5G-Qoe: QoE Modelling For Ultra-Hd video Streaming In 5G Networks

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Abstract- *Traffic on future fifth-generation (5G) mobile networks is predicted to be dominated by hallenging video applications such as mobile broadcasting, remote surgery and augmented reality, demanding real time, and ultra-high quality delivery. Two of the main expectations of 5G networks are b that they will be able to handle ultra-high-definition (UHD)video streaming and that they will deliver services that meet the requirements of the end user's perceived quality by adopting quality of experience (QoE) aware network management approaches. This paper proposes a 5G-QoE framework to address the QoE modeling for UHD video flows in 5G networks. Particularly, it focuses on providing a QoE prediction model that is both sufficiently accurate and of low enough complexity to be employed as a continuous real-time indicator of the" health" of video application flows at the scale required in future5G networks. The model has been developed and implemented as part of the EU 5G PPP SELFNET autonomic management framework, where it provides a primary indicator of the likely perceptual quality of UHD video application flows traversing a realistic multi-tenanted 5G mobile edge network test bed. The proposed 5G-QoE framework has been implemented in the 5Gtestbed, and the high accuracy of QoE prediction has been validated through comparing the predicted QoE values with not only subjective testing results but also empirical measurements in the test bed. As such, 5G-QoE would enable a holistic video flow self optimisation system employing the cutting-edge ScalableH.265 video encoding to transmit UHD video applications in a QoE-aware manner.*

Keywords- QoE, 5G networks, video streaming, UHD.

I. INTRODUCTION

bandwidths, lower end to end delays and improved reliability, are likely to increase demand for mobile video consumption. Similarly, new video compression standards such as High Efficiency Video Coding (H.265/HEVC) [4], [5] and the availability of Ultra-High-Definition (UHD) portable consumer devices may further fuel growth in mobile video traffic. Some portable devices already have screen resolutions of 4K with8K possible by the early 2020's. An 8K laptop screen, using version 1.4 of the embedded Display Port standard (eDP) [6],has already been demonstrated in Japan Display [7].These two technological advances will provide the infrastructure for 'anywhere anytime' access to real time broadcast media and possibly inspire new classes of video services, again increasing the video related load on mobile networks. Despite anticipated improvements in Quality of Service (QoS)and resilience [8] in 5G networks, enormous volumes of video traffic will continue to pose significant challenges for network operators. Recently, the network quality focus has changed from a network provider's QoS perspective to the less easily quantified end user's Quality of Experience (QoE) viewpoint. In this context, the EU 5G PPP SELFNET project [9], [10]has proposed a QoE-aware Self-Optimisation Use Case for UHD video flows using the Scalable H.265 video coding standard. The key enabler in this use case is a QoE prediction model for Scalable H.265 encoded UHD video flows in 5Ginfrastructures. There are a number of technical challenges to achieve this enabler, as explained below. Firstly, finding a reliable, accurate, scalable and robust QoE prediction model for streamed video over mobile networks is an unresolved and very challenging task. The specific set of challenges investigated in this paper cover the immensely important area of delivering UHD video to demanding users in 5G mobile networks. These include significantly increased bandwidth, the predicted growth in video streaming traffic and subjective factors such as user expectations of 5Gnetworks.Secondly, current QoE models including those promoted by standardisation bodies [11] do not focus on 5G networks where additional challenges such as virtualisation, mobility and multi-tenancy requirements exist. Thirdly, although video encoder type is a significant factor in QoE modelling [12], existing QoE models usually only consider single layer video encoders mostly for theH.264 Advanced Video Coding standard (H.264/AVC) [13]or in a small number of cases the latest H.265standard [4], [5].To address the above challenges, this paper investigates QoE prediction of UHD video, encoded using the scalable extension to the H.265 standard (SHVC) [14] over 5G networks. By focusing on fast and efficient prediction of QoE from 5G network congestion indicators, it can predict the QoE of the whole scalable video stream and estimate the QoE achieved by dropping a layer (or layers) from a scalable H.265 video stream. This model is one of the components of the

SELFNET autonomic 5G network management system [10].This work addresses real-time, RTP-based video streaming often used for video conferencing, video chat and video surveillance applications rather than the Dynamic Streaming over HTTP (DASH) based streaming used in Content Delivery Networks (CDNs) such as Netflix [15] or Hulu[16] where a number of pre-recorded and pre-encoded representations of a video stream serve different client types and network conditions. The model was developed and evaluated through subjective evaluation experiments using over 50 human subjects. Validation compared the results of further subjective evaluations with those predicted by the model. Empirical results show that, for a range of different content types, the predictions of QoE produced by the model closely tracked the subjective opinions of the test subjects. In summary, this paper will highlight the following novel contributions:

- A 5G-QoE framework comprising essential building blocks to enable the chain of sensing/monitoring, aggregation, QoE modelling and QoE prediction;
- A low-complexity QoE estimation and prediction scheme that is practical to be deployed in real-world networking environment with real-time processing requirements;
- A 5G-aware QoE system that is capable of extracting video metadata and flow QoS metrics to enable the QoE modelling for video flows over a multi-tenancy 5Ginfrastructure;
- A UHD capable, Scalable H.265 (and H.265) aware QoE system ready for the emerging next generation mainstream video applications in 5G and Internet.

