Mobile Cloud Computing

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Abstract— **Mobile Cloud Computing (MCC) is an infrastructure of data storage and data processing which happens outside of the mobile devices. Mobile cloud computing is the combinations of mobile web, cloud computing, mobile computing and wireless networks. Mobile cloud computing provides unrestricted functionalities, rich mobile computational resources, computational technology, platforms, heterogeneous environment, business opportunities for cloud computing providers, mobile users and network operators. The main aim of Mobile cloud computing is provides the rich mobile applications with rich user experience of mobile devices.**

***Index Terms*— Mobile Cloud Computing, Mobile Cloud Computing architecture, Cloud Computing, Computation Offloading.**

I. INTRODUCTION

Mobile cloud computing concept defined on 5 March 2010 in the Open Gardens blog. Cloud Computing is the metaphor for the Internet. Cloud computing provides virtually abundant amount of dynamic resources, on demand computing capacity, large amount of storage, services to individuals and businesses in the form of heterogeneous environment and autonomous services. Therefore cloud computing extends to mobile devices.

Mobile computing is differ from mobile cloud computing. Mobile computing refers to variety of devices that allow people to access data and information but it facing many challenges like communications with respect to security, mobility and privacy and resources like battery life, storage and bandwidth. Mobile Cloud computing based computation offloading increases the application performance, decreases battery power consumption and executes the applications which all unable to execute from the insufficient mobile device resources. Mobile cloud computing referred in two perspectives: (a) Infrastructure based mobile cloud (b) Ad-hoc mobile cloud. In infrastructure based mobile cloud hardware infrastructure is static as well as provides services to mobile users. Ad-hoc mobile cloud is set of mobile devices it behaves like cloud and permit access to Internet based cloud or local services to mobile devices. Therefore mobile cloud computing prefers Ad-hoc mobile cloud based application/system models. Mobile cloud computing computational resources are virtualized we can identified in distributed servers instead of local servers. The number of applications based on Mobile cloud computing such as Google's Gmail, Navigation, Maps Voice search applications to mobile devices. Platforms for a mobile devices are BlackBerry platform developed by Research In Motion (RIM), iMac developed by Apple, Android platform developed by Google, Moto blur from Motorola, Live Mesh developed by Microsoft.

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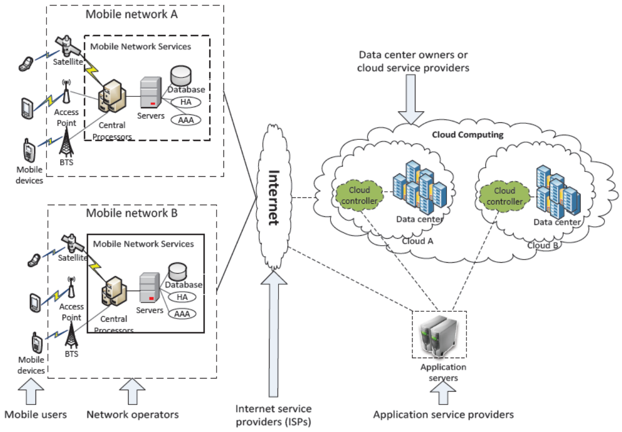
II. MOBILE CLOUD COMPUTING ARCHITECTURE

The Mobile cloud computing architecture shown in Fig 1. The main components are mobile users, Network Operators, Internet Service Providers and Application service providers. Mobile devices establishes a connection to Mobile Network through Satellite, Access Point, Base Transceiver Station (BTS) this connection controls and establishes the functional Interfaces between Mobile devices and mobile networks. Mobile users sends requests and Information (like location and ID) are transmitted to Central Processors and this connected to the Servers it provides Mobile Network Services.

Fig 1 : MOBILE CLOUD COMPUTING



ARCHITECTURE

Network operators will provides services to Mobile Users for accounting, authentication and authorization (AAA) based on subscribers and Home Agent (HA) the Data stored in Database. Database provides and manages Local Data storage information for Mobile devices that depends on Platform. Database provides Thread Safe Concurrent access to all Mobile devices.

