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# Advanced First Responders' Services by using FASTER Project Architectural Solution

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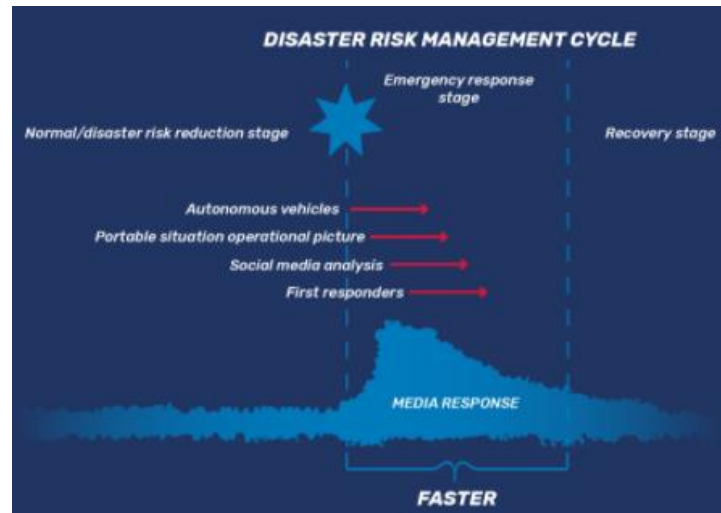
**Abstract.** As the 5G technologies start to become a reality in telecommunication networks, more services and applications are designed to take advantage of the new features that 5G technology is offering. Additionally, several vertical sectors are using advanced applications in order to improve their performances. One important vertical is the Mission Critical Services (MCS) sector, which could significantly exploit 5G networks. When an emergency event occurs, such as a strong earthquake or a flood, the network traffic is proved to be rapidly increased. At the same time, the first responders need all the available resources in order to offer their services efficiently. In a situation like the one described which is extremely demanding and the available resources should be used as a priority by the first responders, the existing 4G network does not seem to be sufficient. It must be ensured that the first responders could be interconnected in a reliable network, which will provide a low latency and ultra-high throughput transmission being able to support all the advanced equipment and devices (UAVs, robots, AMRs, augmented reality and virtual reality glasses, etc.) that the first responders need. These requirements are satisfied by 5G networks. The 5G network architecture has been designed and implemented based on a new approach. The 5G network architecture that was designed and implemented for the needs of FASTER project and the advantages that this architecture offers to the first responders is presented in this paper.

**Keywords:** 5G, first responders, Network Functions Virtualization (NFV), network portability, Network Softwarisation, Non-standalone 5G architecture, Small Cell (SC), Virtual Network Function (VNF).

## 1 Introduction

In the event of an emergency, the first responder is the one who will immediately offer assistance at the scene. FASTER project [1] is focusing on providing solutions to protect first responders in hazardous environments and enhance their capabilities in

terms of situational awareness and communication. For that reason, augmented reality technology equipment, drones and wearables are proposed as part of this innovative toolbox. However, this equipment in order to be useful should be interconnected through a reliable network. As it is presented in Fig.1, the throughput demand is rapidly increased few minutes after the emergency event and when the first responders start offering their services.



**Fig. 1.** Throughput requirements in a disaster risk management cycle [1].

Apart from the requirement of increased throughput [2-3], the increased reliability [4] and coverage [5-6] as well as the very low latency [7-8] are also critical requirements for the network in order to support efficiently the needs of first responders. Although a 4G network includes features that are remarkable and it is quite efficient, the advanced requirements that are needed are so demanding and thus it is difficult for a 4G network to efficiently support them. On the contrary, a 5G network supports all the desired features to realize such cases. For example, the 4G network throughput is 50 Mbps, while the corresponding one for 5G could be more than 1 Gbps; but the most innovative advantages of a 5G network over a 4G network are the low latency, the reliability and the location accuracy.

The low latency is one of the most important parameters of the network, since the first responders will use real time applications. In 4G networks the latency is 200 milliseconds, while in 5G networks it could be even below than 5 milliseconds. That difference could be crucial not only because it will improve the services offered by first responders, since they will use real-time data such as 8K video streams [9-10], and virtual reality (VR) / augmented reality (AR) enhanced features [11], but also the low latency could play an important role in the safety of the first responders allowing high location accuracy because the exact location of first responders could be detected instantly.

