A Study of Mobile Cloud Computing: Architecture, Applications, and Challenges

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ABSTRACT

The intersection of mobile applications and computing with the promising concept of cloud computing resulted in the birth of Mobile Cloud Computing (MCC). MCC has emerged as a remarkable milestone for global mobile services. Enriching its efficiency and productivity to many dimensions, MCC serves a unique blend of mobile computing and cloud computing seamlessly integrated and tries to overcome issues related to environment (e.g., heterogeneity, availability), security(e.g., reliability and privacy) and performance issues(e.g., bandwidth, storage capacity, battery life). This paper provides an introduction of MCC discussing its architecture and advantages; it then takes a look at various existing application models to MCC. The issues, challenges are discussed. In addition, Future research directions of MCC are also studied.

General Terms

Cloud Computing, Mobile Cloud Computing, Ad-hoc Mobile Clouds, IaaS, PaaS

Keywords

Cloud Computing, Mobile Cloud, Mobile Services and applications.

1. INTRODUCTION

Over the years, since the advent of mobile technology, mobile devices (e.g.,smart phones, tablets, PDAs) have become a natural extension of the individual. Mobile Applications (apps) running on various mobile ecosystems (iOS, Android, Windows Phone) and/or remote servers provide an unparalleled user experience essentially based on wireless networks. The reason being that mobile computing has the ability to provide a tool/service to the user when and where it is needed irrespective of user's location (most of the time), hence supporting location independence. Indeed, ‘mobility’ is one of the highlighted characteristics of a pervasive computing environment where the user is able to get done with his/her work seamlessly regardless of his/her movement. However, with mobility come its problems, problems which every mobile device/machine/tool inherits such as resource scarceness, finite energy and low connectivity as outlined by Satyanarayanan [1]. These present a great obstacle on the way of achieving a ubiquitous environment for the user executing applications, According to Tim O’Reilly ‘the future belongs to services that respond in real time to information provided either by their users or by nonhuman sensors’ [2]. Real time applications are just one type of mobile applications demanding peak responsiveness, which require intensive computing resources. Howbeit, the mobile devices are facing many challenges in their resources (e.g., power, storage, bandwidth etc) and communications (e.g., mobility, security etc). The limited resources significantly (majorly the gap between bandwidth/communication system and performance) act as a barrier in service improvement. Cloud computing (hereby then referred to as CC) has been widely recognised as the next generation computing infrastructure. CC is a versatile ability for providing computing services by the internet on demand and pay per use access to a range of shared resources such as but not limited to networks, servers, services, storage and applications, without acquiring physically. As a result, mobile applications can be rapidly provisioned and released with the nearly no or minimal management efforts or service provider’s interactions. MCC brings all new class of services and facilities to mobile users meant to take full leverage of the robust CC background and hence enhancing the overall user experience, with all the real time responsiveness and intense computing resources, right in user’s pocket.

This current study provides an appraisal of MCC. Section 2 answers the fundamental question “What is mobile cloud computing?” discussing its architectures followed by its merits. Section 3 discusses various application models of MCC. In section 4, we take a deep look into existing issues and challenges in the technology, and in addition, we take a look at future research directions. Finally, we conclude in section 6.

2. MCC: AN OVERVIEW

Deficient resources are a major setback of mobile computing. The connotation of MCC has arisen in order to overcome the resource deficiency of mobile devices, especially smart phones. In order to bring a clear understanding of MCC and its challenges, we examine the respective areas of mobile computing, cloud, and cloud computing.

2.1 What is Mobile Cloud Computing?

According to MCC Forum, MCC is stated as follows:

“Mobile cloud computing at its simplest refers to an infrastructure where both the data storage and data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and MC to not just Smartphone users but a much broader range of mobile subscribers[3].”

