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Exploring Mobile Cloud Computing: Integrating Mobile and Cloud Technologies for Future Research Directions

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Abstract

Mobile Cloud Computing (MCC) is a technology that integrates mobile computing and cloud computing, providing users with the ability to access cloud services and resources from their mobile devices. MCC has gained significant attention in the IT industry since its inception in 2009, and its development is still in the early stages. Therefore, a thorough understanding of MCC is essential for identifying future research directions. The background of MCC can be traced back to mobile computing and cloud computing. Mobile computing involves the use of mobile devices, such as smartphones and tablets, to access information and services. On the other hand, cloud computing provides on-demand access to a shared pool of configurable computing resources, such as servers, storage, and applications.

Keywords: *Mobile Cloud Computing; Mobile Computing; Cloud Computing; Research Directions*

1. Introduction

The past few years have seen tremendous growth in network-based computing and on-demand application models, including cloud computing, software as a service, community networks, and web stores [13]. Cloud computing has become a major application model in the era of the Internet, attracting significant research attention from the scientific and industrial communities since 2007[12]. Essentially, cloud computing refers to a range of services offered by an Internet-based cluster system, comprising a group of low-cost servers or personal computers that organize resources based on a management strategy, providing safe, reliable, fast, convenient, and transparent services such as data storage, access, and computing to clients. Cloud computing has topped the list of strategic technology trends for 2012 provided by Gartner, a global analytical and consulting company, implying that it will have an increased impact on enterprises and organizations in that year[22]. Mobile Cloud

Computing (MCC) that combines the features of mobile computing and cloud computing. The main objective of MCC is to provide ubiquitous access to computing resources and services through mobile devices such as smartphones, tablets, and laptops. In MCC, mobile devices act as thin clients that access cloud-based services and applications. The cloud provides the necessary computing power, storage, and bandwidth to support the mobile devices, and the mobile devices provide the user interface and mobility. This combination of cloud computing and mobile computing offers several advantages, including scalability, flexibility, cost savings, and improved performance. MCC has the potential to revolutionize the way we use mobile devices and access computing resources. Mobile cloud computing has indeed seen significant growth over the past decade, with the increasing popularity of smartphones and other mobile devices [4-5]. The virtualization of resources and distribution of computing power allows for more efficient and convenient access to services and applications on these devices. In addition to the examples you mentioned, there are many other popular mobile cloud computing applications today, including Dropbox, Evernote, and Salesforce Mobile. As the technology continues to evolve, we can expect to see even more innovation and growth in this area.

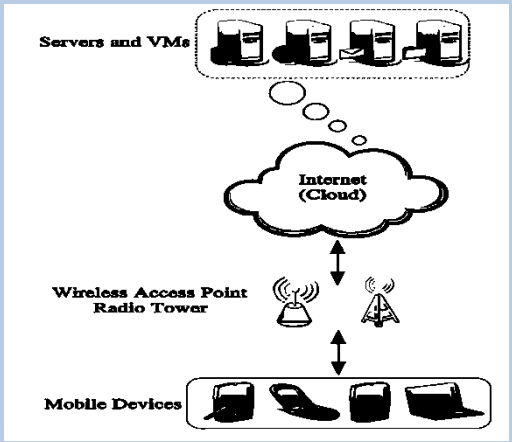

Fig. 1: Mobile Cloud Computing [6]

While mobile cloud computing makes a great contribution to our daily lives, it will also, however, bring numerous challenges and problems. It's important to consider both the benefits and drawbacks of this technology and to work towards solutions that can make it as seamless and efficient as possible [23]. As mobile devices become increasingly prevalent and powerful, the potential for mobile cloud computing to transform the way we access and use information is enormous. However, it will take ongoing research and innovation to fully realize that potential and to address the challenges that arise along the way.

