Review, Trend and Perspectives on Mobile Cloud Computing

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***Abstract*— Mobile Cloud Computing (MCC) which mixes mobile computing and cloud computing, has become one of the tradebuzz words and a major discussion thread in the IT world. As MCC remains at the first stage of development, it's necessary to understand a radical understanding of the technology so as to illustrate the direction of future analysis. With the latter aim, this paper presents a review on the background and principle of MCC, characteristics, recent analysis work, and future analysis trends. a short account on the background of MCC: from mobile computing to cloud computing is given so followed with a discussion on characteristics and up to dateanalysis work. It then analyses the options and infrastructure of mobile cloud computing. the remainder of the paper analyses the challenges of mobile cloud computing, outline of some analysis comes associated with this space, and points out promising future analysis directions.**

Keywords*— *Mobile Cloud Computing; Mobile Computing; Cloud Computing; Research Directions.

I. INTRODUCTION

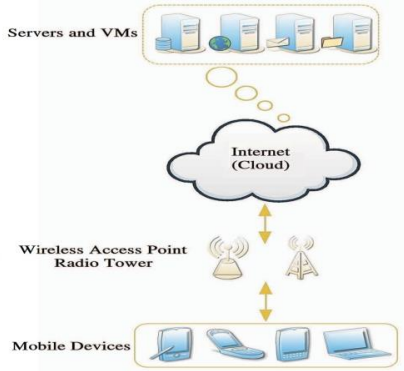
Over the past few years, advances within the field of network primarily based computing associated applications on demand have led to an explosive growth of application models like cloud computing, software as a service, community network, web store, and so on. As a serious application model within the era of the net, Cloud Computing has become a major analysis topic of the scientific and industrial communities since 2006 era. Commonly, cloud computing is said to be services that are provided by associate Internet-based cluster system. Such cluster systems accommodates a bunch of low cost servers or Personal Computers (PCs), organizing the assorted resources of the computers consistent with an explicit management strategy, and giving safe, reliable, fast, convenient and clear services like knowledge storage, accessing and computing to purchasers, Cloud computing \as become more popular which increased its usage in 2012.

Meanwhile, smartphones are considered as the representa- tive for the various mobile devices as they have been connected to the Internet with the rapidly growing of wireless network technology. Ubiquity and mobility are two major features in the next generation network which provides a range of personalized network services through numerous network ter- minals and modes of accessing. The core technology of cloud computing is centralizing computing, services, and specific applications as a utility to be sold like water, gas or electricity to users. Thus, the combination of a ubiquities mobile net- work and cloud computing generates a new computing mode, namely Mobile Cloud Computing.

As an inheritance and development of cloud computing, resources in mobile cloud computing networks are virtualized and assigned in a group of numerous distributed computers rather than in traditional local computers or servers, and are provided to mobile devices such as smartphones, portable ter- minal, and so on. (see Fig. 1). Meanwhile, various applications based on mobile cloud computing have been developed and served to users, such as Googles Gmail, Maps and Navigation systems for Mobile, Voice Search, and some applications on an Android platform, MobileMe from Apple, Live Mesh from Microsoft, and MotoBlur from Motorola. According to the research from Juniper, the cloud computing based mobile software and application are expected to rise 88% annually from 2009 to 2014, and such growth may create US 9.5 billion dollars in 2014.

Fig1: Cloud Computing of Mobile

While mobile cloud computing make a great contributionto our daily lives, it will also, however, bring numerous chal- lenges and problems. In short, the core of such challenges and problems is just how to combine the two technologies seam- lessly. On one hand, to ensure that mobile devices adequately make best use of advantages of cloud computing to improve and extend their functions. On the other hand, to



overcome the disadvantages of limited resources and computing ability in mobile devices in order to access cloud computing with high efficiency like traditional PCs and Servers. Thus, in order to solve the mentioned challenges and point out further research, getting a thorough understanding of the novel computing paradigm - mobile cloud computing, is necessary. This paper introduces the basic model of mobile cloud computing, its background, key technology, current research status, and its further research perspectives as well.

II. BACKGROUND

As a development and extension of Cloud Computing and Mobile Computing, Mobile Cloud Computing, as a new phrase, has been devised since 2009. In order to help us grasp- ing better understanding of Mobile Cloud Computing, let's start from the two previous techniques: Mobile Computing and Cloud Computing.

