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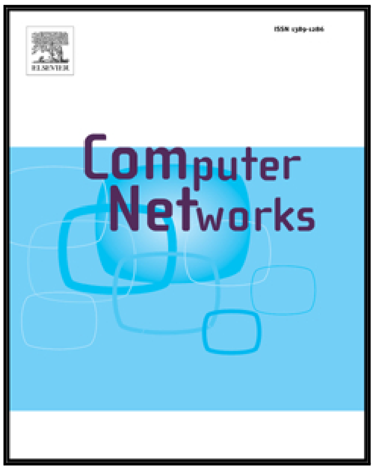

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Won-Suk Kim , Sang-Hwa Chung

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User Incentive Model and Its Optimization Scheme in User-Participatory Fog Computing Environment

Won-Suk Kim and Sang-Hwa Chung*
Pusan National University, Busan, Republic of Korea

* Corresponding author. Tel.: +82 51 5102434; fax: +82 51 5172431. E-mail address: shchung@pusan.ac.kr (S. Chung). 6510, Engineering Bldg #6, Pusan National University, Busandaehak-ro 63beon-gil 2, Geumjeong-gu, Busan, Republic of Korea (609-735)

Abstract. Although fog computing is recognized as an alternative computing model to cloud computing for IoT, it is not yet widely used. The replacement of network equipment is inevitable to implement fog computing; however, the entity in charge of replacement, requiring high cost, is unclear, and also the entity in charge of operating of the infrastructure is unclear. To solve these feasibility problems, we propose an incentive-based, user-participatory fog computing architecture. In terms of inducement of user participation on the proposed architecture, first, users are classified into four categories according to their tendencies and conditions, and the types of incentives, which are paid as a compensation for participation, the payment standard, and the operation model are presented in detail. From the perspective of fog service instance deployment, the instances should be deployed to reasonably minimize the incentives paid to the participating users of the proposed architecture, which is directly linked to maximizing the profitability of the infrastructure operator, while maintaining the performance. The optimization problem for the instance placement to achieve above design goal is formulated with a mixed-integer nonlinear programming, and then linearized. The proposed instance placement scheme is compared with several schemes through simulations based on actual service workload and device power consumption.

Keywords: Internet of things; Fog computing; Software defined networking; Fog container placement; User incentive; Optimization;

1. Introduction

Fog computing is a new computing model proposed to solve various problems, such as high latency, computing and traffic load concentration, and impossibility of location awareness, which may occur when Internet of Things (IoT) services operate in a cloud data center [1]. This concept extends existing cloud services, such as computing, storage, and networks to the network edge near the users or devices. This implies that some of the roles of cloud data centers are moved to a number of geographically distributed physical network devices, such as routers, switches, Wi-Fi access points (APs), and IoT gateways (GWs). Therefore, the application of fog computing can naturally reduce the response time of network services, support real-time services, and enable networking considering location information while realizing all the advantages of cloud computing [2-5].

The main use cases of fog computing consist of Smart City, Smart Building, Autonomous Driving, and the rendering delegation service [6-7]. In Smart City, Wi-Fi APs, IoT GWs, and mobile telecommunication base stations are used as fog devices, which are physical devices that operate fog server instances, to providing IoT services, such as smart traffic systems or disaster detection services, and network access simultaneously [8]. In Autonomous Driving, it is possible to utilize the location awareness feature of fog computing [9]. The advanced driver assistance system of the autonomous vehicle can efficiently utilize traffic information and local features, as well as events on roads at nearby locations, such as construction or accidents, which is rapidly received from a nearby fog device [10]. In the rendering delegation service, when showing information through augmented reality, operations such as augmented reality output data analysis and video processing, which require substantial computing resources and utilize local information, can be processed using computing resources of adjacent fog devices [11]. This is possible because fog computing has a significantly lower latency than cloud computing.

A fog device can be primarily a network device and is typically located between network endpoints, such as the devices and users, and a core network. Unfortunately, if an edge router of the core network becomes a fog device, the overall network performance can be degraded. The edge router provides existing network functions in heavy load, and cannot reflect the local characteristics adequately. Therefore, it is ideal that switches, hubs, Wi-Fi APs, IoT GWs, and base stations in the local network are general purpose fog devices. That is, referring to [12], the fog device in this paper can be a “smart” local network equipment enriched with IT capacities [13-15]. Existing devices, such as sensor nodes, IoT GWs, and smartphones, which are located at a considerable edge of the network, are not suitable for consideration in this study because they may be positioned to provide dedicated services only.

A general-purpose physical server, not a local network device, can also be a fog device, and the server must be connected to a specific local network device for location awareness feature. In terms of service availability, the server should also prevent unexpected events such as power down. Installing this additional high availability server in close proximity of specific local network device is similar to replacing the network devices. In other words, installing an additional server to existing local network device and replacing the network device can be regarded as the same operation.

As with the cloud data center, hardware virtualization is required to provide dynamic resource provisioning to support flexibility and scalability utilizing the fog devices. There are two main types of hardware virtualization, a hypervisor-based virtual machine (VM) and a container. The main difference between these two virtualization is that the VM includes the guest OS and the container does not. That is, the VM provides independent hardware through full hardware virtualization, while the container only supports resource isolation by sharing the kernel. Although each