Towards a Multi-tier Fog/Cloud Architecture for Video Streaming

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***Abstract*—The video streaming services are already responsible for the majority of the Internet traffic. A good cloud-level architecture partially solves some issues related to the video streaming services. However, it introduces other issues such as higher latency and core network congestion, addressed in this work: we propose a multi-tier architecture composed of a set of services to video streaming in a fog computing environment taking into consideration classified hierarchical tiers and the ETSI-NFV architecture. The main goal is to design and assess a reliable, high-quality multi-tier services architecture to be used in Smart City environments. To this end, we introduce a set of video streaming services in the fog-cloud infrastructure, and also discuss how these services may be used to improve the Quality of Experience (QoE) for end-users.**

***Keywords*-fog computing; cloud computing; QoE; video streaming services.**

I. Introduction

Video streaming services have stringent requirements such as a good-quality communication channel as well as a steady and uninterrupted flow of information [1]. Because of that, the employment of such services in a fog/cloud environments have attractive advantages to improve the end-users Quality of Experience (QoE). Examples of services include video transcoding, multiple route video transmission, and cache schemes [2]. A transcoder service can be used to transcode a video with a bit rate of 8 Mbps (1080p) to 5 Mbps (720p), with no visible loss in quality, if the end-user device is not ready to display videos in 1080p. This allows a larger number of users to be served while maintaining a satisfactory QoE. Moreover, smartly caching videos in edge nodes can reduce traffic load and delay, since multimedia content may be readily available closer to the users. Video streaming can be tailored according to the user's device and network characteristics. It is essential to provide a more adequate use of the bandwidth available for nodes at the edge network.

Recent literature has highlighted fog computing to integrate services closer to the users [2], [3] mostly considering an environment with a single fog tier, whereas there are a few works on the analysis of multi-tier fogs. This proposal presents an architecture for the provisioning of video streaming services in multi-tier environments in a hierarchical infrastructure comprised of the cloud and multiple fog tiers at the core and edge of the network, respectively. We briefly discuss which services can benefit from the fog/cloud multi-tier environment to improve QoE.

II. Proposed Hierarchical Fog/Cloud Computing Architecture

The proposed model is responsible for providing a set of multimedia services dynamically deployed in the fog/cloud network. Users can access multimedia content through a variety of heterogeneous communication technologies. In scenarios like this - common in fogs - fog nodes can provide computing and storage services [4]. In this context, we introduce a multi-tier architecture (Figure 1). The top tier is composed of cloud servers, which can be located in a public or private cloud. The clouds may be, for example, a Video-on-Demand provider.

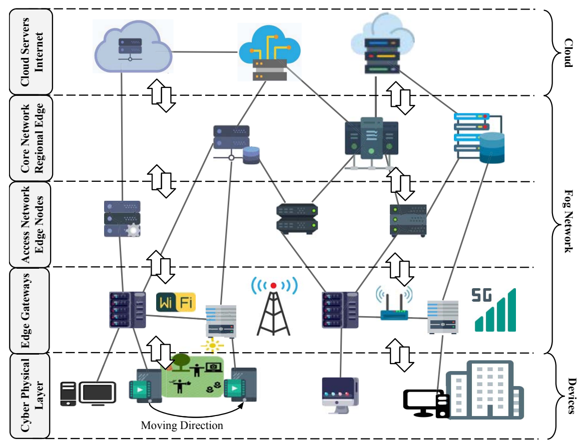

Figure 1. Overview of the hierarchical Fog/Cloud Environment.

The other three layers represent the fog/edge network. This work takes into account edge nodes with computational and storage capacity and classifies them hierarchically according to their coverage and communication technology [2]. In a multi-tier ecosystem, the Core Network Regional Edge could handle, for example, citywide user services such as Baseband Unit (BBU) and Internet Service Provider (ISP). The Access Edge Network, which supports a few dozens or perhaps a few hundred local nodes in the fog, can be represented by a Base Station or Access Point. Edge Gateways can be distributed to local mist nodes such as personal computers, laptops, and smartphones, where the node delegates video content over wireless connections. These end-devices have both high and similar traffic demands, being able to cooperate with each other.

