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Challenges and Future Research Directions in Mobile Cloud Computing

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Abstract— ***In society today, mobile communication and mobile computing have a significant role in every aspect of our lives, both personal and public communication. Mobile cloud computing guarantees a few advantages, for example, additional battery life and capacity, adaptability, and unwavering quality. Be that as it may, there are still several difficulties that must be tended to so as to empower the pervasive deployment and selection of versatile mobile cloud computing. A portion of these difficulties incorporate security, protection and trust, band-width and data transfers, data management and synchronization, energy efficiency, and heterogeneity. We introduce a careful review of mobile cloud computing and separate it from conventional cloud computing. Additionally presented here is a nonexclusive architecture that assesses recently proposed mobile cloud computing research structures. This is accomplished by using an arrangement of assessment criteria. At last, we discuss future research challenges that require further consideration.***

Keywords— Cloud Computing, Mobile cloud computing, cloud computing services, Challenges and Future Research Directions.

INTRODUCTION

The increased use of mobility with Information Communication Technology (ICT) has dramatically changed the way of our lives. Mobile devices such as PDAs, tablet and smarty phones became an integral part of our lifestyle. According to the International Data Corporation (IDC) statistics [1], the worldwide expected growth for smart phones shipments is 40.0% year over year in 2014. Also Cisco Internet Business Solutions Group (IBSG) [2], the usage of smart phones grew from 50 to 80 percent in 2013. Recently, it was reported that more than 240 million of Mobile Cloud Computing (MCC) customers will use cloud services with an earning revenue 5.2 billion dollars in 2015 [3].

MCC is a subset of Cloud Computing (CC) that enables convenient, on demand network access and storage which can be used to deliver different types of services and applications to the mobile users [4]. In MCC environment, CC, mobile computing and networking are combined to offer cloud-based services to mobile users where the data are stored and applications are processed in a centralized computing application located in the clouds. MCC paradigm is employed to mitigate the critical issues in mobile devices including battery life, computational power, limited processing and storage limitations.

In this study, we compare and contrast traditional cloud computing with mobile cloud computing. We compare several recent surveys on mobile cloud computing by highlighting their focus; the components of the proposed architecture for mobile cloud computing if there is any, expressing their contributions, identifying the analysis technique used to determine research challenges for mobile cloud computing and describe these challenges. Moreover, we propose a generic architecture that covers all layers of mobile cloud computing to identify the relevant issues.

To study these research architectures, we identify several assessment criteria. As well, we provide a holistic view of the current status of mobile cloud computing by presenting a quantitative analysis (i.e., where statistical information about mobile cloud computing architectures is used), and benchmark comparison to determine research challenges formobile cloud computing which represent the main contribution of our work. Furthermore, we also discuss future research challenges for mobile cloud computing based on the comparison of the recent representative mobile cloud computing research architectures.

The rest of the article is organized as follows. In Section 2 we pre-sent the related work and compares recent surveys on mobile cloud computing. In Section 3, we present some background information and document a comparison between traditional cloud computing and mobile cloud computing. In Section 4, we propose a generic architecture for mobile cloud computing and identify a set of dimensions which are used for comparing recent representative mobile cloud computing research architectures. In Section 5, we discuss critical research challenges and propose future research directions. In Section 6, we make some concluding remarks and point out the implication of this research.

LITERATURE SURVEY

Mobile cloud computing has been an active research area in recent years and several surveys have been published on this topic. Chetan et al. [5], conducted one of the first surveys that focus on mobile cloud computing issues. This survey presents an overview about how mobile cloud computing works, discusses some problems and possible solutions related to mobile cloud computing, and outlines the ad-vantages of mobile cloud computing. Furthermore, the survey presents some research issues that need to be addressed such as absence of standards, access schemes, security, and the need for elastic mobile applications [2]. Present an overview of mobile cloud computing definitions, architecture, and benefits. The survey proposes architecture of mobile cloud computing which consists of five components including mobile users, network operators, Internet service providers, application service providers, and datacentre owners. Apart from a discussion of the issues, existing solutions and approaches of mobile cloud computing, the survey provides future research directions in mobile cloud computing with a focus on low bandwidth, network access management, quality of service, pricing, standard interface, and service convergence

