Q4HEALTH: Quality of Service and Prioritisation for Emergency Services in the LTE RAN Stack

César A. García-Pérez*, Álvaro Rios*, Pedro Merino*, Kostas Katsalis†, Navid Nikaein†,
Ricardo Figueiredo‡, Donal Morris‡ and Terry O'Callaghan‡
*Universidad de Málaga, Andalucia Tech, Lenguajes y Ciencias de la Computación, España
{cgarcia,alvarorios,pedro}@lcc.uma.es
†Eurecom, Sophia-Antipolis, France
{kostas.katsalis,navid.nikaein}@eurecom.fr
‡Redzinc Limited, Dublin, Ireland
{ricardo,dmorris,terry}@redzinc.net

***Abstract*—Communications for emergency services have been traditionally provided with dedicated radio technology (like TETRA), however mobile communications are gaining more popularity for these scenarios due to their availability, price and spectrum usage. This trend will be more accentuated in the following years with the appearance of 5G systems, that promises better figures in almost all the Key Performance Indicators (KPIs) of the system. LTE can provide many of the functionalities required by emergency services and is currently being evolved toward the 5G era by incorporating heterogeneous networking, over the top applications, network function virtualization and more. Q4Health project is focused on the preparation for market of a video application for first responders based on LTE by designing and executing several novel experiments in order to optimize the communications for this platform.**

I. Introduction

Mission critical communications are very demanding in terms of bandwidth, latency and availability. Some typical services in this scenario are voice or high priority data [1], which have been traditionally supported by proprietary and/or dedicated solutions like Tetra [2]. The use of specialized technologies lead to small market niches that has provoked the increase of the costs of installing and operating these networks. Mission critical scenarios are now demanding consumer communication technologies demanding more and better services. Video service is gaining importance, specially due to the improvement of commercial networks and the appearance of solutions to be used in blue light services (like ambulances, police, etc.), critical infrastructure surveillance, crisis management, etc. Furthermore there is a trend to support emergency services using standard mobile technologies[3][4]. In this trend LTE plays an important role as it has many built-in features to support such type of services and it is widely available and inexpensive compared to other technologies.

This paper is focused on the approach of the Q4Health project towards the optimization of real-time video for emergency services over LTE, using the BlueEye platform, a first responder video system, as the case study. The BlueEye platform is a wearable video system designed to assist first responders in public safety applications. In more detail, the project is implemented as a set of experiments conducted over two FIRE platforms, namely PerformNetworks[1][5] (formerly known as PerformLTE) and OpenAirInterface[2][6]. The motivation is to study video performance in scenarios with wearable live video for first responders, improving its response on LTE-A with a particular innovation focus on 3GPP release 12.

To achieve this goal six different experiments will be performed focused on optimizing a range of Key Performance Indicators (KPIs) as well as resolving the following challenges that have been already identified:

- Currently operators don't support Quality of Service (QoS) requests from external applications. Such QoS must be reached via commercial Service Level Agreements (SLAs) and can not be dynamically modified.
- Latency on the networks is still high. Even when the peers of the communication are camped on the same cell the traffic will go through and back the core network to end in the same eNB.
- Radio access schedulers are not aware of the critically of the traffic and fairly share mission critical streams with data from consumer applications.
- In building handover frequently produces many losses in the video signal, that can be even completely lost.
- Video is not the only application transmitted by eHealth systems that might also include a wide range of sensors with different traffic patterns and QoS demands. No support to smoothly tune this demands is currently provided.

The rest of this paper is organized as follows. In section II we describe the driver case study and the experimental platforms. A summary of the experiment is provided in section III. Section IV provides a detailed description of the experiments focused on the core network while section V. The validation process of the results is explained in section VI. Finally the work is summed up and some details about the future work are provided.

II. BlueEye and the Experimental Platforms

The BlueEye platform is a wearable video system designed to assist first responders in public safety applications [7]. The

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

system comprises mounted safety glasses with a high definition video sensor, a radio stage implemented on a wearable LTE belt, and a backend. The backend includes a video server, a measurement dashboard, and VELOX, a virtual path slice engine that manages bandwidth request. This system is suitable for health-care use cases where for example an ambulance paramedic attends a patient during the "golden hour" [8]. The use case normally includes the assistance to the patient on the place on the incident, as well as the transport to the hospital. Communications can be very challenging in such situations as they involve the mixing of critical real time video streamed over a connection with varying channel conditions, it may involve high user mobility (during the ambulance transport), but also it may involve multiple handovers to support seamless in-building and out-building communications.

