Path to 5G Smart Cities: Experiences from Media and Public Safety Pilots in 5GCity

Gino Carrozzo *
Nextworks, Pisa (IT)
g.carrozzo@nextworks.it

Muhammad Shuaib Siddiqui
Fundació i2CAT, Barcelona (ES)
shuaib.siddiqui@i2cat.net

***Abstract*— 5GCity is an H2020 project within 5G PPP phase 2 which is working on deploying and testing the benefits of 5G technologies in Smart Cities. In particular, 5GCity is developing an architecture for the 5G-ready Neutral Host in which network slicing, SDN/NFV technologies, multi-access edge computing (MEC), and optimized lightweight virtualization platforms (e.g. based on unikernels) are all integrated to manage and orchestrate a distributed 5G cloud and radio platform.**

5GCity has built city-wide pilots in the cities of Barcelona (ES), Bristol (UK) and Lucca (IT) where a number of media and public safety use cases are being simultaneously validated. This paper briefly reports on the key characteristics of these use cases and the main KPIs under evaluation selected to validate Vertical applications of interest and the 5GCity platform management and orchestration features.

***Index Terms*— 5G trial, Media Vertical applications, Public Safety use cases, City Pilots**

I. INTRODUCTION

Validation through use cases is key for the efficient deployment of 5G solution which ca actually serve to the realization of advanced Vertical services [1].

5GCity [2] has designed and deployed city-wide pilots of a distributed cloud and radio platform for municipalities and infrastructure owners acting as 5G neutral hosts. Apart from the usual telecommunication providers, the 5GCity solution targets to municipalities as main stakeholders. These actors quite often own and manage the best urban spaces to host 5G Small Cells, and are undergoing a digital transformation towards becoming Smart Cities, in which various value-added services, powered by 5G technologies, can be designed for the benefit of the end customers, i.e., the citizens.

The main goal of 5GCity is to build a common, multi-tenant, open platform capable to implement flexible and intelligent 5G infrastructure sharing mechanisms, in which network sharing will go beyond traditional infrastructure sharing model. 5GCity is integrating Cloud, Edge computing and radio platform to perfectly align with 5G networks and neutral host model, to support the sharing between infrastructure owners and media service providers. Among 5G PPP Phase 2 projects, 5GCity is the unique initiative which is validating its innovations in three different cities with live trials: Barcelona (ES), Bristol (UK) and Lucca (IT). In these city-wide pilots we are preparing to validate vertical service design solutions together with end-to-end network slices and network service, through the integration of three different categories of use cases as depicted in Fig. 1 and described in details in [3]: (i) neutral host; (ii) media industry use cases; and (iii) public safety services in scenarios of waste management through video analytics. These use cases are developed to simultaneously take place in dense environments such as the cities and that need to co-exist and share the ICT infrastructure with different requirements.

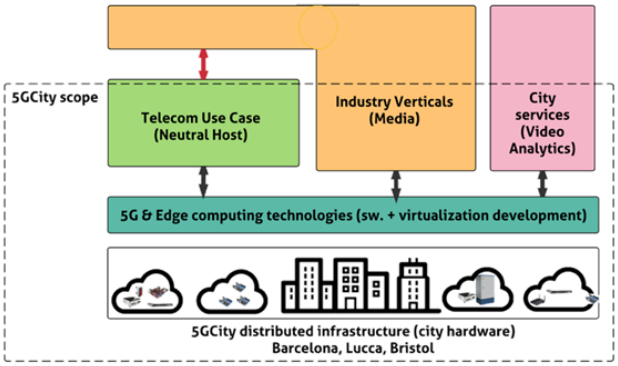

Fig. 1. 5GCity Use case categories

The *5GCity Neutral host* use case implements the category of telecom operator driven scenarios. It will leverage on orchestrated core/edge virtualization platforms in order to enable the cities to create dynamic end-to-end slices containing both virtualized edge and network resources and lease it to third-party operators. For example, a 5G radio operator can become a service provider in cities where it does not have infrastructure, with full management and control capabilities over the slice, further than the typical Mobile Virtual Network Operator (MVNO) use case.

A second scenario (*Industry vertical*) is strictly related to different aspects of the media and entertainment industry and encompass all the Use Cases pivoting around video acquisition, editing and delivery. Three different media Use Cases are taken into account in our validation:

- Mobile real-time transmission;
- UHD video distribution
- Real-time video acquisition and production in edge cloud.

A third scenario (*City Services*) is tailored to the specific needs about security and surveillance of the territory in Smart Cities. 5GCity exploits the cities surveillance cameras and

* Corresponding author

Video Analytics based applications that can process video streams close to the acquisition cameras to rapidly identify illegal waste dumping, violation of accesses.