A. Mobile Computing:

Portability has turned into a prevalent word and quickly in-wrinkling part in the present registering territory. A fantastic development has showed up in the advancement of cell phones, for example, cell phone, PDA, GPS Navigation and workstations with an assortment of versatile figuring, systems administration and security advances. Furthermore, with the improvement of remote innovation like WiMax, Ad Hoc Network and WIFI, clients might surf the Internet a lot less demanding yet not restricted by the links as previously. In this way, those cell phones have been acknowledged by an ever increasing number of individuals as their first decision of working and excitement in their every day lives.

All in all, what is Mobile figuring precisely? In Wikipedia, it is portrayed as a type of human-PC connection by which a PC is relied upon to be transported amid typical use [2]. Portable registering depends on an accumulation of three noteworthy ideas: equipment, programming and correspondence. The ideas of equipment can be considered as cell phones, for example, cell phone and workstation, or their portable parts. Programming of versatile processing is the various portable appli-cations in the gadgets, for example, the versatile program, hostile to infection programming and recreations. The correspondence issue incorporates the foundation of versatile systems, conventions and information conveyance in their utilization. They should be straightforward to end clients.

Features: the highlights of versatile registering are as fol-lows:

1. **Mobility**:
Versatile hubs in portable registering system can set up association with others, even settled hubs in wired system through Mobile Support Station (MSS) amid their moving.

2. **Diversity of system conditions**:
Typically the net-works utilizing by portable hubs are not interesting, such systems can be a wired system with high-data transmission, or a remote Wide Area Network (WWAN) with low-transfer speed, or even in status of disengaged.

3. **Frequent separation and consistency**:
As the lim-itation of battery control, charge of remote correspondence, organize conditions, etc, versatile hubs won't generally keep the association, yet detach and reliable with the remote system inactively or effectively.

4. **Dis-symmetrical system correspondence**:
Servers and passages and different MSS empower a solid send/get capacity, while such capacity in portable hubs is very frail com-paratively. Consequently, the correspondence transfer speed and overhead among downlink and uplink are inconsistency.

5. **Low unwavering quality**:
Because of signs is defenseless to between ference and snooping, a portable registering system framework must be considered from terminals, systems, database stages, just as applications improvement to address the security issue.

Challenges:

Compared with the conventional wired net-work, portable figuring system may confront different issues and difficulties in various viewpoints, for example, flag unsettling influence, security, hand-off postponement, restricted power, low processing capacity, etc. because of the remote condition and various versatile hubs. Also, the Quality of Service (QoS) in portable processing system is a lot less demanding to be influenced by the landforms, climate and structures.

B. Cloud Computing

In the period of PC, numerous clients found that the PCs they purchased 2 years prior can't keep pace with the advancement of programming these days; they need a higher speed CPU, a bigger limit hard plate, and a higher execution Operation System (OS). That is the enchantment of 'Moores Law' which urges client overhauling their PCs always, yet never at any point surpassed the advancement of procedures. In this manner, a term called 'Distributed computing' burst upon our lives.

Distributed computing has turned into a prominent expression since 2007. Be that as it may, there is no consensual definition on what a Cloud Computing or Cloud Computing System is, because of many engineers and associations depicted it from alternate points of view. C. Hewitt [3] presents that the significant capacity of a distributed computing framework is putting away information on the cloud servers, and employments of reserve memory innovation in the customer to get the information. Those customers can be PCs, PCs, cell phones, etc. R. Buyya [4] gives a definition from the point of view of denoting that distributed computing is a parallel and circulated processing framework, which is joined by a gathering of virtual machines with inner connections. Such frameworks powerfully offer figuring assets from specialist co-ops to clients as indicated by their Service level Agreement (SLA). In any case, a few creators referenced that distributed computing was not a totally new idea. L. Youseff [5] from UCSB contend that distributed computing is simply consolidated by numerous existent and couple of new ideas in many research fields, for example, disseminated and matrix registering, Service-Oriented Architectures (SOA) and in virtualization.

In this paper, we consider the distributed computing is an extensive scale financial and business figuring worldview with virtu-alization as its center innovation. The distributed computing framework is the advancement of parallel handling, disseminated and lattice registering on the Internet, which gives different QoS ensured administrations, for example, equipment, foundation, stage, programming and capacity to various Internet applications and clients.