To optimize the BlueEye system several experiments have been designed by combining two FIRE platforms (as depicted in figure 1), namely OpenAirInterface and PerformNetworks, in order to cover a broader spectrum of functionality that range from commercial to research solutions:

OpenAirInteface (OAI): is an open source implementation that covers all the components of a LTE network, from the radio access (OpenAir5G) to the core network (OpenAirCN). It provides an implementation of a subset of relase 10 for User Equipment (UE), evolved Node B (eNB), Home Subscriber Server (HSS), Mobility Management Entity (MME), Packet Gateway (PGW) and Serving Gateway (SGW). The software can be used in a standard Linux distribution using a general purpose processor in combination with a standard RF Software Defined Radio (SDR) equipment (like Ettus USRP, Nuand BladeRF or Eurecom ExpressMIMO2). The Medium Access Control (MAC) layer supports wideband multiuser QoS-aware scheduling and hybrid-ARQ. Furthermore there is a 3GPP Radio-Link Control layer (RLC) and a simple Radio Resource Control (RRC). A Non-Access-Stratum (NAS) driver provides IPv4/IPv6 interconnection with Linux networking services. OAI provides a full real-time open-source implementation of PHY and MAC layers, so it can be used as a playground where to experiment with new real time schedulers and priority-based policies required in the context of the Q4Health project. More information on OAI by means of functionalities and technologies can be found in [6].

PerformNetworks: is a FIRE+ experimental platform designed to offer realistic experimentation by providing a combination of LTE commercial off-the-shelf equipment, emulators and research implementations. The platform has already supported several experiments that range from performance evaluation, to interoperability and live pilots. The PerformNetworks testbed provides the following components:

- LTE conformance testing equipment that can provide end to end connectivity to standard UEs with channel emulation capabilities.
- Several Commercial Off-The-Shelf (COTS) LTE base stations and UEs to enable experimentation with equipment close to market.
- Release 12 Core Network emulator with carrier grade performance supporting negative testing behaviours, traffic impairments and multiple instances of each network element.
- SDR equipment that can be used to execute customized UE and eNB stacks (using open source implementations like OAI or srsUE[3]).
- Different additional instrumentation like power analysers, RF switches and attenuators, drive testing tools, etc.

The set of experiments described in the following sections aims to cover different configuration of the radio access, core network and UE in order to improve an emergency communication service.

III. Summary of experiments

Q4Health consortium has identified six experiments as the relevant way to carried out the objectives in the project. In summary, these experiments can be grouped in the following way:

- Experiments focused on the evolved packet core (EPC) network that will be used to provide VELOX Software Defined Networks (SDN) subsystem with interfaces to standard EPCs that could provide SLAs with operators.
- Experiments on the radio access, carried out in several stages. Three different radio access platforms will be used depending on the purpose of the measurement campaign:
  - COTS LTE base stations, focused on the adaptation of the service to current commercial solutions.
  - LTE Conformance testing equipment, that will be used to prepare the system for short term market improvements in LTE technology like new transmission modes and to validate the setup with controlled channel conditions in different bands to adapt the system to international markets.
  - OAI, an open source implementation that can be used both as UE and eNB, that will be used to provide new improvements in the network or behaviours out of the standards that might be beneficial for the performance of the system and the adaptation toward 5G technologies.
- Experiments on the UE, based on commercial devices, that will be focused mainly on the selection of the more appropriate antennas but also based on OAI to explore modifications to the UE behaviour.

All the experiments start with the establishment of a baseline for the KPIs identified for each of them. This baseline will be used as a reference in the final evaluation to measure the impact of the project on the different components of the system. In the following subsections we provide a description per category and per experiment.