This paper reports on initial experiences of deployment and validation of these use cases in the three 5GCity infrastructures and briefly describes the main KPIs under evaluation selected to validate Vertical applications of interest and the 5GCity platform as a whole.

A. Design challenges of the 5GCity platform architecture

5GCity is designing a completely de-centralised 3-tier architecture where compute, storage and networking are allocated between core and edge segments of the 5G network infrastructure [4]. Key challenges to address in this context are: i) availability of a unified control and orchestration framework for the orchestration of all 5G-based edge services and capable also to control the underlying city infrastructure with slicing; ii) availability of powerful APIs through which it is possible to access, define and program the different edge services and the orchestrator functionalities; and , iii) offering access via a service SDK to a rich set of primitive functions for network and vertical application services (e.g. programmable connectivity with QoS, media acquisition and transcoding, traffic monitoring).

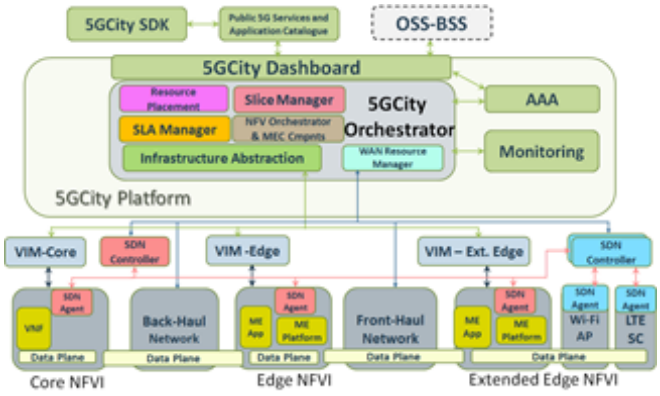

Fig. 2. 5GCity high level architecture

A distributed edge infrastructure such as the one in the cities relies, among other factors, on a collection of smart computing technologies applied to critical infrastructure components and services. What is missing in state of the art is a framework to make it relatively easy to deploy and manage services over a shared platform. Through adopting the ETSI NFV MANO architecture, 5GCity is building such a framework which will provide different mechanisms in addition to lifecycle management, in order to enable both data-centric programming model for edge-based services, optimized resource consumption at edge and micro datacenters (through unikernels) and a Service Development Kit (SDK) towards third-party users who will be enabled to dynamically deploy their own services over the distributed edge city infrastructure. Through the modular virtualization capabilities activated and coordinated by the 5GCity orchestrator layer, it is possible to monitor and manage multiple performance metrics of the 5G virtualized infrastructure. These performance metrics can be used to better differentiate the network capabilities, feed in the decision engines for resource allocation and optimization, guarantee QoS/QoE targets to individual service requests. A summary overview of the resulting 5GCity platform architecture [4] is presented in Fig. 2).

The need to coordinate a distributed core/edge infrastructure in 5G poses critical challenges on the orchestration layer. The 5G management and orchestration capable to release 5g production services for real environments with end users needs to

- be capable of scaling up to a large number of devices, and control distributed NFV infrastructures at core and edge micro datacenters
- be fast to react to changing conditions of the infrastructure and attached end-users/devices
- allow Service Providers to supply end-users with connectivity services on top of a Neutral Host infrastructure (i.e. ordinary mobility management and session management procedures, user plane procedures, etc.)
- provide security and separation of Service Providers slices/shares/MEC nodes (multitenancy).

On the management of resources and network slices, key challenges addressed by the 5GCity architecture are:

- The ability to allocate or de-allocate resources (NW slices/shares and MEC nodes) to the Service Providers according to their own SLA (QoS, etc.)
- The ability to dynamically reallocate resources to the Service Providers to align with the changing needs of different users and applications
- The ability to reduce per-VM memory footprint (down to MBs or even KBs);
- The ability to shorten creation times to support justin-time deployment of virtualized applications (e.g., in 100 of msecs or less) and migration times (down to 100 msecs or less).

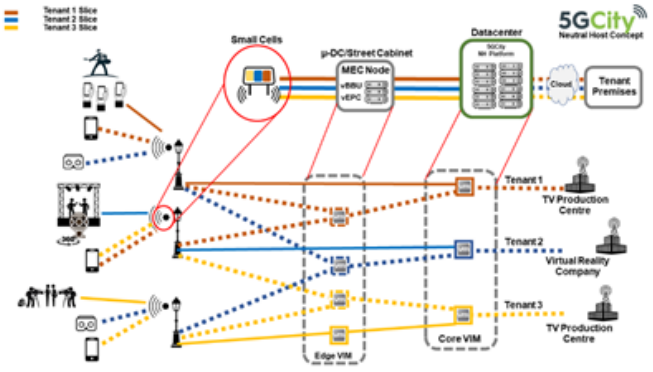

Fig. 3. 5GCity Neutral Host model for network slicing

The resulting 5GCity network slicing platform allows to orchestrate the creation of slices that include chunks of various layers of the 5G network (Cloud and edge IT resources, core and radio access in different standards, i.e. LTE, 5GNR and WiFi), as depicted in Fig. 3.