The rest of the paper is organised as follows, Section II reviews the state of the art in QoE modelling for streamed video, scalable video codecs and, where relevant in this context, advances towards autonomic functionality in 5Gnetworks. Section III provides an insight into the QoE-driven, self-optimising features of the SELFNET 5G network management architecture, whilst Section IV explains the methodology used and the subjective testing experiments undertaken. In Section V, the QoE prediction model is developed and the results of validation experiments presented. Finally, Section V concludes the paper.

II. RELATED WORK

This section reviews existing QoE modelling techniques and highlights key technologies relevant to this work.

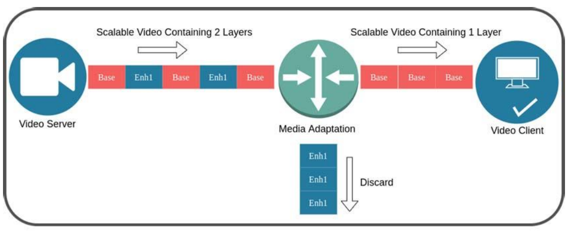
A. QoE Modelling Approaches

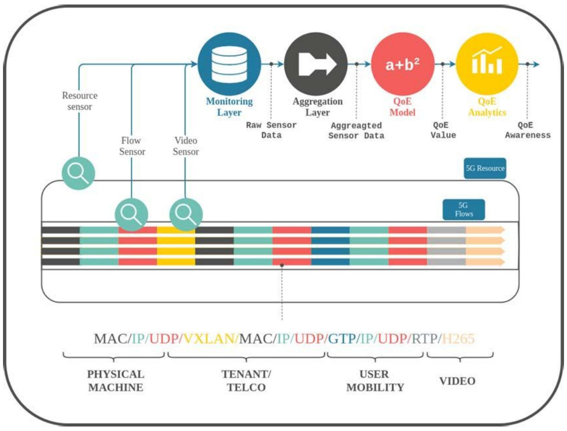
Existing QoE assessment and modelling for video can be divided into two broad categories, subjective or objective. Irrespective of which modelling technique has been employed, all QoE models, through some function or mapping, provide a prediction of the perceived subjective quality of a video under a given set of circumstances. The metric used in these models is normally predicted Mean Opinion Score (MOS).QoE prediction models are commonly validated by comparing the outputs of the model with the results of subjective(from human subjects) evaluations of quality. Where models target a networking environment, they may be further validated experimentally using a network simulator or a test bed. As there are several recent comprehensive survey papers(e.g., [17]–[19]) in this domain, this subsection only summarises the technical approaches that are most relevant to this paper.

1) Subjective QoE Assessment and Models: Subjective QoE assessment methods employ organised sessions of end users who view video content and rate the visual quality using a MOS metric. ITU-T recommendations [20] for subjective quality evaluation follow strict setup and testing conditions.MOS scores are considered to reliably reflect the quality perceived by the Human Vision System (HVS) and therefore, can also be used to validate an objective QoE model. Nevertheless, subjective QoE tests are time-consuming, labour - intensive, expensive and do not scale. Additionally, subjective testingdoes not provide an instantaneous QoE metric suitable for real-time video assessment or prediction. Subjective video quality models attempt to leverage insights into HVS through psychological or psychophysiological factors such as user expectations of a service, service type, age, mood and time of day to predict how a user will perceive the quality of a particular video. For instance, Reiter *et al.* [21]have shown that age, sex and socio-economic status are all factors influencing QoE, while Kara *et al.* [22] claim that economic context such as the brand perception of viewing device(in their case a smart phone) and the price, if any, paid to view the content were significant factors. However, such factors are also difficult to manage and correlate in a unified model for efficient, real-time systems

.2) Objective QoE Models: In light of the drawbacks of subjective QoE assessment and modelling, objective QoE modelling has gained significant popularity over the years. Some models directly map an objective measurement of video quality such as the well-known Peak-Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Matrix (SSIM)metrics directly to a prediction of user perceived quality. However, these metrics are often criticised for either requiring full (or reduced) reference comparisons to the original video frames or for being unreliable for QoE evaluation.