In addition, the survey proposes a mobile cloud computing architecture which consists of five components including privacy and security manager, context manager, resource handler, cost manger, and job handler. Furthermore, the study provides an overview of cost models in mobile clouds and a comparison of connection protocols used in mobile clouds. Based on the results of the comparisons, the authors think that the challenging re-search issues in mobile cloud computing include operational, presentation and usability, service level, privacy and security, context awareness, and data management. Rahimi et al. [6], present a survey on mobile cloud computing and provide a comparison of 16 mobile could computing systems based on a set of criteria including objectives, used technology, wireless connectivity type, and security and privacy. The surveys discuss some research open issues such as power and execution time efficiency, communication bandwidth efficiency, and security and privacy.

More recently Stergiou and Psannis [7], in their more generic survey cover the latest advances in mobile cloud computing and Internet of Things (IoT) is concerning big data applications. There is an emphasis on the main features and trade-offs concerning IoT and mobile cloud computing. Furthermore, the survey discusses research challenges such as security, connectivity, performance, latency, and privacy [8]. Look at existing infrastructure-based mobile cloud computing applications in their analysis. They categorizes mobile cloud computing into four categories namely i) crowdsourcing applications, ii) collective sensing applications (e.g., traffic monitoring, social networking, and healthcare), iii) location-based applications, and iv) augmented reality and mobile gaming applications.

Furthermore, the research challenges that emerge in their paper include code computation (off-loading), task-oriented mobile services, elasticity and scalability, security, and cloud service pricing. Abdo and Demerjian [9], investigate mobile cloud computing architectures and applications. In particular, the survey proposes a mobile cloud computing architecture characterized by four components specifically E-UTRAN, mobile operator's core network, internet, and cloud service provider's network. Moreover, their study presents a comparison of four mobile cloud computing architectures' performance against non-quantifiable requirements which include privacy, mobility, scalability, and multi-cast capability. In addition, the survey compares 14 mobile cloud computing applications performance when deployed across different mobile cloud architectures. The application performance is measured using quantifiable metrics such as cost, delay, and power consumption.

Furthermore, the challenges they found requiring further analysis concerning authentication in mobile cloud computing include heterogeneous infrastructure, seamless handover, identity privacy, and resource scheduling. Gai et al., 2016a [10], explore intrusion detection techniques for mobile cloud computing in heterogeneous 5G. In their comparison of 5 intrusion detection techniques for mobile cloud computing, they employ a set of metrics comprising methodologies, principle, performance, and limitations. Offered here is a high level framework for leveraging mobile cloud computing-based intrusion detection systems onto mobile applications. This framework consists of five components including mobile users, mobile apps, cloud-based applications, cloud-based intrusion detection systems, and heterogeneous 5G network.

Similar issues were covered by Paranjothi et al. [11] who investigated mobile cloud computing offloading, computing distribution, and privacy. They pro-posed an architecture for mobile cloud computing which consists four components; mobile devices, wireless core, WiFi AP, and Regional Data Centres (RDC). Moreover, the research compares current frameworks in mobile cloud computing such as Clone Cloud, MAUI, and Odessa. Furthermore, the survey discusses mobile off-loading applications in mobile cloud computing and some privacy approaches that can be used when off-loading such as encryption (Cui et al., 2013). Look at energy efficiency in mobile cloud computing devices. More specifically, the authors present an overview of the universal energy estimation model for mobile devices, and provide a summary of energy-efficient wireless transmission mechanisms.

Barbera et al. [12] present a feasibility study on both mobile computation offloading (i.e., where computation is done in the cloud) and mobile application data storage in the mobile cloud computing environment. They demonstrate that mobile cloud computing can help reduce financial costs and energy consumption when reasonable data synchronization intervals (i.e., situations when mobile data needs to be synchronized with the cloud) are being considered Ma et al., [13]. In their analysis focus on the issue of locating sensing energy efficiency in the mobile cloud computing environment. In particular, the authors propose architecture for mobile cloud computing which consists of six components: end users, wireless network interface, hardware layer, infrastructure layer, platform layer, and application layer. Moreover, the author's differentiate several methods for locating sensing energy efficiency based on different criteria such as the tracking target, sensors used, and scheme.