A. Framework:

Cloud computing systems actually can be considered as a collection of different services, thus the framework of cloud computing is divided into three layers, which are infrastructure layer, platform layer, and application layer (see Fig. 2).

1. **Infrastructure layer**:

It incorporates assets of com-puting and capacity. In the base layer of the structure, physical gadgets and equipment, for example, servers and stockpiles are virtualized as an asset pool to give registering capacity and system administrations clients, so as to introduce task framework (OS) and work programming application. Accordingly it is indicated as Infrastructure as a Service (IaaS). Ordinarily benefits in this layer, for example, Elastic Computing Cloud of Amazon [6].

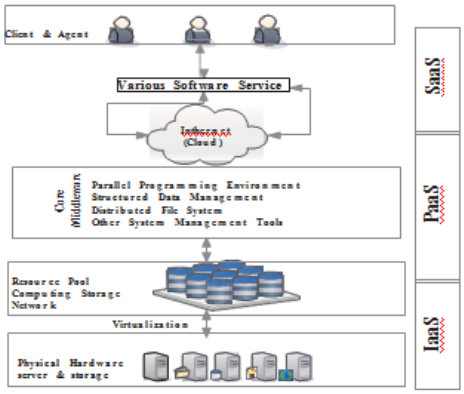


Fig. 2: The Framework of Cloud Computing

2. **Platform layer**:

This layer is considered as a center layer in the distributed computing framework, which incorporates the environ-ment of parallel programming configuration, disseminated capacity and the board framework for organized mass information, appropriated record framework for mass information, and other framework the executives instruments for distributed computing. Program designers are the real customers of the stage layer. All stage assets, for example, program testing, running and keeping up are given by the stage specifically yet not to end clients. Subsequently, this sort of administrations in a stage layer is called Platform as a Service (PaaS). The run of the mill administrations are Google App Engine [7] and Azure from Microsoft [8].

3. **Application layer**:

This layer gives some straight forward programming and applications, just as costumer interfaces to end clients. In this manner we name this sort of administrations in the application layer as Software as a Service (SaaS). Clients use customer programming or a program to call administrations from suppliers through the Internet, and pay costs as per the utility plan of action (like water or power) [9]. The most punctual SaaS is the Customer Relationship Management (CRM) [10] from Salesforce, which was created dependent on the force.com (a PaaS in Salesforce). Some different administrations given by Google on-line office, for example, records, spreadsheets, introductions are all SaaS.

B. Features:

The highlights of Cloud Computing are as follows:

1. **Virtualization***:*

The 'Cloud' can be considered as a virtual asset pool [11] where all base layer equipment de-indecencies is virtualized. End clients get to wanted assets through a program and get information from distributed computing suppliers without keeping up their very own server farms. Besides, some virtual machines (VMs) are regularly introduced in a server so as to enhance the proficiency to utilize assets; and such VMs bolster load relocation when there is a server over-load.

2. **Reliability, ease of use and extensibility:**

Cloud comput-ing gives a protected mode to store client's information while clients don't stress over the issues, for example, programming refreshing, spill fixing, infection assaults and information misfortune. On the off chance that disappointment occurs on a server or VM, the distributed computing frameworks exchange and reinforcement those information to different machines, and afterward erase those disappointment hubs from the frameworks naturally so as to ensure the entire framework has ordinary task [12]. In the interim, cloud can be reached out from even and vertical [13] in a substantial scale arrange, to process various solicitations from a huge number of hubs and hosts.

3. **Large-scale**:

so as to have the ability of supercomputing and mass stockpiling, a distributed computing framework regularly comprises of thousands of servers and PCs. Google Cloud Computing, for instance, has effectively controlled 2% all things considered or around 1 million servers situated in two hundred better places on the planet, and will move upward to 10 million servers in the following decade [14].

