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# Q4Health: Mission Critical Communications Over LTE and Future 5G Technologies

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## Abstract

Mission critical communications have been traditionally provided with proprietary communication systems (like Tetra), offering a limited set of capabilities, and mainly targeting voice services. Nevertheless, the current explosion of mobile communications and the need for increased performance and availability especially in mission critical scenarios, require a broad type of services to be available for these platforms. In this sense the LTE technology is very promising, as it provides mechanisms to enforce QoS, has standardized many useful functions in public safety scenarios (like group communications, positioning services, etc.), while it is being evolved to match future 5G requirements. The Q4Health project aims to prepare for market and optimize the BlueEye system, a video service platform for first responders. In our approach we use two FIRE+ platforms for demonstrations: OpenAirInterface and PerformNetworks. Q4Health is driving the optimization of the system with the execution of a set of experiments focusing on a different aspect of the network (core network, radio access and user equipment) and aims to cover current LTE standards, but also future 5G enhancements. The projects™ outcomes will be the optimization of the overall BlueEye system and the enrichment of the involved FIRE+ facilities with more services, functions and programmability.

**Keywords:** LTE, 5G, Mobile Communications, QoS, QoE.

## 23.1 Introduction

Q4Health project[1] [1] aims to improve two existing FIRE platforms PerformNetworks[2] [2] and OpenAirInterface[3] [3] in order to provide better innovation services to third parties. This is done by a use case provided by the company Redzinc Services Ltd. that provides BlueEye, a wearable real-time video application for first responders, and VELOX, a virtual path slice solution to enable QoS.

The project is based on a scenario in which first responders of a medical emergency (i.e. paramedics in an ambulance) have a wearable video equipment in the form of hands-free glasses with a dedicated LTE connection, and the objective is to guarantee the video transmission to a hospital where a doctor can monitor the condition of the patient in real time and suggest different treatments in its way to the emergency room. The main challenge is to achieve an interruption-free video broadcast while the ambulance pass through different LTE cells and available Wi-Fi hotspot, always within the accepted parameters defined for this type of traffic (under 150 ms for both audio and video transmissions) [4].

Through a series of experiments in several components of a mobile network infrastructure, all the components of the project will be improved. PerformNetworks will support 5G low latency prototypes and new environments to optimize heterogeneous handover, OpenAirInterface will be extended to test antenna performance and to provide an API for the eNodeB scheduler, BlueEye video service will be optimized to react better to channel and network conditions and VELOX will implement new drivers to expand its end to end QoS capabilities. The experiments will cover all the components and stacks of the network, from the physical layer in the eNodeB to a high level parameter optimization in the *Evolved Packet Core* (EPC). The optimization of all the platforms will improve the experimentation services offered by the two FIRE platforms and will accelerate the time-to-market of the BlueEye and VELOX systems. The experiments are designed to overcome the following challenges, that have been previously identified in field campaigns:

[1]http://www.q4health.eu/
[2]http://performnetworks.morse.uma.es/
[3]http://www.openairinterface.org/

- Trigger QoS enforcement procedures dynamically in the LTE network.
- Reduce the end to end latency of mission critical services.
- Improve the behavior of the eNodeB scheduling when attending real-time applications.
- Improve service coverage inside buildings by the introduction of heterogeneous handover and service adaptation.
- Support low latency group communications between adjacent peers.
- Optimize the service quality for the different components and services of an eHealth system (sensors with different criticallity, video, audio, etc.).

The experiments designed to overcome this challenges can be divided in two main groups, one focused on the radio access (described in Section 23.3) which include the base stations and the *user equipment* (UE), and another focused on the EPC (described in Section 23.4) in which new functionality is explored, such as recent 3GPP standards and also the evolution towards 5G.