Other surveys on mobile cloud computing focus on specific aspects such as application execution, augmentation approaches (e.g., off-loading applications), heterogeneity, and multimedia. For example, Ahmed et al., 2015b [14], comprehensively survey the application execution of frameworks applicable to mobile cloud computing. Their proposed architecture for mobile cloud computing consists of three components, these being mobile users, base station, and cloud datacentre. In addition, the survey identifies and classifies seamless application execution enabling approaches. Furthermore, their advantages and disadvantages are specified. Ahmed et al. compare 14 application execution frameworks based on a set of criteria including: cloud usage overhead, mirror deployment, pre-execution delay, caching support, and parallel execution support. Furthermore, these authors document research challenges for mobile cloud computing application execution including user-transparent cloud discovery, unobtrusive application off-loading, optimal live Virtual Machine (VM) migration, seamless computational resources handover, and agile security and privacy mechanism.

Another recent comprehensive survey is that by Zhou and Buyya [15], who focus on mobile cloud computing augmentation frame-works. They present taxonomy of mobile cloud computing augmentation techniques, and these authors identify the advantages and dis-advantages for each type. Moreover, the survey compares 24 mobile cloud computing augmentation frameworks with a discussion of pertinent research challenges in mobile cloud computing augmentation, for example service heterogeneity, service context-awareness, Quality of Service (QoS) management, and reliability and security management. Mobile cloud computing augmentation approaches are also covered by Abolfazli et al. [16], who classify augmentation approaches into two categories, hardware and software. Hardware approaches focus on generating high-end resources while software approaches focus on soft techniques such as conserving local resources and reducing resource requirements. In addition, the authors present a comparison of 7 mobile cloud computing augmentation approaches.

Sanaei et al. [17], explore heterogeneity issues in mobile cloud computing and they classify heterogeneity challenges in mobile cloud computing into two dimensions, namely vertical and horizontal. That is, the categorization is based on where the heterogeneity is found such as mobile devices, clouds, or wireless networks and how it accords the version of the operating system, type of cloud, or type of wireless network.

Based on the comparison, we can observe that most recent surveys used qualitative synthesis and benchmark comparison analysis techniques to determine research challenges for mobile cloud computing and related areas. Conversely, unlike recent research surveys on mobile cloud computing, our work provides a holistic view of the current status of mobile cloud computing, especially given that our survey compares 30 representative mobile cloud computing research architectures that have all been published in the last 7 years. To the best of our knowledge, our survey is the only one that uses quantitative analysis (i.e., where statistical information about mobile cloud computing architectures is used), qualitative synthesis, and benchmark comparison analysis techniques to determine the challenges existing in mobile cloud computing. It is these aspects of our paper that represent the main contribution of our work to the knowledge on this subject.

MOBILE CLOUD COMPUTING

A. Mobile computing

Mobile computing depends on the ability to use computer resources through mobile devices. Moreover, mobile computing enables the execution of tasks that have been traditionally done by normal desktops. In general, mobile computing is supported by three basic concepts: hardware, software, and communication [18, 19]. Hardware constitutes devices (e.g., tablet PCs and smartphones) that can be utilized by users. Software includes applications designed and developed to execute tasks in a mobile environment and communication which includes networks and protocols that can support the communication aspects of mobile computers such as Wireless Local Area Networks (WLAN), Long-Term Evolution 4G LTE and satellite networks.

The mobile computing environment supports the following. First, there is mobility which allows mobile nodes or fixed nodes to connect with other devices' nodes in the mobile computing environment through Mobile Support Station (MSS) (e.g., servers and access points). Second, diversity of network access types refers to mobile nodes which can communicate using various types of access networks, for example Long-Term Evolution 4G LTE or Wireless Wide Area Network (WWAN) each with different communication bandwidths and overhead between the mobile nodes and the MSS. Third, frequent network disconnection means mobile nodes are not able to keep the connection consistent because of limited mobile nodes' resources such as battery energy and communication bandwidth. Fourth, regarding the issue of poor reliability and security, mobile node signals suffer from interference and eavesdropping in mobile networks which make security increasingly more important in mobile computing.