2. Mobile Computing

The rapid development of mobile devices and wireless technology has greatly contributed to the popularity and growth of mobile computing. With the increasing use of smartphones, tablets, and laptops, people can now access the internet, communicate with others, and perform various tasks while on the go. The availability of wireless technology such as Wi-Fi and mobile data networks has further enhanced the mobility of these devices, enabling users to stay connected to the internet and other services even when they are away from their homes or offices [7-8]. As a result, mobile computing has become an integral part of people's daily lives. Mobile computing refers to the ability to use a computing device while on the move, which includes mobile phones, tablets, laptops, and other portable devices. As you mentioned, it involves three main components: hardware, software, and communication. The hardware component consists of the physical devices, the software component includes applications and operating systems, and communication is related to the networks and protocols that allow devices to connect and communicate with each other. Overall, mobile computing enables users to stay connected and productive while on the move. There are the following features of mobile computing mainly Mobility, Diversity of network conditions, Frequent disconnection & consistency, Dis-symmetrical network communication and Low reliability.

a) *Mobility:* In a mobile computing network, mobile nodes can establish connections with other mobile nodes as well as fixed nodes in wired networks through Mobile Support Stations (MSS).
b) *Diversity of network conditions:* normally the net- works using by mobile nodes. Mobile nodes may be connected to a wired network with high-bandwidth, such as when they are connected to a MSS or a fixed network at a stationary location. However, they may also be connected to a Wireless Wide Area Network (WWAN) with low-bandwidth.
c) *Frequent disconnection and consistency:* Mobile nodes in mobile computing often face frequent disconnections and inconsistencies due to variety of factors, such as limitations of battery power, wireless communication range, and network conditions.
d) *Dis-symmetrical network communication:* Mobile computing networks often exhibit asymmetrical communication patterns, where the send/receive ability of servers, access points, and other fixed network elements is much stronger than that of mobile nodes.
e) *Low reliability:* low reliability is a common challenge in mobile computing networks, as wireless signals are susceptible to interference, snooping, and other security threats.

Mobile computing networks face a range of challenges and problems that are not present in traditional wired networks. Some of the key challenges include: signal disturbance, security, limited power, and quality of service (QoS).

3. Cloud Computing

The rapid pace of technological advancement can make it difficult for users to keep up with the latest hardware and software requirements. Moore's Law, which states that the number of transistors on a microchip double approximately every two years, has been a driving force behind this trend [14]. Cloud computing involves accessing and utilizing shared computing resources, such as servers, storage, databases, and software, over the Internet. These resources are typically provided by cloud service providers, who operate large data centers that offer a wide range of cloud-based services. Cloud computing can be broken down into several different categories or models, including Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). IaaS provides users with virtualized computing resources, such as virtual machines, storage, and networking, that they can use to build and deploy their own applications and services [3].