## 23.2 Motivation

In most of the world the *Public Protection and Disaster Relief* (PPDR) services use proprietary technologies for its communication needs [5]. Although these technologies have visible advantages for this kind of services, namely the robustness of the communication and the constant availability, for some time now its users have been looking for alternatives that alleviate its shortcomings. One of the main problems of the systems used by first responders, like the *Terrestrial Trunked Radio* (TETRA) [6] used in Europe, is the cost of deploying and maintain a large network to provide coverage to only a few subscribers. This cost also prevents research and advancements in those systems because only large groups or companies can assume that monetary investment, and these groups are not willing to commit resources to upgrade services that have a very low number of customers. The end result of this lack of investment is that emergency communication services don't evolve with the rest of the technology. We can see an obvious example of the misalignment between the capacity of the systems available to emergency teams and those available to the general public looking at the situations of data transmission in mobile networks. While most of us have a theoretical capacity of transmit tens of megabits per second, the TETRA system mentioned earlier in its basic form has a limit of only 36 kbps.

For these reasons there is a push from both the network operators and the final users to upgrade these aging systems to new technologies like LTE [7, 8] which natively support many of the features required by mission-critical communications [9]. For the formers the main motivation is the cost reduction of providing premium services through already deployed networks, while the users can see a great benefit in the use of new technologies like image or video transmission to the operating centers in emergency situations, capability made unavailable in current systems simply due the lack of bandwidth.

With LTE as a basis of the future 5G mobile technology there is also a need to characterize and optimize data links in the search of low-latency and high priority communications [10]. This involves work in every level of the mobile network stack, from the analysis and optimization of the RF schedulers present in the radio station to the identification and dispatch of traffic from specific users or services in the core of the operator network. There is currently a trend that believes the performance of this classic division in layers and its corresponding architectural function (i.e. latency in the physical layers, throughput and network addressing in higher layers) can be greatly expanded by flattening the network structure with the introduction of *Software Defined Network* (SDN) functionality traversal to the architecture [11, 12].

With these additions new possibilities are suddenly available to optimize the communication paths for the traffic characteristics of the PPDR users. By introducing SDN technology in the access layers we can create new services like data broadcast for groups of users without adding new traffic in the backhaul network, or reducing E2E latency by spread geographically the functionality of some of the entities of the operator network converting them in new *Network Virtual Functions* (NVF) that can be executed in the node that needs such services.

## 23.3 Experiments Focused on the Radio Access

Different radio access equipment can be used in the project depending on the objective of the experiment. The equipment available consists of:

- Commercial equipment used to optimize the platform for the current deployments. This includes the commercial deployments, that can be used just for characterization purposes, and the proprietary indoor deployment available in PerformNetworks, that provides similar functionality but with the possibility of changing the configuration of all the elements.

- Conformance testing equipment. This type of devices is used by manufacturers on the design and verification process of LTE equipment. The conformance testing equipment can be configured to broadcast in any commercial frequency (which allows it to be used with devices of different countries). Furthermore it enables the fine configuration of many parameters on the LTE stack (even non commercially available configurations) and it also provides channel emulation, that can be used to test the UE under different channel conditions but maintaining the reproducibility (enabling exhaustive characterization of the terminals).
- *Software Defined Radio* (SDR) based equipment. This is the more flexible approach for research, as this equipment combined with available open source stacks can be used to test new concepts on the lower layers. This will be the approach for the experiments that required experimentation beyond market.

It is planned to evaluate different LTE dongles in order to have a comparison of their behavior under different channel conditions and their application level performance. This comparison will be mainly performed in the conformance testing equipment and could be used to select the most appropriate for the application. Besides the characterization of different LTE UEs there are additional experiments foreseen, focused in different parameters of the radio interface and covering the antenna and the MAC schedulers.

The modem of the BlueEye platform should be kept in a belt so the selection of an appropriate antenna is very important. The evaluation of the different antennas will be made by the execution of a series of experiments covering multiple topologies under different interfering conditions. Several metrics of the application layer will be considered such as transmission rate, error rate, etc. The setup to be used for these experiments is depicted in Figure 23.1.

