5G Video Optimization Challenges For Entertainment and Remote Driving In Connected Mobility

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***Abstract*—New video use cases, which have never been studied in the past in mobile networks, arise when dealing with high bandwidth and low latency video as 5G is being deployed. Careful planning, measures collection and KPI identification techniques are proposed to ensure viability in the real world.**

Keywords—5G; Video; Latency; MEC; KPI;CCAM;MEC

I. INTRODUCTION

A significant growth of mobile internet Video based traffic has taken place in the recent years. Reason being for such increment are the increasing bandwidth available in 4G deployed infrastructures, as well as the drop in the price per consumed gigabyte in most of the operators.

With the imminent deployment of new networks with 5G capabilities, new uses of video-based services in mobile networks appear, mainly due to a mixture of factors, among which we can highlight: the use of new radio frequencies of a very wide range, a drastic increase in the bandwidth available for wireless communications, a drop in the price of electronic devices for capturing and viewing video, and new needs for automation in driving and in the industrial environment.

It is worthwhile at least to analyze very briefly **two very critical factors in the deployment of video services** in mobile networks:

- In 5G, new bands have been standardized for the use of mobile communications, greatly expanding the available bandwidth. New bands are covering a wide range, from the frequency range of 700 MHz (these bands have a large coverage of the order of 10 km of radius, although they have a few baseband MHz available), 3.5 GHz bands (coverage of the order of 2 km of radius, although with more baseband MHz), going through the 5GHz bands and reaching the millimeter bands of 26-28 GHz (coverage of about 100-200 meters radius, but with baseband bandwidths very large). Each of the bands provides capabilities and limitations that make it valuable for a different type of video services.

- Hybrid scenarios of 4G and 5G. In the first 5G infrastructure deployments we will find hybrid scenarios in which although the user traffic bandwidth is transmitted in the new 5G radio, the authentication, control and management traffic of the mobile network is done using 4G radio. These scenarios therefore require 4G radio coverage to establish the connection of the new 5G mobiles, and 5G coverage to use the new 5G radio capabilities. In many cases, 4G radio coverage must be reinforced before starting 5G tests to ensure coverage of new services.

Other factors in which we will have to continue working in this first phase of 5G deployment are the following:

- The KPIs (Key Performance Indicators) of the 5G networks are being defined in different groups, and it is necessary to advance in their real implementation in the monitoring systems when the new video services so require. The standards are the following:

  - 3GPP TS 22.261 V16.4.0 (2018-06) 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Service requirements for the 5G system; Stage 1 (Release 16)
  - ITU-T M.2410-0 (11/2017) Minimum requirements related to technical performance for IMT-2020 radio interface(s)
  - NGNM ALLIANCE (01/2018) Definition of the testing framework for the NGMN 5G Pre-commercial networks trials. Version 1.0

- The region or continent strategy with respect to the promotion of 5G deployment in a geographical area influences the degree of development of other countries, which may be benefited or harmed not only by their own environment, but also by the rest of the countries. The new capabilities of 5G networks generate very novel services that do not have a priori solid business models for their initial deployments, so their promotion often depends too much on very strategic decisions that sometimes require alignment at many levels of geopolitical environment, business and economic.

- The tangible benefits for the users must be developed progressively as the new 5G modems are imposed on the market. These benefits will be in the personal leisure environment as well as in the business environment, but in both cases, they are pending validation and implementation, always complying with the highest security requirements.

In this article we will analyze the most critical Key Performance Indicators that must be validated on the field by any vertical industry in two use cases, the first will be "Remote Driving Use Case" and the second "Massive High-Resolution Video in Mobile Networks for vehicles". These Use Cases are being tested in the framework of the H2020 ICT-18-2018 5G-MOBIX research project in a road corridor between Vigo in Spain and Porto in Portugal.

II. ENTERTAINMENT AND REMOTE DRIVING USE CASES NETWORK AND VIDEO REQUIREMENTS

With the forthcoming 5G mobile EMBB and URLLC scenarios deployments, we are in the position of offering video services such as 4K Live TV in cars, very low latency video applications aimed to remotely control vehicles or even real time surveillance installations.