After this issue Subscribers sends requests to cloud, cloud delivers requests through Internet. Cloud controllers which are in cloud process/executes the requests with cloud services provides to Mobile Users. The cloud computing services are developed with virtualization, reliability, utility Computing and Service oriented Architecture, thus the layers of cloud computing (Fig 2) is divided into four layers are Data Centers, Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service.

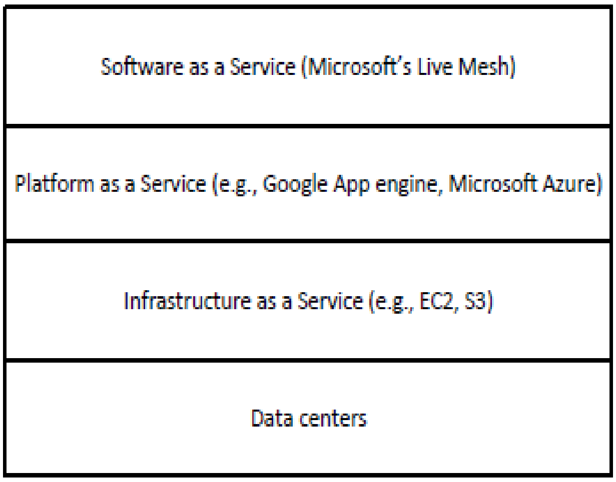


Fig 2 : SERVICE ORIENTED CLOUD COMPUTING ARCHITECTURE

1) Data Centers: This layer based on number of servers it implements a large scale Distributed Network System. It provides an Infrastructure and Hardware facility with high speed, high power supply and low risk for Clouds and provide services to Customers.

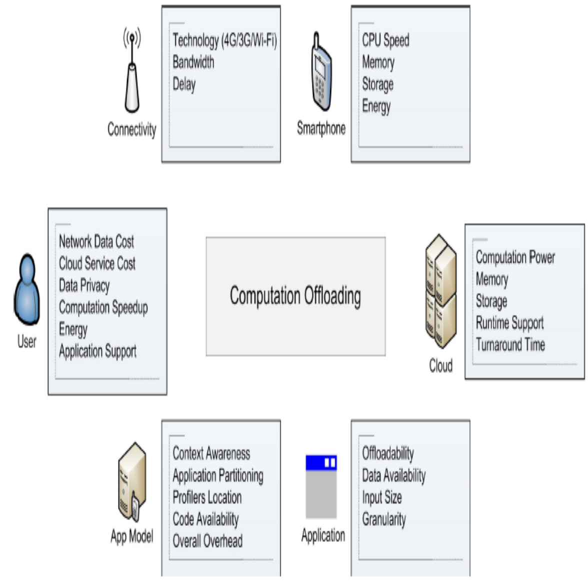
2) Infrastructure as a Service (IaaS): This layer is built on top of the Data centers. IaaS includes computing resources, hardware, storage, network services users and servers. Infrastructure is dynamic in nature it can be shrunk or expand as per requirement. The Users can save money based on how much they used the resources it's like Pays-On-Per-Use resources. The services in this layer are Amazon Elastic Cloud Computing (EC2) and Simple Storage Service (S3).

3) Platform as a Service (PaaS): This layer considered as a core layer. It provides an Advanced Integrated Environment, distributed storage, Management system and distributed file system for cloud computing. The major client for platform layers are program Developers. The platform directly provides resources like program testing, deploying, running and maintaining custom applications. The services in this layer are Google App Engine, Amazon Map Reduce and Microsoft Azure.

4) Software as a Service (SaaS): This layer supports some applications, software distribution, custom interfaces with specific requirements to end users. This layer also called as Application layer. Salesforce is one of the pioneers in providing This Service model provided by one of the pioneer is Salesforce, Google Online Offline and Microsoft's Live mesh such as sharing documents, folder, files and presentations are simultaneously to multiple devices.

