and services are replicated in local data centres so that interaction latencies are minimized, and the integrity of the application is clear to the final user.**
- *They must scale well with thousands of concurrent users:* This is another dimension of parallelism that is orthogonal to the horizontal scaling of data required for global-scale distribution, and **it requires careful attention to synchronization and consistency in distributed systems.**
- *They are built on the assumption that infrastructure is fluid and failure is constant,* so even in the case the failure rate is extremely small, the law of large numbers guarantees that in a global scale even a low probability event can happen.
- *Cloud-native applications are designed so that upgrade and test occur seamlessly without disrupting production.*

- *The above characteristics perfectly "match" the requirements of a smart grid's communication and application layers, entailing the need of adopting 5G.*
- *Due to the need of addressing a huge range of very diverse requirements to deal with across a variety of applications, an approach based on microservices and cloud nativeness is strongly needed, to help the power grid to truly become smart.*

The Cloud Native Context _(3)

- Cloud native is an approach to design, build and run applications/virtual functions that fully exploits the benefits of the cloud computing model.
- It refers to the way how applications are created and deployed, not where they are executed.
- It is based on the principle of decomposing an application into a set of microservices that can be developed and deployed independently to accelerate and optimize the DevOps strategies.
- The microservices are packaged into light-weight containers which are scheduled to run on compute nodes by a container orchestrator.
- As regards data, microservices need to be "stateless", meaning that there must be a separation of the processing logic from the processed data and how it is stored in the cloud.

- In the Smart5Grid platform, the involved partners adopt the cloud native paradigm, "paving the way" towards the integration of the energy infrastructure and the 5G Core Network (CN) SBA (Service-Based Architecture).
- This 5G CN SBA will require several techniques being applied in unison, i.e., NFV and SDN that will require the deconstruction of VNFs into microservices.
- This translates to the containerization of the 5G Core and the gradual decoupling of network functions from VMs in support of containerized network functions.
- The adoption in the early stage of a cloud native approach for the NetApp development will increase the compatibility between telco and vertical infrastructure.

The Cloud Native Context _(4)

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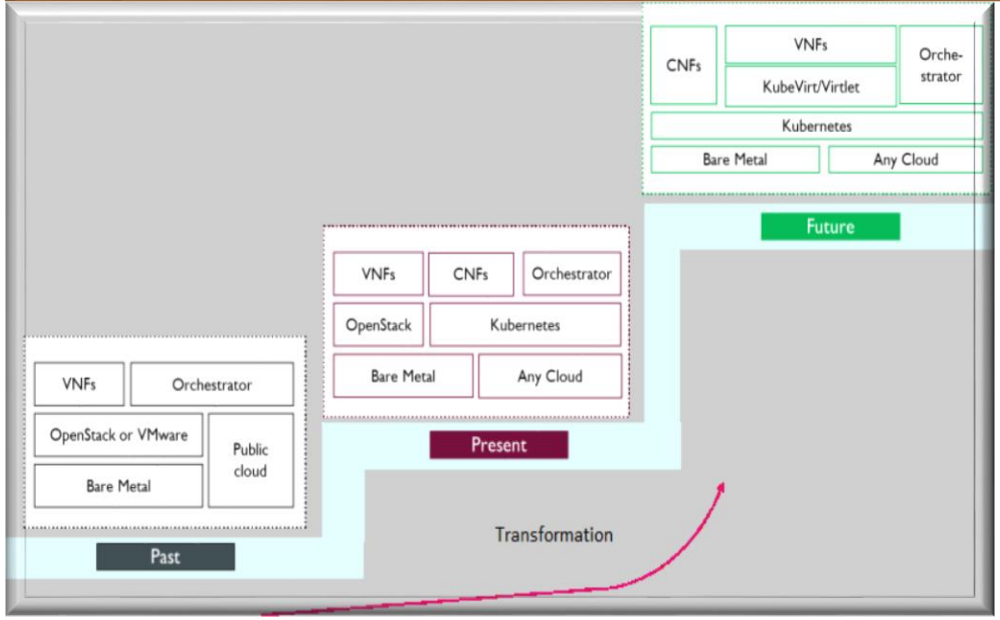
Adoption of the approach proposed by the 5G-PPP "Cloud Native and 5G Verticals' services" White Paper