B. Cloud computing

Cloud computing is a technological approach that aims to increase capacity and capabilities of Information Technology (IT) networks by centralizing how data is stored and processed [20].

It allows consumers to access applications without first installing them and increases access to personal information over the Internet [21]. Furthermore, cloud computing has led to reduced costs of building IT infrastructures, and in acquiring new re-sources. Cloud computing service computers benefit from the multi-tenant architecture by maintaining one application [22]. Cloud services are defined by five essential characteristics which include:

•On-demand self-service: A cloud computing service user leverages computing capabilities such as virtual machine time for processing and storage tasks whenever necessary without seeking the attention of each cloud provider.

•Broad network access: Cloud computing service users can access datacentres resources online using devices such as workstations, laptops, smartphones, or tablets.

•Resource pooling: Multiple cloud computing service users share the cloud service provider's resources (i.e., cloud computing re-sources includes processing power, storage, network bandwidth, and memory) in a multi-tenancy manner, where each user can run and stop these resources as needed.

•Rapid elasticity: Resources are elastically supplied or released automatically or manually depending on the consumer's needs. From a consumer perspective, the cloud resources capabilities are often unlimited and can be used anytime.

•Measured services: Cloud service providers may charge consumers based on a pay as you go pricing model. The cloud computing service usage is monitored and reported in real-time which ensure transparency between the cloud service provider and cloud computing service users.

Cloud service models:

Software as a Service (SaaS): This refers to a service provided by a cloud application supported on a cloud infrastructure. Consumers can interact with the application through a user interface like a Web browser installed on different client devices. Consumers do not need to manage or manipulate any underlying cloud infrastructure such as servers or operating systems. However, they may be given limited control over particular application configuration settings [20].

Platform as a Service (PaaS): PaaS is another type of service which is built on the cloud infrastructure and involves developers acquiring applications and platforms which include tools, libraries and programming languages supported by the cloud service provider. The developer is not required to manage the underlying infrastructure such as network, server, storage except managing the deployed applications and settings of the environment hosting them [21].

Infrastructure as a Service (IaaS): This provides the cloud computing service user access to processing, network, storage, and other basic computing resources. IaaS also allows users to develop and exe-cute software as well as operating systems and applications. The cloud computing service user is not required to manage the cloud infra-structure but still has control over the operating systems, applications and other resources like storage and networks applications, for example firewalls [22].

Deployment models:

According to the NIST definition of cloud computing, cloud services can be deployed using four development models including: (i) Private cloud, (ii) Community cloud, (iii) Public cloud, and (iv) Hybrid cloud [20] as shown in Fig. 1.

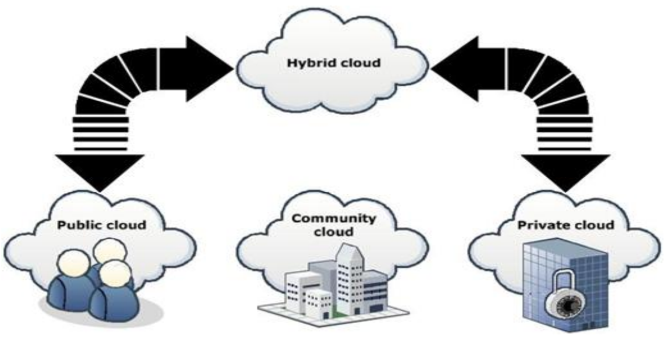

Fig. 1. Cloud services development models

Private cloud: In this deployment model, a particular organization owns a datacentre regardless if it is managed by a third party or by itself. This cloud is usually for exclusive use and may be located onsite or offsite.

Community cloud: In this deployment model, the datacentre is shared among one or more organizations in the community regardless if it is managed by a third party or one of the organizations owning it. This cloud is also for exclusive use and may be located onsite or offsite.

Public cloud: In this deployment model, the datacentre can be used by any cloud computing service user (e.g., a single user, research laboratory, company, or all of them together). This cloud is located at the same site as the cloud service provider.