A. Fog-Cloud Architecture

This work follows the framework architecture specified by the European Telecommunications Standards Institute (ETSI). This framework takes advantage of Software Defined Network (SDN) and Network Function Virtualization (NFV) principles [5]. The SDN/NFV-based approach allows virtualizing specific services on remote servers. In this way, the migration of services can be virtualized in different

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datacenters on the fog/cloud networks. Figure 2 depicts the architectural framework with the proposed video streaming services. Note that different service implementations could exist together. As depicted, a video streaming network is composed of different services. All these services become virtualized and deployed as virtual network function (VNF) instances.

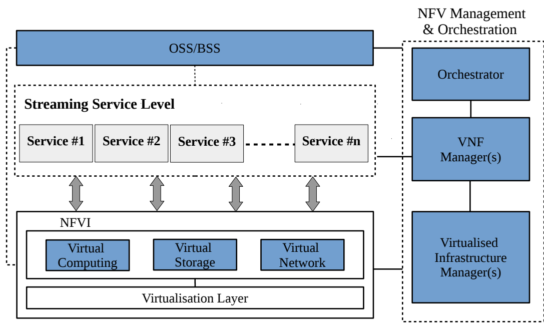

Figure 2. Multi-Tier Fog/Cloud Architecture.

The ETSI-NFV framework architecture includes mainly three functional modules, namely NFV Orchestrator (NFVO), VNF Manager (VNFM), and Virtual Infrastructure Manager (VIM). The NFVO is a software component that can orchestrate the lifecycle of virtualized network functions. This includes creating, monitoring, and chaining network services. The VNFM is responsible for handling specific VNF instances, coordinating requests for infrastructure resources between the VNF instance and related network modules management systems. The VIM controls and manages the NFV infrastructure, which includes computing, storage, and network resources. It also coordinates the physical resources necessary to deliver the virtualization of the services. This is particularly visible for Infrastructure-as-a-Service. In summary, VIM is the management glue between the hardware and software resources.

B. Envisioned Video Streaming Services

The Orchestrators and Management blocks run specific methods, including the selection of the virtual services. It also defines the services chaining between the VNFs and then publishes the jobs in the queues of the concerned servers. The envisioned services are described below.

Streaming Service: The streaming service plays a load-balancer role as it receives client requests for playing specific video content and redirects the requests to the proper cache servers. The streaming server tracks also video accesses and sends statistics back to the fog nodes to be used in data analyses. This will help to improve the business intelligence of the video streaming provider.

Transcoding Service: Responsible for generating the video stream at lower resolutions. In this way, the same video does not have to be stored in the cache with different resolutions. In a multi-tier ecosystem, a transcoding service may be deployed closer to a set of end-users and/or fog nodes, and chained with the other services if necessary.

Cache Service: Seeks to provide the multimedia content geographically scattered over the servers. This service stores the video requested by the user as well as the transcoding service output. When an end-user requests a video, the closest server(s) will deliver it. This approach is similar to the cache overlay networks but applied to VNF [6]. A smart caching available on the fog nodes can reduce the traffic load and delay.

Overlay Routing Service: A set of overlay paths are built by the orchestrator or by the overlay routing service itself to avoid having a single point of failure. The edge server, in turn, can download directly from a cache or through alternate overlay paths. Each intermediate node path acts as a forwarder of the request to the next node in the path towards the cache server(s). Using the overlay routing, a service could reduce the download time and increase the availability in a multi-tier network. A deeper discussion about overlay networks can be found in [6].

III. CONCLUSION

This work proposes a multi-tier architecture with a set of video-related services. The services were designed following the ETSI-NFV architecture. It focuses on the demonstration of the suitability of the services for multi-tier fog/cloud environments. In doing that, several properties of fog computing were further characterized. The proposed work combines recent fog/cloud technologies with state-of-the-art multi-tiered computing environments. This justifies the need for investigating specific services for video streaming provisioning. As future work, we intend to implement the principles of NFV-SDN-based on VoD services in multi-tier fog/cloud environments. Another improvement is to assess how service chaining behaves in order to provide a delicate balance between cost and customer satisfaction in terms of QoE.

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