Consequently, practical, no reference QoE modelling is highly desirable. Parametric QoE models, which derive a predicted MOS from a model that is a function of some number of objectively measured parameters, are now the most commonly used objective method of modeling QoE [46]. These parameters have often included QoS metrics such as bandwidth, delay, packet loss, bit error rate etc. In some cases the parameters used have also considered the nature of the video stream being transmitted such as content type, resolution, frame rate etc. QoS to QoE mapping, by exploring and establishing a relationship between QoS metrics and QoE for specific use cases is a primary way to achieve such objective QoE metrics. For instance, the H.264/AVC-encoded 3Dvideo model proposed by Alreshoodi*et al.* [23] maps QoS parameters from both the video encoding layer (content type, spatial resolution and quantization parameter) and the network layer (packet loss rate and mean burst length). Their model was developed using fuzzy logic inference systems, and may have significant system complexity and computational power requirements. Seyedebrahimi*et al.* [24] developed a QoE metric called Pause Intensity (PI) for TCP-based video streaming, in which the PI is determined from video playout rate (λ) and network throughput (η). PI is shown to be the ratio of the rate difference (λ – η) to the playout rate λ. The model was validated through simulations using video sequences encoded with H.264. Another QoS/QoE function n was proposed by Hsu and Lo [25] for cloud-based multicast video streaming using a simulated platform. Finally, Khan *et al.* [26] designed a QoE metric for H.264 video in 3G networks imulated by the ns-2 simulator. Compared with these existing studies, this paper proposes a new objective QoE model for UHD video streaming encoded using the latest standard Scalable H.265. The modeling ethodology has leveraged subjective QoE assessment information and has been validated using both subjective and objective approaches and further empirically validated in a realistic 5G test bed.

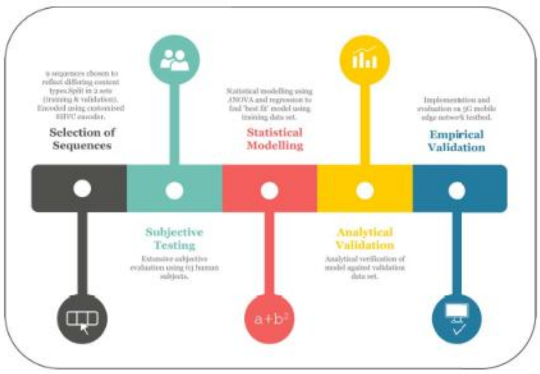




IV. METHODOLOGY &SUBJECTIVE TESTING

A. Methodology

This section describes the methodology employed to firstly determine and subsequently validate the proposed 5G-QoE system. Firstly, a set of 4k resolution video clips, with varying content types, were obtained and encoded in a scalable H.265 format, and these video clips were then used in an extensive series of subjective evaluations, with a large sample size of 64, during which subjects viewed and compared both reference videos and live streamed videos where a network impairment (bandwidth limitation) had been introduced. The videos (and subjective tests) were split into two sets, a training set and a validation set. The results of the first set of subjective evaluations (training set) were used in a statistical modelling approach to derive a candidate QoE prediction formula. This formula was initially analytically validated against the subjective scores for the validation set and then subsequently implemented and empirically evaluated in the SELFNET 5G mobile edge network test bed where all of the QoE system components described in Section III were used to provide empirical evidence of the effectiveness of the QoE modelling system. Fig. 3 provides a diagrammatic representation of the methodology and workflow.



VII. CONCLUSION

This paper has presented a fast and scalable method of estimating the perceived quality of experience of users of UHD video flows in the emerging 5G networks as part of a comprehensive5G-QoE framework. The model has been analytically and empirically evaluated against the results of subjective testing with results showing an accuracy of up to 94%. The5G-QoE framework has been implemented on the EU 5G PPPSELFNET platform, where the model has been demonstrated to work as part of the SELFNET mobile edge infrastructure, taking account of all tunnelling overheads introduced to the video flows by 5G infrastructure to achieve multi-tenancy and mobility, and providing empirical QoE scores that closely match both those predicted by the model and actual MOS scores of the test subject, with the maximum variance of only0.06 and 0.17 respectively. Future work will concentrate on building a QoE-aware video adaptation system that leverages the 5G-QoE framework to analyse and optimize likely user perception of quality for scalable

H.265 encoded UHD video streams. This system will act as a first line of defence and will inform decisions for smart traffic engineering, for example, when and which layers of a scalable video stream should be dropped in the concerned network congestion ituations in order to maximize benefit to network operations while minimising the impact on perceived QoE.

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