Development and Implementation of a Smart City Use Case in a 5G Mobile Network's Operator

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***Abstract* — Presently, one of the critical challenges for mobile operators is how to implement in the near future a 5G network. This network must support a variety of use cases each of them with different requirements. 5G use cases are so diverse and challenging that the 5G networks must be customizable for the broad range of individual scenarios. We analyze in this paper the steps, objectives, architecture and specific requirements necessary for development and implementation of a Smart City Use Case in a 5G mobile network's operator. We consider that this use case will be the first that will use the 5G network, deployed by Orange Romania, in the near future.**

***Keywords* —Intelligent Lighting, IoT, KPI's, LoRaWAN, LTE-M, Pole, Sensor, Smart City , Use Case, 5G**

I. Introduction

SMART City is an important worldwide initiative. Over the last decade, the evolution of information technologies and communications networks, sensors, actuators, cloud infrastructure, big data and products/ services based on these enablers has changed the way people live in a city. Access to information, services and communication is now provided anywhere and anytime by smartphones and modern people have adapted to this new way of living. Meanwhile, various actors that create "smart city technologies" are trying to convince the governments and the public administrations that these technologies can help cities improve the efficiency, availability, quality and cost of providing city services. At the same time, governments make transition to online services, but they must ensure that no one is left behind, not even those without access to this technology.

In this paper we study the Intelligent Lighting use case in the context of 5G Smart City. This use case will be implemented and tested by Orange, in Alba Iulia city, in the near future.

The paper is organized as follows: Section 2 presents generalities about Smart City use cases and verticals; Section 3 presents our proposal for Smart City Intelligent Lighting use case with its basics concepts, its main objectives, the high level architecture needed to support this solution and the end-to-end requirements that our future 5G network must meet to successfully implement it. Finally, Section 4 presents the conclusions.

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II. Generalities about Smart City Use Cases and Verticals

A use case is a software and system engineering term that describes how a user uses a system to accomplish a particular goal. A use case acts as a software modeling technique that defines the features to be implemented and the resolution of any errors that may be encountered [1].

The most important vertical industries in Europe are: Factories of The Future, Automotive, Health, Energy and Media & Entertainment. It is expecting that 5G will integrate different telecommunication technologies (e.g. mobile, fixed, satellite and optical), spectrum-regulatory frameworks (e.g. licensed and unlicensed) and enabling capabilities (e.g. Internet of Things - IoT) for the benefit of these vertical industries. 5G architecture will accommodate a wide range of use cases with advanced requirements in terms of latency, resilience, coverage and bandwidth. These use cases originating from verticals industries should be considered as drivers of 5G requirements.

In the perspective of future 5G networks, there are three main categories of use cases: massive broadband (xMBB) that delivers gigabytes of bandwidth on demand, massive machine-type communication (mMTC) that connects billions of sensors and machines and critical machine-type communication (uMTC) that allows immediate feedback with high reliability [2].

These three main categories could be further divided in some families, each of them including some of use cases. From Orange Romania point of view, the IoT family, including the Smart City use case, presents interest. This family includes devices (sensors, actuators) with a wide range of characteristics and demands for which the 5G must perform a massive deployment. A sensor detects and

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responds to inputs from physical environment. An actuator is responsible for moving or controlling a mechanism or a system. Sensors feel the measured characteristic and basis of that action can be performed by the actuators. The IoT family includes both low-cost/long-range/low-power MTC as well as broadband MTC.

Services of a Smart City consist in metering solution (gas, energy, water), remote monitoring of city infrastructure (pollution, temperature, humidity, noise), real-time traffic information and control, city or building lights management and public safety alerts for improved emergency response times, besides aggregation of these services with very different characteristics (which have to be combined in a common communication and interworking framework).

III. Smart City Intelligent Lighting use case

A. *Intelligent Lighting use case basics*

Alba Iulia was the first Smart City from Romania, developed by Orange, and is a key driver for the other cities or operators that want to develop such a solution. Alba Iulia, a small to middle size city in Romania with about 70k inhabitants, is moving forwards as a smart city by adopting the latest ICT technologies including Low Power Wide Area Networking (LoRaWAN), Long Term Evolution for Machines (LTE-M) and finally 5G enablers. For the smart city use cases Orange proposes an open data strategy and open architecture (Fig. 1.-Fig. 3) that give access to further development of new applications by monetizing datasets from the city itself. Alba Iulia has been selected by Orange to demonstrate the capabilities of the targeted Smart City high level architecture in dealing with critical smart lighting infrastructure under the **Intelligent Lighting** use case.

