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Exploring the Future: A Study on Mobile Cloud Computing

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Abstract

"Mobile devices, which include smartphones, tablets, and other personal digital assistants (PDAs), are essential in attaining efficient and effortless communication in the modern world characterized by rapid change. In the rapidly evolving world of information technology and business, the expansion of mobile computing (MC) has become a formidable force that must be considered. However, it does not come without its own set of difficulties; the success of these devices is contingent on the battery life span, storage capacity, bandwidth, security, and mobility. The development of the service quality of these devices has been held down due to these different issues. The implementation and storage of data in cloud computing are helping to solve the inherent difficulties associated with mobile computing. Various service providers host the distribution of mobile apps in addition to mobile device service providers. This is accomplished by employing a variety of service providers. Mobile cloud computing is a subset of cloud computing that offers its customers the benefits of convenience and mobility in their computing experience. Cloud computing services that are accessible in a mobile context are called mobile cloud computing. This research provides a comprehensive understanding of the capabilities and limitations associated with mobile cloud computing.

Keywords: Mobile Cloud Computing, Cloud Computing, Computing Technology"

Introduction

The humble mobile phone began as a simple voice communication device and has since developed into a highly functional digital device with many functions, such as a camera, video recording capabilities, radio, web browser, global positioning system, games, and even television viewing [1].

Mobile networks provide a plethora of data-centric services in the modern world. Mobile devices can store more data, including financial and personal data, than previous technologies. [2] Online users may peruse various services, such as micropayment processing, stock trading, bank account administration, and data storage.

Location flexibility is made possible by the fact that users may utilize the tools made accessible by mobile computing whenever and wherever they need to, without worrying about their mobility. Because it enables users to do their tasks uninterruptedly no matter where they are, "mobility" is a phrase used to describe a feature widely used in the computer environment [3]. However, Satyanarayanan says this flexibility comes

with its own challenges, such as low energy, limited resources, and poor connectivity [4]. This creates a barrier since it hinders the implementation several beneficial applications that may benefit users and provide a ubiquitous environment [5].

Cloud computing, or CC for short, is quickly becoming a next-generation information technology infrastructure mechanism. CC provides several advantages concerning its Platform, infrastructure, and software. One of these benefits is the wealth of user-friendly apps that CC providers like Google, Amazon, and Salesforce make available at reasonable costs. It offers many benefits as well. Furthermore, users may use the services whenever they think it best suits their requirements [6].

The main advantages of cloud computing are the resources provided by providers in the form of infrastructure as a service (IaaS), Platform as a service (PaaS), and software as a service (SaaS) [7]. Numerous investigations have been carried out on CC [3, 8–19]. That being said, the main focus here is on the potential growth of CC and the challenges it can provide in a setting where CC is mobile [3].

The rapidly growing consumer demand for mobile apps led to the development of mobile cloud computing, or MCC. This work aimed to integrate cloud computing with the mobile environment. Additionally, through its widespread access mobile service, MCC offers new, cutting-edge facilities and services that mobile users can take advantage of to explore CC, in addition to the benefits of a typical CC, such as not requiring any initial investment, reduced cost of operations, easy accessibility, and high scalability [20]. Because of the resources of cloud computing and the flexibility of mobile computing, MCC is further advanced in its development path than these two technologies. These benefits will enable a broad spectrum of mobile clients to benefit from ubiquitous computing, regardless of location, time, or device type [21]. We shall talk about MCC in the following sections, covering both its benefits and the drawbacks of this technological development.

Mobile Cloud Computing

Overview of Mobile Cloud Computing

One of the most recent developments in cloud computing is mobile cloud computing, rapidly becoming a highly beneficial technology. The primary objective is to manage and store data on mobile devices utilizing cloud computing techniques. MCC offers advantages not just to organizations but also to individuals who

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use mobile devices. The market for mobile devices is continuously growing at a rapid pace. Over the past few years, there has been a meteoric rise in the number of individuals who use mobile devices. Most people have access to mobile devices such as smartphones and other mobile devices. Due to the Internet's most tremendous reach and rising concerns over mobility, MCC is anticipated to experience immense development in the information technology industry [22].

As seen in Figure 1, MCC may be broken down into two categories: mobile computing and cloud computing. Computers, personal digital assistants (PDAs), mobile phones, and other electronic devices might be among these devices that connect to the Internet over 3G, WiFi, or GPRS. Because the vast bulk of computing and data processing duties have been moved to the "cloud," and because the capacity of mobile devices is restricted, a number of mobile devices that are less costly, or even mobile devices that are not smartphones, may also access MCC by utilizing a cross-platform middleware [23]. However, cloud computing, often known as CC, continues to be the most important idea, despite the fact that the majority of MCC users now use mobile devices rather than desktop computers.

