EXPLORING CLOUD COMPUTING AND MOBILE CLOUD COMPUTING: A COMPREHENSIVE REVIEW

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Abstract: Cloud-based storage has gained popularity due to its adaptable nature and concerns regarding security and privacy. Within computer science, cloud computing represents a relatively novel concept, wherein users leverage fewer local resources in favor of cloud-based alternatives. Mobile Cloud Computing (MCC) merges cloud computing, mobile computing, and wireless networks, offering extensive computational capabilities to mobile users. Cloud computing involves accessing data centers via the Internet, catering to a wide audience. This paper aims to offer a comprehensive overview of both cloud computing and mobile cloud computing, exploring their delivery and deployment models along with the primary attributes of mobile cloud computing.

Keywords: *cloud computing, mobile cloud computing, delivery models, deployment models, computational capabilities*

INTRODUCTION

In recent years, the evolution of network-based computing has led to a proliferation of modeling methods such as software as a service, online marketplaces, community networks, cloud computing, and more (Qi & Gani, n.d.).

Cloud computing, a contemporary technology, enables a third-party "cloud provider" to deliver services to users from anywhere, at any time, and under various conditions. Leveraging virtualization and service delivery techniques, cloud computing furnishes customers with cloud resources to fulfill their requirements. Instead of storing and accessing data from their own devices, users utilize cloud services, thereby remaining unaware of the underlying network infrastructure (Shukur et al., 2020). This paradigm enables users to access content and utilize applications from any connected device (A. Rashid & Chaturvedi, 2019).

Cloud computing encompasses a distributed computing system that supplies software, processing power, memory, storage, and other computing resources. It offers products and services on-demand to users, operating on a pay-per-use model (Mahmood Ibrahim et al., 2021). The technology of cloud computing relies on three key components: Data Center, Virtualization, and On-Demand Computing (Z. N. Rashid et al., 2021).

Within a cloud system, task distribution enhances resource utilization, a critical requirement (R. Z. Z. S. S. K. J. K. et al Najat Z, 2018). Moreover, with the rapid advancement of wireless network technology, smartphones have become ubiquitous devices already connected to the network. The key attributes of next-generation networks, ubiquity, and mobility, provide a diverse range of personalized network services through various network terminals and access methods. Central to the concept of cloud computing is the consolidation of computers, services, and specific applications as a utility provided to users. Consequently, the integration of ubiquitous mobile networks and cloud computing gives rise to a new computing paradigm known as Mobile Cloud Computing (Qi & Gani, n.d.).

A cluster of mobile devices can be harnessed to establish a distributed computing system, where each node is characterized by a device and connectivity structure reliant on wireless communication systems (Massari et al., 2016).

The realm of Mobile Computing (MC) has garnered significant attention in recent years, driven by notable advancements in mobile networks and technology. Consequently, this review paper delves into defining MC, elucidating how people have transitioned from utilizing traditional desktop PCs to preferring mobile devices such as personal digital assistants (PDA), iPads, tablets, and similar gadgets for computing tasks (Arun & Prabu, 2017).

Moreover, the swift proliferation of mobile devices coupled with the rapid evolution of cloud computing has given rise to a contemporary computing model termed Mobile Cloud Computing (MCC). This novel paradigm effectively overcomes the storage, connectivity, and processing constraints inherent in mobile devices (He et al., 2018).

The review paper is structured into two main sections: Section II, which delineates the primary approaches to distributed cloud computing, and Section III, which expounds upon the fundamental mobile cloud computing technologies. Additionally, Section IV delves into the pivotal features, while Section V serves to conclude the paper.

2. Distributed Cloud Computing

In the domain of Distributed Cloud Computing, there is a noticeable surge in interest among researchers towards cloud-based scientific applications, with many large enterprises contemplating a shift towards hybrid clouds. Given the intricacies of executing tasks for complex applications, parallel processing becomes imperative. Synchronization and communication among parallel processes facilitate more efficient utilization of CPU resources, necessitating the maintenance of a data center's responsiveness to parallel tasks while ensuring effective node usage (R. Z. Z. S. S. K. J. K. et al Najat Z, 2018). Distributed computing, as a sector within computer science, focuses on systems where computers and other devices interact via message exchanges. The utilization of distributed computing systems has expanded owing to reduced hardware costs and advancements in computer network technology (Zebari et al., 2020).