Intelligent Lighting use case will be considered in the scope of the 5G mMTC category where the challenge is to accommodate the massive number of connected actuators/controllers without impacting the Quality of Services (QoS) and Quality of Experience (QoE). Another service requirement to be met by the Intelligent Lighting use case is to assure ultra-high network reliability and availability, while low-power, context awareness and location awareness requirements for managing the connected actuators/ controllers over the access and transport layers can further improve the solution cost efficiency. This will be especially important during the daytime when the smart streets lighting poles infrastructure is supposed to remain powered to facilitate other city services (e.g. public safety surveillance, air quality monitoring, public Wi-Fi hotspots, and advertising).

In case of Alba Iulia, Orange Romania plans to build a live testing infrastructure of at least 100 smart controllers (actuators) that will be deployed on the main roads of the city. This will help the authorities understand the aggregated benefits of the solution and compare them with the status quo.

The Intelligent Lighting use case will facilitate three key functionalities that are impossible or hard to be efficiently provided today over legacy city lighting infrastructure and even modern lighting infrastructure, regardless the development of modern LoRaWAN technology or cellular IoT technologies (LTE-M, NarrowBand IoT - NB-IoT):

1. The responsible entity will be able to remotely control in real time and in a secure way every single lighting pole from the target network, in order to adjust the lighting intensity and efficiently manage energy consumption. The system will give public lighting distribution company reporting to the city manager, the ability to automatize the control of the lights, including the on/off and diming capability according to certain policies (e.g. day time moment, natural light intensity, location, traffic). This system, combined with the adoption of more efficient LED based ballast lamps, is anticipated to generate a reduction of energy costs for up to 80%, and a return of investment in just four - five years. According to a report [3], only about 10% of the 300 million street lights poles in the world are using energy-efficient LEDs, and just 2% are connected thanks to legacy communication technologies such 2G/3G.

2. Moreover, the system will allow real time and history based energy consumption measuring. The city of Los Angeles made energy savings of 63% in 2016 just by switching to 100% LED street lighting, generating cost savings of USD 9m and reducing its annual greenhouse gas emissions associated with public lighting by 47,000 metric tons. This is equivalent to the greenhouse gas emissions from almost 10 passenger vehicles driven for one year [3].

3. The entity responsible with the streets lighting infrastructure operation and maintenance will be able to proactively spot the malfunctions, energy loss or energy theft tentative on the public lighting network, as the system will generates intervention ticket in real time per pole or branch of poles. This capability will highly improve the city lighting service availability and will decrease the operational costs with maintenance activities. There is an international standard [4] that specifies a set of indicators meant to define and measure the performance of quality of life and city services. This is applicable to any city or municipality that targets to measure its performance in a comparable and verifiable manner, irrespective of size and location. Street lighting can consume between 15 – 50% of public electricity [4]. Electricity consumption of public street lighting is calculated as the total electricity consumption of public street lighting (numerator) divided by the total distance of streets where street lights are present (denominator).

B. *Objectives*

The main goals for which we want to implement Intelligent Lighting use case in Alba-Iulia are:

- Specification of business, functional and security requirements for Smart City IoT – Smart Lighting infrastructure with focus on energy consumption optimization and intelligent lighting to be supported by the 5G architecture;
- Prototype demonstration of the use case over 5G;

➢ Demonstration of the coexistence of selected Smart City IoT applications in the shared 5G infrastructure, without decreasing the value for KPIs achieved in the initial setup demonstration;
➢ Integration and testing of this vertical use case within the project's 5G communication framework;
➢ Demonstration of the openness of 5G to different radio access technologies;
➢ Timing service creation from weeks or days to hours;
➢ Extended network coverage, new service capabilities and new business models;
➢ Enhanced network management and network control;
➢ Usage of different types of Radio Access Network (RAN) terminals.

A best practice for us will be to create a measurement framework that can monitor and evaluate city-level impacts of smart and connected lighting investments thanks to the Intelligent Lighting System. The adoption of 5G based Smart City datasets will help to build the investment case for smart technology projects. These datasets can clearly define how investments can improve infrastructure of QoS and QoE across the city and deliver benefits to its citizens.

C. High level architecture for Intelligent Lighting use case

Presently, Orange Romania, has at Alba Iulia implemented the solution depicted in Fig. 1. in which the network infrastructure is based on LoRaWAN.