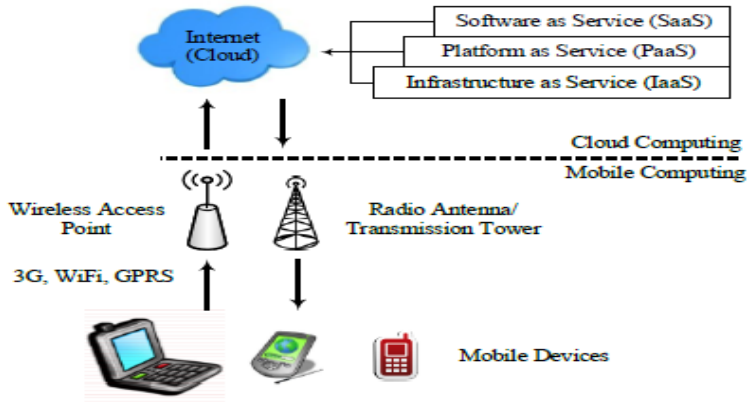

Figure 1. Two main parts of MCC [23]

The concept of cloud computing served as the inspiration for the language used in mobile cloud computing. It's been the focus of a lot of people in the business sector since it's a solid business model that can reduce operational expenses or be used to create mobile applications. Utilizing a specific kind of technology, the mobile devices provide mobile services at very low prices and mark a major advancement in the use of environmentally friendly information technology [24]. The part that follows [25] has comprehensive details on the concepts, architecture, and advantages of MCC in addition to its history.

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On March 5, 2010, the Open Gardens blog provided the first description of mobile cloud computing, which was defined as "the availability of cloud computing services in a mobile ecosystem." This encompasses a broad variety of elements, such as transcoding, end-to-end security, home gateways, mobile broadband-enabled services, and consumer, enterprise, and femtocells [26].

The three MCC descriptors that are currently accessible correlate to a range of concepts, as per Fernando et al. [3]:

As seen in Figure 2, the practice of running an application like Google's Gmail [27] on a server rich in remote resources is sometimes referred to as "massively concurrent computing" (MCC). Other mobile devices function as thin clients as well, connecting via 3G service providers to distant servers. Additional services that fit into this category include Facebook's location awareness services, Twitter for mobile devices, and mobile-friendly weather widgets.

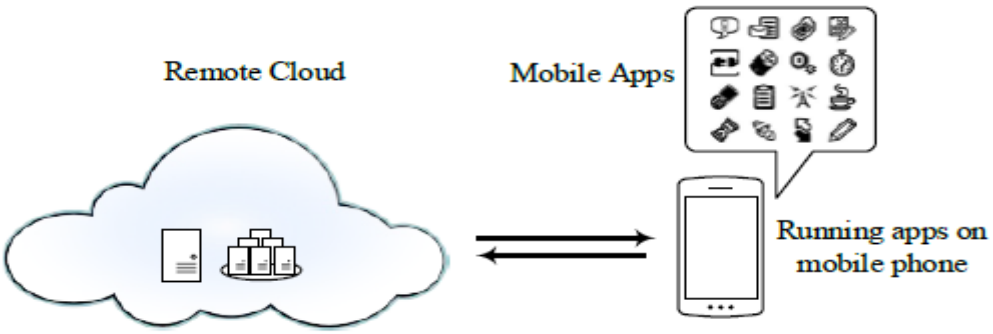

Figure 2. Providing services for mobile devices by cloud server [3]

One further way to consider mobile devices as cloud resource providers is via the use of a mobile peer-to-peer network [28]. The use of all of the resources that are available from the different mobile devices that are present in the locations, as well as those that are available from other stationary devices, is shown in Figure 3. This method allows users to move about freely while simultaneously determining the capability of mobile clouds to perform collective sensing. There are peer-to-peer systems available for mobile self-organization, such as SATIN [29]. However, these systems are mainly concerned with systems of component models, which are intended to represent systems that are composed of local components that are able to interact with one another. This is in contrast to the traditional approach of allocating tasks to local mobile resources. Specifically, the latter kind of work is the primary focus of this study.

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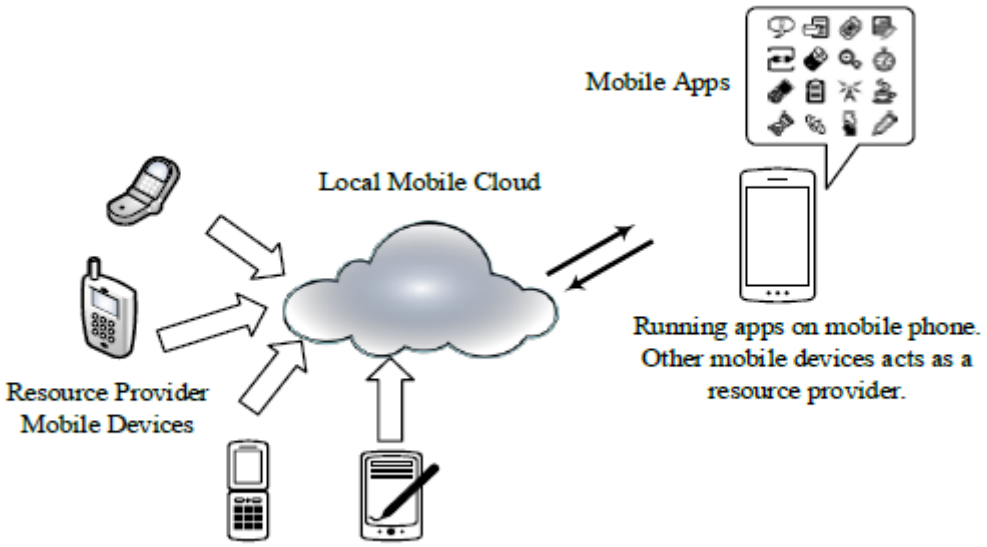