Even though it may seem affordable to offer such kind of services from a theoretical perspective, there a lot of factors involved in the scenarios. Offering a guaranteed minimum bitrate for video streaming can only be achieved by carefully measuring and planning the 5G radio deployment taking into consideration several factors. It turns out that there is a critical component in 5G deployment that we need to add to the equation. This is the MEC (Multiaccess Edge Computing) [1] [2] which results in 2 outstanding improvements.

a) As the MEC is deployed quite near the end users the path is reduced and so the different latency values to be cumulated.

b) As the high bit rate video traffic is not traveling through the core 5G network it scales out and can be offered to thousands of users without collapsing the fixed core network.

A. *Remote Driving Use Case*

Figure 1 Remote Driving Using Real Time Video

We will analyze the use case in which one user connected using 5G mobile network wearing HMD and watching real time VR360 video from the car can control this car. For this scenario we need to analyze the following factors:

In this use case the end-to-end latency of the reality to remote display latency plus the latency of the execution of the remote-control command is critical, so this total latency must be minimized and guaranteed to drive in a secure environment. We will study an initial approach to provide a secure framework for the remote driving experimentation.

5G requirements shows that 1ms latency in the radio layer can be achieved and enjoyed in URLLC use cases, but other 5G radio latencies are acceptable also depending on the level or remote car accuracy and speed that is targeted.

TABLE I. REMOTE DRIVING VARIABLES

Required Variables, descriptions and units		
Description	***Variable name***	***Units***
Speed at which the car moves	Sc	m/s
Time to capture 1 Video frame	Tc	ms
Tine to encode 1 Video frame	Te	ms
E2E Latency Round Trip (*)	Lr	ms
Transmission bit rate (**)	Bt	Mbps
Encoded Video Bit Rate	Be	Mbps
Encoded Video Frames Per Second	Fps	1/s
Tine to decode 1 video frame	Td	ms
Time to render 1 video frame	Tr	ms
Human reaction time (***)	Th	ms
Car commamd exec delay (local)	Txl	ms
Car commamd exec delay (remote)	Txr	ms

A formula for computing the total delay since the video frame is captured in the car side until a command is executed as a reaction from the remote human being controlling the car with the HMD is:

$$Latency = Tc + Te + Lr + \left(\frac{Be}{Bt}\right)\frac{1}{Fps}1000 + Td + Tr + Th + Txl + Txr \quad (1)$$

(*) This can be measured using ping or qperf tools

(**) This can be measured using iperf tool

(***) Please see [3] for minimum value of 13 milliseconds.

The video encoding and decoding performance will also be critical to decrease the total latency, for example if we encode the video with a configuration of 1920x1080 video 50 fps, we cannot use H264 or H265 typical compression schemas using I, B and P frames. This configuration with B frames introduces a big video buffer increasing the picture presentation latency.

Instead we must use either M-JPEG compression which will allow decoding every frame separately without dependencies from other frames. Then we will have at least 1 frame latency (hardware-based encoding) plus the 1 frame duration.

Let’s evaluate the scenario with

Sc=5Km/h; Tc=1ms; Te=20ms; Lr=20ms; Bt=50Mbps; Txr=5ms

Be=75Mbps; Fps=50; Td=1ms; Tr=1ms; Th=13ms; Txl=5ms;

Replacing the values in the formula (1)

Latency=1+20+20+((75/50)/50) *1000) +1+1+13+5+5= 96ms

To calculate which distance the car moves in 96 ms at 5 Km/h D = V * t = 0.096 * 1.38888 = 0,1190 m => 13.3 cm

Next phase is to analyze the impact of the network in the use case. We get poor performance and we get 4mbps instead and 50 ms round trip latency instead of 20.

For this case the E2E Latency is: 471ms => 65 cm at 5Km/h. Probably not acceptable. We will refer to this distance as deviation from now on.

We need to take measures around the areas in which the vehicle will probably move, we can establish whether it is possible or not remote driving the car.