According to [36] mobile cloud computing was defined in a 5 March 2010 entry in the Open Gardens blog as "the availability of cloud computing services in a mobile ecosystem. This incorporates many elements, including consumer, enterprise, femtocells, transcoding, end-to-end security, home gateways, and mobile broadband-enabled services." The design of small, powerful devices enables mobility in wireless networks that supports a trend toward computing on the go, known as mobile computing. Satyanarayanan [4] describes the vision of mobile computing as “information at fingertips anywhere, anytime”, while Imielinski and Korth [5] discuss that “The mobile computing no longer requires users to maintain a fixed and universally known position in the network and enables almost unrestricted mobility”.

Figure 1 Mobile Cloud Computing

2.2 Vision for Mobile Cloud Computing

MCC is the state-of-the-art mobile technology with a goal to improvise a plethora of mobile devices, especially smartphones and cope up with their resource deficiency. Mobile users can access their data and cloud services through the Internet by leveraging mobile web [6].These futuristic accomplishments will be employed in several spheres from health to education and social networking to information technology industry. Technological advancement in manufacturing high-end resources for mobile use is slower than the ever-growing demand by mobile users and application requirements. Hence, soft resource augmentation is necessary for delivering breakthrough computing capabilities [7] equaling and even succeeding user's expectations. We advocated that cloud computing is the predominant technology recently deployed to augment smartphones by reducing application resource requirements. Several efforts such as [8], [9], [10]–[11] deploy cloud computing technology to enhance the capabilities of smartphones. Moreover, Cloud computing has a strong information safety and security system. Storing data in smartphones' local storage is a risky practice as they are susceptible to theft, loss, and physical damage. Cloud data storage is envisioned to enhance data safety and security, provide pervasive accessibility, and facilitate data portability and synchronisation among several devices (e.g., Smartphones and PCs). MCC associates the idea to reduce the development cost and raise the execution of resource-hungry mobile applications by combining distant resources to enhance the quality of user experience.

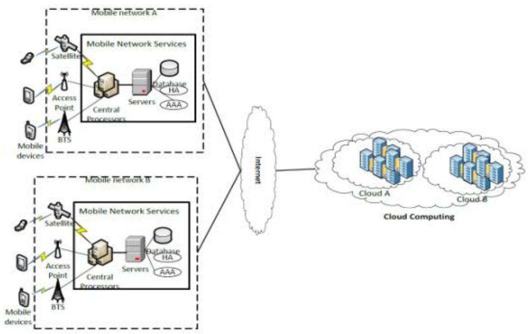

Figure 2 Mobile Cloud Computing Architecture [46]

2.3 Architecture

The general concept of Mobile Cloud Computing is shown in Fig. 2. In Fig. 2, mobile devices are connected to the different or same mobile networks via base stations (such as satellite or access point) that establish and operate the connections (air links) and functional interfaces between the networks and mobile devices. Mobile users' requests and information (viz. ID and location) are transferred to the central processors that are connected to servers providing network services. In such situations, mobile network operators can provide security services to mobile users as authentication and accounting. After that, the subscribers' requests are transported to a cloud through the Internet. In the cloud, cloud management processes the requests to provide mobile users with the set of cloud services. These services are developed with the concepts utility computing, virtualisation, and service-oriented architecture (such as the web, application and database servers).

2.4 Advantages of Mobile Cloud Computing

2.4.1 Enterprise Advantages

MCC can provide many advantages in an enterprise. It can reduce investments on tools as they can be shared and the saved money can be used to buy new tools to provide new features to customers. MCC can increase the reach of product to customers across its network and to other networks as well; also more developers from different areas can join the Cloud. Advantages like this results in large margins of profit.

2.4.2 Alleviation of Mobile Resource Poverty

a) **Extending battery lifetime.** The battery is the lifeline of mobile devices. Several solutions have been proposed to enhance the CPU performance [12] and to manage the storage, screen, and other sensors in an efficient manner to reduce device power hunger. However, these changes are fundamentally hardware-based that resulting in increased cost and not even feasible for all mobile devices. Computation offloading technique is proposed to transfer the large computations and complex processing from resource-limited devices (i.e., mobile devices) to resourceful machines (i.e., servers in clouds). Cloud computing saves time and processing power spent on a mobile device, which turns out to be very expensive from the energy perspective. Rudenko et al. [13] and Smailagic and Ettus [14] evaluate the effectiveness of offloading techniques through several experiments. The results are clearly in favour of the offloading. The process saves energy significantly. Especially, Rudenko et al. [13] assess large-scale numerical computations and shows that energy consumption can be reduced for large matrix calculation upto an extent of 45%. Many mobile applications take leverage of this remote processing.