B. 5GCity Use cases and pilots

The mapping of the three Use Case scenarios targeted in 5GCity (i.e. Neutral Host, Media Industry and City services) is presented in Table I.

TABLE I
5GCITY US CASES AND SELECTED CITIES FOR PILOTS

Use case	City		
	Barcelona	Bristol	Lucca
UC1 - Unauthorized Waste Dumping Prevention	-	-	✓
UC2 - Neutral Host	✓	✓	✓
UC3 - Video Acquisition and Production for community media	✓	✓	-
UC4 - UHD Video Distribution and Immersive Services	-	✓	✓
UC5- Mobile Backpack for Real-time Transmission	✓	-	-
UC6 - Cooperative, Connected and Automated Mobility (CCAM)	✓	-	-

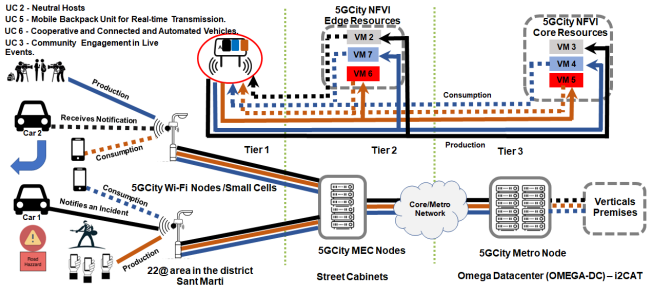

Fig. 4. 5GCity use cases in Barcelona (ES)

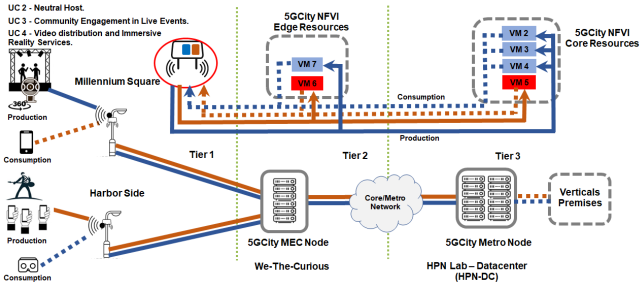

Fig. 5. 5GCity use cases in Bristol (UK)

For these use cases different areas for the trial have been identified in the three target cities of Barcelona (ES), Lucca (IT) and Bristol (UK), as depicted in Fig. 7. In the Cities of Barcelona and Lucca, the 5GCity radio segment is implemented with LTE RAN access components by Accelleran (Accelleran E1013 Small Cells) operating in band B42 (3.4 3.6GHz) and B38 (2.579-2595 MHz). In Bristol we use NOKIA Air scale + RRH in 2.6 Ghz and an experimental National Instrument 3.5 Ghz 5GNR radio solution as 5GCity Small Cell. In the three cities Edge/MEC Nodes will be deployed at street cabinets while core nodes are deployed

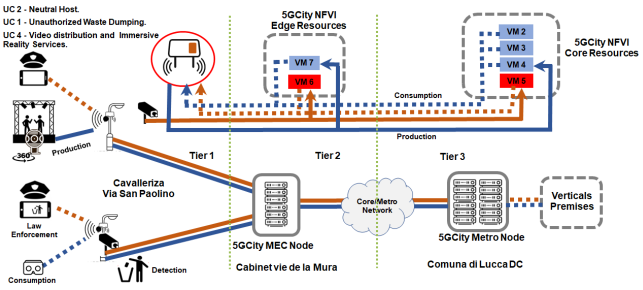

Fig. 6. 5GCity use cases in Lucca (IT)