- *Consideration of the EC's and the EU industry's view.*
- *Depiction of the evolution from the classic solution based on VNF implemented to run inside VMs.*
- *Depiction of a possible evolution of the term VNF to CNF (Cloud Native Function), that is another way to indicate VNF but with strong emphasis on the cloud design.*

- *Observing the present phase, we notice that the classic solution is based on running VMs on top of bare metal/public cloud and on the use of hypervisors such as VMware or VirtualBox.*
- *At the same time, OpenStack has been used as the de facto cloud computing platform.*
- *This architectural approach adopted in the Telecom sector follows the NFV MANO (Management and Orchestration) specification.*

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The Cloud Native Context _(5)

Smart5Grid

Facing current problems:

- *In multi-domain orchestration environments, as those used commonly in 5G services, the management of several VIMs - Virtual Infrastructure Managers (e.g., OpenStack) in a multi-cloud environment is a complex and a hard task, not easy to solve.*
- *It is difficult to manage multiple VNFs in a consistent way, due to the hard dependency between the hardware and element management systems that exist in the real environments.*
- *At implementation level, it is also hard to combine different blocks from different vendors.*

Towards implementing could native applications in the Smart5Grid platform, we will need:

- *Small, stateless microservices architecture, running in containers, which are faster to get deployed and upgraded with the use of few cloud resources, with the purpose of deploying just what is needed instead of the entire network function.*
- *Open architecture and Application Programming Interfaces (APIs) so it is possible to continuously apply onboard innovation. (For example, the 5G Core uses an SBA with well-defined APIs for network functions to offer services or call on each other. This, merged with the cloud-native service mesh, enables rapid manipulation of the 5G Core, allowing the integration of new network functions, or rapidly scaling & deploying different slices).*
- *Cloud agnostic and infrastructure agnostic, to eliminate the hardware dependencies.*
- *DevOps for automation and fast time to market.*

Multi-access Edge Computing _(1)

Essential approach:

- *MEC allows a smooth transition into the 5G network rollout, removing the need for major upgrades when the expected time for transition arrives.*

- *Another focus area for transitioning to the 5G networks is about re-using the existing deployed systems in the process. Due to the MEC's virtualised characteristics, it is very easy to monitor performance and resource needs of an application which, in turn, enables more accurate pricing for operators towards application providers for hosting the applications.*

- *The common feature set of:*
  (i) providing much-improved capabilities at the edge of the network;
  (ii) improved intelligence about resources needed at the edge, and;
  (iii) the ability to charge for service delivered by cycles, memory, storage and bandwidth,
  makes it "quite attractive" to start the deployment in (early) 5G test sites.

Multi-access Edge Computing _(2)

Ways of implementing MEC compatibility towards 5G networks, by:

- *Integrating the MEC data plane with the 5G system's data plane for routing traffic to the local data network and steering to an application.*
- *An Application Function (AF) interacting with 5G Control Plane Functions (CPFs) to influence traffic routing and steering, acquire 5G network capability information, and support application instance mobility.*
- *The possibility of reusing the edge computing resources and managing/orchestrating applications and/or 5G network functions, while MEC still orchestrates the application services (chaining).*

- *In the 5G context, edge computing is identified as one of the "key technologies" necessary to:*
  - *support low latency together with mission critical and future IoT services and*
  - *enable enhanced performance and quality of experience.*
- *Several enabling functionalities can provide flexible support for different MEC deployments.*
- *There is a growing consensus that in the long term, 5G deployments will increasingly integrate fixed-mobile networks infrastructures with cloud computing and MEC.*

Multi-access Edge Computing _(3)

In the Smart5Grid framework, the core aim is to focus on the deployment of four selected UCs of strong market relevance for revolutionising the energy vertical industry.
This is done in parallel with the introduction of an open 5G experimental facility to support integration, testing and validation of existing and new 5G services and NetApps from third parties.

- *MEC reduces latency to milliseconds and allows for constant connectivity. Plus, when the edge network experiences high traffic, the edge may offload data to the cloud to maintain a quick and reliable connection.*

- *MEC shall provide a multiplicity of explicit benefits for the provision of the related services to any participating market actor – especially to network operators – and will support the effective transition towards a reliable 5G implementation.*

The Smart5Grid NetApp _(1)

The Smart5Grid NetApp provides a means for developers to define vertical applications by interconnecting together new and/or existing pieces of software in the form of VNFs.

By splitting the functionality of the NetApp into decoupled VNFs, the reutilization of software functions is encouraged.