This formula depends on the Encoding resolution selected, the level of the video quality compression and the hardware capabilities in terms of decoding and encoding. This means that if we increase the resolution and decrease the frame rate we might require network KPIs which are not achievable even in 5G networks.

So, as a conclusion, there are different maximum speeds based on the end to end latency for a given deviations.

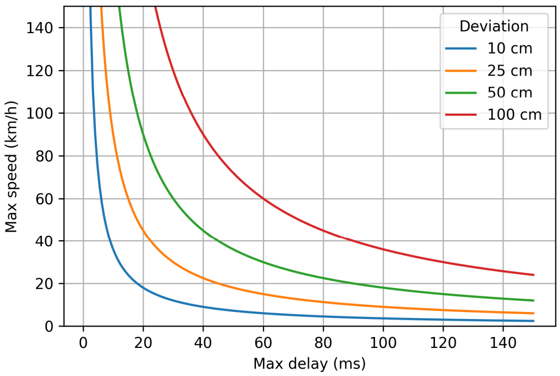


Figure 2 Acceptable Maximum Speed vs Latency

Depending of the use case for remote driving requirements of speed and video quality, we can provide different solutions for slow remote control that can be used in most of the cases, or more advanced solutions with more video quality and network performance. In any case the 5G network reliability and the full autonomous car capabilities will be critical for final scenarios.

B. *Massive High-Resolution Video in Mobile Networks for vehicles*

There are several methods for providing users with OTT and Live Streaming video in IP networks. Though the same techniques and methods can be used for delivering video in the mobile network, current LTE network infrastructure, capabilities and topologies will not actually support a massive amount of client devices accessing simultaneously to the video streams without a different strategy and a careful planning and measurement planning process.

Highly efficiency encoding compression schemas are required to be selected for being able to deliver new ultra-high-resolution video 4K format. In order to do so we will propose and describe the encoding requirements in the scope of HEVC (H.265) format.

In terms of transport format for these streams we will use HLS Adaptive Streaming format as a reference. Using this format allows simultaneous qualities of the same stream with different bit rates which can be selected by the end user device based on the instant bandwidth available from the video player perspective.

In order to limit the study in this paper we will focus on trying to offer the highest quality and resolution available (4K) and check which are the related KPIs and network topology requirements.

Live broadcast scenario will also need to have not very high delay from traditional DVB broadcast. Using HLS segmenting for adapting streaming implies a typical delay of around 6-10 seconds to DVB TV. This is something that is a fact in fixed network as the video is segmented in 2 to 6 seconds duration segments and it is not available until these segments are stored either in memory or disk.

So far it has been confirmed (VQEG, VMAF) [4] that moderately high bit rates are suitable for 4K video and full HD resolutions respectively.

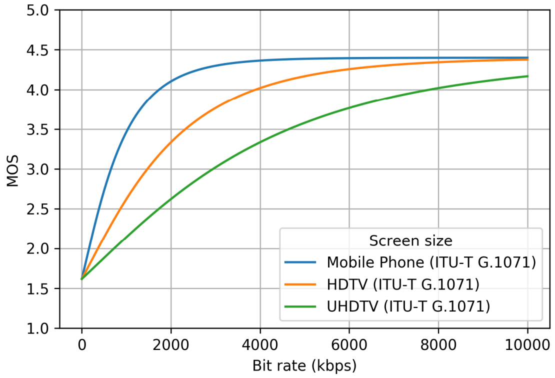


Figure 3 Video MOS vs Encoding Bit Rate

Figure 3 illustrates the relationship between the video bit rate and its perceived subjective quality (MOS: Mean Opinion Score). in three different displays: a mobile phone, a full HD television screen and a 4K display. The associated standardized curves, as defined in Recommendation ITU-T G.1071 for the equivalent screen resolutions are 1280x720, 1920x1080 and 3840x2160 respectively. In either case, the conclusions are the same: there is strong dependency on the available bit rate and the subjectively perceived quality, and this relationship is also heavily influenced by the size of the screen where the user is consuming the video

If we have a theoretical 40 Mbps of capacity [5] [6] there might be no issue when having any HEVC stream for instance as reference in terms of radio efficiency.