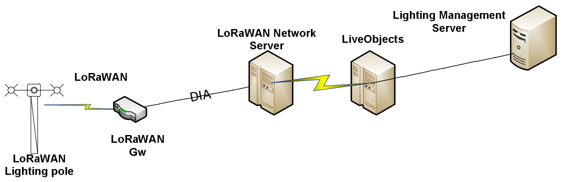

Fig. 1. Intelligent Lighting System using LoRaWAN

In the near future, we will implement in Alba-Iulia the solution from Fig. 2., where the LoRaWAN technology will be replaced by the LTE-M. This transition is a big step further in achieving our final purpose, the development of the Intelligent Lighting System in Alba Iulia Smart City, using 5G infrastructure. The architecture of this desired implementation can be observed in Fig. 3.

The high level architecture (depicted in Fig. 1-3) is constructed on three levels: data collection and transport layer, open IoT middleware layer and application layer.

The data collection and transport layer will provide LoRaWAN, LTE-M and 5G specific connectivity for all sensors, actuators and consequently raw datasets that will be generated from the Smart City solutions.

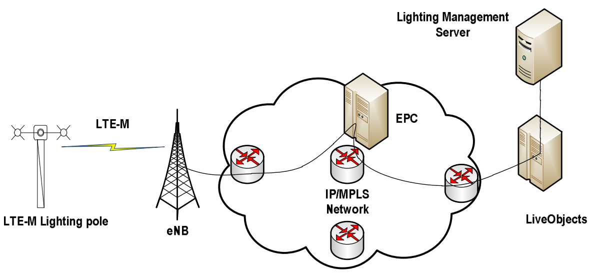

Fig. 2. Intelligent Lighting System using LTE-M

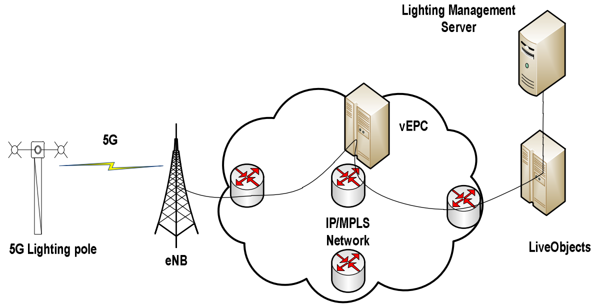

Fig. 3. Intelligent Lighting System using 5G network

These datasets will be sent to the open middleware platform to be stored, processed and secured. The open middleware can work also with other datasets that are not real time accessible through sensors or actuators. The Intelligent Lighting solution, presented in Fig. 3., will reside in the cloud edge part of the 5G Architecture. It is not a low latency or high bandwidth solution and in this particular case, the virtualization of this service doesn't have to stay near (location wise) to the deployment. The lighting poles provide and transmit to Management Server indicators related to power, voltage, electrical current, active/ reactive/ apparent power, power factor, energy (active /reactive) and functioning time.

From the transport network perspective, the traffic is characterized by small bursts of data from a large number of devices. The size of packets transmitted by lighting pole counters 30 bytes.

The functionality of the Intelligent Lighting solution is described on the Provisioning flow depicted in Fig. 4. The end-to-end steps from this provisioning flow are:

1. Lighting pole system is installed.
2. Lighting pole is powered on.
3. The pole system is trying to connect to the communication network.
4. The system is authenticated with the communication network.

a. If authentication succeeds, go to step 5.
b. Else go to step 4, the failed cause to be analyzed at network level.

5. The pole lighting system is authenticated to the management server.

a. If Yes, authentication succeeds, system starts working.
b. Else, go to step 5, the cause to be analyzed at management server level.

We can observe from the Fig. 4. that the device must communicate through the 5G network with the Cloud edge and must be able to control the lighting pole.

Success conditions: the lighting pole is powered on and is attempting to authenticate to 5G virtual Core (vCore) network.

Failed End protection: the device will not be able to communicate through the 5G network with the Cloud edge and will not be able to control the lighting Pole; connection between lighting poles and Lighting Management server is flapping; data sent by lighting pole lost on transit due to network congestion or Virtualized Network Function (VNF) overloading.