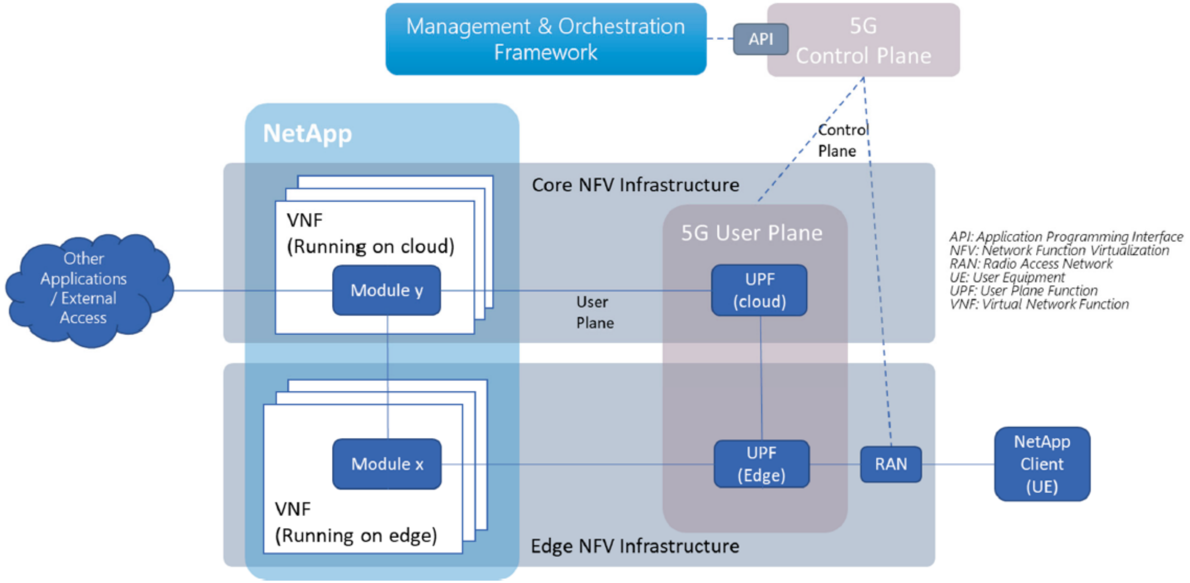
- The ETSI NFV framework describes the reference architecture, information models and tools required for management.
- A Smart5Grid proposed NetApp is a cloud native application. *Thus, it is made up of VNFs based on OS (Operating System) containers' technology.*
- Consequently, a corresponding NetApp contains the necessary components to offer a service as a software (SaaS) application for the energy vertical *(i.e., it is a complete and standalone (SA) vertical application).*
- However, this does not imply that the service provided by this vertical application cannot be consumed by other external or legacy applications *(e.g., from a north-facing API).*

The Smart5Grid NetApp _(2)

- NetApp components can be deployed as container-based VNFs.

- A NetApp can contain one or more VNFs.
- *By splitting these components whenever possible in the implementation, the NetApp brings the opportunity to take advantage of the cloud/edge infrastructure.*

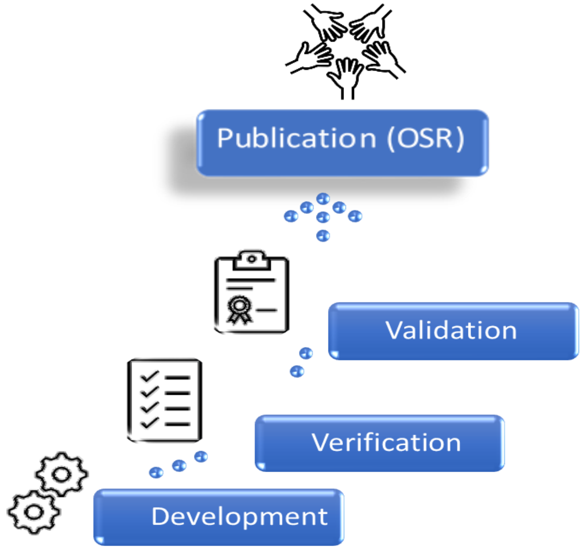
- *An example of this could be, in the case of a NetApp composed by two components (as in figure below), where*
  - *the NetApp function that requires low latency input or responses could be placed at the edge of the computing infrastructure,*
  - *while the other function that may be resource-intensive, not suitable for an edge deployment and not requiring its benefits, should be placed in a cloud data centre where resources are not constrained.*

