Self-Restoring Video User Experience in 5G Networks Based on a Cognitive Network Management Framework

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***Abstract*—Video applications such as streaming are expected to dominate the traffic of the incoming Fifth generation (5G) networks. It is essential for 5G service video providers and/or network operators to provide assurances for both the overall status of the network and the quality of their video transmissions in order to meet the final users' expectations. In this contribution, we propose a video optimisation scheme which is implemented as a Virtualised Network Function (VNF), which in turn, facilitates its on-demand deployment in a flexible way in response to an intelligent analysis of the current network traffic conditions. We leverage a cognitive network management framework to analyse both network status metrics and video stream requirements to evaluate if any optimisation action is required. The testing and evaluation focus on the functional tests and scalability evaluation of the proposed scheme. Moreover, the bandwidth saving is assessed to demonstrate the significant benefit in traffic reduction for a 5G system that adopts the proposed approach.**

***Keywords*—5G; Artificial Intelligence; Video.**

I. Introduction

Video applications trend to dominate the traffic over the coming years [1]. In fact, High Definition (HD) and Ultra High Definition (UHD) services have been gaining growing popularity and are foreseen as main driving applications in 5G networks. Video services are generating continuously heavy traffic load to the network and leading to congestion and thus overall performance downgrading in the 5G system. Besides, virtualised 5G networks impose a complex network protocol stack to isolate and differentiate network traffic at different layers, to what is known as Network Overlays. Such complexity plus the fact of using the latest video codec (e.g, H.265/HEVC) and its scalable extension SHVC [2] makes extremely difficult to find a video tool able to deal with all such requirements. Therefore, it is essential to design and develop a new video optimiser that is capable of parsing the 5G traffic and processing the video traffic encoded by the latest codec, likewise, it is also fundamental to make an intelligent analysis of the current state of the network to provide autonomous self-optimization capabilities. This research focuses on the scalability of the proposed video optimiser approach by deploying instances of the service as a response to an alarm of a possible downgrading of the video quality.

II. Design

This section lists of requirements of both the video optimiser and the management layer as well as its architectural components. Furthermore, we present the methodology that provides the methods and procedures used in this research study.

Video Optimizer: Video optimiser is able to work with the new generation video codec and to inspect trough different overlay network layers existing in virtualised 5G networks; The VNF where video optimiser is deployed has to be instantiated on-demand when a downgrading in the quality of any video flow is detected (mainly due when impairments in the network); System should minimise the negative impact on the user's perceived quality for video applications and should mitigate network congestion by maximizing bandwidth saving; System should also cope with scalability aspects when thousands of users are using a video streaming service; The application of video optimisation requires direct communication within the upper layers of the cognitive framework in order to autonomously apply user video policies when congestion is detected.

This research makes use of an ETSI MANO [3] compliant management framework and architectural components (Figure 1) required for providing self-optimisation capabilities following the Self-Organising Networking (SON) principles to automatically adapt video flows over a multi-tenant 5G network data path. In summary, it uses a VNF *Orchestrator* for orchestrating the deployment of different VNFs, *VNF Management* for having control of the life cycle of the VNFs managed in the infrastructure, and a *Virtual Infrastructure Manager* (VIM) for the management of the physical and virtual resources of the infrastructure (compute, storage and networking).

Cognitive Framework: The cognitive framework has a policy engine to define quality of service agreements; The framework *Monitor* information coming from the network sensing pipeline, *Analyzes* such information in order to determine if the network is congested and led to a *Decision Maker* that will decide what type of video optimization need to be done. The *Planner* module will then refine the decision providing an implementable and ordered plan to enforce such decision. Such optimization plan will then be orchestrated by the ETSI MANO *Orchestrator*. The framework has a network sensing layer providing both network metrics and also per-flow video metrics. It also has a resource and network flow inventory with an updated list of physical and logical hardware equipment, network flows and services. The framework has also a network actuation later providing adaptation capabilities over the video flows.

This study presents a realistic scenario where a cognitive network management framework is used to detect congestion problems in the data plane and subsequently deciding on a specific action to be taken to mitigate the impact of such problem in the final user's video quality perception. The framework relies on a cognitive intent-based algorithm to calculate, based on the current state of the network condition and the specific video flow bitrate requirements, a parameter called Congestion Index (CI). CI is calculated as the maximum bitrate that a specific video flow is going to reach, divided by the current available bandwidth in the network (As shown in Equation 1). Both subjective and objective video metrics gathered from our previous work in [4], have provided the network congestion limits where users perceive a degradation of video quality. Such limits are called Quality Index (QI). Therefore, the periodically CI calculation produced by the *Analyzer* is mapped within those QI boundaries to provide QoE quality degradation alerts.