Figure 3. The resources are provided using neighbor mobile devices [3]

As an additional viewpoint, Satyanarayanan [30] put up the idea of cloudlet in relation to the definition of mobile cloud computing. As seen in Figure 4, this method entails the mobile device moving its workload into a local "cloudlet" that consists of many multicore machines connected to remote cloud servers. PlugComputers8 are a great replacement for cloudlet servers because of their tiny physical size, low power consumption, and broad availability. They have a simple design that is similar to a desktop computer's, but they are less expensive, smaller, and use less power. They are thus perfect for applications that need tiny servers that use shared infrastructures. Placed in neighborhood eateries or other public spaces, these cloudlets allow mobile devices to connect to them and act as the cloudlet's thin client. On the other hand, a cloud server located in a remote area could have issues related to latency and bandwidth.

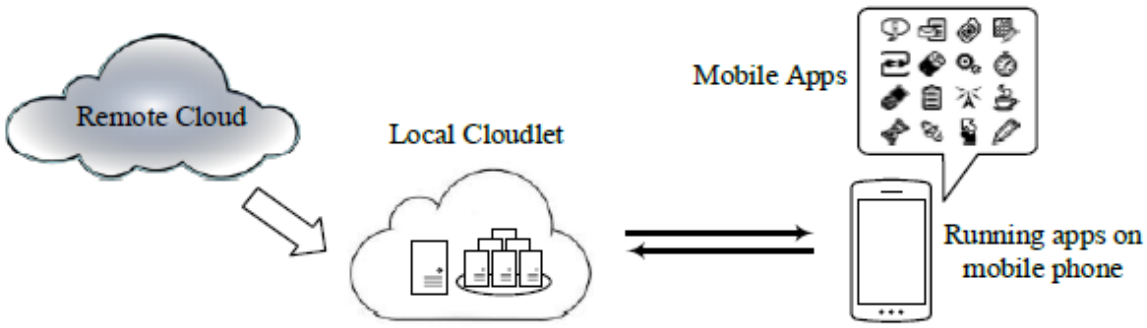

Figure 4. The Cloudlet concept [3]

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There is the possibility of integrating the mobile web platform, which is often used by mobile users in order to get access to Internet services and apps, with CC in order to produce MCC [31, 32]. Cloud computing services, such as data processing and storage, are among the offerings that MCC provides to its customers. Mobile devices that are utilized for this purpose do not need to have a high memory capacity or performance [25]. This is because the cloud is responsible for handling the sophisticated processing modules.

Services that fall under the umbrella of cloud computing may be broken down into three distinct categories: Platform as a Service (PaaS), Software as a Service (SaaS), and Infrastructure as a Service (IaaS). The interaction between the client and the cloud, which is distinct from the qualities that are often associated with a cloud computing (CC) [33], is given priority by MCC.

According to Jason H. Christensen [31], there are three distinct architectural approaches that may be used when developing mobile applications that are in accordance with the most current standards. The combination of smart devices, cloud computing that is enabled by context, and cloud computing that is based on REST are included in this category. These three components are a representation of the "Client-Connection-Cloud" transmission paradigm that is used in the MCC.

Figure 5 gives an illustration of the vertical component of the reconstructed conceptual model. Both the client and the cloud are visible on the left and right sides of the screen. The "Transmission Channel," which is positioned between the client and the cloud, is where the "Context Management" and "Resource Scheduling" components are put. The client, which is aware of the context, and the cloud, which offers clients freedom and services that can be accessed on demand, are both essential for this strategy. In the following paragraphs, a top-down explanation of the model's three midsections will be presented [33].

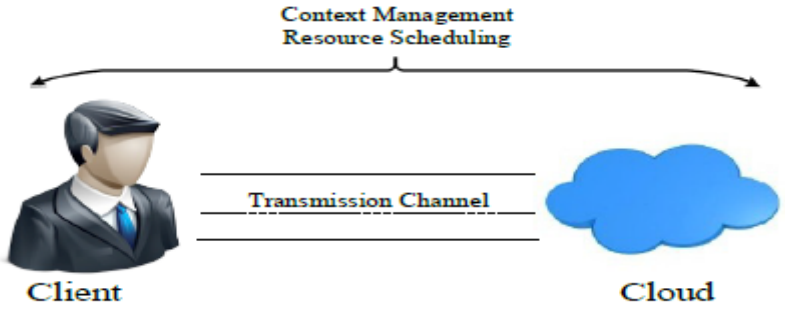

Figure 5. Mobile Cloud Computing Concept Model

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The transmission channel has many wireless communication protocols contained in it. It is possible for the mobile client to connect to the cloud via these protocols. Virtual machines are used in combination with resource scheduling to manage computers and storage resources. The scheduling of virtual machines is decided upon by a separate component of the scheduler. It utilizes physically available resources as well as virtual machines (VMs) [34]. The Context Management records the context parameters and modifies them based on the specific context conditions. Numerous innovative applications, such Location Based Services (LBS), spatial augmented reality (SAR), and explicit spatial contexts, are being researched in order to fully use this feature [33].

