# Chapter 4
# Introduction to Fog Computing

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## ABSTRACT

*Pushing computing, control, data storage, and processing into the cloud has been a key trend in the past decade. However, the cloud alone encounters growing limitations, such as reduced latency, high mobility, high scalability, and real-time execution in order to meet the upcoming computing and intelligent networking demands. A new paradigm called fog computing has emerged to overcome these limits. Fog extends cloud computing and services to the edge of the network. It provides data, computing, storage, and application services to end-users that can be hosted at the network edge. It reduces service latency, and improves QoS/QoE, that results in superior user experience. This chapter is about introduction and overview of fog computing, comparison between fog computing and cloud computing, fog computing and mobile edge computing, possible fog computing architecture, applications of fog computing, and possible research directions.*

## INTRODUCTION

The future Internet of Everything (IoE) would become the linkage between extremely complex networked organizations (e.g. telecoms, transportation, financial, health and government services, commodities, etc.), which would provide the basic ICT infrastructure that supports the business processes and the activities of the whole society in general (Brech, Jamison, Shao, & Wightwick, 2013.), (Mitchell, Villa, Stewart-Weeks, & Lange, 2013). Frequently, these processes and activities should be supported by orchestrated cloud services, where a number of services work together to achieve a business objective (Zhang, Zhang, Chen, & Huo, 2010).

However, these demands can only be partially fulfilled by existing mobile cloud computing solutions. This is because the future Internet would exacerbate the need for improved QoS/QoE, supported by services that are orchestrated on-demand and are capable to adapt at runtime, depending on the con-

DOI: 10.4018/978-1-7998-5339-8.ch004

textual conditions, to allow reduced latency, high mobility, high scalability, and real-time execution. In addition, the emerging wave of Internet of Things (IoTs) would require seamless mobility support and geo-distribution in addition to location awareness and low latency. Also, the existing cloud computing security mechanisms such as sophisticated access control and encryption have not been able to prevent unauthorized and illegitimate access to data.

A new paradigm called Fog Computing, has emerged to meet these requirements (Bonomi, Milito, Zhu, & Addepalli, 2012; Mouradian, Naboulsi, Yangui, Glitho, Morrow, & Polakos, 2017). Fog Computing extends cloud computing and services to the edge of the network. Fog computing would combine the study of mobile communications, micro-clouds, distributed systems, and consumer big data. It is a scenario where a huge number of heterogeneous (wireless and sometimes autonomous) ubiquitous and decentralized devices communicate, and potentially cooperate among them and with the network to perform storage and processing tasks without the intervention of third parties (Vaquero & Rodero-Merino, 2014; Liu, Fieldsend, & Min, 2017). These tasks support basic network functions, or new services and applications that run in a sand-boxed environment. Users leasing part of their devices to host these services get incentives for doing so. The distinguishing fog characteristics are its proximity to end-users, its dense geographical distribution, and its support for mobility. Therefore, fog paradigm is well positioned for real-time big data analytics. Services are hosted at the network edge or even end devices such as set-top-boxes, or access points (Gao, Luan, Liu, & Yu, 2017). By doing so, fog reduces service latency, and improves QoS, resulting in superior user-experience. It supports emerging IoE applications that demand real-time/predictable latency (industrial automation, transportation, networks of sensors and actuators).

This chapter provides an introduction and overview of fog computing. Initially it provides an overview of cloud computing, mobile edge computing, and fog computing. Then it makes a comparison between fog computing and cloud computing, as well as fog computing and mobile edge computing. After that fog computing features are discussed. Finally, at the end fog computing open research directions and conclusion of the chapter are provided.

## CLOUD COMPUTING

The idea of cloud computing is based on a very fundamental principal of reusability of IT capabilities (Zhang, Zhang, Chen, & Huo, 2010). Cloud computing is a computing paradigm, where a large pool of systems is connected in private or public networks, in order to provide dynamically scalable infrastructure for application, data and file storage (Dialogic Corporation, 2010). At the same time, the shared cloud resources (networks, servers, data warehouses, applications and services) can be rapidly provisioned and managed with minimal interaction by service providers.

The cloud computing users may use these resources for development, hosting and running of services and applications on demand in a flexible way at any device, at any time and at any place in the cloud. With the advent of this technology, the cost of computation, application hosting, content storage and delivery is reduced significantly.

The framework for cloud computing is defined in the recommendations ITU Y.3501 (ITU-T, Cloud Computing Framework and High Level Requirements, 2013) and Y.3510 (ITU-T, Cloud Computing Infrastructure Requirements, 2013) as well as the NIST standards for cloud computing (NIST, 2013).