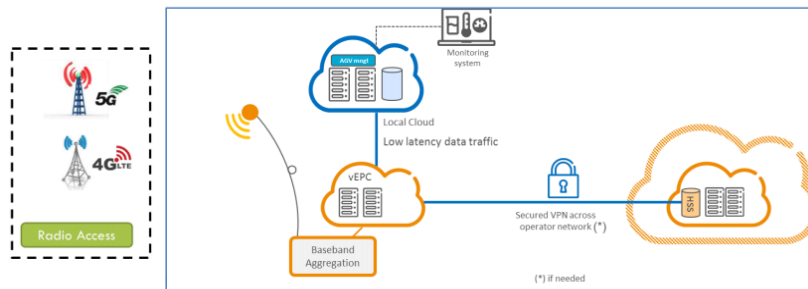
Finally, high reliability is a network requirement which is crucial for the services offered by the FASTER project. The first responders will be connected to a control

centre and to each other, by using wearables or smart phones. This connectivity must be uninterrupted. Any interruption of communication could be dangerous, given the conditions under which first responders offer their services. The way 5G network ensures the high reliability is by boosting higher traffic capacity and by supporting the slicing feature. The network is divided into slices, each of which may have specific requirements. For example, in a case where an earthquake occurs it is proven that network users rapidly increase the used throughput of the network since they are trying to communicate to each other. That phenomenon could lead to a significant reduction of the available throughput of a legacy network, causing interruptions or connection inability. The slicing feature could resolve such sort of problem in a situation like this, by offering a unique slice to be used by the first responders. Therefore, the necessary network resources are secured and first responders are served according to MCS stringent requirements. There are 3 main slices specified by 3GPP (3rd Generation Partnership Project) Release 15 [12]: Ultra-reliable low-latency communication (URLLC), enhanced Mobile Broadband (eMBB) and massive Machine Type Communications (mMTC). The URLLC applications require network capabilities that are also required in the FASTER framework, such as reliability (target value 99.999%), low latency (target value 1 msec), location accuracy and high throughput.

It is important to be mentioned that reliability and low latency could also be achieved by the outdoor small cell architecture. The original macro cell could be divided into smaller cells. These smaller cells are using short-range and low-power base stations to ensure connectivity to the network [13]. The advantage of this architecture is that it can offer higher throughput by reusing the same frequencies in several small cells, taking full advantage of available spectrum.

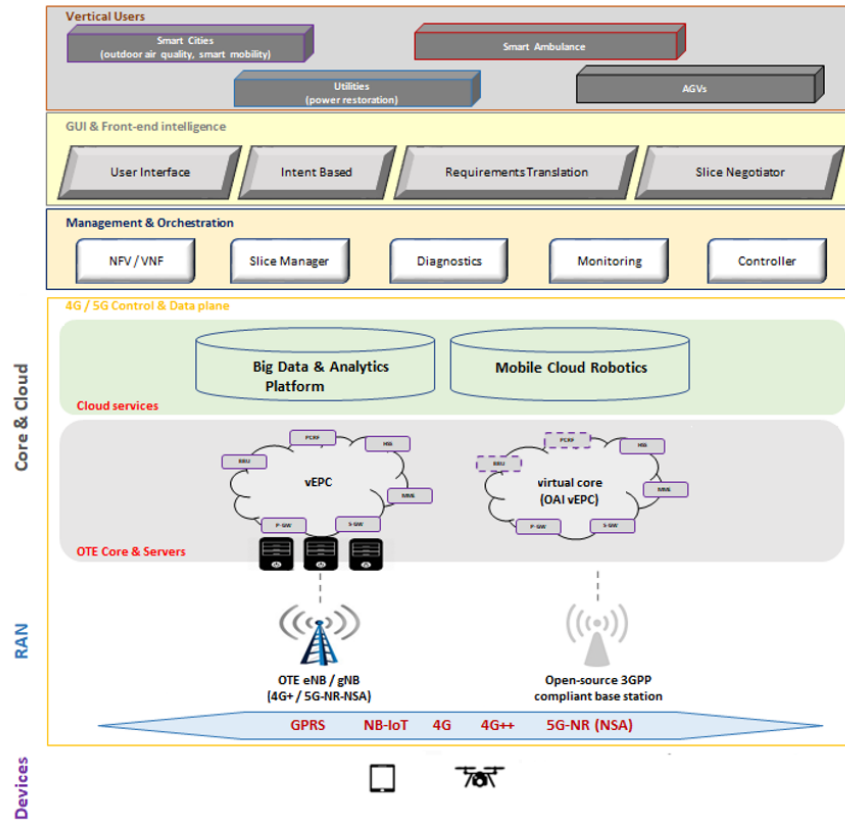
## 2 FASTER 5G-enabling Network

For the purposes of the FASTER project, the Non-Standalone architecture is adopted. The Non-Standalone (NSA) architecture is designed to take advantage of the 4G network equipment, offering 5G services. On the contrary, the Standalone (SA) architecture is solely using 5G equipment. Taking into consideration the large number of new hardware that must be deployed in a SA network architecture, the NSA architecture is preferred by operators in the first stage of the 5G deployment.