Architecture

A diagram of the MCC architecture may be seen in Figure 6. Specifically, it demonstrates how base stations, which include the satellite, access point, and base transceiver station, are used in order to connect various devices to mobile networks. It is the central processors, which are connected to servers that provide network services, that are responsible for receiving the requests and data (ID and location) that are coming from mobile users. It is thus possible for mobile network providers to give customers with services such as authorization, accounting, and authentication based on the information that is held in the databases on the subscribers and the home agent. After then, the subscribers will utilize the Internet to send their requests to the cloud so that they may be processed. The controllers of the cloud will take into consideration the requests that have been made and will deliver the services that are required. Techniques such as utility computing, service-oriented architecture (SOA), and virtualization are used in the design of the services [25].

Depending on the approach, the particulars of the architecture of the cloud might be different. In the context of grid computing and cloud computing, for instance, the concept of the four-layered architecture is [35]. Aneka, a service-oriented architecture (SOA), was developed to enable developers to build continuously. In the same manner as other programs do, Microsoft.NET is able to handle a number of different programming paradigms [36] and application program interfaces (APIs). [17] provides a description of the architecture that leads to a cloud that is focused on the market, and [37] advises that this architecture be used to supply commercial activities via the web. In order to accomplish this project's objective, an architecturally layered CC will be created. It will be shown by the architecture how effectively the CC model satisfies the

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requirements of the users [38].

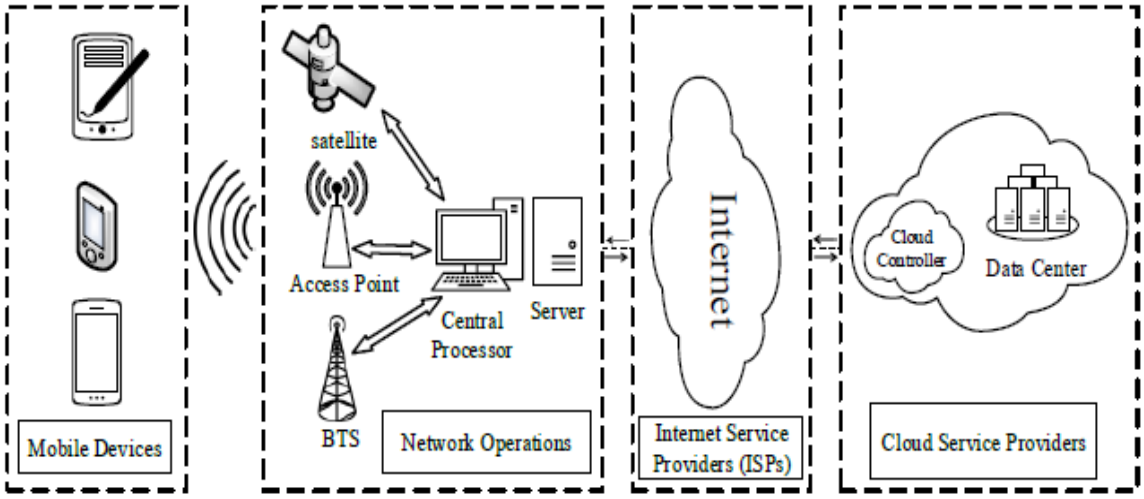

Figure 6. Architecture of Mobile Cloud Computing [39]

The typical configuration of CC is that of a large-scale distributed network system that is achieved by using several servers located inside a data center configuration. The cloud services are primarily organized according to a notion that is layered over them. Infrastructure as a Service, Platform as a Service, and Software as a Service are piled in the higher levels of the paradigm. These layers are stacked in the sequence described above. Layers composed of data centers provide both the physical component and the infrastructure of the cloud. In order to fulfill the requirements of the users, this location has a number of servers that are linked to networks that have a high speed. The majority of the time, data centers are located in distant places that are characterized by a low risk of natural disasters and a high and consistent supply of electricity [25].

IaaS, which stands for infrastructure as a service, is meant to be placed on top of the tiered data center. The infrastructure as a service (IaaS) is responsible for providing storage, servers, networking components, and hardware. The costs are often levied to the customer on a pay-as-you-use basis in an average situation. Because the customer only pays for the amount of resources that are really used, this results in cost savings for the client. It is possible to dynamically decrease or increase the infrastructure in response to changing needs. The Amazon Simple Storage Service and Elastic Cloud Computing (S3) are two kinds of infrastructure as a service that fall under this category.