4. **Autonomy**:

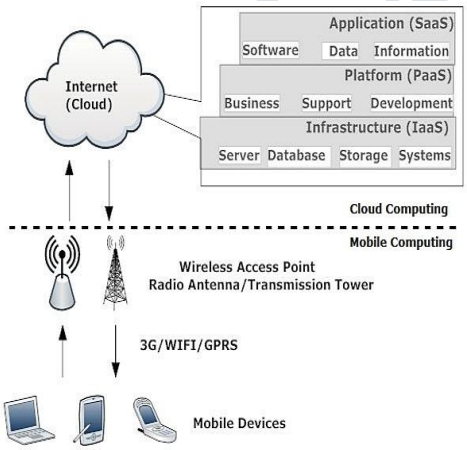
A cloud framework is an autonomic framework, which consequently designs and designates the assets of equipment, programming and capacity to customers on-request, and the administration is straightforward to end clients.

5. Challenges:

As a matter of first importance, distributed computing needs an enhanced component to give a protected and high productivity administration as the various summoned outsider programming and foundations are executing in processing. Furthermore, because of server farms of asset utilizing a mass of power, proficient asset planning system and strategies are required so as to spare vitality. Besides, as a Service Level Agreement (SLA) is set up among clients and specialist co-ops in distributed computing, so the execution and examination of administrations are important to be observed. To wrap things up, basic and advantageous application interfaces are imperative for specialist co-ops in distributed computing, hence a uniform standard is required energetically.

III. MOBILE CLOUD COMPUTING

These days, both equipment and programming of cell phones get more prominent enhancement than previously, some cell phones, for example, iPhone 4S, Android serials, Windows Mobile serials and Blackberry, are never again simply customary cell phones with discussion, SMS, Email and site program, yet are day by day necessities to clients. Then, those cell phones incorporate different detecting modules like route, optics, gravity, ori-



entation, etc. which brings an advantageous and intelli-gent portable experience to clients. In 2010, Google CEO Eric Schmidt depicted versatile distributed computing in a meeting that 'dependent on distributed computing administration advancement, cell phones will turn out to be progressively confused, and advance to a convenient super PC' [15]. Notwithstanding different versatile cloud administrations given by Microsoft, Apple, Google, HTC, etc, clients might be befuddled about what portable distributed computing precisely is, and what its highlights are.

A. Concept and guideline

Comparable with Cloud Computing, there are a ton yet no consensual definitions on what portable distributed computing is. In this paper, we think of it as is a novel registering mode comprising of versatile figuring and distributed computing, which give cloud based administrations to clients through the Internet and cell phones. On one hand, the versatile distributed computing is an advancement of portable figuring, and an augmentation to distributed computing. In portable distributed computing, the past cell phone based escalated registering, information stockpiling and mass data preparing have been exchanged to 'cloud' and in this way the prerequisites of cell phones in processing capacity and assets have been decreased, so the creating, running, conveying and utilizing method of versatile applications have been completely changed. Then again, the terminals which individuals used to get to and obtain cloud administrations are appropriate for cell phones like cell phone, PDA, Tablet, and iPad yet not limited to settled gadgets, (for example, PC), which mirrors the points of interest and unique expectation of distributed computing. Consequently, from the two parts of versatile registering and distributed computing, the portable distributed computing is a combi-country of the two innovations, an improvement of circulated, network and brought together calculations, and have expansive prospects for application.

As indicated is the Fig. 3, portable distributed computing can be essentially separated into distributed computing and versatile processing. Those cell phones can be PCs, PDA, cell phones, etc. which interfaces with a hotspot or base station by 3G, WIFI, or GPRS. As the figuring and significant information handling stages have been moved to 'cloud', the capacity require-ment of cell phones is constrained, some minimal effort cell phones or even non-cell phones can likewise accomplish versatile distributed computing by utilizing a cross-stage mid-product. Al-however the customer in versatile distributed computing is changed from PCs or settled machines to cell phones, the principle idea is still distributed computing. Versatile clients send administration solicitations to the cloud through an internet browser or work area application, at that point the administration segment of cloud designates assets to the demand to build up association, while the checking and ascertaining elements of versatile distributed computing will be actualized to guarantee the QoS until the association is finished.

Fig. 3: Architecture of Mobile Cloud Computing

B. Challenges and arrangements

The principle goal of portable distributed computing is to give a helpful and quick strategy for clients to get to and get information from the cloud, such advantageous and fast technique implies getting to distributed computing assets viably by utilizing mo-bile gadgets. The significant test of portable distributed computing originates from the characters of cell phones and remote systems, just as their own confinement and constraint, and such test makes application planning, programming and conveying on versatile and dispersed gadgets more convoluted than on the settled cloud gadgets [16]. In versatile cloud com-puting condition, the constraints of cell phones, nature of remote correspondence, kinds of use, and backing from distributed computing to portable are terrifically vital elements that influence surveying from distributed computing. Table 2 gives a diagram

of proposed difficulties and a few arrangements about versatile distributed computing.