OAI eNodeB will be used as base station as it can provide measurements on the power reported by the UE while being connected to the PerformNetworks EPC[4]. The evaluation scenarios include:

- Static UE (the UE is not moving). The UE will be located in different fixed locations from the eNodeB and the measures will be acquired with and without obstacles.
- Moving UE. The idea of this scenario is to test the antennas in mobility conditions. In the laboratory scenarios the mobility profile will be pedestrian but a vehicular one could be used when evaluating on external networks.

[4]Provided by Polaris Networks.

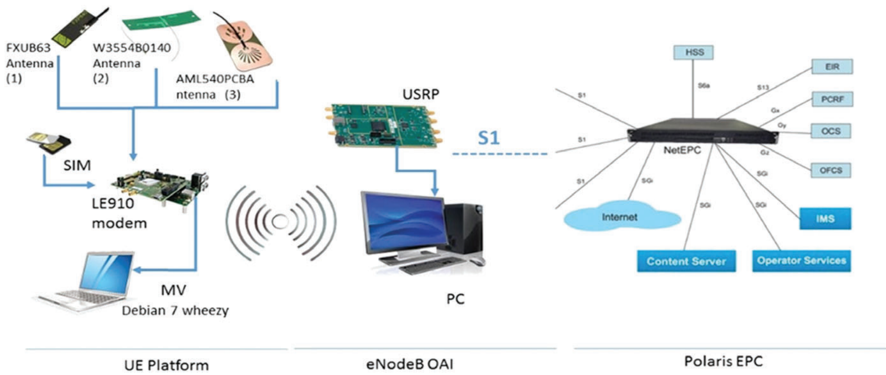


**Figure 23.1** Antenna experiments overview.

The behavior of the scheduler is very important as it has a big impact on the performance of the applications. This is especially relevant in mission critical real-time communications that are very sensitive to the latency and traffic shaping introduced by the scheduler. Current schedulers algorithms do not differentiate their behavior based on the traffic type (this information is not available in the MAC layer) but introducing these parameters into the decision process could achieve gains in the performance of the applications. To to add them the OAI eNodeB will be modified in order to support passing of information to the scheduler during execution time.

The main objective of the scheduler experiments is to analyze what are the optimal cell-specific and protocol configurations available for a base station as wells as a scheduling policy that is able to consider traffic characteristics to meet the application requirements. The technical approach considers the introduction of programmable *Radio Access Network* (RAN) technologies, using the SDN design paradigm, on the OAI eNodeB. The data plane will be decoupled from the control plane, with a remote controller communicating with a local agent residing in the base station. Execution time decisions will be made regarding MAC scheduling and Resource Blocks allocation to facilitate real time prioritization of video traffic for the first responder. Figure 23.2 depicts the scheduler experiment setup. A new API will be included in the OAI eNodeB that could be accessed by third party applications.