Cloud computing architectural provides services flexibly and efficiently to users.

III. CHALLENGES AND ISSUES OF MOBILE CLOUD COMPUTING



1) Computation offloading:

FIG 3 : COMPUTATION OFFLOADING

Mobile cloud computing application detects the connectivity to cloud resources and availability and then it decides whether computation offloading is needed depending on users. If it is needed then Computation offloading is performed. The decision of Computation offloading (FIG 3) is complex process it may affects by other entities such as User, Connectivity, Smartphone, Cloud, Application and application Model.

a) User: A user may enable or disable the computation offloading based on network data cost, cloud service cost, importance of data privacy and job turnaround time. Moreover, the decision is also dependent on the users' desired objective. For instance, a user may be interested in saving energy, enhancing application performance or executing an application that does not have sufficient resources on the smartphone.

b) Connection: Different communication technologies have their own limitations. For instance, Wi-Fi based connections provide high bandwidth and shorter delays. Alternatively, 3G connections provide lower bandwidth and suffer from higher delays compared to Wi-Fi connections [14]. Therefore, if both connections are available, then user may prefer to use Wi-Fi connection. However, Wi-Fi connectivity is not always feasible, particularly in mobile environments. Therefore, 3G/4G connections that charge for bandwidth usage are used. Hence, from a connection point of view, the computation offloading decision can be affected by network bandwidth, delay, and cost.

c) Smartphone: The smartphones have achieved great development in terms of hardware resources in the past few years. The latest smartphones are equipped with high performance processors, memory, sensors and storage. For instance, Sony Xperia S [8] comes up with 1.5GHz Dual Core processor, 1GB RAM, 32GB data storage support, and 1750mAh battery. Similarly, HTC One X [9] has 1.5Ghz Quad-core processor, 1GB RAM, 32GB data storage support, and 1800mAh battery. Therefore, it is obvious that users with high performance smartphones may require mobile cloud support less frequently, compared to the users that have low performance smartphones and runs out of resources quickly.

d) Application Model: The mobile cloud application models differ from each other in terms of design and objectives. For instance, the objective of computation offloading may be energy efficiency, application performance or application execution for devices that do not have sufficient resources. The application models may also differ in terms of context awareness, application partitioning, code availability in the cloud, profilers and overhead.

e) Application: The computation offloading decision also depends on the nature of the application. For instance, an application that requires local hardware resources (GPS, camera, and sensors) may not be able to execute in the cloud unless the application is partitioned into components, and local-resource independent components are moved to the cloud. Similarly, if the application data is unavailable in the cloud and the input data size is too large, then smartphone side computation may be favorable. Alternatively, transferring a large amount of data may incur higher turnaround time and consume higher energy in terms of communication, which may offset the benefits of offloading.

f) Cloud Service*:* The selection of cloud service is very crucial for computation offloading. Therefore, if a user requires mobile cloud support for computation offloading, then it is important that the cloud must have runtime support for the offloaded application/component. Moreover, the leased cloud service must be rich in resources in order to gain advantage of computation offloading. For example, if a smartphone and a Virtual Machine (VM) [4], [11] (deployed in the cloud) have the same specifications (computational power, memory), then the user may not get any improvement in the application performance. Although the scenario may be beneficial in terms of energy (depending on data/code size), it is not beneficial for enhancing application performance. In fact, the application performance may decrease due to the additional computation and delay involved in the offloading process. Fig 3 represents different entities these can affect the computation offloading in different multiple ways. Every entities have there own importance depend on there importance in application take into consideration. Computation offloading is main key feature of Mobile cloud Computing to improves battery lifetime and increase the application performance, efficient and dynamic offloading to Mobile devices depends on environment changes.

2) Security, Trust and privacy: Users needs security and trust, Security is the most prominent bottleneck performance in the Mobile cloud computing. Mobile Cloud computing involves number of Security issues for instance, Data distribution, Data access control Data integrity, secure communication and service availability these issues make mobile cloud computing more challenging.