1. **Limitations of cell phones**:

While talking about mo-bile gadgets in cloud the main thing is asset compel. In spite of the fact that cell phones have been enhanced clearly in different angles, for example, ability of CPU and memory, stockpiling, size of screen, remote correspondence, detecting innovation, and task frameworks, still have genuine impediments, for example, restricted processing capacity and vitality asset, to send entangled applications. By stand out from PCs and Laptops in a given condition, these cell phones like iPhone 4S, Android serials, Windows Mobile serials decline multiple times in handling limit, multiple times in memory, 5 to multiple times away limit and multiple times in system data transfer capacity.

Regularly, cell phone should be charged ordinarily as di-alling calls, sending messages, surfing the Internet, people group getting to, and other web applications. As indicated by past improvement slants, the expanded versatile processing capacity and quick advancement of screen innovation will prompt more

TABLE I: Challenges and Solutions of Mobile Cloud Com-puting

Challenges	Solutions
Limitations of mobile devices	Virtualization and Image, Task migration
Quality of communication	Bandwidth upgrading, Data delivery time reducing
Division of applications services	Elastic application division mechanism

what's more, increasingly entangled applications conveyed in cell phones. In the event that the battery innovation can't be enhanced in a brief timeframe, at that point how to viably spare battery control in cell phone is a noteworthy issue we meet today.

The preparing limit, stockpiling, battery time, and commu-nication of those cell phones will be enhanced reliably with the improvement of portable processing. Be that as it may, such gigantic varieties will continue as one of significant difficulties in portable distributed computing.

2. **Quality of correspondence**:

Conversely with wired net-work utilizes physical association with guarantee transmission capacity con-sistency, the information move rate in versatile distributed computing condition is continually changing and the association is spasmodic because of the current freedom in system overlay. Moreover, server farm in extensive undertaking and asset in Internet specialist organization ordinarily is far away to end clients, particularly to cell phone clients. In remote system, the system inertness postponement may 200 ms in 'last mile' yet just 50

1.Upgrade transmission capacity for remote association, make the web content progressively appropriate for portable system utilizing local server farms.

2.Deploy the application handling hub at the 'edge' of cloud so as to lessen information conveyance time.

3.Duplicate cell phones to cloud utilizing virtualization and picture advancements, to process Data-Intensive Computing (DIC) and EnergyIntensive Computing, for example, infection check ning in cell phones.

4.Dynamically streamline application push in cloud and the division with portable terminals.

C. Related work

So far, industrial and scientific communities have been do- ing various researches for responding to the above challenges. Some typical research projects and cases are presented in the following.

1. **Augmented Execution**:

So far, industrial and scientific communities have been doing various researches for respond- ing to the above challenges. Some typical research projects and cases are presented in the following.
CloneCloud is introduced by B. Chun [17] in 2011. The core method is using virtual machine migration technology to offload execution blocks of applications from mobile devices to Clone Cloud seamlessly and partly, in order to fully or semi-automatically extend or modify the smartphone-based execution to a distributed environment (smartphone computing plus cloud computing). In a CloneCloud system (see Fig. 4).

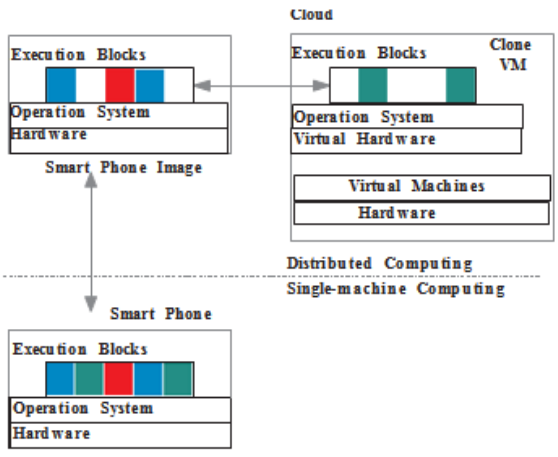


Fig. 4: ClouеCloud System Architecture

The 'Clone' is a perfect representation of a cell phone running on a virtual machine. By stand out from cell phones, such a 'clone' has more equipment, programming, arrange, vitality assets in a virtual machine which gives increasingly reasonable condition to process entangled tasks.In the chart, an assignment in cell phone is separated to 5 diverse execution squares (we mark them as various hues), and the cell phone is cloned (virtualized) as a picture in appropriated registering condition. At that point the picture passes some registering or vitality serious hinders (the Green squares) to cloud for preparing.