b) **Increasing reliability**. Mobile devices are prone to physical as well as data level damages. Cloud Computing reduces the chance of data and application getting lost on the mobile devices as the data is stored in infrastructures specially built for this. Moreover, MCC can be designed as a data security model for both sides, i.e., service providers and users. Thus increasing reliability. [17] and [15] discusses some of its applications such as piracy check, virus scan and ID authentication process.

c) **Increasing computing capability and storage capacity**. In case of mobile devices, low storage is also a fundamental problem. Devices can't handle large sums of data required by certain applications. Even if they can store it, it will turn too expensive for on system memory hence, not feasible. Examples include Google Drive [18] from Google inc., which provides its users facility to store their data in the cloud. iCloud [19] by Apple Inc. features the same capabilities as Google Drive, along with other ecosystem-based features (exclusively for iOS and Mac OSX) such as Continuity [20] and Keychain [21]. Instagram [22] is a free, photo-sharing mobile application that used cloud storage to save user's photos. Users can save energy and storage spaces as all the images are stored and processed on the Cloud(s). ShoZu [24] and Flicker [23] are also the successful mobile photo sharing applications based on MCC. Facebook is the most successful social network application today [35].

3. EXISTING APPLICATION MODELS FOR MOBILE CLOUD COMPUTING

3.1 Modularised Applications

Mobile clouds feature a diverse environment, thus executing applications in such an environment demands real-time or dynamic partitioning of programs and remote execution of some components for achieving better performance and efficiency. There could be a significant rise in performance if the mobile applications divide some section of theirs to run on a high-performance remote server.

Giurgiu et al. [26] developed an application middleware that is concerned with automatically sectioning different modules or layers of an application software between the mobile client and the server after taking in considerations such as data transfer, expense, latency , etc. The approach is driven by automated module management, which carefully determines which partitions of application will run on the client and the ones to be executed on the server. This whole process is done in such a way that produces most optimised results at minimal costs. Giurgiu et al. employ the AlfredO [27] framework to perform the distribution of the application modules between the mobile device and the server. The AlfredO framework provides developers with the capability to dissolve and distribute the presentation and logic layer of the software, while the data layer always stays on the server side. Only the UI of software needs to be run on client side.

MAUI [16] is a system that carefully offloads mobile code to the cloud server, maximising the battery life of a mobile phone. Developers mention which methods are to be offloaded, during programming stage. Applications are offloaded from phones to surrounding infrastructure—i.e. local and remote servers. Implemented in.NET, MAUI's partitioning is done at runtime and is very dynamic. The profiling information is collected for functions offloaded once; this information is further used for determining which function is to be overloaded. The profiling information, network connectivity measurements, bandwidth and latency estimations are used as parameters for determining which method is to be offloaded for best possible optimisation, periodically. Compared with [26], MAUI allows an offloading technique down to the level of single methods, where [26] the offloading happens on complete software modules.

A reference framework that breaks down the application into several components called weblets, with highly dynamic execution developed by Zhang et al. [29], [30].The weblets, are platform independent and can be executed on mobile devices or IaaS (Infrastructure as a Service) cloud providers such as Amazon EC2 and S3. The application is broken down to a UI component called weblets, and a description of the application (Weblets are autonomous software units and perform computing, storing and network tasks). An elasticity manager is present to take decisions on migration, instantiation of the weblets. The merit of using weblets , over AlfredO and R-OSGi is that weblets do not stick to one particular programming language or paradigm, allowing a broader range of applications.

