Simulation Modelling Practice and Theory 50 (2015) 3–19

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

journal homepage: www.elsevier.com/locate/simpat

CoSMiC: A hierarchical cloudlet-based storage architecture for mobile clouds

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ARTICLE INFO

Article history:
Available online 11 August 2014

Keywords:
Storage
I/O caching
Multi-level
Mobile computing
Cloud

ABSTRACT

Storage capacity is a constraint for current mobile devices. Mobile Cloud Computing (MCC) is developed to augment device capabilities, facilitating to mobile users store/access of a large dataset on the cloud through wireless networks. However, given the limitations of network bandwidth, latencies, and devices battery life, new solutions are needed to extend the usage of mobile devices.

This paper presents a novel design and implementation of a hierarchical cloud storage system for mobile devices based on multiple I/O caching layers. The solution relies on Memcached as a cache system, preserving its powerful capacities such as performance, scalability, and quick and portable deployment. The solution targets to reduce the I/O latency of current mobile cloud solutions. The proposed solution consists of a user-level library and extended Memcached back-ends. The solution aims to be hierarchical by deploying Memcached-based I/O cache servers across all the I/O infrastructure datapath.

Our experimental results demonstrate that CoSMiC can significantly reduce the round-trip latency in presence of low cache hit ratios compared with a 3G connection even when using a multi-level cache hierarchy.

1. Introduction

A drastic increase in the number of applications and amount of digital contents such as pictures, songs, movies, and home films on the one hand and the limited storage capacity of mobile devices on the other hand, decelerate usability of mobile devices. While PCs are able to locally store a huge amount of data, smartphones space is limited to few gigabytes, which are mostly occupied by system files, user applications, and personal data [1].

Some recent examples of mobile cloud storage are Apple's iCloud, Google Drive, and Dropbox [2]. These solutions allow users of mobile devices to synchronize their application data such as photos, iTunes music, calendars, email, and messages. Although there is steady growth in mobile storage capacity, the ever increasing appetite of users for high-resolution videos and images promises the increasing popularity of cloud storage [3]. Given the current popularity of cloud computing and the current growing usage of mobile devices since the release of iPhone and Android, two approaches were instantly taken. First, adapting existing cloud services to mobile usage. Second approach is to use nearby mobile devices to collaborate in a common task.

Mobile Cloud Computing (MCC), as defined by Liu et al. [3] "is a model for elastic augmentation of mobile device capabilities via ubiquitous access to cloud storage and computing resources". An extended definition was proposed by Sanaei

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http://dx.doi.org/10.1016/j.simpat.2014.07.007
1569-190X/

et al. [4] "mobile cloud computing is a rich mobile computing technology that leverages unified elastic resources of varied clouds and network technologies toward unrestricted functionality, storage, and mobility to serve a multitude of mobile devices anywhere, anytime through the channel of Ethernet or Internet regardless of heterogeneous environments and platforms based on the pay-as-you-use principle". The objective of mobile cloud computing proposed solutions so far is to extend the capabilities of mobile devices, especially on their weakest areas: computing power, battery life, mobile network bandwidth and latency, and storage capacity.

Another problem addressed in cloud computing environments is data management. Currently, one of the techniques to optimize I/O systems in cloud environments is to decouple the virtual instances from the storage resources [5]. Moving information between different domains has never been a simple task. First, it is costly to deploy virtual machines that need to process a huge amount of data. Second, data access between geographically dispersed infrastructures is significantly increasing the latency perceived by users. Existing cloud computing tools tackle only specific problems, such as parallelized processing on massive data volumes [6] or large data storage [7]. However, these tools provide little support for mobile clouds, where data access is mainly limited by the network bandwidth and latency.

Abolfazli et al. [8] argued that there are open challenges waiting to be resolved in the MCC research area. Among them, we highlight seamless ubiquity, context awareness, and resource scheduling due to the following reasons. First, current mobile infrastructures have to ensure connectivity in all possible scenarios. Second, given the huge amount of data generated by smartphones, data must be allocated as close as possible in order to reduce data transfer latency [9]. Third, an adequate usage of the resources is completely necessary for reducing system peaks and overheads. Recently, Aminzadeh et al. [10] points that the energy consumption of mobile devices is one of the open issues to be addressed in MCC.

This work aims to present the architecture of a hierarchical storage solution for large scale mobile cloud systems. The storage solution fills the latency gap between mobile devices and the final cloud-based storage systems. We present a cloudlet-based cache storage infrastructure, namely CoSMiC. Our solution could be used to deploy storage in-a-box systems, on all the levels of the datapath hierarchy. Mobile applications benefit from this solution by improving data locality, reducing application execution times, and saving money and battery life in mobile devices due to the use of Wireless Local Area Network (WLAN) connections instead of Wireless Wide Area Networks (WWAN) such as 3G or HSDPA.

The contributions of this work are the following. First, we present a cloudlet-based hierarchical storage system that reduces data access latency of current large scale mobile cloud infrastructures. Second, the proposed solution could be easily deployed on heterogeneous and low power computational systems, including clusters and clouds. Third, using both configurable hash and address algorithms included in Memcached [11] client library, the CoSMiC front-end is completely decoupled from the I/O servers, resulting in an increase of scalability. Fourth, CoSMiC allows system monitoring, taking into account the usage of Memcached statistics with extended metrics. Fifth, CoSMiC have been evaluated in a realistic environment, demonstrating that it can reduce the round-trip latency perceived by mobile devices.

The remainder of this paper is organized as follows. Section 2 reviews related work and background. Section 3 presents the design details of CoSMiC. In Section 4 we present some possible scenarios and deployment examples. In Section 5, we show our evaluation results. Finally, we conclude and discuss about future uses of CoSMiC in Section 6.

2. Related work

Mobile devices have very limited resources, being their main weak points computing power, storage space, and battery life. To augment computing power and improve battery life, highly compute demanding applications are offloaded to the cloud. In order to achieve this objective, several solutions have been presented, some of them, based on the use of Hadoop [12,13] over virtual machines and focused in determining cost-benefits of the offloading, considering also the data transfer required before and after computation. CloneCloud [14] and MAUI [15] are examples of compute offloading in distant fixed clouds, while Hyrax [16] and Phoenix [17] propose a solution for offloading between nearby mobile devices.

In the following subsection we present and compare previous works related to CoSMiC. We will focus on traditional immobile cloud solutions for storage and hybrid-based approach for MCC. Finally we discuss about similar works that rely on distributed caches as a storage infrastructure.

2.1. Immobile cloud resources for storage

The most common approach for mobile cloud storage is the adaptation of already known and highly used cloud storage services like Apple iCloud, Google Drive, Microsoft SkyDrive, or Dropbox [18], and cloud storage back-ends such as Amazon S3 [19] and Windows Azure Storage [20].

Currently, one of the most used cross-platform solution is Dropbox, which offers platform-independent storage, applications for almost every mobile and desktop platforms, secured data with AES-256 encryption, and highly-reliable Amazon S3 as storage system back-end. Also, to minimize the impact of synchronization, it uses binary-delta encoding functions to only upload the changes on each file. Apple iCloud, Google Drive, and Microsoft SkyDrive are leading alternatives and have the advantage of being embedded into their respective operating systems, but as their main negative point, they are cross-platform restricted and lack some of the features offered by Dropbox.