In Mobile cloud computing security analyzed By two perspectives are mobile devices and cloud. Mobile devices must be clean for avoid malicious codes (viruses, worms and horses) because these can change behavior of an applications, causes data corruption and privacy leakage. Therefore, keep Mobile devices clean. Security applications for scanning process must be used regularly for mobile devices. Alternatively the Cloud must have Multiple backup with Integrity these supports for avoid data loss, alternatives in data, data leakage or denied. Trust is essential for Success of Mobile cloud computing and its occurrence depends on mobile users, Internet and cloud providers.

Privacy is big issue in the big convergence of network technologies, it means when Cloud users stores sensitive data/information and trust Cloud Providers on Public Data Warehouses.

3) Authentication : This is used to secure the Data access compares for mobile environments. It combines implicit authentication platform to authenticate the Mobile users , it supports an integration authentication methods and builds an implicit authentication system by using mobile information (calling logs, location, website accesses and SMS messages) for already existing Mobile environment. This application requires Input it makes difficult to Mobile users, to use difficult passwords or PIN. This leads to use short and simple passwords or PINs. If input fails authentication provides request back to user or denies request.

4) Low Bandwidth: Bandwidth is one of the big issues in MCC since the radio resource for wireless networks is much scarce as compared with the traditional wired networks. [23] proposes a solution to share the limited bandwidth among mobile users who are located in the same area (e.g., a workplace, a station, and a stadium) and involved in the same content (e.g., a video file).

The authors model the interaction among the users as a coalitional game. For example, the users form a coalition where each member is responsible for a part of video files (e.g., sounds, images, and captions) and transmits/exchanges it to other coalition members. This results in the improvement of the video quality. However, the proposed solution is only applied in the case when the users in a certain area are interested in the same contents. Also, it does not consider a distribution policy (e.g., who receives how much and which part of contents) which leads to a lack of fairness about each user's contribution to a coalition.[64] considers the data distribution policy which determines when and how much portions of available are shared among users from which networks (e.g., WiFi and WiMAX). It collects user profiles (e.g., calling profile, signal strength profile, and power profile) periodically and creates decision tables by using Markov Decision Process (MDP) algorithm.

Based on the tables, the users decide whether or not to help other users download some contents that they cannot receive by themselves due to the bandwidth limitation, and how much it should help (e.g., 10% of contents). The authors build a framework, named RACE (Resource-Aware Collaborative Execution), on the cloud to take advantages of the computing resources for maintaining the user profiles. This approach is suitable for users who share the limited bandwidth, to balance the trade-off between benefits of the assistance and energy costs.

5) Availability: Service availability becomes more important issue in MCC than that in the cloud computing with wired networks. Mobile users may not be able to connect to the cloud to obtain service due to traffic congestion, network failures, and the out-of-signal. [25] and [26] propose solutions to help mobile users in the case of the disconnection from clouds. In [25], the authors describe a discovery mechanism to find the nodes in the vicinity of a user whose link to cloud is unavailable. After detecting nearby nodes that are in a stable mode, the target provider for the application is changed. In this way, instead of having a link directly to the cloud, mobile user can connect to the cloud through neighboring nodes in an ad hoc manner.

However, it does not consider the mobility, capability of devices, and privacy of neighboring nodes. [26] tries to overcome the drawbacks of [25]. In particular, [26] proposes a Wi-Fi based multi-hop networking system called MoNet and a distributed content sharing protocol for the situation without any infrastructure. Unlike [25], this solution considers moving nodes in the user's vicinity. Each node periodically broadcasts control messages to inform other nodes of its status (e.g., connectivity and setting parameters) and local content updates. According to the messages, each node maintains a neighboring node list and a content list and estimates role levels of other nodes based on the disk space, bandwidth, and power supply. Then, the nodes with the shortest hop length path and the highest role level are selected as the intermediate nodes to receive contents. Besides, the authors also consider security issues for mobile clients when they share information by using account key (to authenticate and encrypt the private content), friend key (to secure channel between two friends), and content key (to protect an access control).