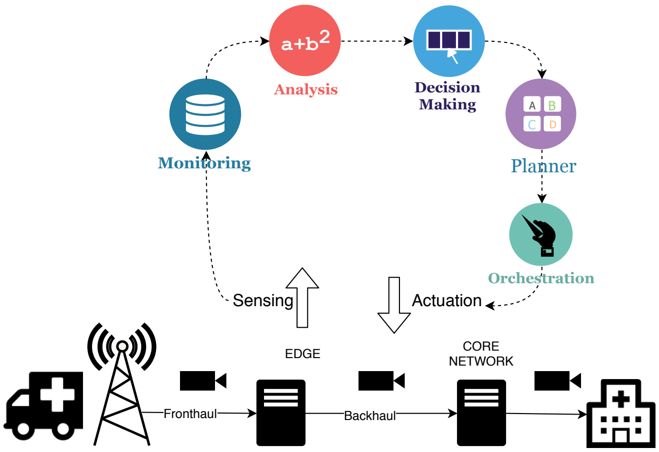

Fig. 1: Cognitive Framework Overview

$$CI = \frac{MaxVideoBitrate}{(NicSpeed-(CurrentBwdConsumed-CurrentVideoBitrate))} \quad (1)$$

Then, After the alert is triggered, the *Decision Maker* module will decide either to deploy a new vOptimizer instance of the service or to perform the adaption of the video flow in an existing one. This decision implies the understanding of network topologies, together with their inter-connectivity in order to determine where better to perform such adaptation.

III. Experimental Results

Previous experiments have been conducted to stress one VNF Optimiser to select the maximum simultaneous video flows that a single vOptimiser is able to handle without incurring a negative effect on the transmission. 128 has been empirically calculated for the video adaption service achieving no packet loss and an acceptable value of delay and jitter. A scalable approach is therefore presented herein where thousands of video flows are managed simultaneously by scaling up the number of VNF Optimizers according to the needs of the network.

Bitstreams are encoded in SHVC at 1 Mb/s and streamed between video sender (an LTE-based smartphone) and video receiver located after Serving Gateway (SG), in hospital premises. This scenario is in the context of the SliceNet eHealth use case where paramedical doctors held an LTE-based smartphone to stream video to a doctor in the hospital to perform a real-time patient assessment. In this particular case, a set of scalable videos has been streamed and optimised by a number of vOptimisers (128 video flows per each vOptimiser). Each video flow has been composed by a base video layer with FHD spatial resolution and an enhancement layer in UHD. A selective dropping of the enhancement layer per each video flow produced a significant amount of bandwidth saved. This experiment has been conducted by sending scalable videos of 3.8Mbytes in a bitrate of 1,010,000bps, with a stream duration of 30.57s. In the most stressful scenario, 1536 video flows have been being processed by the 12 vOptimisers in the system.

A. Test Results

As can be seen in Figure 2, at the end of the transmission about 2,981MBytes (close to 3GBytes) has been saved. From the network point of view, congestion has been mitigated; from the users' point of view, the perceived quality remained stable since there is no uncontrolled packet loss but just a downgrading of the video resolution under imperceptible boundaries for the human eye in smartphone devices.

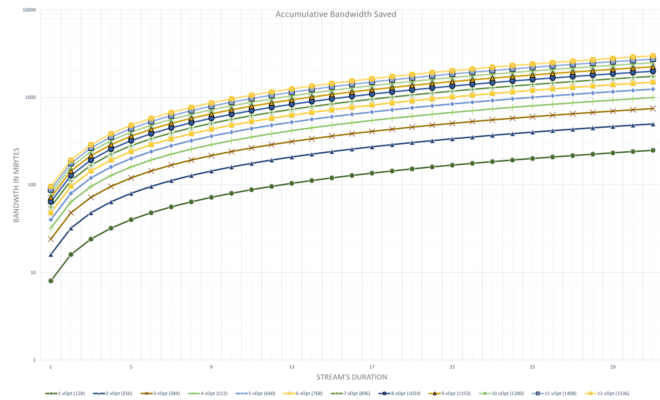

Fig. 2: Accumulative bandwidth saved per second along the streaming

IV. Conclusions

This paper has presented the design and implementation of a new video optimiser that is compliant with the latest video codec and can be flexibly deployed in virtualised 5G networks as a VNF. An intent-based intelligence algorithm has been presented for real-time provisioning of video adaptation rules into such VNFs. Experimental results gained from a realistic 5G testbed have validated the capabilities of the proposed video optimiser in parsing and processing 5G video traffic over the new virtualised and multi-tenanted infrastructure. Moreover, the proposed video optimiser has yielded high scalability, which is important to be able to handle the tremendous video traffic effectively. In addition, huge bandwidth saving has achieved during the video optimisation.

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