While cloud computing presents numerous advantages, it also addresses challenges faced by corporate executives and IT teams. Among the most common concerns that continue to shape perceptions of the cloud are issues related to inconsistent performance and security vulnerabilities. As a distinct form of internet technology, cloud computing offers a range of resources including web-based networks, RAM, software resources, storage, and CPU capacity (Eshtawie, n.d.).

Cloud computing leverages hardware and software to deliver services over a network. Users have the ability to access information, share resources, software, and various services at their convenience, all while managing costs through cloud computing, which is widely utilized over the internet as an on-demand service. The term "cloud" can be used to represent the entirety of the internet, and utilizing the cloud leads to reduced development and operational expenses (Z. A. S. A. et al Najat Z, 2019). Additionally, the responsibility for maintaining and managing the data stored in the cloud falls upon the cloud provider (Alam, n.d.).

2.1 The Deployment Model of Cloud

Different application models can be implemented through cloud computing service models, with deployment methods tailored to their distribution nature, determined by the location of the cloud service (Alam, n.d.). There exist four primary types of cloud deployment models: private, public, community, and hybrid clouds (Kumari & Singh, 2021):

1. **Private Cloud:** This type of cloud is designed to serve a single company or organization, operating as a dedicated cloud for a specific entity (A. Rashid & Chaturvedi, 2019). Private clouds offer benefits such as enhanced data security, flexibility, scalability, and reliability (Bokhari et al., 2018).

2. **Public Cloud:** The majority of services are provided within a public cloud environment, granting consumers access to a resource pool managed by a hosting company. However, this setup may introduce significant security concerns due to its public nature (Alam, n.d.). Managed and overseen by a third-party public cloud service provider, these clouds are suitable for non-sensitive data (Saudi Computer Society et al., n.d.).

3. **Community Cloud:** In this deployment approach, the entire cloud infrastructure is shared among multiple organizations within the same community (Singh & Kumar Baheti, 2017). It enables the storage and remote access of files across multiple machines. Community clouds may be maintained cooperatively or by a designated cloud service provider (Tavbulatova et al., 2020).

4. **Hybrid Cloud:** This deployment architecture involves two clouds, where essential data is stored on a private cloud while less sensitive data is stored on a public cloud (Haris & Khan, 2018). Despite their integration, each cloud maintains its distinct identity, facilitating various deployment scenarios (A. Rashid & Chaturvedi, 2019).

2.2 Services model of Cloud Computing

The essential components, such as servers, hardware, and networks, facilitate the operation of cloud computing. Users of cloud computing also have the flexibility to choose how they want to utilize the cloud computing services as needed (Ouda & Yas, 2021). This review paper also delineates cloud services, typically categorized into three types, structured hierarchically based on the abstract capacity level and the supplier's service model (Sunyaev, 2020).

1. Infrastructure as a Service (IaaS): The Infrastructure as a Service (IaaS) cloud provides customers with virtual computing resources like a Virtual Machine (VM) (Auxsorn et al., 2020). Service providers in this model allow participants to utilize virtual servers within their data center, enabling clients to utilize virtual servers, i.e., the underlying hardware, without the need for infrastructure maintenance (Eshtawie, n.d.). In contrast to other categories, customers are responsible for managing components such as programs and operating systems in this scenario (Rita & Pinto, 2021).

2. Platform as a Service (PaaS): PaaS offers an infrastructure or platform for developing applications and technologies to be distributed over the Internet without requiring downloading or managing the user interface (Mustafa Mohammed & M Zeebaree, 2021). Users can utilize programming languages, packages, resources, and tools provided by the cloud operator to deploy customer-created or purchased applications to a cloud infrastructure. While users control the distributed apps and the configuration information of the application-hosting environment, they do not manage or control the cloud infrastructure (Sunyaev, 2020). PaaS provides a software development platform with computer language libraries and tools, enabling users to create and deploy applications (Floerecke & Lehner, 2018).

3. Software as a Service (SaaS): SaaS is a software distribution model where a distributor or provider hosts the software and makes it available to consumers via the internet (Mustafa Mohammed & M Zeebaree, 2021). Customers do not need to purchase or download software to their data centers; instead, they can utilize it via a service (SaaS) from the cloud (Nguyen, 2021).