Two applications are introduced, i.e., WiFace and WiMarket that are two co-located social networking. This approach is much more efficient than the current social networking systems, especially in the event ase of disconnection.

6) Heterogeneity: MCC will be used in the highly heterogeneous networks in terms of wireless network interfaces. Different mobile nodes access to the cloud through different radio access technologies such as WCDMA, GPRS, WiMAX, CDMA2000, and WLAN. As a result, an issue of how to handle the wireless connectivity while satisfying MCC's requirements arises (e.g., always-on connectivity, on-demand scalability of wireless connectivity, and the energy efficiency of mobile devices).

IV. Advantages of Mobile Cloud Computing

a) Extending battery lifetime: Battery is important concerns to Mobile devices. It enhance CPU performance to maintain the disk and in intelligent manner screen reduces power consumption. Mobile device require changes in structure or new hardware some times it causes exponential growth of cost for devices. [18] and [19] evaluate the effectiveness of offloading techniques through several experiments. The results demonstrate that the remote application execution can save energy significantly. Especially, [18] evaluates large-scale numerical computations and shows that up to 45% of energy consumption can be reduced for large matrix calculation. In addition, many mobile applications take advantages from task migration and remote processing. For example, offloading a compiler optimization for image processing [20] can reduce 41% for energy consumption of a mobile device. Also, using memory arithmetic unit and interface (MAUI) to migrate mobile game components [21] to servers in the cloud can save 27% of energy consumption for computer games and 45% for the chess game.

b) Improving reliability: Storing data or running applications on clouds is an effective way to improve the reliability since the data and application are stored and backed up on a number of computers. This reduces the chance of data and application lost on the mobile devices. In addition, MCC can be designed as a comprehensive data security model for both service providers and users. For example, the cloud can be used to protect copyrighted digital contents (e.g., video, clip, and music) from being abused and unauthorized distribution [29]. Also, the cloud can remotely provide to mobile users with security services such as virus scanning, malicious code detection, and authentication [30]. Also, such cloud-based security services can make efficient use of the collected record from different users to improve the effectiveness of the services.

c) Improving processing power and data storage capacity : Mobile Cloud Computing which helps to reduce running cost for computational intensive mobile applications. Mobile Cloud Computing stores large amount of data for mobile users on the cloud computing.

d) Scalability: Mobile cloud computing meets unpredictable user requirements because of flexible resource. Service providers easily they can add and expands applications and services with or without constraints, on resource usage.

e) Multi-tenancy: Sharing of resources and applications occur in between Network operator, data center owner and service providers.

f) Ease of Integration: Multiple applications from various service providers together becomes integrated very easily through Internet and the Cloud to meets the users' needs/demands.

V. Applications of Mobile cloud computing

A. Mobile commerce (m-commerce) : supports for business models like mobile advertising, mobile financing and shopping. The m-commerce applications have to face various challenges (e.g., low network bandwidth, high complexity of mobile device configurations, and security). Therefore, m-commerce applications are integrated into cloud computing environment to address these issues. [22] proposes a 3G E-commerce platform based on cloud computing. This paradigm combines the advantages of both 3G network and cloud computing to increase data processing speed and security level [13] based on PKI (public key infrastructure).

The PKI mechanism uses an encryption-based access control and an over-encryption to ensure privacy of user's access to the outsourced data. In [14], a 4PL-AVE trading platform utilizes cloud computing technology to enhance the security for users and improve the customer satisfaction, customer intimacy, and cost competitiveness.