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An environment that is highly developed and integrated is provided by the Platform as a Service, also known as PaaS. This environment is used for the development, testing, and deployment of applications that are constructed from scratch. The Microsoft Azure [40], Google App Engine [41], Simple Storage Service (S3) [42], and Amazon Elastic Map Reduce (EMR) [43] are all examples of services that fall under this category.

Software as a Service, often known as SaaS, is a service that offers assistance for the deployment of software that has certain specifications. Users are able to access information and apps remotely via the use of the Internet by using this layer, and they just have to pay for the amount of money they utilize. Salesforce was one of the people that pioneered this sort of service business. In addition, Microsoft's Live Mesh offers the capacity to simultaneously share folders and data across a number of different devices.

It is possible to divide the CC architecture into four layers; however, in order to do this, the layer that is at the top must be built to be precisely below the one that comes after it. In the case of the SaaS application, for example, it is possible to construct it directly on the IaaS rather than on the PaaS. In addition, there are some of the services that are composed of more than one layer respectively. With regard to the data storage service, for example, it is possible to see it as both the PaaS and the IaaS. It is possible for users of this architectural paradigm to have both flexibility and efficiency in the service they get [25].

Assessment of MCC Features

Advantages of Mobile Cloud Computing

The advantages of MCC are connected to the fact that it specializes in upgrading the current mobile computing in addition to the potential of the many applications that are continually being presented. The applications are categorized into a number of different categories, including image processing, natural language processing, multimedia search, querying, crowd computing, sharing GPS, sharing Internet access, and sensor data applications [44]. There are a number of advantages that are discussed in the following [3].

“One of the most appealing aspects of CC is that it allows users to take use of the resources necessary for computing when they are traveling from one location to another. When it comes to traditional models, resource provisioning is done based on high demand. On the other hand, when it comes to the CC, dynamic resource provisioning is done based on the current demand, which clearly results in a reduction in operating expenditures [18]. When it comes to service delivery, automated service provisioning is in reality a recurrent

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problem from the past. Numerous previous studies [45, 46] have shown that dynamic resource provisioning for applications that run on the Internet is a topic that most researchers are interested in.

It is possible to stretch the constraints of mobile devices, particularly with regard to their processing power and data storage, with the assistance of the MCC environment, which offers generic resource management for a wide variety of mobile devices. As can be shown in Figure 7, the cloud is the entity that is accountable for the creation of an agent for every conceivable kind of gadget. The mobile device is able to establish a connection with the agent as well as with individuals who are not part of the current domain [33]. The cloudlet-based and resourceful mobile computing framework was first presented by Mahadev Satyanarayanan [30]. With this design, the user is able to make use of the virtual technological machine in order to personalize the software service of the cloudlet that is geographically nearest to them and to use the service via a wireless local area network. The mobile device is typically the client of the service provider with regard to the work at hand. It is possible for other people to browse its cycles of processing and space for storing that is located nearby mobile computers. A cloudlet is a cloud that is very distributed and is not dependent on the architecture of the Internet. It is because of this usage that the WiFi bases will be expanded, which will allow the processes, memory, and storage space to be linked to the device [33].

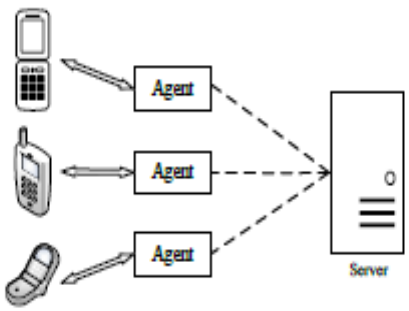

Figure 7. Architecture of Agent-client in MCC

Xinwen Zhang [47] presented the concept of adaptable applications, which result in an expansion in the size of platforms that are limited in regards to their resources. A flexible application may have one or more weblets, each of which functions independently but is connected to other weblets at the same time. After this application has been started, the manager of the elastic app will be able to monitor the needs of the weblets for the resources that are required and identify the appropriate moment to deploy the application. The calculated weblets often place limitations on the processors of mobile devices and have the capability to be

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released on many cloud platforms for use. While this is going on, the user interface element (UI) or those that need an extensive access point are being deployed on the device [33].

The cloud and the Internet are able to include a wide variety of services from a variety of suppliers, which enables customers to access the services whenever they need them [25]. Cloud computing is characterized by its architecture, which provides an integrated and distributed computing potential [48]. The system will make it simple to integrate capabilities that are cross-domain for energy efficiency, on-demand availability, dependability, and flexibility, as well as accessibility to the infrastructure via the use of developing technologies on virtualization.