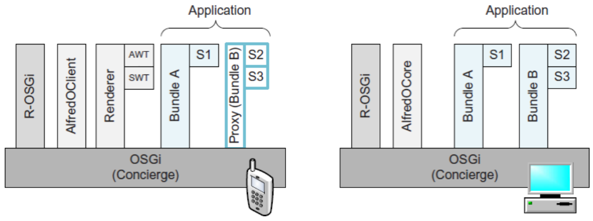

Figure 3 AlfredO Architechture

Scavenger [40] is another approach that uses cyber-foraging using WiFi as a connectivity medium and mobile code for partition and distribution of jobs. It also incorporates a scheduler for cost evaluation. Its technique of cost assessment is based on the speed of the surrogate server, and it uses a benchmarking method to do this. According to tests running the application on multiple proxy servers is more efficient in terms of performance; we can use this approach via Scavenger. However, it is not dynamic as this method is about surrogating and not sharing, also it does not talk about tolerance mechanisms. It is still unclear that such a method can be used on mobiles as all the surrogates are desktops.

3.2 Ad-hoc Mobile Clouds

The ad hoc cloud is an infrastructure in which software is shared over resources gathered from existing machines within a region. Unlike the data centre cloud model, resources are not dedicated to clouds while in use. The machines participating in Ad-Hoc Could are assigned specific jobs [31].Offloading to nearby mobile devices saves monetary cost because data charges are avoided, especially favoured in case of roaming. However, such an approach requires the support for spontaneous interaction networking with availability and agreement of mobile peers. Guidelines to create a framework imitating conventional cloud service providers' using shared resources of nearby mobile devices is put forward by Huerta-Canepa and Lee [32]. This approach allows avoiding a connection to infrastructure-based cloud providers while still reaping the benefits of computational offloading, a virtual mobile cloud focusing on common goals in which mobile device are considered as resource providers. On a surrogate device, the tasks are implemented on a virtual machine acting as a protected space thus ensuring the security of device data.

Marinelli [33] has presented 'Hyrax' for Android smartphone applications that are distributed both in terms of data and computation based on Hadoop [34] ported to the Android platform. Hyrax examines the possibility of using multiple mobile phones as resource provider and explains the feasibility of same. This ported version is used for sharing of processing tasks and storage. Communication is based on the Extensible Messaging and Presence Protocol (XMPP)[34]. Hadoop is an Open Source implementation of MapReduce [35] and provides a virtual interface to a cluster of computers scaled randomly. In Hyrax, data and jobs are coordinated and scheduled by a central server having access to each mobile device. The phones are connected using an isolated 802.11 g network.

3.3 Augmented Execution

Augmented execution represents a technique used to overcome the resource poverty of smartphones; in terms of computation, memory and battery. Chun and Maniatis [10] propose a framework that tries to overcome these challenges by offloading execution from the phone to a more resource equipped machine (cloud) where cloned replica of the smartphone's software is running. Some or all of the computation and memory demanding apps of mobile devices are transferred to cloud. The cloud runs a cloned image of device. The result so produced is then combined upon completion. This method uses loosely synchronised virtual or emulated clones of the mobile device in the cloud. Thus, it creates an illusion that the mobile device is more powerful (than in reality). The developer is programming such majestic device without having to manually distribute the application processes to overcome any lack of resource.

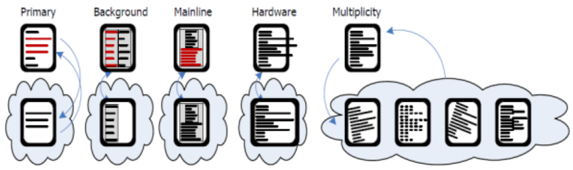

Figure 4 Categories for augmented execution [47]

Figure 4 shows categorisation of possible augmented execution for mobile phones:

a) **Primary** - This is like a client-server application.

b) **Background** - Good for processes that run in background.

c) **Mainline** – this is a blend of both primary and background.

d) **Hardware** - A cloned replica which runs a rather more powerful virtual machine.

e) **Multiplicity** - Good for parallel jobs.