IV. Experiments Based on the Core Network

The experiments on the core network will be based on the Polaris Core Network available at PerformNetworks when

[3]https://github.com/srsLTE/srsUE

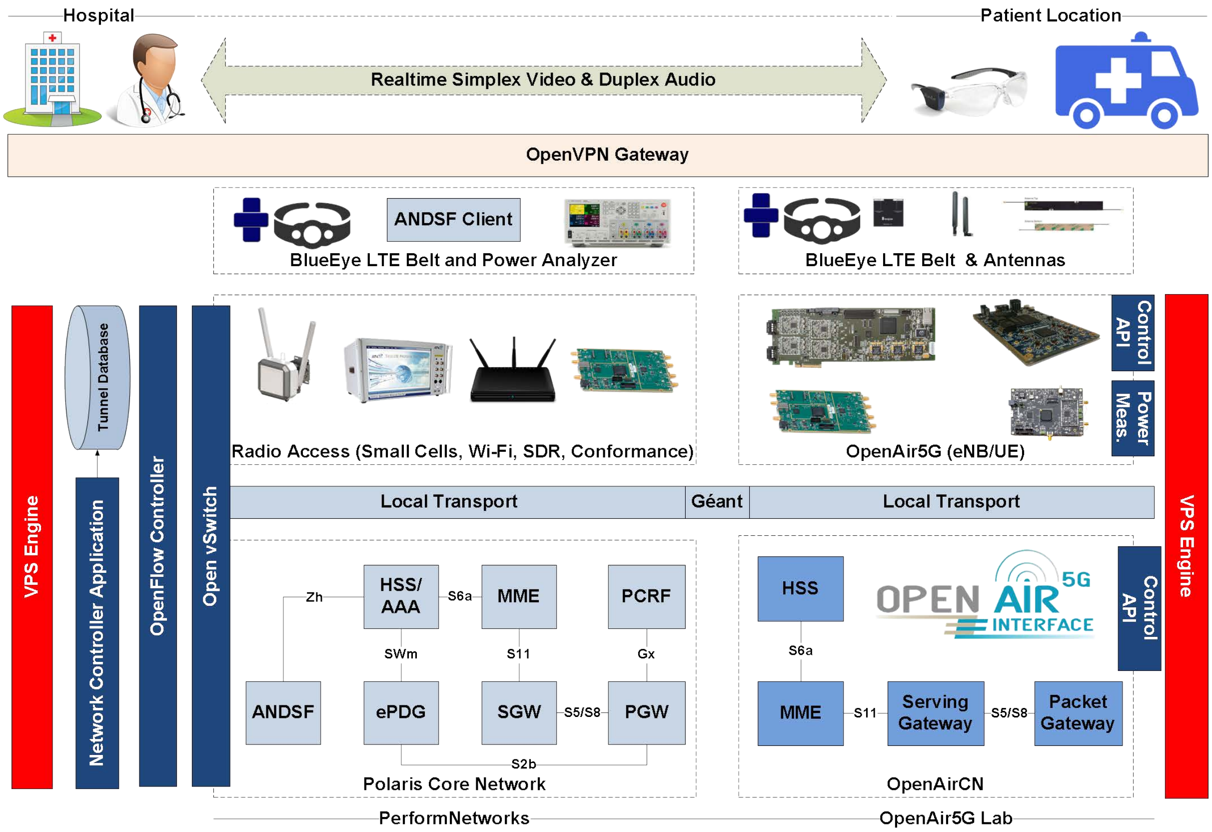

Fig. 1. Q4Health Architecture

standard interfaces are required and on OpenAirCN when research implementations requiring the modification of the components of the EPC are needed.

A. Experiment A: Over the Top Services

The main focus of this experiment is to enable the first responder application to demand QoS resources to the network. The standard LTE architecture provides mechanisms to support such demands via the Rx interface in the PCRF (Policy Charging Rules Function). This interface was designed to be used within the IP Multimedia Subsystem (IMS) but later was also extended to be accessed by external applications [9], an important feature considering the wide range of applications requirements expected in future 5G technologies[10].

This experiment is an extension of the SAFE experiment carried out in the Fed4fire[4] project. SAFE was executed on PerformNetworks and shows the feasibility of integrating external applications within the core network by means of the Rx Diameter interface. The objective now is to explore this integration more deeply, by finely characterizing the QoE and some indicators from the business side. The QoE measurements were originally done with a group of users, Q4Health projects aims to have automatic QoE estimation based on objective measurements.