As we can see there are lot of factors which may result in different outcome for this EMMB scenario.

We need to develop a measurement system that

- Collects data from the network (CellID, RSSI, GPS)
- Recaps info for video from End User Perspective
- Gets measures for video from streaming server perspective (in MEC)

III. DEVELOPMENT FOR ONBOARDED APPLICATION

We need to distinguish two parts of the development required for this section: the onboarded virtualize appliance(s) inside MEC, and the critical systems that will be operated in the car.

A. *MEC related onboarded software*

It is highly recommended that this appliance is packaged, onboarded and deployed using TOSCA ETSI MEC standard [7]. This will cover both frequent scenarios consisting on either deploying a Virtual Machine or some “docker” type services. Part of this deployment will be a video server capable of HLS adaptive streaming with HEVC both for VOD and live flavors.

MEC will also help to reduce latency when remote control commands are sent from the control platform towards the vehicle, and the upload of vehicle information packages as well. This includes information to be displayed in the control platform for the analysis of the maneuvers and decision making for the remote human driver (speed, steering wheel angle, brake pressure, etc.…).

B. *Car related onboarded systems*

Let’s start with the video part. One 360 VR camera is required for the remote driving scenario. The camera needs to communicate with the mobile network either via a 5G modem which will provide it with internet access. To reduce the latency, direct cable connection between the camera and the modem will be desirable. As explained in previous sections, real time M-JPEG encoding is recommended, then some piece in between needs to make the encoding stream available to the end user which is remotely connected to the car.

For the second use case a 4K Player needs to be installed in the vehicle, this player should implement a big video buffer in

order to support small periods of low radio coverage, this player must be resilient to video mobility scenarios.

The second important element is the communication control unit that receives remote driving commands into the vehicle. This communication unit must translate remote commands into vehicle moving commands according to the defined safety standards and vehicle protocols (most commonly used are Automotive Ethernet, CAN, Flex Ray, etc.).

Another critical element for this unit has to guarantee the cybersecurity mechanisms without compromising latency. This means that only the allowed authority will be able to remotely control the vehicle, and the certification mechanism has to be robust and fast enough to guarantee this without requiring a check time that imply delay between the sent command and the car actuation command.

Finally, for safety reasons any remote command will be matched with a safety maneuver protocol, which is made by the vehicle actuators to avoid dynamic prohibited maneuvers. For example, if the car is driving at 120 Km/h, a remote command of steering the steering wheel 90 degrees to any direction will be discarded as it may produce an undesired situation or accident.

IV. NETWORK PLUS VIDEO CHARACTERIZATION AND KPI STRATEGY

A. *Strategy For Data Collection*

The strategy for data collection will be based into 3 principles:

- Capture the data which is closer to the end user device and use case description
- Capture as much data as possible in terms of space and time. This means capturing and covering the geographical area with acceptable resolution and collecting as many samples as possible.
- The capture process should be agile, using applications that can be installed on generic android devices and using simple formats (CSV or JSON)
- The reliability of the network, the end to end latency and the maximum available user throughput are the most relevant 5G KPIs required in the corridor.

To measure these KPIs, some specific applications have been developed in Android and Linux which are able to capture network data and post it almost in real time to a remote server using a REST API.

There is a server in which the data is received and stored. This server has been developed using nodeJS due to its portability and simplicity. The data is initially stored in CSV format. After that, several post processing is performed:

- Inserted into Logstash via custom pipeline in Kibana
- Converted into KML format for Google Earth rendering.
- Pushed csv into Google Maps for Geo view of the data

Same NodeJS can act also as a gateway for offering a GET REST JSON API in which other applications using for instance ReactJS or whatever other Javascript framework can be graphically rendered