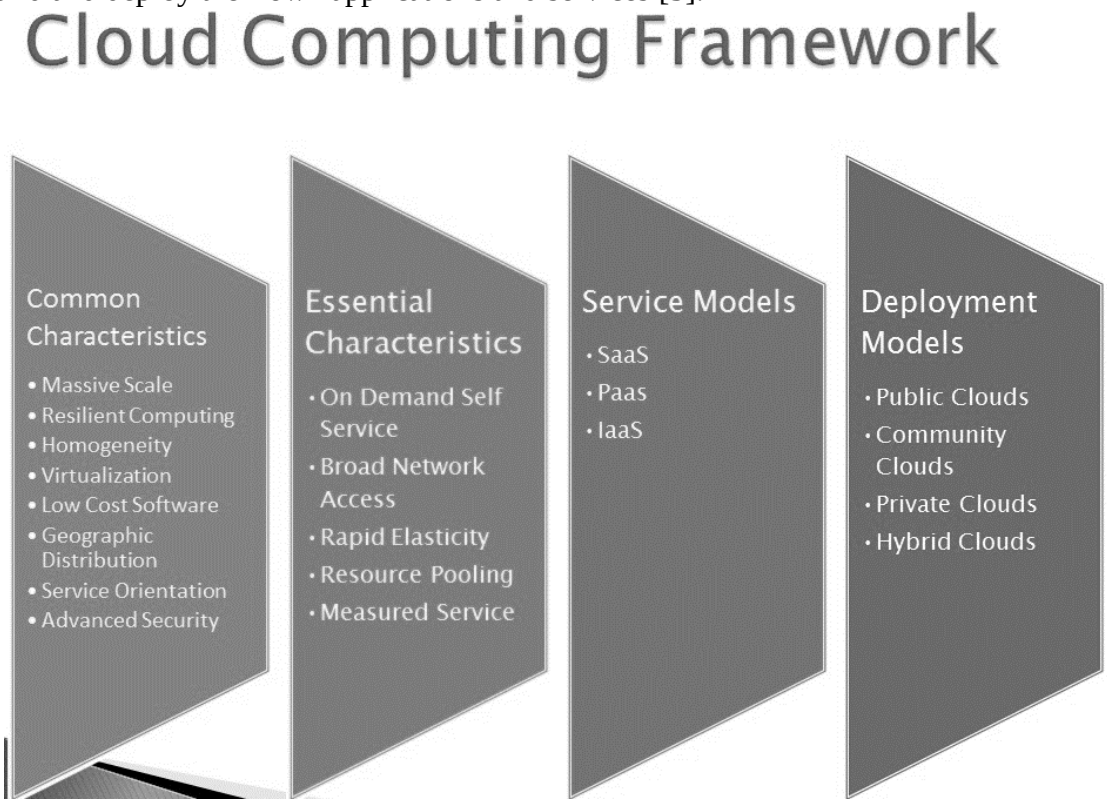

Fig. 2: The Framework of Cloud Computing [15]

PaaS provides users with a platform to develop, test, and deploy their own applications without having worry about the underlying infrastructure. SaaS provides users with access to pre-built software applications that they can use on demand, without having to install or maintain the software themselves. Cloud computing also typically involves some degree of automation, which allows users to easily provision and manage their computing resources. This can include features such as self-service portals, APIs, and automated scaling and deployment tools. In

this paper, we consider cloud computing is indeed a large-scale economic and business computing paradigm that leverages virtualization as its core technology [11]. It builds on the foundations of parallel processing, distributed computing, and grid computing, and provides a range of services, including hardware, infrastructure, platform, software, and storage, to different Internet applications and users.

1) *Framework:* framework of cloud computing can be divided into three layers, which are infrastructure layer, platform layer, and application layer.

a) *Infrastructure layer:* The infrastructure layer is the lowest layer in the cloud computing framework and includes the physical resources and underlying software needed to support cloud computing services. This layer provides a virtualized pool of computing and storage resources that can be accessed by users over the internet. Infrastructure as a Service (IaaS) providers typically offer a range of services, including virtual machines, storage, networking, and security services [14].

b) *Platform layer:* The platform layer is the middle layer in the cloud computing framework, sitting above the infrastructure layer. This layer provides a platform for developers can use to build and deploy application on the top of infrastructure layer. The platform layer is also known as Platform as a Service (PaaS). The typical services are Google App Engine, Heroku and Azure from Microsoft [2].

c) *Application layer:* The application layer is the top layer in the cloud computing framework, sitting above both the infrastructure and platform layers. This layer is where end users interact with the cloud computing service through various applications, such as web or mobile applications [3]. The application layer is also known as Software as a Service (SaaS), and it provides users with access to wide range of cloud-based software applications and services. These applications and services may include productivity tools, customer relationship management (CRM) systems, human resources management (HRM) systems, and many others. SaaS providers include Salesforce, Dropbox, and Google Apps.