A similar kind of approach is discussed by Satyanarayanan et al. [36]. In this method, a mobile user utilises Virtual Machines to quickly start a service software on a nearby cloudlet and uses the service over WLAN. A cloudlet is a trusted, resource-rich computer or a set of computers connected to the Internet and are ready to be used. The cloudlets eliminate the long latency that was caused by wide-area networks for using the cloud resources. As a result, the responsiveness and interactivity are increased. The mobile client acts as a thin layer, with all significant computation going on in a nearby cloudlet.

3.4 Application Mobility

Many mobile devices of diverse configurations access the mobile cloud. Same application needs to be run of these devices seamlessly. The application mobility plays a vital role in achieving this. Application mobility, as the name suggests, is the process of transferring active applications from a host to another in their current state [38], [39]. Application mobility is closely related to process migration. It is an Operating System feature, which allows moving an active application to another machine by pausing on former and resuming after relocation. It promises seamless mobility and has been the focus of many research projects [42]. However, application mobility involves more than process migration, e.g., migration tasks to different architectures or UI adaptation.

Satyanarayanan et al. [37] discusses a framework called Internet Suspend/Resume (ISR). ISR allows seamlessly resume a job on different machine after suspending it on some other machine over Internet. Its implementation is based on virtual machine technology and distributed file system. The distributed file system is responsible for transporting the state where each VM packs distinct customisation and execution state. However, it has some drawbacks, one being that migration of complete VM consumes more time and bandwidth.

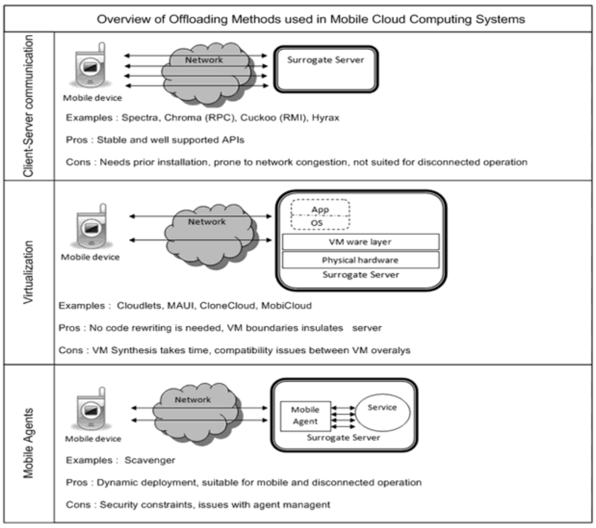

Figure 5 overview of offloading methods in mobile cloud computing (adapted from [41])

3.5 Comparison of Approaches

The comparison of existing application models and approaches for mobile cloud computing will point out the way for future advanced models for mobile applications. Here, we point out the above-mentioned models, according to following parameters:

i) **Core technologies:** what are the foundational technologies powering the model and achieving desired characteristics?

ii) **Cost Analysis:** Are the models giving the most optimised performance?

iii) **Programming model**: Are programming methods and tools robust enough to create rock-solid applications, along with full control over all the components?

iv) **Generality:** does the solution exists and is possible for all the applications?

v) **Scalability:** Is application able to scale?

vi) **Development complexity:** what is the level of complexity in developing an application?

vii) **Network loading:** How much load does the model impose on network, what is the degree of latency introduced?

viii) **Static and Dynamic Adaptation:** What is the distribution of processes between server and client side?

A tabulated comparison of the existing approaches and models, on the basis of above described parameters, is presented in Table 1.

4. ISSUES AND CHALLENGES IN MCC

MCC is a technology not devised far back in time, bringing the sophisticated and powerful concept of cloud computing to mobile computing certainly gives birth to some issues in the technology, which are a direction for future research. In this section, we discuss the various existing problems and issues, both addressed and unaddressed yet. The problems can be categorised as issues in mobile communication and issues in computing side.

