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Augmenting the Computational Capabilities of Mobile Devices with Cloud Computing

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Abstract—*The evolution of cloud computing and mobile computing technologies has drastically revolutionized the current panorama on distributed computing. Smart Mobile Devices (SMDs) have become beneficial and necessary tools of daily life for communication and complicated pervasive mobile applications. SMDs are predicted to be the essential computing devices in the near future with excessive user expectations for accessing computational comprehensive applications analogous to the powerful stationary computing machines. However, applications on the latest generation of SMDs are still overshadowed by battery power, CPU potentials, memory capacity, wireless network bandwidth and the intrinsic limitations in the mobile computing environment. Mobile cloud computing (MCC) mitigates resources limitations of SMDs by extending the services and resources of rich cloud data centers. Distributed application processing has been implemented to leverage the limitations of resources on SMDs by outsourcing the application processing load of mobile device to cloud server nodes entirely or partially.*

Keywords*: Cloud Computing, Mobile Cloud Computing, Computational Capabilities, Application Partitioning, Offloading*

1. INTRODUCTION

Cloud computing is one of the fastest implementing technology in the decade. It has been extensively recognized as the next generation's computing infrastructure. Many companies are trying to implement and introduce clouds because of its simple and flexible architecture. Cloud computing has been adopted by organization which includes, social networking websites, online application design by Google app managers and by Google doc which are some of the important implementation and a step ahead in cloud computing. Cloud models use virtualization technology; this technology helps in slicing a single data centre or high power server to act as multiple machines. It offers some benefits by allowing users to use infrastructure, platforms and softwares provided by cloud providers at low cost.

Mobile devices such as smart phone, tablet PCs etc have become a vital part of human life as they are the most effective and convenient communication tools that are not bounded by time and place. In recent years, applications of mobile devices have increased tremendously with applications in diverse categories such as entertainment, news, games, business, social networking, health and travel. The adulation of these applications can be clearly visible by browsing through Apple's iTunes or Nokia's Ovi suite. Mobility is one of the main characteristics of a prevailing computing environment where the user can continue his/her work seamlessly irrespective of his/her movement. However, the mobile devices are confronting many challenges in their resources such as battery life, storage, bandwidth and mobility and security issues in case of communications. Thus inadequate resources impede the improvement of service qualities.

Advancements in computing technology have extended the use of computers from desktops and mainframes to a vast range of mobile and GPS navigation, environmental sensing, robots etc. A large number of these applications run on mobile systems with limited resources. For instance, mobile phones are battery powered, slow processors and slender amounts of storage. Majority of these applications utilize wireless networks and their bandwidths are of magnitude lesser than wired networks. Meanwhile, increasingly intricate programs are running on these systems like video processing on mobile phones. Thus there is a widely increasing gap between the availability of limited resources and the demand for complex programs.

Distributed application processing is an important software level technique for enabling computationally intensive mobile applications on SMDs. A number of augmentation algorithms have been proposed for alleviating the resources limitations of SMDs—energy augmentation , memory augmentation and application processing introduced the concept of computational outsourcing to conserve mobile device's energy and this was subsequently extended to include remote application execution. In distributed application processing, the resource intensive components of the mobile application are migrated to remote server nodes, which could either be nearby surrogate or remote cloud server node. Distributed application processing enables the execution of computationally intensive applications on SMDs and

conserves utilization of the local resources such as memory, battery, and CPU on SMDs.

2. COMPUTATIONAL CAPABILITIES ENHANCED BY MCC

Cloud computing is a promising solution for mobile computing because of various reasons such as communication, mobility and portability. Further, it is explained how the cloud can overcome the challenges in mobile computing, thereby highlighting the advantages of Mobile Cloud Computing.

- Extending battery lifetime

The battery is one of the major concerns for mobile devices. Various solutions have been proposed to boost up the CPU performance and to handle the disk and screen in a smart manner to curtail the power consumption. However, these solutions require modifications in the design of mobile devices, else they require a new hardware that causes an upshot of cost and may not be attainable for all mobile devices. The technique of Computation offloading is recommended with the aim to migrate the heavy computations and intricate processing from resource-limited devices to resourceful machines. This evades taking an overlong application execution time on mobile devices that out-turns in enormous amount of power consumption.