[4]http://fed4fire.eu/

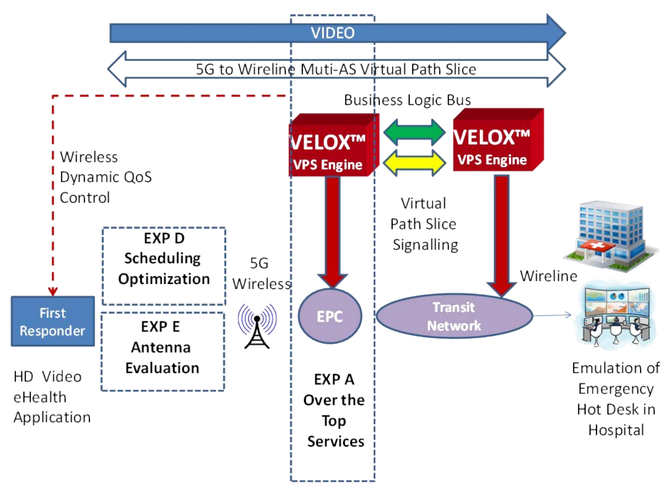

Fig. 2. Architecture for Experiments A, D and E

B. Experiment B: Heterogeneous handover

Due the huge amount of traffic increasing expected during the following years operators are now deploying and exploring solutions to offload to unlicensed spectrum. In order to provide this offloading to other non 3GPPP radio access technologies the the ePDG (evolved Packet Data Gateway) and the ANDSF (Access Network Discovery and Selection Function) components were introduced in the LTE standards [11]. Another of

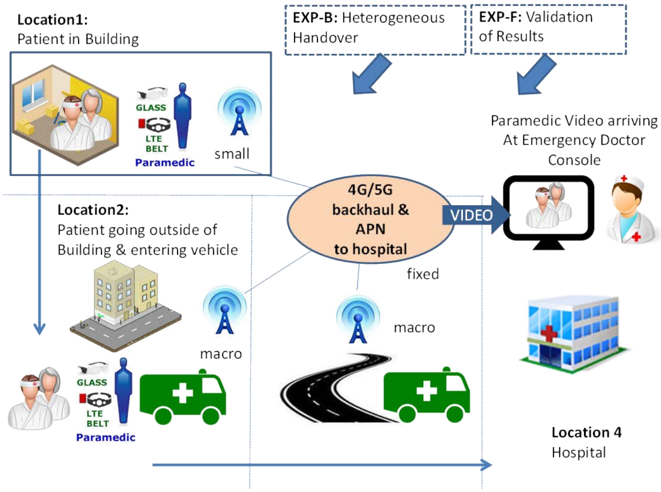

Fig. 3. Architecture for Experiments B and F

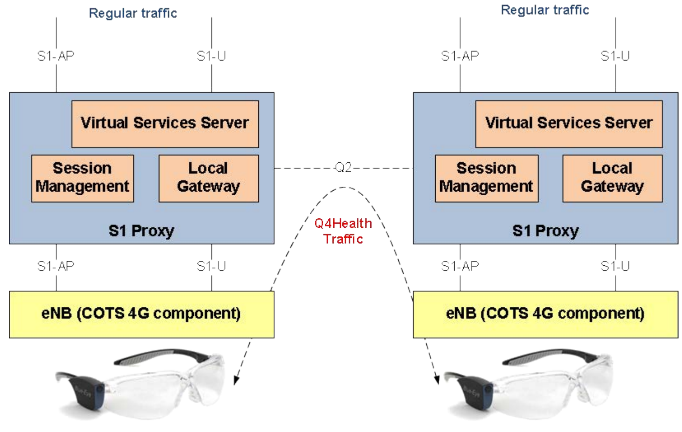

Fig. 4. Experiment C: S1-Proxy First Iteration

the techniques to increase the capacity of the network is the densification of the radio access by introducing small cells that will coexist with macro ones to improve considerably coverage and capacity.

Experiment B will prepare the BlueEye platform for these upcoming technologies. The focus of the experiment will be on handovers which are more frequent on ultra-dense networks and have an impact on the performance of services [12]. Q4Health will use a combination of small cells and a pico cell with programmable RF switches and attenuators providing an interface capable of selecting two base stations as well as their radiated power. This setup will be used to trigger handovers and measure their impact on the overall performance of the equipment.