4.1 Mobile communication issues

i) **Heterogeneity:** Many heterogeneous nodes connect to mobile cloud using different connection technologies such as GPRS, WCDMA, WAP, WiMAX, LTE etc. Therefore, maintenance of mobility and the requirements of mobile cloud computing for different network technologies bring a multitude of problems.

ii) **Availability**: The availability of services becomes a major issue in case of Mobile Cloud Computing than that with Cloud Computing (Wired). Various problems such as network congestion, network failures, and low-signal connectivity. Huerta-Canepa and Lee [32] propose a solution to the problem of 'disconnection from clouds'. In [32] authors put forward a mechanism to discover a cloud-connected node in the vicinity of the user, experiencing the issue. After this, target provider for the application is changed. Thus in ad-hoc manner user can overcome problem. The main challenge before this approach is the privacy and capability of neighbouring mobiles. Zhang et al. [43] tries to overcome the setbacks of [32]. In [43], authors propose WiFi based multi-hop networking system called MoNet and a protocol for distributed content sharing in case of service unavailability. Each moving node distributes messages containing information about the device such as power, storage, bandwidth, connectivity, etc periodically. Based On these continuous updates, nodes identify other nodes in vicinity with highest resources and lowest hop.

iii) **Low-Bandwidth**: One of the major issues in mobile context is the deficiency of bandwidth of wireless networks in comparison to the traditional wired ones. Jin and Kwok[44] propose a solution to this problem for users accessing the same content in an area(e.g., Video file). In the proposed framework, users in an area form a coalition, where each member handles a part of the file(sounds, images, subtitles, etc.) and transmits/shares this resource with other members. This results in overall improved video quality. However, the solution works only in a case where all the members are accessing the same content.

4.2 Computing Side Issues

4.2.1 Computing Offloading:

In section 3, we discussed the concept of computational offloading and its relevance to MCC. It improves battery longevity by saving energy and shifts high-end computational task to cloud servers for improved performance of mobile applications. Howbeit, there are certain problems regarding efficient and dynamic offloading under heterogenous environments.

i) **Static offloading:** It is known that offloading saves power, experiments in [13] point out that offloading does not save power always. Under some situations, it might be sucking more energy out of the device. For example; offloading sucks 5% of the device's energy, when communicating compiled code worth 500KB of size. Whereas, onboard processing consumes nearly 10% of battery. If the size of compiled code reduced to half, i.e., 250KB, efficiency falls off by 30%. When the code is small in size, local processing seems more advantageous than offloading. Therefore, it turns out that deciding which portions of the code is to be offloaded and when, for achieving most optimised performance is a tough job for mobile devices. Furthermore, heterogeneity in terms of mobile communication technologies, data transfer rates and related energy consumption varies.

ii) **Dynamic Offloading**: Offloading in a dynamic environment invites more issues, due to changing parameters such as signal strength, bandwidth. For example, sent data may not reach its destination or data to be received through server after computation may not reach the device.

4.2.2 Trust, Security and Privacy

An endless issue will always be the need of better security and ensuring user privacy/secrecy in cloud computing related to multi-tenancy, concurrency, scale and distribution. Firstly, grave concerns for characteristics such as lacking control over data and distribution of code in scattered infrastructures, potential data loss. Secondly, indirect issues arise from making virtually unlimited computational resources available to perhaps untrusted entities or personnel [45].

4.2.3 Enhancing the efficiency of data access

With an outburst of cloud services, the demand of on-cloud resources is also increasing. Thus, a related operation on data resources such as accessing, manipulating, storing and managing on such a large scale poses a great challenge. In case of MCC, the problem gets more tough due to various limitations associated with mobile devices namely, low bandwidth, Battery power, low computational power and mobility. Commercial providers perform every I/O operation at file level resulting in increased communication costs for mobile users.

5. CHALLENGES IN MCC

On the basis of related works, we discover that the under-listed issues have not met a plausible solution yet these pose a gap in reviewed work and are potential future research directions in the field.

a) **Incentives for users:** If it is desired to bring more users to network for the purpose of exposing their resources and collaborating harmoniously with other users, there must be some benefit or incentive whether it monetary or social, to serve as attraction/motivation for new users to join in. The service may work fine when all the users have a common objective, but what if there isn't? Will such a network persist? And even if we agree on providing monetary incentives. What would be the basis of measuring scale for it? In case of high heterogeneity in mobile ecosystems, how will the resources contribute measured?

b) **Security in MCC:** Albeit security is an issue of great importance, it has not been successfully achieved yet. Also, any significant researches are not carried out in this direction. A sense of confidence regarding their security and privacy must be invoked in the user so that they can offload their data and applications with peace of mind and satisfaction.