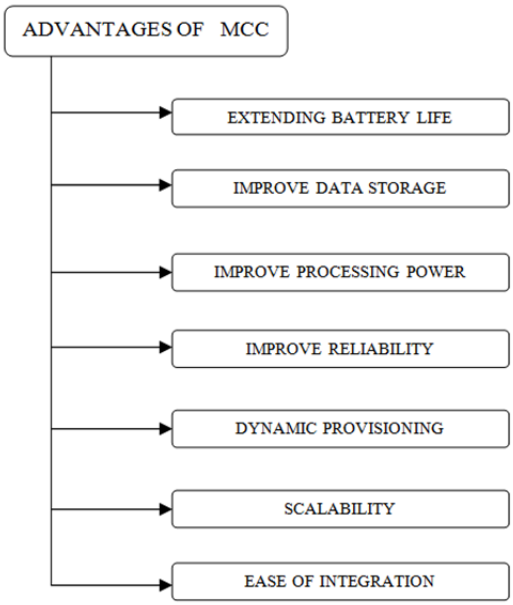

Fig. 1: Advantages of MCC

- Enhancing data storage capacity and processing power

The Storage capacity is an impediment for mobile devices. MCC has emerged to validate the mobile users to store/access the massive data on the cloud through wireless networks Amazon Simple Storage Service is the first example that supports file storage service. Image Exchange is another example which uses the massive storage space available in clouds for mobile users. This service enables mobile users to immediately upload the captured images to the clouds, thereby sharing their photos. Users may retrieve all pictures from any devices. Facebook is the booming social network application currently.

- Improving reliability

Storage of data or running of the applications on clouds is an efficient way to upgrade the reliability since the data is stockpiled and backed up on a large number of computers. This minimizes the chance of losing the data and application on the mobile devices. Furthermore, for both service providers and users, MCC can be outlined as a data security model. For instance, the cloud can be used to preserve copyrighted digital contents such as video, music from being misused and unauthorized distribution.

Additionally, MCC also inherits few assets of clouds for mobile services listed as follows:

- Dynamic provisioning

Dynamic on-demand provisioning of resources is an adaptable way for service providers and also the mobile users to run their applications without any prior reservation of resources.

- Scalability

The deployment of mobile applications can be executed and scaled to handle the unforeseeable user demands because of the flexible resource provisioning. Service providers can append and expand an application and service with great ease.

- Ease of Integration

Multiple services from various service providers can be integrated effortlessly through the cloud and the Internet to handle the users' demands.

3. APPLICATIONS OF MOBILE CLOUD COMPUTING

Mobile applications are gaining increasing share in a global mobile market. Many mobile applications have used the benefits of MCC. In this section, some basic MCC applications are introduced

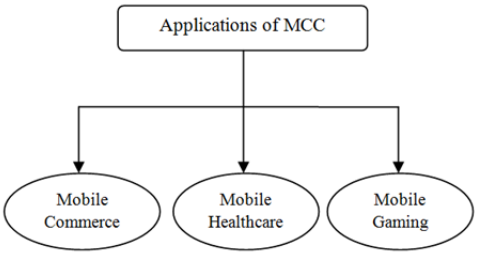

Fig. 2: Applications of MCC

- Mobile Commerce

Mobile commerce is a business model for commerce operating on mobile devices. The m-commerce applications usually fulfill some tasks that need mobility such as transactions and payments, messaging, and ticket booking using mobiles. These m-commerce applications face various challenges like scarce network bandwidth, excess complexity of mobile device configurations, and security. Hence, m-commerce applications are incorporated into cloud computing environment to resolve these issues.

- Mobile Learning

Mobile learning (m-learning) is mapped out on the basis of electronic learning (e-learning) and mobility. Nevertheless, traditional m-learning applications have shortcomings in terms of lofty cost of devices and network, meagre network transmission rate, and slender educational resources. Cloud-based mobile learning applications are initiated to resolve these limitations. For instance, utilizing a cloud with the enormous storage capacity and potent processing ability, the applications furnish learners with great services in terms of data (information) size, speedy processing speed, and prolonged battery life gives advantages of merging m-learning and cloud computing to boost up the communication quality.

- Mobile Healthcare

The purpose of using MCC in medical applications is to curtail the limitations of traditional medical treatment such as little physical storage, security and errors). M-healthcare gives mobile users help to access resources like patients' records quickly. Besides, m-healthcare provides hospitals and healthcare organizations a broad range of on-demand services on clouds.

- Mobile Gaming

Mobile game (m-game) is a prospective market producing revenues for service providers. M-game can entirely offload game engine requiring huge computing resource such as graphic rendering to the server present in the cloud, and gamers interact with the interface on their devices only. Offloading (multimedia code) can retain energy for mobile devices, thereby extending game playing time on mobile devices.