Hybrid cloud: In this deployment model, two or more of the previously mentioned deployment models are used in a particular datacentre. This deployment model requires standards or patented technology which allows the portability of data and applications

ARCHITECTURE OF MOBILE COMPUTING

Mobile phones are now ubiquitous in most people's daily activities and this has motivated companies to develop applications that can be easily accessed through mobile phones. The Internet, GPS and games applications are behind the worldwide popularity of mobile devices. However, limited resources (e.g., CPU, memory, and data storage) of mobile devices pose some design challenges to mobile application developers. To overcome these challenges, cloud computing is being used. Today's lifestyle often requires one to stay in touch through mobile communication technologies. Sending and receiving data are becoming easier to do. Mobile cloud computing combines the concepts of cloud computing and mobile computing [2, 5]. This new technology makes use of the capability of data storage and data processing by using cloud computing infrastructure through the Internet.

Fig. 2 depicts the architecture of mobile cloud computing which consists of three different layers: (i) Mobile User Layer; (ii) Mobile Net-work Layer; and iii) Cloud Services Provider Layer. These are discussed in more detail below.

•Mobile User Layer. This layer consists of many mobile cloud service users who access cloud services using their mobile devices (e.g., smartphones and tablets). These mobile devices connect to the Mobile Network Layer using Wireless Access Points (WAPs), Base Transceiver Station (BTS), or satellite.

•Mobile Network Layer. This layer consists of multiple mobile network operators which handle mobile users' requests and information is delivered through base stations. Mobile user requests and information transfers are handled by mobile network services such as Authentication, Authorization, and Accounting (AAA) which are provided by the Home Agent (HA). At this point, the mobile network operators help to identify the subscribers' data that is stored in their databases through their HA. After successful authentication and authorization, the operator delivers the mobile users' requests to a cloud through the Internet. The mobile user is then able to access the corresponding services as provided by the controllers in the cloud.

•Cloud Services Provider Layer. This layer consists of multiple cloud computing service providers which provide all types of cloud computing services including IaaS, PaaS, and SaaS. These cloud computing services are elastic and can be increased or reduced based on what cloud computing service users demand. Cloud computing provides services to users including those with mobiles can access cloud services via the Internet.

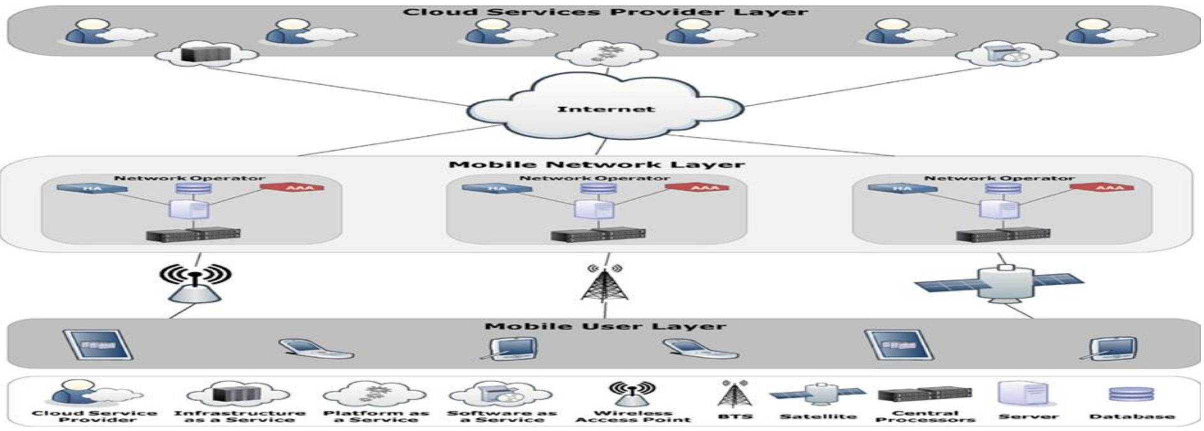

Fig. 2. Architecture of mobile cloud computing

Early studies on augmented execution include CloudLet [23] and CloudClone [24]. It is well-known that one severe limitation of mobile devices is their limited resources. Various devices have been designed with cloud computing support in mind to execute various processing and storage tasks often through wireless communication technologies. For instance, Image Exchange requires that a device be enabled to process and store large amounts of data. Through cloud computing, individuals are able to upload photos to the cloud immediately after capturing them where more energy can be saved. Facebook has taken advantage of this facility, and it became popular very quickly for this reason. MCC also simplifies data management by enabling the synchronization of several files and folders.

