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Mobile storage augmentation in mobile cloud computing: Taxonomy, approaches, and open issues

Nazanin Aminzadeh *, Zohreh Sanaei, Siti Hafizah Ab Hamid

Faculty of Computer Science and IT, University of Malaya, Kuala Lumpur, Malaysia

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ABSTRACT

Worldwide employment of mobile devices in various critical domains, particularly healthcare, disaster recovery, and education has revolutionized data generation rate. However, rapidly rising data volume intensifies data storage and battery limitations of mobile devices. Mobile Cloud Computing (MCC) as the state-of-the-art mobile computing aims to augment mobile storage by leveraging infinite cloud resources to provide unlimited storage capabilities with energy-dissipation prevention. Researchers have already surveyed varied MCC aspects and its challenges, but successful futuristic Mobile Storage Augmentation (MSA) approaches demand deep insight into the current storage augmentation solutions that highlights critical challenges, which are lacking. This paper thoroughly investigates the main MSA issues in three domains of mobile computing, cloud computing, and MCC to present a taxonomy. Also, it examines several credible MSA approaches and mechanisms in MCC, classifies characteristics of cloud-based storage resources, and presents open issues that direct future research.

1. Introduction

Mobile data volume has been increased drastically in recent years. Analysys Mason's report [1] forecasts 6.3 times growth of mobile data volume traffic amid 2013 and 2018. One reason, among the bevy of inducements is the exploitation of mobile devices in various critical domains of healthcare [2], disaster recovery [3], and education [4]. The voluminous and rapidly generated data in various modalities, which is known as big data [5], demands high capacity, flexible, and reliable storage infrastructure.

However, mobile devices are characterized by storage constraints, limited processing, and a short span battery. Storage limitation and energy consumption are critical factors for resource constrained non-stationary computing devices, especially smartphones. High performance and energy-efficient data storage ensures the battery life's augmentation. Despite advancements for augmenting a mobile device's storage including employment of flash and Secure Digital (SD) cards, current rich mobile applications [6] demand higher storage capacity. Reducing the effects of mobile devices' deficiencies and unreliable wireless connections in comparison with wired networks, are the ultimate goal in the plethora of efforts [7,8] and research to realize end-users' demand.

The emergence of the cloud as a rich resource with unlimited computing and storage capacities can be considered as a good solution to mobile devices' resource constraints. The use of a wireless medium, the offloaded data, the dependency

* Corresponding author. Tel.: +60 1125273423.
E-mail addresses: nazanin.aminzadeh@gmail.com (N. Aminzadeh), sanaei@ieee.org (Z. Sanaei), sitihafizah@um.edu.my (S.H. Ab Hamid).

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Table 1
List of acronym definitions.

Acronym	Description
ACID	Atomicity, Consistency, Isolation, Durability
DBMS	Data Base Management System
DSP	Decryption Service Provider
ESP	Encryption Service Provider
GPS	Global Positioning Systems
I/O	Input/Output
IaaS	Infrastructure as a Service
ICN	Information Centric Network
iSCSI	Internet Small Computer System Interface
LMH	Large Mobile Host
MANET	Mobile Ad-hoc Network
MCC	Mobile Cloud Computing
MNO	Mobile Network Operators
MSA	Mobile Storage Augmentation
PC	Personal Computer
PDA	Personal Digital Assistants
PP-CP-ABE	Privacy Preserving-Ciphtertext Policy-Attribute Based Encryption
SaaS	Storage as a Service
SAL	Storage Abstraction Layer
SD	Secure Digital
SIM	Subscriber Identity Module
SLA	Service Level Agreement
SMH	Small Mobile Host
SOA	Service Oriented Architecture
VM	Virtual Machine
WAN	Wide Area Network
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network

on a specific vendor, and data replication are among several challenges in this domain. Comprehensive studies [9–11] have reviewed and tried to address challenges in this area. However, the latest endeavor is to deploy cloud resources to augment computing [12] and storage [13] capabilities for a multitude of mobile devices which leads to the state-of-the-art MCC.

The MCC paradigm combines cloud computing, mobile computing, and networking [14] to enhance the performance and capacity of mobile devices. It is characterized by inherited mobility and rich services from mobile and cloud computing where a resource poverty (storage, computation, and battery) can impede the vision of time-, location-, and system type-free ubiquitous computing [15].

In the previous works [14–19], the MCC domain have been comprehensively investigated from various perspectives. In [19], authors presented an extensive survey of heterogeneity in the MCC domain, presented an MCC definition, identified major MCC challenges, devised its taxonomy, and highlighted several crucial open issues that help to identify future research directions. Cloud-based augmentation [16] surveys the recent mobile augmentation efforts that employ cloud computing infrastructures to enhance computing capabilities of resource-constraint mobile devices, especially smartphones. To the extent of our knowledge, investigation of storage augmentation issues in the MCC domain is a nascent literature and requires comprehensive study and analysis.

In this paper, we comprehensively analyze MSA issues in the context of mobile computing, cloud computing, and MCC where each domain's issues are investigated. Based on the investigated issues, we classify MSA issues into three classes of mobile device, cloud-based and converged issues. Based on a review of prominent MSA approaches in MCC, we classify cloud-based storage characteristics in a taxonomy that encompasses architecture, capacity, tiering, mobility, location, and back-end connectivity. The paper highlights several open issues in MCC for MSA to pave the way for future efforts. Mobile devices and smartphones are used interchangeably in this paper. Table 1 provides a list of acronyms used throughout the paper.

The remainder of this paper is presented as follows. Section 2 presents the motivation for MSA in MCC based on a devised taxonomy of issues. Section 3 reviews current approaches for MSA in MCC. Section 4 provides a taxonomy of cloud-based storage characteristics in MCC. Open issues are highlighted in Sections 5 and 6 concludes the paper.

2. Motivation

Contemporary smartphones are dominant mobile devices that not only provide the basic telephony features of traditional cellphones, but also incorporate the functionalities of several other digital devices, particularly Personal Digital Assistants (PDA), Global Positioning Systems (GPS), sound recorders, and digital cameras [20] and are contributing to rapid digital data generation rate by producing data files, including emails, spreadsheets, bank statements, and multimedia files (i.e., video,