

Fog computing and Internet of things: An Overview of Research Opportunities

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Abstract—Internet of Things (IoT) brings more than an explosive proliferation of endpoints. Despite the broad utilization of cloud computing, some applications and services still cannot benefit from this popular computing paradigm due to inherent problems of cloud computing such as unacceptable latency, lack of mobility support and location-awareness. It is disruptive in several ways. In this paper we examine those disruptions, and propose a hierarchical distributed architecture that extends from the edge of the network to the core nicknamed Fog Computing. Fog is an emergent architecture for computing, storage, control, and networking that distributes these services closer to end users along the cloud-to-things continuum. Fog Computing extends the Cloud Computing paradigm to the edge of the network, thus enabling a new breed of applications and services.

Index Terms—Edge computing, edge networking, edge storage, fog, fog computing, fog control, fog networking, fog storage, Internet of Things (IoT).

I. Introduction

The Internet of Things (IoT) shall be able to incorporate transparently and seamlessly a large number of different and heterogeneous end systems, while providing open access to selected subsets of data for the development of a plethora of digital services. Building a general architecture for the IoT is hence a very complex task, mainly because of the extremely large variety of devices, link layer technologies, and services that may be involved in such a system.

Over the past decade, moving computing, control, and data storage into the cloud has been an important trend. In particular, computing, storage, and network management functions are shifted to centralized data centers, backbone IP networks, and cellular core networks. Today, however, cloud computing is encountering growing challenges in meeting many new requirements in the Internet of Things (IoT).

An emerging wave of Internet deployments, most notably the Internet of Things (IoTs), requires mobility support and geo-distribution in addition to location awareness and low latency. We argue that a new platform is needed to meet these requirements; a platform we call Fog Computing. Fog, simply because the fog is a cloud close to the ground.

The Fog is an architecture that distributes computation, communication, control and storage closer to the end users along the cloud-to-things continuum. Sometimes

the term "Fog" is used interchangeably with the term "edge," although fog is broader than the typical notion of edge. The relevance of fog/edge is rooted in both the inadequacy of the traditional cloud and the emergence of new opportunities for the Internet of Things, 5G and embedded artificial intelligence.

Fog Computing enables a new breed of applications and services, and that there is a fruitful interplay between the Cloud and the Fog, particularly when it comes to data management and analytics. Fog Computing extends the Cloud Computing paradigm to the edge of the network. While Fog and Cloud use the same resources (networking, compute, and storage), and share many of the same mechanisms and attributes.

The Internet of things (IoT) will be the Internet of future, as we have seen a huge increase in wearable technology, smart grid, smart home/city, smart connected vehicles.

This paper is organized as follows. In the second section we introduce the Fog Computing paradigm, delineate its characteristics, and those of the platforms that supports Fog services. The following sections will take the range of new challenges in the emerging IoT and the difficulty to address these challenges with today's computing and networking models. It then discusses why we will need a new architecture—fog for computing, storage, networking, and control—and how it can fill the technology gaps and create new business opportunities.

2. The fog computing platform

"Fog Computing" is a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional Cloud Computing Data Centers, typically, but not exclusively located at the edge of network.

The following figure (a) presents the idealized information and computing architecture supporting the future IoT applications, and illustrates the role of Fog Computing.

Cloud and Fog are built around the same basic services, "Edge of the Network", however, implies a number of characteristics that make the Fog a non-trivial extension of the Cloud. The fog extends the cloud to be closer to the things that produce and act on IoT data.

These devices, called fog nodes, can be deployed anywhere with a network connection: on a factory floor, on top of a power pole,

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