2) *Features:* the features of Cloud Computing are as follows:

a) *Virtualization:* Virtualization is a key technology that underlies cloud computing. It allows physical hardware resources, such as servers and storage devices, to be abstracted and pooled into a virtual resource pool that can be dynamically allocated to different users and applications [16]. Virtualization allows multiple virtual machines (VMs) to run a single physical server, which can greatly increase the efficiency and utilization of hardware resources.

b) *Reliability:* Cloud computing provides a reliable mode of storing user data, with built-in backup and disaster recovery mechanisms [1]. In the event of server or VM failure, the cloud computing system automatically transfers and backs up data to other machines, ensuring that the data remains accessible and secure. Cloud providers also typically offer Service Level Agreements (SLAs) that guarantee a certain level of uptime and availability.

c) *Large-scale:* cloud computing systems typically consist of thousands, or even millions, of servers and PCs in order to provide the computing power and storage capacity necessary to handle large-scale data processing and analysis. Companies

like Google, Amazon, and Microsoft have invested heavily in building out their cloud computing infrastructures to support the increasing demand for cloud-based services [20-21].

d) *Autonomy:* cloud computing systems are often designed to be automatic systems, meaning they are self-configuring and self-managing. This enables the system to automatically allocate computing resources such as hardware, software, and storage as needed to meet the demands of users and applications.

4. Cloud Computing Services

There are three main types of cloud computing services:

- Infrastructure as a Service (IaaS)
- Platform as a Service (PaaS)
- Software as a Service (SaaS)

IaaS provides access to virtualized computing resources, such as servers, storage, and networking, over the internet. This allows users to run their own operating systems, applications, and software on the cloud infrastructure. PaaS provides a platform for developers to build, deploy, and manage applications without having to worry about the underlying infrastructure [17-18]. The cloud service provider manages the infrastructure, including the operating system, runtime, and middleware. SaaS provides access to software applications that are hosted on the cloud and accessed over the internet. This allows users to use software without having to install or manage it on their own devices. Some of the popular cloud computing service providers include Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform, IBM Cloud, and Oracle Cloud. These providers offer a range of services, including compute, storage, database, networking, security, analytics, and machine learning, among others.

5. Models of Cloud Computing

Public, Private and Hybrid are three main cloud computing models. Public cloud services are provided by third-party cloud service providers who own and manage the infrastructure. Users can access these services over the internet, typically on a pay-per-use basis. Public cloud services are scalable, flexible, and cost-effective, making them a popular choice for businesses of all sizes [10]. Examples of public cloud service providers include Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform. Private cloud services are dedicated to a single organization and are not shared with other users. Private clouds are typically hosted within the organization's own data centers, and the infrastructure is managed and maintained by the organization's own IT staff. Private clouds provide greater control, security, and privacy than public clouds but can be more expensive to set up and maintain. Hybrid cloud services combine elements of public and private clouds, allowing organizations to leverage the benefits of both. Hybrid clouds can be configured to allow data and

applications to move between public and private clouds as needed, providing greater flexibility and scalability [22]. Hybrid clouds can also help organizations to optimize their use of resources, reducing costs and improving efficiency. In addition to these main models, there are also other cloud computing models, such as community cloud (where a group of organizations share a cloud infrastructure) and multi-cloud (where an organization uses multiple cloud service providers) [9]. There are several challenges that must be addressed in order to ensure the safe, efficient, and reliable operation of cloud computing systems. Some of the key challenges include: Security and privacy, Energy efficiency, Service performance and monitoring, and Standardization [19]. Overall, addressing these challenges will require ongoing research and development efforts to improve the safety, efficiency, and reliability of cloud computing systems, while also addressing environmental and ethical concerns.

6. Conclusion

Mobile Cloud Computing (MCC) has emerged as a promising area of research due to its ability to combine the advantages of mobile computing and cloud computing. MCC face several challenges related to the limitations of mobile devices, quality of communication, and division of application services. To address these challenges, three main optimization approaches have been proposed. Firstly, virtualization and image technology can be used to effectively address the limitations of mobile devices. Secondly, reducing the proportion of data delivery in wireless environments and upgrading bandwidth are effective ways to improve communication quality. Finally, deploying an effective elastic application division mechanism is deemed to be the best solution to guarantee application services in MCC, despite being complicated. With continued research and development efforts, MCC has the potential to become a key resource for data processing in commerce and science.

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