The second part of the experiment is focused on Wi-Fi offloading. To perform the experiments the BlueEye platform will have to integrate an ANDSF client. This scenario will be used to explore when can should the offloading be triggered and how this offloading affects to the dedicated bearers established by demands on the Rx Interface. The experiments based on the Wi-Fi offloading will also be analysed in terms of successful handover rate, service quality when offloading, system interruption time, comparison to non offloading scenarios and more. The objective is to determine is this type of technology can be adapted to make it successful in emergency communications environments.

C. Experiment C: Latency reduction

Experiment C explores different techniques to reduce the latency in the communication between peers in the same eNodeB. This could be useful in emergency situations where a control centre is deployed to receive data from the emergency staff. In the current architecture communication between entities in the same cell will have to go through and back the core network introducing an unnecessary delay.

S1Proxy will be the first iteration of a solution to reduce latency. It is ”intrusive”, this is it is an intermediate component to be introduced in the standard architecture between the eNB and MME and SGW. Operators are normally sceptical about introducing this type of solutions on their networks so a second iteration will be based exploiting the SDN switching that is being introduced in the transport networks.

Figure 4 depicts the high level overview of S1Proxy. The system tracks users and their traffic in the S1 interfaces. When Q4Health traffic is detected (this will be done based on a local subscriber database) it will be treated by the local gateway and a virtual services server (a server that can be used to deploy fog computing systems). The rest of the traffic is forwarded normally to the actual MME or SGW. The Q2 interface can be logical, in which case it could also be used to reduce signalling towards the EPC by grouping the heartbeats of different cells) or an actual communication interface (depeding on the operator deployment).

The next iteration of the component is based on the Open vSwitch and the VPS Engine as depicted in figure 1. The controller will install rules to capture the S1-MME interface in order to generate the local user database and the rules to capture the GTP traffic. The behaviour when GTP packets are identified as Q4Health traffic is the same than in the intrusive version, they will be forwarded to the SGW or injected in the tunnel of other/s Q4Health user/s.

In these experiments the focus will be on analysing the latency as well as the performance of the solution to see if the regular traffic is impacted due to the introduction of the proxy or the SDN network controller. Also the functional level will be explored in order to evaluate some of others possible uses of this system like signalling reduction, traffic analysis and group sharing.

V. Experiments Based on the Radio Access

Two experiments were selected that are related with the Radio Access Network (RAN) itself. These are the scheduling optimization and the antenna evaluation.

A. Experiment D: Scheduling Optimisation

This experiment is designed to characterize and optimize the resource allocation performed at eNodeB to accommodate the user-specific traffic characteristics with particular attention in high bandwidth real time video. In LTE, the radio resources are hierarchically divided in Frames, Subframes and Resource Blocks, and the eNodeB usually assigns them according to a predefined policy (e.g. Round Robin) to all users despite the intrinsic user-specific application traffic. While such scheduling algorithm is enough to serve the bursts of data that models voice communications and low-quality video, it is insufficient for real time video with the required reliability.

The main objective of this experiment is to analyze what are the optimal cell-specific, protocol configurations available for a base station as well as the scheduling policy that is able to consider traffic characteristics to meet the application requirements. In the context of the project a programmable scheduler framework (PSF) following the SDN principles will be explored. Removing the control logic from the lower layers and integrating to a higher level controller will promote agility and facilitate RAN programmability, with new open APIs that will be build in the context of the project. With the goal of providing real-time priorities in the Uplink video traffic, we will utilize these new APIs for the necessary modifications of core data-plane operations or for other purposes like statistics gathering.

B. Experiment E: UE Antenna Evaluation

In this experiment the impact of antenna design and the relevant configurations on system performance will be investigated. Paramedics are used to wear equipment on their belt (scissors, tape, knife, tetra, bandages etc) and the belt is the chosen location for the 4G LTE unit. Using extensive comparison tests we seek to obtain the optimal performance, by selecting the most appropriate antenna. We note that the current design uses High Efficiency, Low Mass Wideband LTE Dipole Antenna. A number of parameters like the *size* and *weight* will be examined and various key performance indicators like sensitivity, transmitting power etc, will be investigated.