**Fig. 2.** Network architecture for an industrial enterprise URLLC application.

The FASTER network architecture is based on URLLC applications as it is presented in Fig.2 [14]. This figure depicts the 5G New Radio access network (5gNR), which is connected to the virtual Evolved Packet Core (vEPC). The vEPC is finally connected with the Open Source MANO (OSM).



**Fig. 3.** High-level network architecture.

In Fig.3, the architecture that is used in the FASTER project is presented in more details. It is shown that it is separated into three distinct parts:

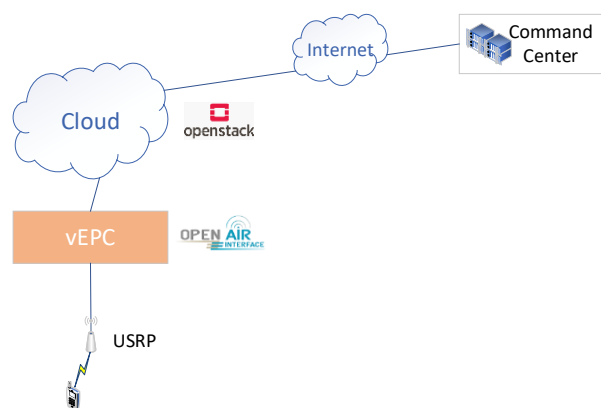
- The User Equipment (UE) is the part of the network which includes all the equipment that can be connected to the network, such as wearables, smart phones, drones and AR equipment.
- The UE layer is connected wirelessly with Radio Access Network (RAN), which in the FASTER case is the 5gNR. A RAN is separated into the hardware (baseband node and radio units) and the software (components needed to operate the 3GPP wireless system including LTE and 5G) part.

- The Core Network (CN) is the third part of the FASTER 5G NSA architecture, which is based on a virtual EPC (vEPC). The vEPC is composed of the following network elements:
  - Packet Data Network Gateway (P-GW), which is responsible for ensuring the network quality-of-service (QoS). Additionally, it collects charging information.
  - Baseband unit (BBU), which is responsible to ensure the communication through the physical interface.
  - Policy and Charging Rules Function (PCRF) which determines policy rules in a multimedia network and operates in real-time.
  - Home Subscriber Server (HSS) is the user's database. All the user subscription data (username and password) are hosted in HSS.
  - Mobility Management Entity (MME): The MME is responsible for the user authentication. Additionally, it verifies whether the UE is authorised to camp on the service provider's Public Land Mobile Network (PLMN).
  - Serving Gateway (S-GW) is a gateway which routes packets to and from the base station.

The 5G network has the ability to meet all the advanced first responders' requirements, since it supports high throughput, low latency, high reliability and location accuracy. However, in case of an emergency there is one more parameter that should be taken into consideration: the network facilities may be damaged in the area where the disaster took place. Therefore, the existence of a portable network for emergency situations is critically important.

Such a network is not yet designed. However, for the needs of the FASTER project, a 5G network emulator was used in order to emulate a situation like this.

The network emulator that was used is the Open Air Interface (OAI). OAI includes several built-in tools such as monitoring and error tools, protocol analyser, simulation functions, performance profile and configurable login system. Additionally, its hardware is based on Ettus USRP cards and it can support both 4G and 5G network architecture [15-16]. The architecture based on OAI is presented in Fig.4.



**Fig. 4.** 5G testbed based on Open Air Interface platform.

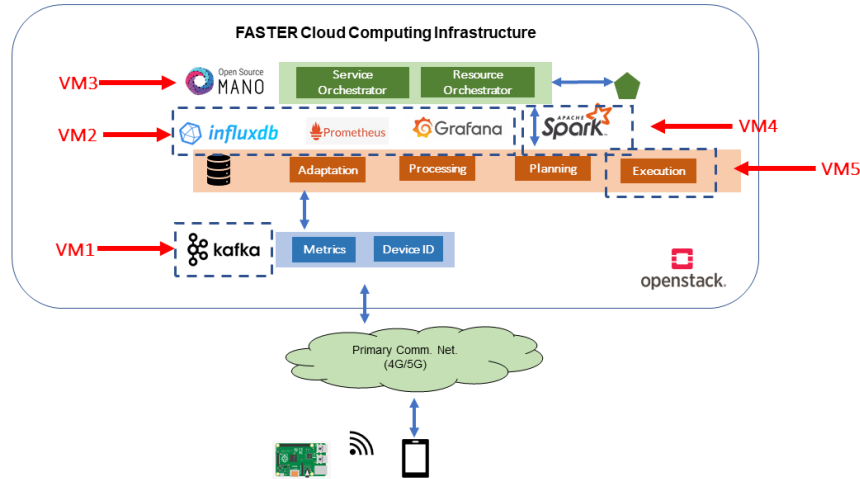
The advantages of the use of OAI are significant. Taking into consideration its technical characteristics, it can provide an Internet connection, since it is an actual network, and not a simulated one [17]. Additionally, it could offer flexibility in design and upgrade, since is based on software defined elements.