When those execution squares have been finished, the yield will be passed from CloneCloud to the cell phone. A noteworthy favorable position of the CloneCloud is upgraded cell phones execution. Byung steps through an exam by executing a face following application in a cell phone with and without CloneCloud. The outcome demonstrates that just 1 second is spent in CloneCloud condition yet right around 100 seconds in the cell phone without CloneCloud. Another favorable position of CloneCloud is diminished battery consump-tion as cell phones don't utilize its CPU as every now and again. The detriments of CloneCloud are handover delay, transmission capacity impediment. As we realize that the speed of information transmission among cell phones and base station isn't steady (air conditioning cording to the circumstance), along these lines, the CloneCloud will be inaccessible if portable clients stroll in the flag's visually impaired zone.

In view of the CloneCloud, X. Zhang has presented an Elastic application programming model for versatile cloud com-puting in [18] to evacuate the limitations of portable stages by stretching out these portable terminals to cloud through a dis-tributed structure. This model partitions a solitary application into a scope of versatility designs called weblets, and dynamic adjustment of arrangement running on web based cloud and cell phones. Accordingly, the capacity of cell phone can be improved to process for progressively complete assignments. Moreover, a cost model is connected in Zhangs research to modify the examples execution arrangements. Notwithstanding, in this model, despite everything we need a system to deal with the communi-cation between weblets in cell phones because of such gadgets changing their correspondence channel, (for example, 3G to WIFI or GPRS). Another test for this model is that a rapid transmission capacity or media channel is required to guarantee the nature of correspondence between weblets.

Despite the fact that the above techniques can decrease control utilization on cell phones successfully, they may at present meet a potential long communication reaction in information transmission between a cloud and terminals. In this way, offloading all applications from cell phones to the cloud can't be supported for power con-sumption, particularly for some lightweight applications which are reasonable to be conveyed in neighborhood cell phones. (In any case, isn't worth to be conveyed to cloud). Y. Lu [19] proposed an answer, called Virtualized Screen, to move screen rendering from cell phones to a cloud as an administration. In his strategy, just piece of cell phone's screen is virtualized in cloud, which includes a gathering of information in showcase pictures, content substance, video and sound, contribution of console, contacting, and pen on cell phones. Alternate applications with vitality escalated processing keep running on cloud. Along these lines, parts of uses and cooperations are offloaded and executed in cloud, and some light power utilization activity or applications are sent in neighborhood cell phones, which could viably lessen control consump-tion and collaboration delay. There still remains a future research point here: making an ideal component to choose which application is conveyed in cloud, and which one in nearby cell phones. What's more, some different issues, for example, protection, security or dependability likewise should be considered in the movement procedure.

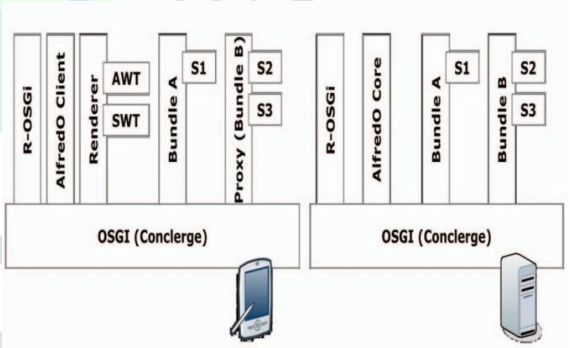
2. Elastic Applications:

In request to give a more effec-tively portable cloud application, analysts have created what's more, expanded CloneCloud-based calculations utilizing progressively relocating segment of uses to the remote server in cloud.

