Fog-Cloud Services for IoT

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ABSTRACT

The Internet of things (IoT) [1] devices are increasingly becoming an integral part of our lives. It is estimated that the number of such devices will grow into billions within few years. These devices are highly distributed and have limited storage and processing capacity. To support the computational demand and the latency-sensitive applications of these distributed IoT devices, a new computing paradigm, Fog computing, has been introduced. Fog computing is considered as the promising extension of the Cloud computing paradigm that brings virtualized Cloud services to the edge of network to control the IoT devices. This paper introduces Fog commuting technologies and their applications to IoT.

CCS CONCEPTS

• **Networks → Network services**; Cloud computing; • **Human-centered computing → Ubiquitous and mobile computing**

KEYWORDS

Cloud computing, Fog computing, Internet of Things (IoT), Devices, Management

1 INTRODUCTION

The nature of Information Technology (IT) is that there are always new ideas being cultivated and implemented. The Internet of Things (IoT) does not fall outside of this dynamic. Gartner, one of the world's leading Information Technology research and advisory companies, forecasts that 6.4 billion connected things will be in use worldwide in 2016, up 30 percent from 2015, and will reach 20.8 billion by 2020. In 2016, 5.5 million new things will get connected every day [14]. IoT is generally characterized by physical things (devices) equipped with computation and communication capabilities that could be seamlessly integrated into the Internet. These devices are widely distributed and have limited storage and processing capacity.

The constant communication allows for tons of gathered data. This data, once interpreted and analyzed, becomes the focal point of the purpose for IoT. The real time interpretation and application of live data is what makes IoT useful. Due to the technological constraints (storage, processing, and communication) on IoT devices, Cloud computing is considered as a promising computing paradigm, that can provide elastic resources to applications on these devices [4]. In addition, it is the Cloud that allows these applications to work anytime and anywhere. In spite of attempts of augmenting IoT applications with the virtually unlimited capabilities and resources of the Cloud, there are still problems unsolved in that IoT applications that usually require location-awareness, mobility support, geo-distribution, and low latency [16].

Most of the Cloud datacenters are geographically centralized and situated far from the proximity of the IoT devices/users. As a consequence, real-time and latency-sensitive computation service requests that require a response from the distant Cloud datacenters often experience network congestion, unacceptable round-trip latency, and poor service quality to name a few. To resolve these issues, a new concept named Fog computing has recently been proposed [12]. The fundamental idea of Fog computing is to bring the computation facilities closer to the source of the data and end-user. More precisely, Fog computing enables data processing at the edge network [12]. Many IoT applications require both Fog localization and Cloud globalization, particularly for data analytics.

The use of IoT is rapidly evolving and growing. Many IoT applications are being developed and/or deployed in various industries including smart city, smart grid, workplace and home support, healthcare services, inventory and production management, and transportation [15].

2 FOG COMPUTING –A BRIDGE BETWEEN IoT and the CLOUD

Fog computing can act as a bridge between the IoT devices and large-scale cloud computing and storage services. In the perspective of Cisco, Fog computing is considered as an extension of the Cloud computing paradigm from the core of network to the

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edge of the network. It is a highly virtualized platform that provides computation, storage, and networking services between end IoT devices and the traditional Cloud servers [3]. The distinguishing Fog characteristics are its proximity to devices/end-users, its dense geographical distribution, and its support for mobility.

IoT is a broad collection of devices—all connected to and communicating with applications, websites, social media, and other devices. To maximize value, much of the data generated by these devices must be processed and analyzed in real time. This sort of real-time, high-bandwidth application requires a new distributed Cloud model that brings cloud networking, compute, and storage capabilities down to edge of the network — and Fog computing is the solution [12].

In a Fog computing environment, a big part of local data processing would take place in a fog node, rather than having to be transmitted. The main characteristics of the Fog computing are [3, 12]:

- Low latency and location awareness
- Wide-spread geographical coverage
- Heterogeneity of devices and data sources
- Support for mobility
- Support for real-time interactions
- Support for online data analytics and interplay with the cloud
- Interoperability and federation between service providers

2.1 Fog Nodes Configurations

Fog computing is considered as the promising extension of cloud computing paradigm to handle IoT related issues at the edge of network. However, in Fog computing, computational nodes (Fog nodes) are heterogeneous and distributed. These nodes provide compute and runtime resources for applications. Besides, Fog based services have to deal with different aspects of constrained IoT environment [12]. Any device with computing, storage, and network connectivity can be a Fog node—examples include routers, switches, servers, and industrial controllers [6]. There are many types of Fog node configurations including Fog servers, networking devices, and fog brokers. Fog servers are virtualized and equipped with storage, compute and networking capabilities. Fog servers enhance the computation and storage capacity in Fog computing. Devices like routers and switches can act as potential infrastructure for Fog computing. Fog brokers are responsible for receiving IoT device request/services, providing services/search, and delegating service to other cloud/fog environments [3, 6, 12].