B. Mobile learning : Mobile learning (m-learning) is designed based on electronic learning (e-learning) and mobility. However, traditional m-learning applications have limitations in terms of high cost of devices and network, low network transmission rate, and limited educational resources [15], [16], [17]. Cloud-based m-learning applications are introduced to solve these limitations. For example, utilizing a cloud with the large storage capacity and powerful processing ability, the applications provide learners with much richer services in terms of data (information) size, faster processing speed, and longer battery life. [28] presents benefits of combining m-learning and cloud computing to enhance the communication quality between students and teachers. In this case, a smartphone software based on the open source JavaME UI framework and Jaber for clients is used. Through a web site built on Google Apps Engine, students communicate with their teachers at anytime. Also, the teachers can obtain the information about student's knowledge level of the course and can answer students' questions in a timely manner. In addition, a contextual m-learning system based on IMERA platform [29] shows that a cloud-based m-learning system helps learners access learning resources remotely. Another example of MCC applications in learning is "Cornucopia" implemented for researches of undergraduate genetics students and "Plantations Pathfinder" designed to supply information and provide a collaboration space for visitors when they visit the gardens [30].

The purpose of the deployment of these applications is to help the students enhance their understanding about the appropriate design of mobile cloud computing in supporting field experiences. In [21], an education tool is developed based on cloud computing to create a course about image/video processing. Through mobile phones, learners can understand and compare different algorithms used in mobile applications (e.g., de-blurring, de-noising, face detection, and image enhancement).

C. Mobile healthcare (m-healthcare) : It offers healthcare, hospital organizations and medical reports and over comes from the traditional medical report. There are a few schemes of MCC applications in healthcare. For example, [24] presents five main mobile healthcare applications in the pervasive environment.

Comprehensive health monitoring services enable patients to be monitored at anytime and anywhere through broadband wireless communications. Intelligent emergency management system can manage and

coordinate the fleet of emergency vehicles effectively and in time when receiving calls from accidents or incidents.

Health-aware mobile devices detect pulse-rate, blood pressure, and level of alcohol to alert healthcare emergency system. Pervasive access to healthcare information allows patients or healthcare providers to access the current and past medical information. Pervasive lifestyle incentive management can be used to pay healthcare expenses and manage other related charges automatically . Similarly, [25] proposes @HealthCloud, a prototype implementation of m-healthcare information management system based on cloud computing and a mobile client running Android operating system (OS). This prototype presents three services utilizing the Amazon's S3 Cloud Storage Service to manage patient health records and medical images. Seamless connection to cloud storage allows users to retrieve, modify, and upload medical contents (e.g., medical images, patient health records and bio signals) utilizing web services and a set of available APIs called REST. Patient health record management system displays the information regarding patients' status, related bio signals and image contents through application's interface.

Image viewing support allows the mobile users to decode the large image files at different resolution levels given different network availability and quality. For practical system, a telemedicine homecare management system [26] is implemented in Taiwan to monitor participants, especially for patients with hypertension and diabetes. The system monitors 300 participants and stores more than 4736 records of blood pressure and sugar measurement data on the cloud. When a participant performs blood glucose/pressure measurement via specialized equipment, the equipment can send the measured parameters to the system automatically, or the participant can send parameters by SMS via their mobile devices. After that, the cloud will gather and analyze the information about the participant and return results.

The development of mobile healthcare clearly provides tremendous helps for the participants. However, the information to be collected and managed related to personal health is sensitive. Therefore, [17], [18] propose solutions to protect participant's health information, thereby increasing the privacy of the services. While [17] uses P2P paradigm to federate clouds to address security issue, data protection and ownership, the model in [18] provides security as a service on the cloud to protect mobile applications. Therefore, mobile health application providers and users will not have to worry about security issue since it is ensured by security vendor.

D. Mobile gamming (m-gamming) : It generates a high potential marketing to service providers. M-game provides Graphic rendering in cloud, saves energy and increases game playing time. [29] demonstrates that offloading (multimedia code) can save energy for mobile devices, thereby increasing game playing time on mobile devices. [21] proposes MAUI (memory arithmetic unit and interface), a system that enables fine-grained energy-aware offloading of mobile codes to a cloud. Also, a number of experiments are conducted to evaluate the energy used for game applications with 3G network and WiFi network. It is found that instead of offloading all codes to the cloud for processing, MAUI partitions the application codes at a runtime based on the costs of network communication and CPU on the mobile device to maximize energy savings given network connectivity.