Grid computing, parallel computing, and distributed computing are all integral components of cloud computing. Load balancing, a function that distributes the load across nodes in a cloud environment, is a significant concern in cloud computing (Z. A. S. A. et al Najat Z, 2019).

One of the primary motivations for utilizing cloud computing is cost reduction. Geo-replication, redundancy, and reliability are all advantages of distributed cloud computing. A distributed cloud, connecting numerous globally dispersed smaller data centers, could be a robust alternative to today's large, centralized data centers. By offering neighboring compute and storage resources, a distributed cloud can minimize connectivity overheads, delays, and costs. Enhanced data locality can also contribute to improved confidentiality (Coady et al., n.d.).

Efficient resource allocation is crucial in the proposed distributed cloud, ensuring that identified resources not only meet user requirements but also are utilized effectively. Issues such as free-riding in the peer-to-peer architecture of the distributed cloud must be addressed. Allowing customers to contribute resources and assess the users' involvement factor is a key solution to these issues. The primary objective of the distributed cloud is to analyze and determine the feasibility and efficiency of the system architecture. The main goal is to design and evaluate distributed cloud storage and computing (Khethavath et al., 2017).

Latency is another driving factor in distributed cloud computing. Utilizing a nearby data center may be advantageous when collaborating on an interactive document with a group of mobile users or playing computer games. Customers of a local cloud can include humans, self-driving automobiles, robots, and computers (Coady et al., n.d.).

3. Mobile Cloud Computing

The rapid progress in mobile computing, wireless technology, and networking has led to a significant increase in mobile subscribers (Eshtawie, n.d.). Mobile phones have become the preferred personal devices for most individuals, and users worldwide generate large volumes of data daily (Borcea et al., n.d.). Mobile Cloud Computing (MCC) has experienced rapid growth in recent years, driven in part by the growing demand for enterprise mobility (Eshtawie, n.d.). The volume of data generated by mobile devices during routine operations has also surged (Miguel Castanheira Sanches, n.d.). MCC benefits users by providing access to infrastructure, services, and applications from cloud providers in a cost-effective on-demand manner (Eshtawie, n.d.). Operating systems like Android, iOS, and Blackberry have demonstrated the capability to handle complex computational tasks since the advent of the Smartphone era (Salem, n.d.).

Individuals with various health conditions have found mobile computing technology beneficial, as they now have access to multiple sensors for various purposes. The resource limitations of mobile devices can be effectively addressed by integrating mobile computing technologies with cloud computing (Ponciano et al., 2020).

MCC integrates mobile computing, cloud computing, and wireless networks to manage and analyze data outside of the mobile device (Najat et al., 2020). Representing a new era in computing, MCC allows cloud users to access a variety of services over the Internet (Mitrpanont et al., n.d.). This combination effectively addresses the resource-constrained challenges of smartphones. As the number of MCC service types increases, distributed MCC is being utilized in more practical applications, enabling various Cloud Service Providers (CSPs) to offer consumers a range of cloud services. However, in the MCC environment, where messages are transferred through wireless connectivity, adversaries can easily manipulate the communication channel, intercepting, delaying, and altering transmissions.

However, the MCC services system faces a higher susceptibility to various threats compared to a conventional cloud computing services environment. It is imperative to devise new security measures for the system to ensure that only authorized users can access MCC services and to prevent adversaries from gaining unauthorized access. Privacy-aware authentication (PAA) emerges as a crucial method for addressing security concerns in MCC services environments as it can authenticate participants' identities while safeguarding their privacy. Despite the introduction of several PAA solutions in recent years, many are ill-suited for MCC services due to significant security vulnerabilities or poor performance. Consequently, the development of new PAA schemes becomes necessary to ensure safety and confidentiality in the MCC services context (He et al., 2018).