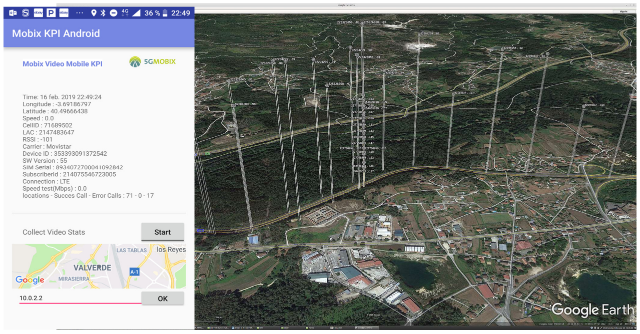
B. *Strategy For Data Collection and Field Testing*

The way for capturing the data is as follows

0.Start up nodeJS server in the remote side.
1.Install iperf/qperf tools server in the server side
2.Install the android application in the device
3.Start it up and configure nodeJS URL.
4.Start moving around with the vehicle
5.Optionally video segment speed test can be issued.
6.Execute ping/qperf/iperf tests (1 to 10 parallel sockets).
7.Execute ping/qperf tests against the server.
8.nodeJS calculates distance to the serving base station.
9.Mix data including base station frequency band.

Several measures have been collected near in Spain in Galicia near the Portuguese border in 4.9G. This is an ongoing activity of 5g-MOBIX H2020 project.

After 2 days measuring in the corridor in a significant number of Km, we manage to capture data in which we can see which are the cell Id which a mobile device goes through as well as most of the KPIs data sources.



Time: 16 feb. 2019 22:49:24
Longitude : -3.69186797
Latitude : 40.49666438
Speed : 0.0
CellID : 71689502
LAC : 2147483647
RSSI : -101
Carrier : Movistar
Device ID : 353393091372542
SW Version : 55
SIM Serial : 8934072700041092842
SubscriberId : 214075546723005
Connection : LTE
Speed test(Mbps) : 0.0
locations - Succes Call - Error Calls : 71 - 0 - 17

10.0.2.2

Figure 4 Google Earth rendering of RSSI in bars and Android Measuring Application

V. OPTIMIZATION AND PLANNING FOR MASSIVE NETWORK DEPLOYMENT

A. *Real Network Elements Required and Placements*

The collected data provides info regarding which is the density of the different cell IDs and how is the handover across cells performed. Obtaining a long distance to the serving tower, indicates that either there is a significant distance across base stations (typically for 800 MHz case) or there is lazy policy in terms of handover, keeping the connections alive for the end user device. Ideally, we will require having this sort of lazy handover policy for the remote driving testing and a more agile one for the massive video use case for optimizing the bandwidth attaching to higher frequency bands where base bands are bigger and with more aggregation capabilities.

B. *5G Elements Involved in the Deployment*

Currently we have performed a first round using a video server Over the Top, so first step for a 5G Ready like deployment will consist on installing at least one MEC server which will provide increased bandwidth and a lower latency. Of course, providing 800 MHz, 1800 MHz, 21000 MHz and 3.5 GHz radio bands in the eNBs will allow increasing the capacity for the measured cells (currently 800 and 1800 MHz)

C. *Further Tuning And Analysis*

Analyzing all the combinations of hardware devices, encoding profiles and 5G network topologies for an optimized tuning is a subject of more advance studies. Such studies may be executed with big data machine learning techniques which can show which are the features that have more influence in every use case or even detect some hidden patterns.

VI. CONCLUSIONS

The complexity of the use cased exposed in this paper forces a detailed planning and exhaustive measure analysis for providing new 5G video services with a minimum degree of success. Understanding the network architecture and the challenges in terms of latency and scalability in every piece of the chain are key to deploy such services with a minimum level of reliability. Simple scenarios with only one frequency must be validated before test on the field with carrier aggregation. A few 5G KPIs are relevant in each scenario, like E2E latency, user throughput or network reliability. Real time monitoring tools to keep track of current state of the field tests are mandatory for providing feedback to testers that want to validate performance in road environments covering long distances. New tools with more information will be developed for the road corridor validation during the next years as the new 5G infrastructure is optimized and rolled out.

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