4. RELATED WORK

A number of recent studies have spotlighted the various aspects of MCC (Abolfazlietal.,2014b; Shirazetal.,2013a,b; Abolfazlietal.,2014a; Sanaeietal.,2014; Ganietal.,2014). Yu et al. (2013) studied application mobility in pervasive computing, which classifies and compares mobile application frameworks along with the four dimensions of design concerns in application migration. Their findings provide a systematic reference for developers to leverage different migration strategies for seamless application mobility. Fernando et al.(2012) reviewed previous researches on MCC and proposed a taxonomy for key issues in MCC—operational, end user, service levels, security and context awareness issues—for accessing cloud services. Similarly, Dinh et al.(2011) highlighted different research domains of MCC and provided an overview of the Mobile cloud computing including the definition, architecture, and applications. Recent studies, however, have omitted the procedure of application partitioning for MCC. Jieyao Liu, Ejaz Ahmed, Muhammad Shiraz, Abdullah Gani, Rajkumar Buyya, Ahsan Quresh(2014) have contemplated application partitioning to be an independent facet of dynamic computational offloading and therefore viewed the present status of application partitioning algorithms (APAs) to pinpoint the issues and challenges. The similarities and differences of current APAs are compared on the basis of partitioning granularity, partitioning model, programming language support, partitioning objective, profiler, allocation decision and analysis technique.

The key contributions of this paper are the advantages of mobile cloud computing and analysis of the current techniques based on relevant parameters to identify the issues which impede goals of distributed application processing in MCC. The paper is organized into the following sections. Firstly the fundamental concepts of cloud computing and MCC have been discussed then the benefits and applications of mobile cloud computing have been listed. It also presents an analysis of current APAs based on selected parameters. The next section highlights the issues and challenges in MCC. Finally, next section concludes the paper.

5. CHALLENGES IN MOBILE CLOUD COMPUTING

As mentioned n the previous section, MCC has many benefits for mobile users and service providers. Despite of that, because of the integration of two distinct fields i.e. cloud computing and mobile networks, MCC faces many technical issues. This section enumerates various research challenges in MCC that are related to mobile communication and cloud computing.

- Issues related to Mobile Communication
- Low Bandwidth

Bandwidth is one of the major issues in MCC as the radio resource for wireless networks is skimpier as compared to the traditional wired networks.[63] suggests a solution to share the restricted bandwidth among mobile users who are situated in the same area may be a workplace or a station and engrossed in the identical content like a video file. The authors represent the interaction among the users as a game. Yet the presented solution is only applied when the users in some area are interested in the alike contents.

- Availability

Service availability has become a principle issue in MCC than it is in the cloud computing with wired networks. The Mobile users are unable to connect to the cloud to acquire service due to traffic congestion, out-of-signal and network failures. [6] and [7] presents solutions to guide mobile users in case of the from clouds disconnection. In [6], the authors elucidate a discovery mechanism to locate the nodes in the proximity of a user whose link to the cloud is not available. After nearby nodes which are in a stable mode have been discovered, the target provider for the application is altered. Despite that, it does not take into consideration the mobility, privacy of neighboring nodes and capability of devices.[7] tries to overcome the drawbacks of [6]. Unlike [6], this solution requires moving nodes in the user's vicinity. Each node broadcasts control messages periodically to inform other nodes of its status like connectivity and setting parameters and other local content updates.

- Heterogeneity

MCC would be used in the overly heterogeneous networks in regards of wireless network interfaces. Several mobile nodes access the cloud by means of various radio access technologies like WCDMA, WiMAX, CDMA2000, GPRS and WLAN. Consequently, an issue of how to manage the wireless connectivity while fulfilling MCC's requirements emerges. [7] Suggests an architecture to give an intelligent network access methodology for mobile users to cope up with the application requirements.

➢ Issues related to mobile Computing

- Computing Offloading

Offloading is one of the prime features of MCC to enhance the battery lifetime of the mobile devices and to maximize the performance of applications. But, there are many related challenges including dynamic offloading under environment changes. The main operation in any mobile cloud would be the offloading of jobs that take place from the resource-constrained mobile device to the cloud.

- Security

Protecting user privacy and data/application secrecy from the adversary is a key to establishing and maintain consumers' trust in the mobile platform. The security related challenges in MCC are introduced in two categories: the security for data and the security for users.