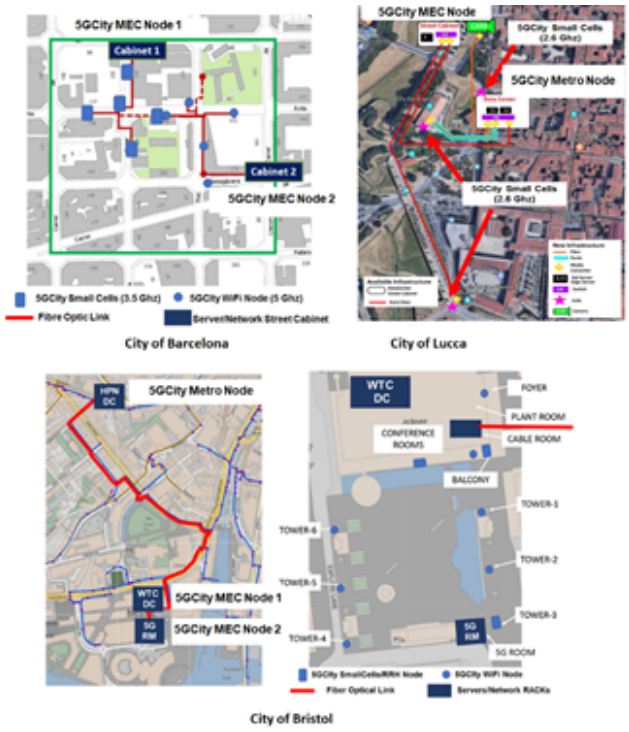

Fig. 7. 5GCity Pilots in Barcelona (ES), Bristol (UK) and Lucca (IT)

in datacenters/PoPs. Details of the infrastructures designed for the three cities are reported in [5].

Focusing on the use cases related to public safety (UC1) and media services (UC3, UC4, UC5), for each city pilot and use case scenario we are defining a standard suite of tests to evaluate specific KPIs. WIth teh test suite we aim at measuring:

- **User Experienced Data Rate.** We intend to monitor uplink bandwidth when a single UE generates traffic towards the application server. Performance targets for this User Experienced Data Rate metric are:
  - UC1: 4-10 Mbps per camera
  - UC3: 2-8 Mbps per mobile device
  - UC4: 4-10 Mbps per HD, UHD 4K and Video 360
  - UC5: $>$ 8Mbps per camera for a HD transmission

  An early evaluation of this KPI with an early demonstration of UC3 was successfully conducted in the partially deployed 5GCity testbed of the City of Bristol. The measurements confirm an average of 25 Mbps UL and

70 Mbps DL per UE, when 3 UEs where recording HD video and one UE was producing and broadcasting HD video to another 3 UEs.

- **Data Plane and Control Plane Delay.** Here we measure the time that takes to transfer a given piece of information from a source to a destination, either in data plane or in control plane. Performance targets for these metrics are:
  - UC3 Data Plane delay $<$ 5s
  - UC4 Data Plane delay $<$ 10ms
  - UC5 Data Plane delay $<$ 1s
  - For all UCs, target Control Plane delay $<$ 20ms
- **Availability.** Here we measure the percentage value of the amount of time the end-to-end communication service is delivered according to an agreed QoS, divided by the amount of time the system is expected to deliver the end-to-end service according to the specification in a specific area. Performance targets for this availability metric are:
  - UC3: $>$ 99.5% (fail for max 1.83 days/year)
  - UC4: $>$ 99,999% (fail for max 5.26 minutes/year)
- **Service Creation Time.** This metric measures the time needed to activate a Network Service that comprises multiple VNFs in a service chain. The metric applies to all the use cases and in a multi-tenant condition of ≥ 3 slices it aims at performance targets of:
  - Edge service instantiation time in $<$ 2 mins
  - Reallocation of service flows in $<$ 1 min

The 5GCity platform deployments with basic network tests are planned to be concluded by May 2019. Consequently, detailed tests with conclusive assessments of the achieved performances are not available at the time of writing this paper, and are planned by Q3 2019.

II. CONCLUSIONS

This paper briefly reports on the key characteristics of the 5GCity platform architecture and the use cases related to public safety and media service. The work in the project is progressing to deploy the use case elements and integrate their service lifecycle within the 5GCity NFV platform.

The main performance KPIs validation for the 5GCity use cases in the three 5GCites is planned to be executed from June 2019 and to complete the assessment by Q4 2019. Demonstrations of 5GCity platform, SDK and some of these use cases are planned for EUCNC2019 in Valencia (ES), including scenarios for an outdoor demo in the conference area with elements of Use case 5 (Mobile Backpack for Real-time Transmission).

ACKNOWLEDGMENT

This work is supported by the H2020 5GCity project, which has received funding from the European Union under Horizon 2020 research and innovation program with grant agreement No 761508.

REFERENCES

[1] 5G PPP, ERTICO, EFFRA, EUTC, NEM, CONTINUA and Net-world2020 ETP, "5G empowering vertical industries, Available online: http://tiny.cc/1nv25y," Tech. Rep., Feb. 2016.
[2] The 5gcity project website. [Online]. Available: http://www.5gcity.eu/
[3] 5GCity project, "Deliverable 2.1, 5GCity System Requirements and Use Cases, DOI 10.5281/zenodo.2558209," Tech. Rep., Dec2017.
[4] ——, "Deliverable 2.2, 5GCity Architecture Interfaces Definition, DOI 10.5281/zenodo.2558242," Tech. Rep., May 2018.
[5] ——, "Deliverable 5.1, 5GCity Infrastructure Design and Definition,DOI 10.5281/zenodo.2574000," Tech. Rep., May 2018.