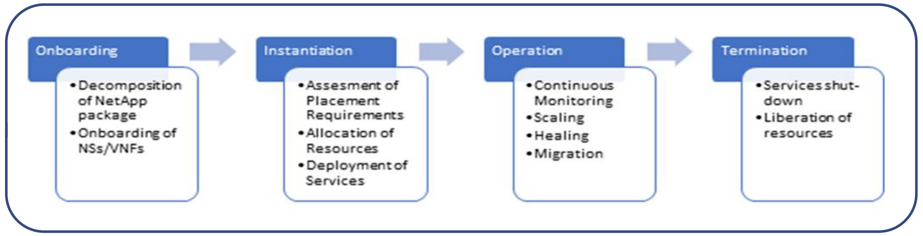


The Smart5Grid NetApp _(3)

The lifecycle of a NetApp in the Smart5Grid platform comprises of four main steps:

- ***Development:*** First, the developer must develop their application and test it in their local environment. The application must adopt the Smart5Grid NetApp convention in order to be tested.
- ***Verification:*** Then, different types of verification tests will be performed, *namely Syntax, Integrity and Topology verification test.* If the verification tests are successful, then the NetApp will pass to the next stage; if some of the verification tests fails, then it will go back to the development stage for improvement.
- ***Validation:*** After verification, the NetApp will have to pass some unitary tests on a staging environment, which requires deployment and instantiation on the Smart5Grid Telco infrastructure. If validation fails, the NetApp will go back to the development phase.
- ***Publication:*** Finally, once all verification and validation tests have been successfully passed, the NetApp might be published in the Smart5Grid OSR if the owner wish so.





Concluding Remarks_(1)

Synopsis

- *5G networks are a vital element for the expansion of smart grid technologies, allowing the grid to adapt better to the dynamics of renewable energy and distributed generation.*

- *5G allows an efficient integration of unconnected devices to smart grids with the aim of precise monitoring and improved forecasting of their energy needs. Managing energy demand can thus become more efficient, requiring less investments, as the smart grid has the ability to balance easier the energy load, reduce electricity peaks and reduce energy costs.*

- *Smart5Grid project intends to complement contemporary energy distribution grids with access to 5G network resources through an open experimentation 5G platform and innovative Network Applications (NetApps).*
- *The project proposes an **innovative architecture** and creates a **dedicated platform** to fulfill its innovative objectives, which is characterised by several essential features.*

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Concluding Remarks _(2)

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Smart5Grid foresees to deliver a more secure, reliable, efficient, and real-time communication framework for the modern smart grids.

The project platform supports the current energy sector stakeholders to adopt smart grids to:

*(i) Easily and effectively **create** advanced energy services;*

*(ii) **interact** in a dynamic and efficient way with their environment; and;*

*iii) **automate and optimise** the planning and operation of their power and energy services.*

The Smart5Grid virtualisation framework is also based on cloud native applications that have been architected as a set of microservices running in Docker containers.

- *This enhances the Smart5Grid platform with the **ability to support applications designed specifically for cloud infrastructures** that consist of loosely-coupled microservices and enabling zero-touch orchestration and agile DevOps practices.*
- ***Each microservice will remain self-contained** and will encapsulate its own code, data, and dependencies.*
- ***The cloud native approach takes full advantage of the scalability and resiliency features,** found in modern serverless platforms.*

Concluding Remarks _(3)

Smart5Grid "paves the way" for applying the key features of Multi-Access Edge Computing

- The main target is to push computation, storage, and network resources closer to the devices that consist the power grid so that to solve the resource limitation problem and to offload NetApps directly to edge servers.
- This will allow a significant reduction of latency for devices to access the network and to reduce energy consumption.
- MEC is also going to ensure data security and integrity by enabling ubiquitous last-mile service access to the smart grid devices.
- It will also offer deployment of network slices within minutes, coupled with value-added capabilities for the smart grid NetApps (such as bandwidth assurance, life cycles management of network services, and overall balancing of service loads).

A NetApps' main purpose is to hide the complexity of the 5G telco network to the energy application developers so that they can develop an application not having to deal with the underlying network.

- Smart5Grid will support most of smart grid's functionalities by enabling an environment where cloud-native NetApps can realize the integration between the energy vertical and 5G networks, and;
- with a special focus on deployments that leverage edge infrastructure.

Thank you for your Attention!

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