The main advantage of OAI is that it could be used in a rear case scenario where portability is needed. For example, in a case of a strong earthquake there are many cases where the local network elements could not operate appropriately. In that case network portability could be a very crucial feature. OAI could play the role of the portable network in the FASTER project trials and simulate this scenario even though it is not developed for this purpose.

### 3 FASTER QoS Monitoring Framework

The ability to deploy and monitor the performance of the network elements and services on cloud computing environments is one of the advanced features of 5G technologies that the FASTER platform will take advantage of. This feature will offer high flexibility and dynamicity to the operational characteristics of first responders.

In this respect, in the context of the FASTER project, services and tools for the monitoring of the cloud infrastructure and the services running on it, are designed and implemented, as it is presented in Fig.5.



**Fig. 5.** Services and tools running on FASTER cloud resources.

Creating an architecture that will be based on the innovative and emerging principles of cloud-native computing, 5G networking and Machine Learning (ML) is not straightforward, given the requirements posed by the First Responder (FR) operations in the field, as expressed in the FASTER use cases. The architecture shown



in Fig.5 specifies the QoS provisioning, through the monitoring of specific and relevant metrics, such as latency, bandwidth, computation efficiency, etc., collected not only from the infrastructure but also from the running services deployed in virtual machines (VMs) – as shown in Fig.5 – or containers. Special attention has been paid in order to include the monitoring of cross-layer interactions between network and application related metrics.

One of the main innovations of the FASTER architecture is the optimized management of the network service (NS) / virtual network functions (VNFs) lifecycle, especially under the prism of the interchangeable utilization of different environments (edge/fog/internet) that would be able to provide resilience on the communication infrastructure. In order to cope with such requirements, FASTER QoS Monitoring Framework system consists of two main components that collaborate to achieve optimization of the service quality and processing, namely, the Monitoring Analysis Planning Execution (MAPE) framework and the Management and Orchestration (MANO) platform. In this perspective, the framework will allow for the timely reaction of the service with respect to scaling and/or placement of the service (or functions), in order to optimize the performance of the service and thus satisfy the user requirements during runtime.

With respect to the MAPE components, their realization is based on VMs and docker containers running on them. This approach is quite suitable for the development of the FASTER ecosystem because it provides two advantages: first, the deployment of services on VMs leads to easy scalability that might be needed in future requirements; and, second, the containers are easy to manage and the containerized services provide fast instantiation times. The VMs are provided and managed by an OpenStack environment consisting of one controller node and two compute nodes. The MAPE component introduces five internal services with distinct corresponding roles and responsibilities. Specifically:

- The Message broker (kafka) where metrics from different types of sources (NFVI (network functions virtualisation infrastructure), VMs, containers, applications, etc.) are collected.
- The Adaptation service which correlates the collected metrics with the running instances of VNFs and CNFs (core network functions) by incorporating information from the OSM (Open Source MANO).
- The Analysis services which prepares and executes ML algorithms to forecast resource demand, future network conditions and service performance,
- The Planning and Execution service which is responsible to enforce the recommendations and configuration directives to the Service Orchestrator of the OSM (through its northbound interface).
- The Monitoring service which consisting of an InfluxDB database, Prometheus server and a Grafana server connected with Prometheus.

With respect to the Management and Orchestration platform, the overall assessment [18-19] showed that all MANOs have their own strengths and weaknesses. In particular, the ETSI supported architectural approaches, as presented by OSM and SONATA [20], make them the most prominent candidates under the considered criteria and given the resources and use cases of FASTER. Taking also into consideration the sustainability issue OSM has been selected as the most suitable

platform for the resource management and orchestration (MANO) in FASTER. The OSM instance runs on VM and it is connected with the same OpenStack environment but it uses different tenant with admin privileges. This set up can guarantee isolation between the FASTER services and the user NS which are initiated via the OSM.

## 4 Conclusion

In this paper, the 5G network solution proposed by the FASTER project was presented. The network is designed in a way to meet two main needs of first responders, that is: their safety and the offering of advanced means to optimize their services' ability.

The safety of the first responders can be ensured by using several wearables which will inform the control center and the other first responders about the situation of each first responder. Additionally, in order to optimize their services, the first responders will use advanced equipment such as smart phones, smart bracelets and other wearables. This equipment should be connected to the network, which must satisfy several requirements such as high throughput, low latency, high reliability and coverage.

These requirements could be satisfied by a 5G network. Therefore, the 5G network solution that is proposed for the needs of first responders was presented. This architecture is separated into 3 layers: the access and the core layer and the cloud. Additionally, the importance of network virtualization was presented as well as the solution that is adopted by the FASTER project. Finally, the use of OAI as a tool to support both network requirements and the ability of portability was explained and the architecture was presented.

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