Battery life is the primary worry when it comes to mobile mobile devices. There have been quite a few suggestions made to improve the performance of the central processing unit (CPU) [49, 50], as well as to intelligently control the screen and disk in order to decrease the amount of power that is used. As a result of the ideas, the construction of mobile devices will either need to be altered or new hardware will be required, both of which would result in increased costs and may not even be reliable. An approach known as computation offloading is being suggested in order to transfer complicated processes and computations from the restricted resources of mobile devices to tools that have a greater capacity for resource utilization, such as servers located in the cloud. It is because of this that the extra time that is required for apps to function on mobile devices, which need enormous power sources, is reduced. The findings of the study conducted by Rudenko et al. [51] and Smailagic and Ettus [52] demonstrated that the effectiveness of the offloading approach has been verified via extensive testing. The findings demonstrated that the applications, when run remotely, had the potential to result in significant quantities of energy being saved. The results of large-scale numerical computations demonstrated that the amount of energy required for big matrix calculations may be decreased by forty-five percent, as stated by Rudenko et al. [51]. In addition, a great number of mobile applications make use of the ability to perform tasks remotely and migrate these activities. As an example, outsourcing the compiler maximization that is used in image processing [53] has the potential to minimize the amount of energy that is consumed by mobile devices by over 41%. For the purpose of shifting segments in mobile games [54] to cloud servers, the use of units of memory arithmetic and interface, also known as MAUI, may result in a 27% reduction in energy consumption for the provisioning of computer games and a 45% reduction in energy consumption for a chess game console.

The computing resources that are provided by a cloud provider are combined in order to provide services to

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a large number of consumers. This is accomplished via the use of the multi-tenancy or virtualization model, which includes a large number of resources that are both physically and virtually allocated in accordance with consumer demand [55]. This paradigm of computing that is built on pooled approaches is based on two characteristics that are vital, and those are economies of scale and specialization. One of the results of the combined model is that the users do not have the ability to view the computing's physical resources. This is because consumers typically do not have any knowledge or control about the architecture, location, and origins of the resources, such as the database and the CPU. When it comes to the cloud, they are unaware of the whereabouts of their data.

In order to improve the reliability of the MCC, the data and applications are kept on cloud servers, which ensure that the data is backed up. User authentication, virus scanning, and detection of dangerous code are some of the additional security services that are provided to mobile users via the usage of cloud-based remote security services [56]."

Additionally, MCC has the potential to be created as a model for data security that is comprehensive for both service providers and consumers. This would be a significant advantage. As an example, the cloud is used to protect digital documents that are protected by intellectual property rights from being unlawfully transferred or pirated [57].

Because of the enormous potential that cloud computing has in terms of scalability and storage, data migrations from service providers to databases (ODB) that are outsourced in the cloud are made possible. These services, which are referred to as DaaS or data base as a service on the cloud computing platform [58], include AMAZON SimpleDB [59] and Microsoft AzureTM [40]. The customers are provided with a streamlined tool that allows them to save, access, and generate their database. Migrating the location of the mobile system's information database to a cloud database is an important activity that must be completed [60].

In light of the fact that the cloud is operated on the basis of the virtual concept, it is possible to simply provision it into a new computer environment in a short amount of time. As a result, users do not need to be concerned with the process of setting up the full computer configuration. When there is a need for a change in the computer environment, it is possible to get a customized infrastructure by renting it on the cloud as well [61].

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Limitations of Mobile Cloud Computing

"As was noted earlier, MCC has a number of advantages that are beneficial to both mobile customers and service providers. MCC, on the other hand, is confronted with a number of technological challenges as a result of the integration of two distinct domains, namely mobile networks and cognitive computing. The research topics in MCC, which are linked with CC and mobile communication, are outlined in the following sections after this introduction. Following that, an analysis of the various means by which these issues may be resolved will be carried out.

It is possible to regard as heterogeneity in this technology the employment of multiple infrastructures, architectures, and technologies in various parts of the MCC. It is necessary to make use of cutting-edge technology in order to facilitate cooperation across these diverse components. Figure 8 provides a description of the MCC heterogeneity categorization, as stated by Sanaei et al.

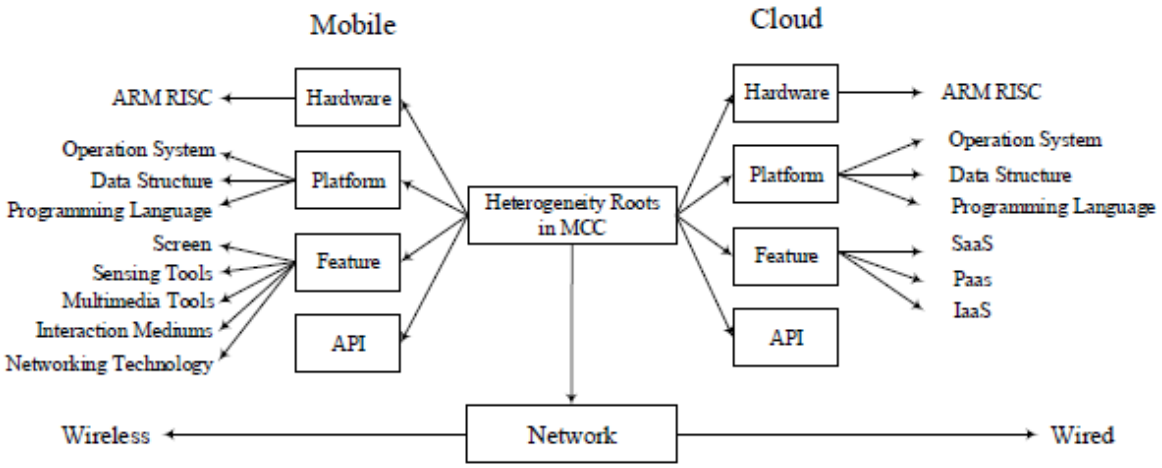

Figure 8. The MCC heterogeneity classification [63]