Table 1 Comparison of existing approaches and models.

Application models/frameworks	Core technologie s	Cost analysis	Programmin g model	Generalit y	Scalability	Developmenta l complexity	Networ k loading	Static adaptattio n	Dynamic adaptatio n
Offline	Vendor SDK	/	/	medium	low	low	high	high	low
Online	Web services, HTML5.0	/	high	low	high	low	medium	high	high
Chun and Mantiatis[14] (CloneCl-oud)	DalvikVM (An- droid)	in [14]	/	low	high	high	low	high	low
Girgiu et al [31](AlfredO and R-OSGi)	OSGi, Java	consumpt-ion graph	high	medium	medium (vertical)	low	low	high	low
Cuervo et al.[12] (MAUI)	.NET	linear optimisati -on	high	high	high	low	low	high	high
Zhang et al. [13] (Weblets)	REST, C#	Na ̈ıve Bayes Classifier	high	high	high	low	/	high	high
Ahlund et al.[44]	P2P	/	/	low	/	low	/	medium	/
Satyanarayanan et al. [43] (ISR)	VM, Distributed File System	/	medium	low	medium (vertical)	low	high	low	low
Huerta-Canepa and Lee [38]	Hadoop, XMPP	/	high	low	high(hori-zontal)	low	high	medium	low
Cao et al. [50] (Mo-bile WS)	Web services	/	high	medium	medium (vertical)	low	medium	medium	low
Satyanarayanan et al. [42] (Cloudlets)	VirtualBox Dynamic VM syn-thesis	/	high	low	low(vertic-al)	low	low	/	/
Marinelli [39](Hyrax)	Hadoop	/	high	medium	high(horizo -ntal)	low	high	medium	medium

c) **Seamless cloud connectivity on the go:** Mobile Devices using cloud services on mobile networks such as 3G or 4G LTE. Even if the services are satisfactory, data costs and latency has a profound impact on running applications, which access remote server for execution.(e.g., Apple Siri, Dictionary, Google Translator). The 'cloudlet' concept put forward to such problems may aid but would not fully support the user who is truly 'mobile', such a user must be moving in a certain region span of a local cloud server such as a 'cloudlet' to access its services. Thereby, if a user walks out of the span of a local server, while a task yet to reach its completion, it would result in failure of that task until the support additional network exists. Such local servers at public places are an infrastructural concern, even for most developed countries.

d) **Standard Interface.** Interoperability is a major question when it comes to interaction and communication between mobile users and cloud. In the present scenario, the interface between mobile devices and cloud servers are mostly web based. However, web services may not be the best answer to the above-mentioned question as the web services are not devised specifically for mobile needs.

Therefore, may lead to additional overheads. Also, compatibility among heterogenous mobile ecosystems could pose an obstacle. In this situation, the standard protocol, signalling, and interface for interacting with mobile users and cloud servers would be required to achieve seamless services.

6. CONCLUSION

The power and sophistication of Cloud Computing added to the convenience and mobility of Mobile Computing has created a brand-new research impetus in mobile technology, known as Mobile Cloud Computing (MCC). The foundational motive behind MCC was to enrich the existing Mobile computing experience by releasing it from limitations due resource poverty of mobile devices. With the addition of raw-computing power backed by cloud, just in inches of space and available on the go, has a promising future ahead, with global market for MCC expected to crash at unbelievable $46.90 billion by 2019 [46].

In this paper, we gave an overview of MCC, its definitions, architectures, advantages and motives. Further, existing application models for MCC were discussed. Later on, we saw various issues and problems in the technology. In the end, we outlined challenges and future research directions in MCC.

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