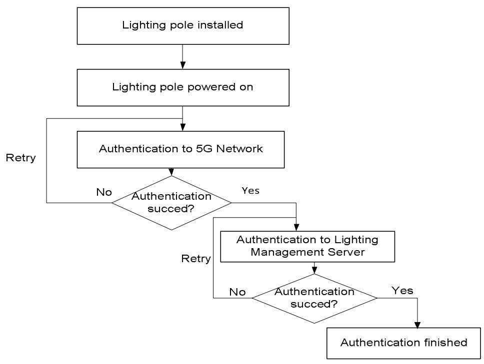

Fig. 4. Provisioning flow of the Intelligent Lighting solution

D. End-to-end network requirements

In case of Intelligent Lighting it is proposed to provide the management functionality for the underlying virtual and physical infrastructure. The solution for a large smart city implementation involves up to millions of devices connected through the communication network to the management system. The requirement is to provide access to the "slice" into an easy way, scalable and efficient, by deploying at large scale smart sensors. Devices and sensors need to be addressable and identifiable for precise management and automation into the dedicated slice, as registered with the network and management systems. The slice must assure and guarantee the performance, availability, capability to cope with very large numbers of devices accessing the resources into a planned or triggered mode and must to respond to the identified Smart City lighting requests for communication. The slice should be offered and available, when it is needed. The network slicing is requested in the core part, as dynamic capabilities of scaling of virtual network functions for the dedicated lighting use case. The slice requirement may be integrated as a "Smart City Slice" approach.

The Smart City use case for Intelligent Lighting has specific requirements regarding RAN capabilities: high reliability, dense coverage, accommodation of small bursts of data and accommodate large density of devices/ km2.

The general core requirements are depicted by the system architecture from Fig. 5. From the Core Network perspective, the requirements associated to Intelligent Lighting use case for system communication are: VNFs provisioning (virtual Mobility Managemnet Entity - vMME, virtual Packet Gateway –vPGW and virtual Serving Gateway- vSGW), service chaining, IP/MPLS (Multiprotocol Label Switching) transport network and end-to-end authentication for devices.

A relevant scenario is covered by the possibility of slicing definition and creation at the core network level, through the set of communication components, as VNFs structures and/or links to the Physical Network Function (PNF) network. It will be defined a specific sliced system with dedicated resources for the communication capabilities within the Smart City scenario:

- ➢ Low bandwidth needs;
- ➢ Low delay;
- ➢ Fast deployment of core system on demand;
- ➢ Massive communication type devices;
- ➢ Large number of devices and sensors;

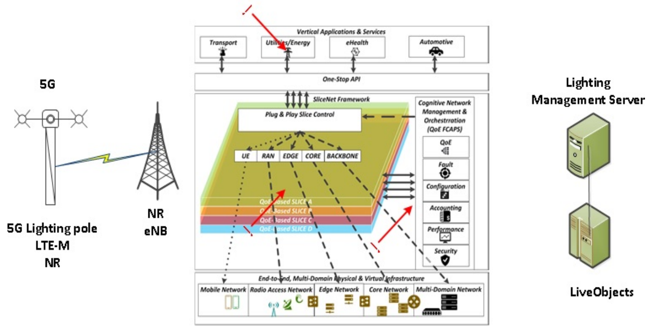

Fig. 5. System architecture for Intelligent Lighting 5G use case

- ➢ High requirements for signaling capabilities;
- ➢ Sensitive response to the system triggers;
- ➢ Easy to accommodate new devices;
- ➢ Economic aspects, for business cases sustainability, accommodating of slicing principles over the dedicated hardware infrastructure.

In conclusion, the Smart City Lighting model must offer in normal condition low-power, low-energy capabilities, with basic functioning on battery extended time range, and providing permanent or temporary scheduled or triggered functioning.

IV. CONCLUSIONS

The prototyping of the Intelligent Lighting use case will enable the management of the poles in Alba Iulia city (~100 poles) on the new slicing concept, comparing the different technologies of access, from LoRaWAN to LTE-M and NB-IoT and also highlighting the KPIs. The testbed will use a dedicated slice core network.

The use case presented in this paper will be implemented and tested by Orange, in Alba Iulia city and also in the lab environment, and the results will be compared with existing functionality network infrastructure based on LoRaWAN to highlight the benefits of 5G.

Taking into account the characteristics depicted above, the Intelligent Lighting use case under 5G network will be something different with these new capabilities: it provides higher wireless area capacity and more varied service capabilities compared to 2010, can save up to 80% of energy per service provided, reduces the average service creation time cycle, can create a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision, facilitates very dense deployments of wireless communication and enable advanced user controlled privacy.

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