Networks that are very diverse in terms of the wireless network interfaces are the ones that make use of MCC. The cloud environment may be connected to by a variety of mobile device nodes via the use of a number of different wireless accessibility technologies. These technologies include GPRS, WiMAX, WCDMA, WLAN, and CDMA2000 systems. This gives rise to the problem of managing wireless connectivity while simultaneously satisfying the objectives of the MCC, which include being constantly connected, making effective use of energy by mobile devices, and having the flexibility to scale wireless connections on demand [25].

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When it comes to MCC, one of the primary challenges is the problem of mobile devices that have a very restricted amount of resources. Comparatively speaking, mobile devices have a much lower capacity for storage, processing power, visibility, and battery power than computers do. Additionally, mobile devices have a limited battery life. an example of a solution to this issue may be found in [64], which involves starting the offloading calculation. It is necessary to take into account the cost of energy in addition to issues about security, privacy, handling, and dependability. The resolution of these issues calls for a significant amount of energy [22].

One of the most important features of MCC is offloading, which extends the life of the battery and boosts the speed of apps. Nevertheless, according to the findings of a number of earlier research [51], this concept cannot be considered an efficient procedure for reducing energy consumption and enhancing the performance of mobile devices.

As a result of the fact that MCC is connected to the ownership of the digital material that is acquired, the following problems have arisen. It is possible to save the purchased media files (video, music, e-books, or database) on the cloud rather than keeping them locally. This has the advantage of being more convenient. On the other hand, this raises the issue of who really owns the files that are in dispute. If a certain service is used to acquire the media and the media is stored remotely, there is a risk that the media that was bought will no longer be accessible without the service. In the event that the service that is being given goes bankrupt, for example, the provider has the ability to revoke access to users for any reason that they choose [65].

One of the most important requirements for the MCC is the demand for constant and ongoing communication, which is based on the creation of novel methods and the undertaking of further research. When compared to wired networks, wireless networks experience transmission space that is less reliable, has a lower bandwidth, and is characterized by intermittent transmission. The denial of always-on connection, disproportionate delays in application execution, and excessive use of mobile resources that are restricted are some of the most significant issues that contribute to a decline in quality of service (QoS). In addition, the fundamental characteristics of a seamless ubiquitous layout in a dynamic environment are the presence of intra-system signal handoff plans, dependable inter-systems, and inter-connectivity of heterogeneous wired networks and wireless networks. Nevertheless, in order to address these issues, the future generation

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of wireless networks [66] provides some potential solutions in MCC [21].

The MCC is responsible for ensuring that there is a connection to the Internet that is both quick and regular. The mobile device maintains a continuous connection to the cloud network, allowing the user to access it from any place and at any time they want to stay informed. The Hypertext Markup Language, or HTML5, is a relatively recent technology that has made it possible to cache data on mobile devices. This makes it possible for cloud applications to continue operating normally even when there is a disruption in connection [22].

The dynamic supply of resources on a precisely aligned, self-service basis in virtually real-time, without taking into mind the peak demands from the customers, is what makes cloud computing services scalable. In the context of the MCC, this need is of the utmost importance. Mobile apps may be built in the cloud or on the device, and they can be moved between the two platforms based on the dynamic changes that occur in the computing environment or the preferences of the person using the program. On top of that, the processing of applications will be subject to additional limits due to the limitations of mobile device resources. In light of this, it is recommended that flexible application models be proposed in order to resolve the fundamental processing concerns [33].

Because of this fundamental obstacle, the MCC solutions are restricted to a technique that has a low latency. There are two primary metrics in processing applications that are distant and are negatively impacted by latency in the MCC environment. These metrics include efficient energy consumption [67] and response-time that is interactive [68]. The idea of using WLAN rather than HSDPA (High Speed Download Packet Access) to manage heavy capabilities in nearby computing systems that are referred to as "cloudlets" has been proposed [30]. This is done with the intention of reducing the extended WAN latency. In spite of this, the most significant obstacles that stand in the way of the proposed solution to persuade the user to have faith in the cloudlet's outsourced infrastructure are concerns over security and trust. As a result, further research is necessary in order to build systems that are reliable and provide prompt replies. In a study that was conducted not too long ago by the Nokia Research group [67], it was shown that the bit-rate of data transmission places a considerably greater emphasis on the efficient use of energy in cellular networks in comparison to WLAN. Any increase in the bit rate of the transmission will result in an increase in the efficiency with which the transmission uses energy. Therefore, it is possible to draw the conclusion that a dynamic environment will lead to a context-aware system that is both more intelligent and scalable in the

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MCC [21].