MOBILE CLOUD COMPUTING CHALLENGES AND FUTURE RESEARCH DIRECTIONS

For mobile cloud computing environments, we need efficient techniques to: first, satisfy the needs of mobile cloud service providers; and second, enable mobile users to fully utilize mobile cloud computing benefits so that longer battery life and increased storage, scalability, and reliability can be realized. Unfortunately, several issues concerning the mobile cloud computing environments still need to be addressed due to the connection limitation, energy sufficiency, dynamics, and distributed nature of mobile cloud computing environments. In particular, we identify the following research challenges, namely security, privacy and trust, bandwidth and data transfer, data management and synchronization, energy efficiency, and heterogeneity.

• Security, privacy, and trust. Security and privacy are crucial for mobile cloud computing environments because these characteristics determine the level of trust mobile users have when they off-load some of their jobs on their mobile devices and store their personal data in the cloud environment [3]; [25]; [26]; [2]; [5]. However, due to the dynamic and distributed nature of mobile cloud computing environments, achieving such requirements is still a major challenge.

• Bandwidth and data transfer. Mobile cloud computing promises several benefits such as longer battery life and storage for mobile de-vices which can be accomplished through centralized processing and storage at the cloud service's datacentre. This approach, how-ever, may lead to more communication overhead because of the increased bandwidth consumption and data transfers [3, 12]. Unfortunately, the increased communication overhead can also lead to additional hidden costs for mobile users and can constitute a barrier between mobile cloud computing consumers and the mobile cloud computing service providers.

• Data management and synchronization. Due to the hardware limitations of mobile devices, mobile cloud computing allows computation off-loading where some computation tasks are transferred to the cloud datacentre. This process requires a proper data management system. In addition, cloud datacentres can synchronize mobile devices' applications and data to allow data accessibility from different devices or restoring data after a lost event. However, there is clearly a trade-off between off-loading compute-intensive tasks and band-width utilization.

• Energy efficiency. Energy efficiency is one of the significant issues in mobile computing and mobile cloud computing is supposed to solve this issue and complement the hardware limitation in mobile de-vices [27]. Energy consumers in mobile devices include the CPU, screen, GPS, cell radio, Bluetooth, wireless network interface card and other sensors.

• Heterogeneity. In mobile cloud computing, we have a wide range of hardware and software technologies, communication networks, platforms, data formats and so on that need to interact and collaborate with each other (i.e., heterogeneity in hardware, software, and networks) [17]. Mobile users need to access different types of data across multiple platforms which may increase complexity, for instance, different mobile applications use varied data structures.

Referring to the issue dimension, none of the reviewed MCC research architectures addressed the issue of heterogeneity. Therefore, we need novel approaches that can effectively support heterogeneity so that multiple devices and platforms in the mobile cloud computing environment can collaborate.

CONCLUSIONS

Mobile cloud computing has developed to defeat the hardware impediments of mobile phones. In this work, we have showed an extensive review of recent (concentrating on the most recent eight years) mobile cloud computing models. We contrasted traditional mobile computing and versatile mobile cloud computing. Further, we thought several overviews distributed from 2010 to the present day on portable distributed computing. Featured here was their focus, parts of the proposed architecture for mobile cloud computing, the commitments they make, the examination strategy used to decide research challenges for mobile cloud computing and portraying these difficulties. Also, we have proposed a generic architecture to evaluate recent instructive mobile cloud computing research designs utilizing an arrangement of assessment criteria. In this work, we have exhibited an all-encompassing perspective of the current status of mobile cloud computing through a quantitative examination and benchmark correlation with decide the significant research challenges confronting mobile cloud computing. Based on analysis, we recognized a few research challenges that need facilitate investigation. These difficulties incorporate security, protection and trust, band-width and data exchange, data management and synchronization, energy efficiency, and heterogeneity.

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