Chapter 1
Quality Evaluation of Cloud and Fog Computing Services in 5G Networks

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ABSTRACT

Because of the increased computing and intelligent networking demands in 5G network, cloud computing alone encounters too many limitations, such as requirements for reduced latency, high mobility, high scalability, and real-time execution. A new paradigm called fog computing has emerged to resolve these issues. Fog computing distributes computing, data processing, and networking services to the edge of the network, closer to end users. Fog applied in 5G significantly improves network performance in terms of spectral and energy efficiency, enable direct device-to-device wireless communications, and support the growing trend of network function virtualization and separation of network control intelligence from radio network hardware. This chapter evaluates the quality of cloud and fog computing services in 5G network, and proposes five algorithms for an optimal selection of 5G RAN according to the service requirements. The results demonstrate that fog computing is a suitable technology solution for 5G networks.

INTRODUCTION

Today we are witnesses of the enormously increased volume of mobile traffic, the fast development of the broadband mobile networks and the appearance of intelligent mobile devices. According to some predictions, it is expected an increase of the global mobile traffic from 2010 to 2020 for 1000 times (ZTE, 2014). This is due to the widespread of smart mobile devices, and the increased demand of advanced

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multimedia services such as UHD (Ultra-High Definition) and 3D video, as well as extended reality and experience (Cisco, 2015; Cisco, 2017) as well as the social networks (Hedin, 2008). However, this would result with an increased demand for mobile broadband services, which demand high data rates, high mobility, low latency, broadband spectrum and high energy consumption.

Due to these demands, many research initiatives are already gathering an increased interest and momentum around the world for the next generation of mobile and wireless networks, also known as the Fifth Generation, or 5G (Wang, 2014). The International Telecommunication Union (ITU) has already specified target requirements for 5G in IMT-2020, such as peak data rates of 20 Gb/s, user experienced data rates of 100 Mb/s, a spectrum efficiency improvement of 3 times, mobility support for up to 500 km/h, 1 ms latency, a connection density of 106 devices/km^2, a network energy efficiency improvement of 100 times and an area traffic capacity of 10 Mb/s/m^2 (ITU-R SG05, 2017).

In order to satisfy these demands, the key trend in the last decade was to push computing, control, data storage and processing in the cloud computing data centers (Armbrust, 2010; Dihn, Lee, Niyato, & Wang, 2011). However, in order to meet the computing and intelligent networking demands in 5G network, the cloud alone encounters too many limitations, such as requirements for reduced latency, high mobility, high scalability and real-time execution.

Therefore, a new paradigm called Fog Computing has emerged to overcome these limitations (Bonomi, Milito, Zhu, & Addepalli, 2012). Fog distributes computing, data processing, and networking services to the edge of the network, closer to end users. It is an architecture where distributed edge and user devices collaborate with each other and with the clouds to carry out computing, control, networking, and data management tasks (Vaquero, & Rodero-Merino, 2014).

Instead to concentrate data and computation in a small number of large clouds, many fog systems would be deployed close to the end users, or where computing and intelligent networking can best meet user needs. The basic idea is to take full advantages of local radio signal processing, cooperative radio resource management, and distributed storing capabilities in edge devices, which can decrease the heavy burden on front haul and avoid large-scale radio signal processing in the centralized baseband unit pool (Peng, Yan, Zhang, & Wang, 2016).

Cloud and fog form a mutually beneficial, inter-dependent continuum (Chiang, 2015). They are inter-dependent, e.g., coordination among devices in a Fog may rely on the Cloud. They are also mutually beneficial: certain functions are naturally more advantageous to carry out in Fog while others in Cloud. The analysis of local information is performed locally with the fog computing and networking devices, and the coordination and global analytics are performed at the cloud computing centers (Romana, Lopeza, & Mambob, 2016). Cloud and fog applied together in 5G network may significantly improve network performance in terms of spectral and energy efficiency, enable direct device-to-device wireless communications, and support the growing trend of network function virtualization and separation of network control intelligence from radio network hardware (Kitanov, Monteiro, & Janevski, 2016).

This chapter evaluates the quality of cloud and fog computing services in 5G network. Initially, the Sections 5G Network, Cloud Computing and Fog Computing provide an overview of 5G network, cloud computing and fog computing. Then, the Section 5G Mobile Network in Cloud and Fog Computing Environment, proposes 5G network architecture in cloud and fog computing environment. The Section Quality Evaluation of Cloud and Fog Computing Services in 5G Mobile Network evaluates the quality of cloud and fog computing services in 5G network in terms of end-to-end delay (E2E delay), user throughput, and energy efficiency. The obtained results about the E2E delay, user throughput, and energy efficiency clearly demonstrate that fog computing outperforms cloud computing, and therefore