On the other hand, mobile cloud computing is poised to significantly impact our daily lives, albeit with various challenges and concerns. The crux of these issues lies in effectively integrating the two systems. This involves maximizing the benefits of cloud computing for mobile devices to enhance their capabilities while addressing the limitations posed by smartphones' constrained resources and computational power in accessing cloud computing with the same efficiency as traditional PCs and servers. To tackle these challenges and identify avenues for further research, a comprehensive understanding of the innovative computational paradigm - mobile cloud computing - is essential. The unique characteristics of mobile devices and wireless networks present significant obstacles to mobile cloud computing, highlighting its constraints and limitations. This complexity complicates the development, programming, and deployment of applications on mobile and distributed devices compared to stationary cloud systems. Factors such as the limitations of mobile devices, the efficacy of wireless connectivity, the nature of applications, and the support from cloud computing to smartphones all influence evaluations of cloud computing in a mobile cloud computing environment (Qi & Gani, n.d.).

3.1 Mobile cloud computing architecture

As mobile phones become increasingly ubiquitous in people's daily routines, organizations are driven to develop apps that are easily accessible via mobile devices. The widespread adoption of mobile devices can be attributed to features like Internet access, GPS functionality, and gaming applications. However, mobile device designers face challenges due to limited resources such as CPU, data storage, and memory. To address these challenges, cloud computing is being leveraged.

In today's lifestyle, mobile communication devices play a crucial role in staying connected. The ease of data transmission and reception is improving, aided by the combination of cloud computing and mobile computing in mobile cloud computing (MCC). This innovative approach utilizes cloud computing technology over the Internet to harness data storage and processing capabilities.

MCC, a technique that utilizes computing resources external to the smartphone, becomes essential due to mobile devices' limited computing and storage capabilities, as well as significant power constraints related to battery lifespan. To efficiently process large-scale workloads, smartphones must offload tasks to an external cloud service.

The architecture of MCC is shaped by its operational characteristics. Mobile devices communicate with networking infrastructure, typically through base stations, to execute tasks. These base stations manage network connectivity and facilitate communication with centralized processors linked to servers that provide mobile network services. Cloud administrators process user requests and deliver the appropriate cloud services to mobile users.

Various MCC architecture models raise concerns about data security. The service-oriented architecture (SOA) of MCC typically comprises three layers:

1. Mobile User Layer: This layer consists of mobile cloud service customers accessing cloud services through their devices, such as smartphones and tablets, connected to the Mobile Network Layer via wireless access points or base transceiver stations.

2. Internet Service Layer: This layer connects mobile networks to the cloud, facilitating the transmission of customer requests over high-speed Internet connections. Users can access cloud services smoothly via wired connections or advanced 3G or 4G technologies.

3. Cloud Services Provider Layer: This layer encompasses multiple service providers offering various cloud services like Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). These services are flexible, expanding or contracting based on demand. The cloud controller receives and analyzes customer demands, delivering services according to their needs.

To operate resource-intensive applications, smartphones are constrained by their battery capacity, particularly when users are on the move and cannot rely on external power sources. The limited battery life of smartphones poses a challenge as it can drain within a few hours, exacerbated by their restricted storage capacity compared to laptops. While smartphones typically offer only 8 GB of storage, laptops provide significantly larger storage capacities, typically starting from 500 GB and expandable with external memory options. Additionally, smartphones are limited in processing capacity due to their reliance on ARM CPUs, which can execute only a limited number of programs compared to laptops equipped with various processors such as i3, i5, and i7. However, upgrading the processor of a mobile device is often not feasible.

Furthermore, traditional technologies like EDGE, GPRS, and GSM offer limited bandwidth, resulting in slower data transmission rates. In contrast, more advanced technologies like 3G and 4G provide higher bandwidth, enabling faster data transfer speeds. However, these advanced technologies are predominantly available in urban areas and towns, limiting their accessibility in rural or less developed regions.

3.2 The Benefit of Mobile cloud computing

Mobile cloud computing (MCC) offers numerous advantages to both end-users and organizations, eliminating the need for customers to concern themselves with infrastructure development and maintenance. This architecture distinguishes MCC from other frameworks and is responsible for several benefits:

1. Battery Life Extension: By offloading data storage and processing to the cloud, MCC automatically extends the device's battery life. This is particularly beneficial for resource-intensive tasks that quickly deplete the device's battery power. MCC employs a battery-saving scheme by transferring such tasks to the cloud, completing them there, and then returning the results to the mobile device.