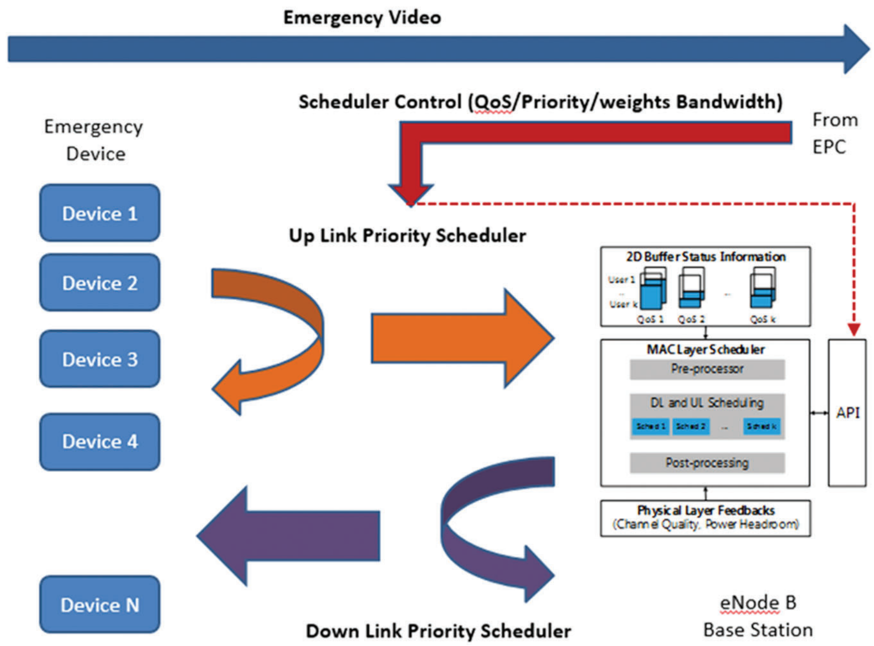


**Figure 23.2** Scheduler overview.

## 23.4 Experiments Focused on the EPC

The experiments based on the EPC contemplates the measurements of metrics on standard procedures of the core network but also the evolution of it to integrate SDN techniques, *Mobile Edge Computing* (MEC) and *Over-The-Top* (OTT) QoS requirements of third party applications. Figure 23.3 depicts the target testing architecture for the core network. The following domain division has been assumed:

- Operator Domain is the operator private network and it is normally not available to third parties.
- Operator Domain for Third Party Network Applications is still part of the operator domain but it provide access to third parties to some functionality such as the *Rx* interface or a SDN controller.
- Internet Domains, this will be outside the operator domain and it comprises many different domains.

The components of the EPC are the standard ones plus the addition of an instance of *Open vSwitch* (OVS) in the backhaul. This OVS can be used to

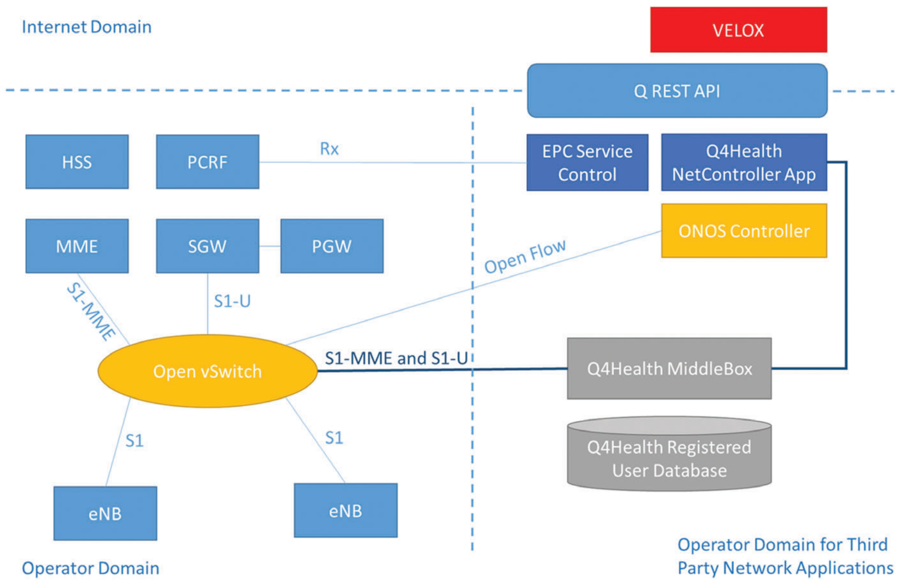


**Figure 23.3** EPC architecture overview.

forward the control and data plane of the eNodeBs towards a Middlebox. The rules to do so will be injected via a network application running on top of an ONOS SDN controller. The Q REST API provides access to different functionality such as group video communications, low latency services and OTT QoS demand from third party applications.