AlfredO [20] is a middleware stage to naturally circulate diverse layers of use in cell phones and cloud, individually, by demonstrating applications as a consump-tion diagram, and finding the ideal modules. The test outcome demonstrates that such stage enhances the execution of applica-tions in distributed computing viably. AlfredO framework comprises of three packages (the interface epitome on Java classes and administrations): AlfredOClient and Renderer on the customer and AlfredOCore on the server.

Fig. 5: AlfredO Architecture

At the point when a customer asks for an application, AlfredOCore first models such application and processes the ideal convey ment, and afterward send application descriptor and the rundown of administrations to AlfredO Client. Renderer utilizes the descriptor to create the comparing AWT or SWT interface, while AlfredO Client gets the predetermined administrations by



means of R-OSGi [21].Similar with [19], AlfredO executes parts of utilization remotely to spare battery vitality and broaden asset of the cell phone successfully. Notwithstanding, such models don't sup-port stage autonomous agreeable connection in an open system, and this issue is should have been considered in future research.

S. Jeong [22] from Samsung presents a novel flexible ap-plication show which gives a consistent and straightforward utilization of cloud to broaden and settle the constraint of cell phones. This model empowers a parcel to a solitary application into numerous parts called Weblet, and powerfully sends these Weblets in execution as per a setup strat-egy at cloud and versatile terminals. Notwithstanding, some overhead is produced in the correspondence among Weblets, between the Internet and Weblets, and the executing Weblets amid the model preparing. So as to limit the above additional overhead and advance the expense of flexible applications, the creators

displayed a cost model in their system, which gathers sensor information, (for example, battery life, heaps of gadgets and cloud, arrange conditions, etc.) from both cell phones and cloud as info, and actualizes the ideal calculation to powerfully yield an execution setup for the applications, for example, sending of Weblet, asset allotting of cloud, choosing of various system association, etc.

3. Migration Optimization:

As the versatility include in cell phones, give a consistent relocation condition to information transmission or administration ensure has turning into another hot issue in portable distributed computing research. An ideal relocation system can diminish communication delay, upgrade handling ability, and enhance client's experience adequately.

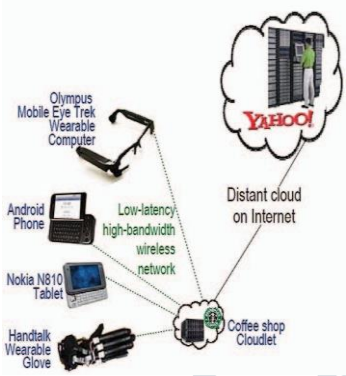


Fig. 6: Concept and Infrastructure of Cloudlet

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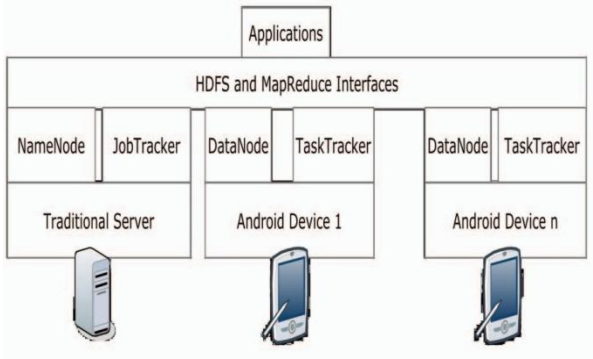

Fig. 7: Hyrax Infrastructure

VI. CONCLUSION

With the high increasing of data computation in commerce and science, the capacity of data processing has been consid- ered as a strategic resource in many countries. Mobile cloud computing (MCC), as a development and extension of mobile computing (MC) and cloud computing (CC), has inherited the high mobility and scalability, and become a hot research topic in recent years. We conclude that there are three main optimization approaches in MCC, which are focusing on the limitations of mobile devices, quality of communication, and division of applications services. Firstly, using virtualization and image technology can address it effectively, and immigrate task from terminal to cloud is also a good way to achieve better results. Secondly, as we know the quality of communication in wired network is better than in wireless network, so reducing the proportion of data delivery in wireless environment is an effective way to improve the quality. In addition, upgrading bandwidth is envisaged to be a simple way to increase per- formance but it incurs additional cost to users. Deploying an effective elastic application division mechanism is deemed to be the best solution to guarantee the application service in MCC; its complicated, but promising high impact results.

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