2. Storage Capacity: Unlike personal computers, the cloud can handle and store significantly larger amounts of data without the need for additional infrastructure investments or server additions. This eliminates concerns about data storage limitations and reduces the need for enterprises to upgrade their computer hardware, thus lowering overall IT costs.

3. Processing Power Enhancement: Many applications, such as transcoding, gaming, and multimedia streaming services, require substantial processing power, which MCC provides by shifting these activities to the cloud.

4. Disaster Recovery and Backup: Most cloud computing providers offer comprehensive, reliable, and flexible backup and recovery services. Data backup and restoration become simpler with cloud-based storage, as data is stored in the cloud rather than on physical machines. In some cases, the cloud serves solely as a backup repository for data stored on local systems.

5. Scalability: Mobile applications can be easily scaled up or down to meet the evolving needs of new users. Scalability encompasses web scalability, cloud scalability, and mobile scalability in terms of both users and devices.

6. Reliability: The cloud is perceived as more reliable compared to smartphones. Cloud-based applications can include features such as virus detection and malware identification, enhancing overall reliability. Additionally, MCC offers various authentication methods to prevent unauthorized access to cloud resources or sensitive information, eliminating the need for users to install such measures on local devices.

4. Discussion

Cloud computing facilitates the integration of diverse data and applications across different locations to serve users efficiently. Distributed cloud computing, in particular, enables users to share data across multiple locations, offering significant benefits. Additionally, mobile cloud computing extends extensive computing resources to mobile users, leveraging its capabilities effectively. These benefits influence users' utilization of both cloud technology and mobile computing, given the amalgamation of the two.

One crucial feature of cloud computing is load balancing, which involves distributing tasks among different servers to enhance performance and resource utilization. This approach optimizes cloud computing performance while ensuring balanced resource consumption.

Moreover, the utilization of powerful servers and various mobile devices enhances power efficiency and performance. This innovative approach addresses dual objectives: prolonging smartphone battery life and accelerating mobile applications.

Scalability improvement is another significant aspect discussed in various studies. By harnessing the computational power of multiple devices, scalability is enhanced, allowing multiple devices to contribute to computing requests without significantly increasing latency.

The benefits of adopting distributed cloud computing and mobile cloud computing are illustrated in Table 1 and Table 2. Each benefit has a distinct impact on the utilization of both distributed cloud computing and mobile cloud computing, underscoring their importance in contemporary computing environments.

Table (1): Summary of Distributed Cloud Computing

Feature	**(Z. A. S. A. et al Najat Z, 2019)**	**(Miguel Castanheira Sanches, n.d.)**	**(Salem, n.d.)**
Process batch or stream of data	✓		
Support scalability	✓		
Reduced latency times	✓	✓	
Achieve high performance			✓
High resource utilization		✓	
Performing huge processing	✓	✓	
Utilizing power via cloud domain	✓	✓	
Reduce a huge amount of processing power	✓	✓	✓

Table (2). Summary of Mobile Cloud Computing

Feature	**(He et**	**(Z. A. S. A. et**	**(Borcea et**	**(Salem,**	**(Mishra et**

	al., 2018)	al Najat Z, 2019)	al., n.d.)	n.d.)	al., n.d.)
Solve a long-standing problem	✓				
Identity-based signature scheme		✓			
Less computation time			✓		
Fewer communication costs				✓	
Parallel computations		✓			✓
Better performance		✓		✓	✓
Power saving					✓
Improve performance					✓
Huge computation saving					✓
Increasing scalability					✓

5. Conclusion:

From the analysis presented in section 4 and the comparison tables provided, it can be inferred that previous research in distributed cloud computing primarily aimed at reducing latency, handling large-scale processing tasks, harnessing cloud-based power, and mitigating significant processing demands. While there were contributions towards data stream processing and scalability, deeper exploration into achieving optimal performance and resource utilization was limited. Conversely, mobile cloud computing emphasized parallel computations and system enhancement, addressing persistent challenges such as identity-based security schemes, reduced computation and communication times, substantial computational savings under heavy workloads, and scalability improvements. This paper's primary focus is on mobile cloud computing (MCC), which integrates cloud computing into mobile environments, offering users on-demand resource access. Security remains a crucial concern in MCC, ensuring unauthorized access to critical data is prevented. Future research efforts in mobile cloud development should prioritize addressing security concerns comprehensively.

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