The results demonstrate that MAUI not only helps energy reduction significantly for mobile devices (i.e., MAUI saves 27% of energy usage for the video game and 45% for chess), but also improves the performance of mobile applications (i.e., the game's refresh rate increases from 6 to 13 frames per second). [50] presents a new cloud-based m-game using a rendering adaptation technique to dynamically adjust the game rendering parameters according to communication constraints and gamers' demands. The rendering adaptation technique mainly bases on the idea to reduce the number of objects in the display list since not all objects in the display list created by game engine are necessary for playing the game and scale the complexity of rendering operations. The objective is to maximize the user experience given the communications and computing costs.

Other applications are : A cloud becomes a useful tool to help mobile users share photos and video clips efficiently and tag their friends in popular social networks as Twitter and Facebook. MeLog [11] is an MCC application that enables mobile users to share real-time experience (e.g., travel, shopping, and event) over clouds through an automatic blogging. The mobile users (e.g., travelers) are supported by several cloud services such as guiding their trip, showing maps, recording itinerary, and storing images and video. [12] introduces a mobile locationing service allowing users to capture a short video clip about the surrounding buildings. The matching algorithm run on a cloud can use a large amount of information to search for a location of these buildings. Also, One Hour Translation [13] provides an online translation service running on the cloud of Amazon Web Services. One Hour Translation helps mobile users, especially foreign visitors, receive the information translated in their language through their mobile devices. A cloud becomes the most effective tool when mobile users require searching services (e.g., searching information, location, images, voices, or video clips).

E. Keyword-based Searching: [24] proposes an intelligent mobile search model using semantic in which searching tasks will be performed on servers in a cloud. This model can analyze the meaning of a word, a phrase, or a complex multi-phase to produce the results quickly and accurately. [25] presents an application using the cloud to perform data searching tasks for mobile users. [25] uses Dessy system [26] to find the users' data, metadata, and context information through desktop search (e.g., indexing, query, and index term stemming, and search relevance ranking) and synchronization techniques.

F. Voice-based Searching: [27] proposes a search service via a speech recognition in which mobile users just talk to microphone on their devices rather than typing on keypads or touchscreens. [27] introduces the AT&T speech mashup model that utilizes web services and cloud computing environment to meet the speech service demands of customers. This model optimizes the data transmission in a mobile network, reduces latency, and is flexible in integrating with other services. Several examples are demonstrated (e.g., speak4it, iPizza, and JME local business search).

G. Tag-based Searching: [28] introduces a photo searching technique based on ontological semantic tags. Mobile users search only recall parameters that are tagged on images before such images are sent to a cloud. The cloud is used for storing and processing images for resource-limited devices. The current service is designed for the images stored on private cloud computing environment. In the future, it is expected to expand for searching images in a public cloud environment.

In addition, there are a mobile-cloud collaborative application [9] to detect traffic lights for the blind, a cloud computing framework [8] to monitor different corners in a house through a mobile device, and some efforts which integrate current services (e.g., Bit Torrent, and Mobile Social Network) into the clouds as in [6], [26]. Thereby, we can recognize that MCC is probably a prevailing technology trend with numerous applications in the near future.

VI. Conclusion and Future Scope

Mobile cloud computing is extension and development of both mobile computing and cloud computing it is well accepted technology with fast growth, mobile web, rich user experience with rich applications and portable etc.. Distributed mobile cloud computing over 5G Heterogeneous environment. The future work is reshapes mobile and query authentication method for mobile cloud computing and also New York-based firm, more than 240 million business will use cloud services through mobile devices by 2015. That transaction will push the revenue of mobile cloud computing to $5.2 billion.

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