- Enhancing the Efficiency of Data Access

The demand of accessing data resources (e.g., image, files, and documents) on the cloud increases with an increasing number of cloud services. As a result, a method to cope with data resources on clouds has become a great challenge. However, managing the data resources on clouds is a tedious problem because of the low bandwidth, mobility and the constraint on resources of mobile devices.

6. RESOLVING THE ISSUES IN MOBILE CLOUD COMPUTING

The applications which are involved in runtime partitioning are known as elastic applications. Application partitioning is a technique of splitting up the application into separate components while preserving the semantics of the original application. In recent years, a huge number of cloud server based frameworks of application offloading have been proposed for outsourcing computational inclusive components of the mobile applications to datacenters of the cloud. Runtime computational offloading involves surrogate discovery, resource estimation and application partitioning.

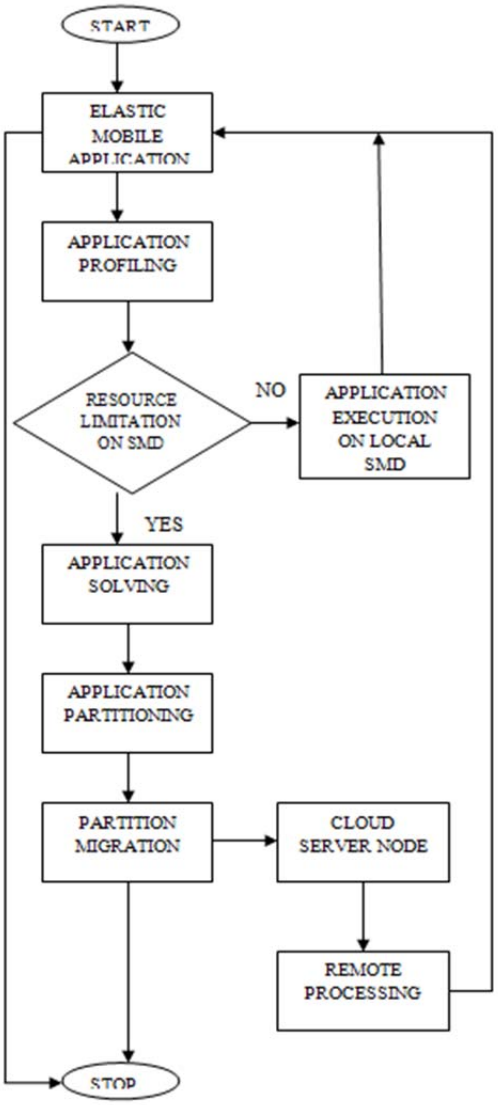

FIG. 3: Flowchart of application partitioning and computational offloading mechanism for MCC

Computational offloading is performed for achieving different functions including saving energy, reducing turnaround time,

conserving memory and CPU of mobile devices. However, in certain cases, the offloading cost could exceed the conserved local resources because of the additional resources utilization in partitioning of mobile application and the deployment of distributed application execution platform. Hence, it is important to adopt appropriate procedures for the partitioning of elastic applications which involve minimal computing resources utilization in the establishment of distributed platform at runtime.

Computation offloading uses partitioning of the mobile application to separate the operational logic of a mobile application into distinct partitions, which are capable of operating independently in a distributed environment. Thus, partitioning of an elastic application is a pre-phase of computational offloading in the contemporary computational offloading frameworks for MCC. Nevertheless, both application partitioning and computation offloading are parts of the execution framework mechanism.

Fig. 3 shows the general flow of operations involving duration of the application partitioning and component offloading for MCC. The elastic application executes on SMD and the application profiling mechanism evaluates computing resources utilization, availability of resources and computing requirements of the mobile application. When there are insufficient resources on the SMD, the application solving mechanism is activated to separate the computational intensive components of the application at runtime. The SMD negotiates with cloud servers for the selection of an appropriate server node and the intensive partition of the application is outsourced to a remote server node for remote processing. Upon successful execution of the remote components of the application, the result is returned to the main application running on the SMD.

7. CONCLUSION

Mobile cloud computing is one of the eminent mobile technology trends in the future as it integrates the benefits of both mobile computing and cloud computing, consequently providing optimal services for mobile users. The applications like mobile commerce, mobile learning and mobile healthcare supported by mobile cloud computing have been reviewed which evidently reveals the mobile cloud computing is applicable to an extensive range of mobile services. The challenges and corresponding approaches for mobile cloud computing have been discussed. Finally, the solutions to curb those issues have been outlined.

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