VI. Experiment F: Validation of the Results

The validation of the results will be done by integrating all the optimization of the system and the networks in a single experiment. The objective of experiment F will be the validation of the end to end functionality but also the generation of the KPIs of each experiment to be compared with the baseline established at the beginning of the project. The identified Q4Health KPIs covers:

- The high level validation of the system functionality and the application level, mainly the evaluation of end to end QoS as well as the audio and video QoE.
- The radio access, for instance the RAN jitter, RAN latency, RAN throughput, etc. but also antenna parameters like weight, size, sensitive, etc.
- The EPC, mainly the procedure success rates, the setup times, the statistics regarding dedicated resources, etc.

VII. Conclusion

This work aims to prepare emergency communications platforms for LTE-A and future technologies by execution of several experiments, driven by a used case, in two different experimental platforms. The focus of the experiments is the preparation for short term market, but also the analysis of possible solutions to be implanted in future 5G mobile communication systems. Q4Health methodology covers the full network, including the stacks and the physical components of the communication.

Acknowledgment

The work described in this paper has received funding from the European Horizon 2020 Programme under grant agreement 688624 (Q4Health project).

References

[1] C.-L. Taylor, D. Nolan, and S. Wainberg, "Priority capabilities in lte supporting national security and emergency preparedness next generation network priority services," in *Technologies for Homeland Security (HST), 2013 IEEE International Conference on*, Nov 2013, pp. 584–588.

[2] T. Doumi, M. Dolan, S. Tatesh, A. Casati, G. Tsirtsis, K. Anchan, and D. Flore, "LTE for public safety networks," *Communications Magazine, IEEE*, vol. 51, no. 2, pp. 106–112, February 2013.

[3] R. Ferrus and O. Sallent, "Extending the lte/lte-a business case: Mission- and business-critical mobile broadband communications," *Vehicular Technology Magazine, IEEE*, vol. 9, no. 3, pp. 47–55, Sept 2014.

[4] A. Kumbhar and I. Guvenc, "A comparative study of land mobile radio and lte-based public safety communications," in *SoutheastCon 2015*, April 2015, pp. 1–8.

[5] A. Díaz Zayas, C. García Pérez, and P. Merino Gomez, "PerformLTE: A testbed for LTE testing in the future internet," in *Wired/Wireless Internet Communications: 13th International Conference, WWIC 2015, Malaga, Spain, May 25-27, 2015, Revised Selected Papers*, vol. 9071. Springer, 2015, p. 46.

[6] F. Kaltenberger, R. Knopp, N. Nikaein, D. Nussbaum, L. Gauthier, and C. Bonnet, "OpenAirInterface: Open-source software radio solutions for 5G," in *EUCNC 2015, European Conference on Networks and Communications, 29 June-02 July 2015, Paris, France*, Paris, FRANCE, 06 2015. [Online]. Available: http://www.eurecom.fr/publication/4634

[7] V. Weerakkody, R. El-Haddadeh, I. P. Chochliouros, and D. Morris, "Utilizing a high definition live video platform to facilitate public service delivery," in *AIAI 2012 International Workshops*, L. Iliadis, I. Maglogiannis, H. Papadopoulos, K. Karatzas, and S. Sioutas, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 290–299. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-33412-2_30

[8] B. Metelmann, C. Metelmann, K. Meissner, M. Wendt, J. Goncalves, P. Gilligan, A. Amadi-Obi, D. Morris, E. Patouni, and M. Heyden, "The potential of telemedicine," in *AIAI 2014 Workshops*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, pp. 30–37. [Online]. Available: http://dx.doi.org/10.1007/978-3-662-44722-2_4

[9] 3GPP; Technical Specification Group Core Network and Terminals, "Study on eXtensible Markup Language(XML) based access if the Application Function(AF) to the Policy and Charging Rules Function(PCRF)," 3rd Generation Partnership Project (3GPP), TR 23.817, Jun. 2014.

[10] N. Alliance, "NGMN 5G White Paper," Next Generation Mobile Networks, Tech. Rep., Feb. 2015.

[11] 3GPP; Technical Specification Group Services and System Aspects, "Architecture enhancements for non-3GPP accesses," 3rd Generation Partnership Project (3GPP), TS 23.402, Dec. 2015.

[12] F. Rivas Tocado, A. Diaz Zayas, and P. Merino Gomez, "Characterizing traffic performance in cellular networks," *Internet Computing, IEEE*, vol. 18, no. 1, pp. 12–19, Jan 2014.