2.2 Fog Computing Platform–IOx

The communication and computing requirement for IoT has been provided by a single open platform for application enablement at the network edge is called IOx [5]. The IOx platform whose architecture is depicted in Figure 1 [8] is the Cisco's implementation of Fog computing that provides Fog nodes with computational abilities for the purpose of managing huge amounts of information pouring out of data from IoT devices. The Cisco IOS software, the industry-leading networking operating system, and the Linux OS, the popular open-source system are combined to form the architecture of IOx [5]. This framework allows users to host their OS and applications in its open and extensible environment. IOx allows effortless integration of novel, specialized communications technology with a common IP architecture—"bring your own interface" [7]. Fog applications can also send IoT data to the Cloud by translating non-standard and proprietary protocols to IP [7]. IOx Components include Fog Director that allows administrators to remotely manage, administer, monitor, and troubleshoot fog applications running in the Cisco IOx environment. The IOx framework also provides an SDK and development tools to help third party developers package their applications for execution on IOx-enabled network infrastructure products [5].

Figure 1: IOx Architecture [8]

3 NEW TECHNOLOGIES INTEGRATION

New innovations on the horizon, across multiple technologies, will provide additional capabilities that will make the potential of Fog computing possible. The key technological innovations include Software-Defined Networking (SDN), Network Function Virtualization (NFV), and 5G Technologies.

The duty of fog network is to connect every component of the fog. However, managing such a network, maintaining connectivity and providing services upon that, especially in the scenarios of IoT is not easy. Emerging technologies, such as SDN and NFV are proposed for future research [9, 12, 16] to create flexible and easy maintaining network environment.

One of the challenges for Fog computing is the design of flexible network architecture that can be realized through the SDN paradigm. SDN is a new networking trend aiming (i) to separate the network control plane from the data forwarding plane and (ii) to introduce a novel network control functionalities based on network abstraction [1]. This separation provides high level of abstraction for management functions and hides the increased complexity in the network management domain [9]. The SDN control plane is placed on a logically centralized controller, which maintains a global view of the network and manages flow control to enable intelligent networking [13]. This controller is the core of SDN and provides a programming interface for network management applications. The communication s between the SDN controller and the data plane devices is commonly achieved via the OpenFlow protocol [13]. Applying the SDN paradigm to manage the Fog nodes will enhance the effectiveness of Fog computing.

NFV is complementary to SDN and refers to the implementation of network functions in software that can run on a variety of industry standard hardware. With the migration from hardware to software appliances, NFV is expected to lower not only equipment costs (CAPEX) but also the operational costs (OPEX) [2]. In the NFV architecture, a Virtualized Network Function (VNF) is responsible for handling specific network functions that run on virtual machines instances. Since the key enabler of fog computing is virtualization and those virtual machines can be dynamically created, offloaded, and destroyed, NFV will benefit Fog computing in many aspects by virtualizing the hardware networking infrastructure, which can include routers, switches, servers, load-balancers, firewalls, and intrusion detection systems and placing those instances on Fog nodes [16].

The evolution to 5G will gradually ensure significant improvements over the 4G/LTE standards currently in use. The massive amount of interconnected devices and the diversified IoT services will create new challenges to mobile communications. 5G embraces some important technologies such as radio access, MIMO, and mobility management to achieve compatibility with the IoT environments [11]. 5G will be capable of connecting billions of devices and will be able to deliver solutions across a variety of scenarios such as massive traffic volume, very-high connection density, and ultra-high mobility [11]. 5G will be fundamental in achieving certain network requirements for IoT and Fog/Cloud computing such as low latency, high throughput and better coverage, all in a more agile way, at a much lower cost [10].

4 CONCLUSION

The IoT devices are closer to action; however, they lack the computing and storage resources to perform analytics. Cloud servers, on the other hand, are very powerful, but are very far away to process data and respond in time. The Fog layer is the perfect junction where there are enough compute, storage and networking resources to mimic cloud capabilities at the edge of the network and support IoT devices for local processing. This paper introduced the benefits of Fog computing. The integration of new technologies such as SDN, NFV, and 5G will be explored.

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