The first set of experiments in the core network will acquire statistics about the signaling procedures of the control plane. Several tools to extract the success rates as well as the mean times of common procedures have been implemented. The statistics extracted with these tools can be used to compare different modems but also to evaluate the effect of the changes introduced in the network. Some of the signaling KPIs to be produced are:

- EPS Attach Success Rate (EASR), that will be used to determine how Q4HEALTH can improve the connectivity in indoor deployments.
- Dedicated EPS Bearer Creation Success Rate (DEBCSR), the QoS demands from the video application will trigger bearer creation on the core network.
- Dedicated Bearer Set-up Time by MME (DBSTM), the setup time is also important as it will determine the time to establish the QoS enforcement in the link, which is important in heavy-traffic scenarios.

- Service Request Success Rate (SRSR), which determines the success rate when the UE goes from idle to connected (for instance after a paging procedure.)
- Mean Active Dedicated EPS Bearer Utilization (MADEBU) determines the resources allocated by the UE, and this could be used as based to determine costs based on potential prices.
- Inter-RAT Handover Success Rate (IRATHOSR), to characterize the performance of seamless handover.

The main line of exploration of the handover procedure will be stress testing by constantly triggering the procedure on the network as well as the seamless heterogeneous handover to Wi-Fi that will be provided by the ANDSF and ePDG [13] components in the EPC. It will be studied under different scenarios including:

- Commercially available networks. The results on live networks will be used as a baseline. In this scenarios the handover will be studied from an RRC perspective by analyzing traces at that level of the stack, obtained with drive testing tools.
- Release 12 Emulator which can be used to test the handover procedure under different channel conditions and network configurations.
- A Small Cells scenario which will be use to test the heterogeneous handover by integrating them with a release 12 EPC with support for non-3GPP access networks.

Another important aspect of these systems is the possibility of configuring quality of service for their systems. This functionality is implemented by the VELOX engine, which supports different drivers to enable it. VELOX will implement a driver for the scheduling request experiments previously described but also drivers to enforce QoS between the different domains (by the insertion of rules in the transport switches) and a driver to trigger QoS demands via the Rx interface in the core network. With these drivers the system will be capable of enforcing a determined QoS in all the elements of the network, improving considerably the overall performance and reliability of the system.

The introduction of the Middlebox depicted in Figure 23.3 has two purposes, on one hand it can be used to provide low latency communications between peers geographically close. On the other hand it can be used to implement group video communications easily. For both functionality the OVS instance in the backhaul will be configured to copy and forward all the control plane traffic to the Middlebox. The Middlebox will analyze this traffic in order to produce a database of all the UEs connected as well as information about the *tunnel endpoint identifier* (TEID) of their tunnels, the endpoints addresses (the addresses of the eNodeB and the SGW) and details on the QoS configuration. The data plane will be redirected to the Middlebox (it will not be sent to the EPC) that will decide if it is able to process the traffic locally or if it has to forward it to the EPC. In the case that the final destination of the traffic is a user or a service registered in the Middlebox, the Middlebox will remove the GTP transport headers and redirect it to the appropriate peer. In the rest of the cases the traffic will be forwarded as usual to the EPC. With this approach the latency could be reduced up to 78% [14] as it reduce the transit times of the backhaul, EPC and transport networks.

## 23.5 Conclusion

These set of experiments designed in the Q4Health project will improve the performance and increase the functionality of the BlueEye project. Furthermore the project will produce an integrated experiment combining all the developments of the project. The objective of this final experiment is to showcase the platform to potential users of the testbed and the BlueEye system.

The combined experimental platform provides a very realistic end-to-end network, with access to the configuration of almost all of the levels of the stack. The functionality covered by the platform is focused in improving the innovation capabilities of the platform's users, but also with an eye in the latest communication trends trying to incorporate tools that enables the latest industry state of the art and best practices.

The development of 5G prototypes both of EPC components and enhanced LTE radio access will boost the number of users the platforms can attract and will also result in scientific contributions. BlueEye will be optimized to support current and future mobile communications in different markets which will boost the business opportunities of the platform.

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