In the realm of cloud computing, data access is a vital requirement due to the fact that the number of cloud services is increasing regularly. The limited resources, poor bandwidth, and mobility of mobile devices are all factors that are contributing to an increasing level of worry on how to manage the data resources that are stored in the cloud. Each input/output (I/O) procedure, including copy, put, list, and cut, is employed by the cloud provider for cloud storage providers that are commercial in nature, such as Amazon S3. Mobile customers see an increase in the cost of network connection and service due to the fact that the I/O operations are often supplied at the file level [25].

Within the context of the MCC, the parameter of the security features is responsible for identifying the concealed security components of the mobile application models. Data integrity, data security, location privacy, identity privacy, authentication, risk management, secure routing, or secure data access management are some of the security elements that are included in this category [69].

Certain applications that are offered as part of the services provided by cloud computing are responsible for managing sensitive personal data, such as credit card card details. Consequently, if cloud service providers were unable to ensure a stringent degree of security, this would constitute a significant risk [70].

An authentication process needs to be carried out on the users in order to get a satisfactory degree of security for communication over the Internet. It is possible to enhance the data security of MCC by implementing the necessary authentication mechanisms via its use. Within the context of MCC, this section delves into the many authentication mechanisms that are available. It is referred to as authentication when the process of verifying the identification of a user is carried out. It's possible that this procedure is the most effective technique to safeguard the data stored on mobile devices. Methods of authentication may be divided into three categories: the first category consists of something that you are aware of, the second category is comprised of something that you own, and the third category is comprised of something that you are [71]. The three distinct types of authentication are based on various aspects of the mobile environment, which are outlined in Figure 9."

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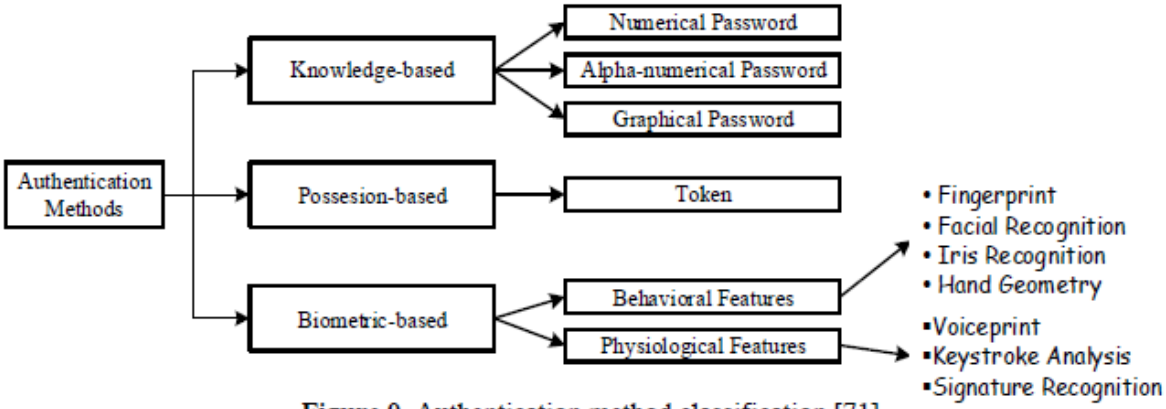

Figure 9. Authentication method classification [71]

As a result of the issues that were discussed before, a number of observers have come to the conclusion that the MCC may be nothing more than a passing phase that will ultimately pass [3]. In order for MCC to acquire a prominent place in the economic world, it is of the highest importance that these problems be handled in the appropriate manner.

Comparing Traditional Mobile Computing (MC) and MCC

This section compares many aspects of mobile computing computing (MCC) to those of conventional mobile computing in order to provide a better understanding of the features of MCC. A description of the specifics of this comparison may be found in Table 1.

Table 1. MCC features comparison

	MCC	MC
Security and Privacy	Low	Medium
Computational Power	High	Low
Storage Capacity	High	Low
Energy Consumption	Low	High
Scalability	High	Low
Reliability	High	Low
Mobility	Unlimited	Unlimited
Integrating Different Services	Yes	No
Multi-tenancy Provisioning	Yes	No
Dynamic Provisioning	Yes	No
Elasticity	High	Low
Availability	On-demand	Periodic

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Conclusion

The empowerment of mobile devices via the use of cloud computing services is the primary objective of mobile cloud computing. Mobile users have access to a limitless amount of resources in MCC, independent of the limits that are inherent to mobile devices. An introduction to the MCC computing idea, which is a computing concept that utilizes cloud computing features in mobile computing, is presented in this work. Despite the fact that it has a number of unique chances, MCC also presents a number of difficulties. This article provides a concise introduction to mobile cloud computing and discusses its many applications. Additionally, the most important benefits and the most difficult aspects of this computer technology are explored.

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