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Mobile Cloud Computing: The Emerging Computing Paradigm for the 21st century

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Abstract: During the last few years, there is a revolutionary development in the field of computing paradigms, multimedia communication and wireless technology. Together with an explosive growth of the mobile applications and emerging of cloud computing concept, mobile cloud computing (MCC) has been introduced to be a potential technology for mobile services. MCC integrates the cloud computing into the mobile environment. MCC has revolutionized the way in which mobile subscribers across the global leverage services on the go, it also enable the user to access value added services anytime, anywhere. This paper gives a survey of cloud computing, mobile computing and mobile cloud computing which helps general readers have an overview of the computing paradigms including the definition, architecture, and applications etc. for future opportunities and legal issues for developing countries. In addition, the future research directions of computing paradigms are discussed.

Keywords: computing paradigms, cloud computing (cc), wireless networks, mobile computing (mc), mobile cloud computing (mcc).

I. INTRODUCTION

The idea of delivering the computing power as a utility was first put forth by John McCarthy [1] in 1961 and was reinforced by Leonard Kleinrock [2] in 1969, but, was lacking technological support to realize. The last decade has witnessed rapid advances in many key technologies pertaining to Information and Communication leading to the 21st century vision of utility computing, which involves delivery of commoditized computing services like public utilities such as electricity, water, gas, and telephony [3]. Most prominent of these technologies belong to the category of parallel and distributed computing developed with an objective to achieve either high performance or high availability economically. The list of such technologies include, Cluster computing, Grid computing, Peer to peer computing, Ubiquitous computing and Mobile computing. The cloud symbol is used to represent any network in network diagrams [17]. But, very often it is used to represent the internet. The term 'cloud' as a metaphor for the internet has been around since 1990s. . Cloud computing can be considered as a confluence of all the technologies listed out earlier, and therefore may be treated as a superset of these technologies. Forming a thorough ground in this paradigm demands at least a brief knowledge about its enabling technologies.

There is a lot of ambiguity in the computer industry regarding cloud computing and it's supporting technologies due to the overlapping that exists in their implementation. All these technologies are matured enough so that their complete discussion is beyond the scope of this paper. A brief discussion of key aspects related is presented below.

Parallel computing, which involves simultaneous execution of more than one tasks can be considered as the starting point in the evolutionary scenario of cloud computing. The evolution of **distributed systems**, which involves independent networked computers working together for a single objective, contributed to a great extent with flexible and scalable architectures to achieve the high performance in a most economical manner. R. K. Buyya's [3] effort in defining and distinguishing the cluster, grid and cloud indicates that all the three computing architectures basically belong to the category of distributed systems.

Grid computing, inspired by electrical power grid, involves a variety of geographically distributed computational resources like high-end servers, supercomputers, clusters, storage systems, data and other specialized resources, that work collectively for a large scale application demanding enormous resources [3,10].

Finally, the most important technology that made the dream of delivering computing as a utility come true is **virtualization**. The three existing forms of virtualization categorized as: Server virtualization, Storage virtualization and Network virtualization, have inexorably led to the evolution of Cloud computing. Virtualization," which is a method of cloud computing that enables one piece of hardware to run multiple virtual environments.

Finally, to understand more about what cloud computing is and is not, it is important to understand how this model of computing has evolved. As Alvin Toffler notes in his famous book, *The Third Wave* (Bantam, 1980), civilization has progressed in waves (three of them to date: the first wave was agricultural societies, the second was the industrial age, and the third is the information age). Within each wave, there have been several important sub waves. In

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this post-industrial information age, we are now at the beginning of what many people feel will be an era of cloud computing in Figure 1.

The remainder of the paper is organized as follows. Section II discusses the cloud computing in detail. Section III discusses the mobile computing in detail. Section IV discusses the mobile cloud computing in detail. Finally, Section V concludes the paper and presents future research directions.

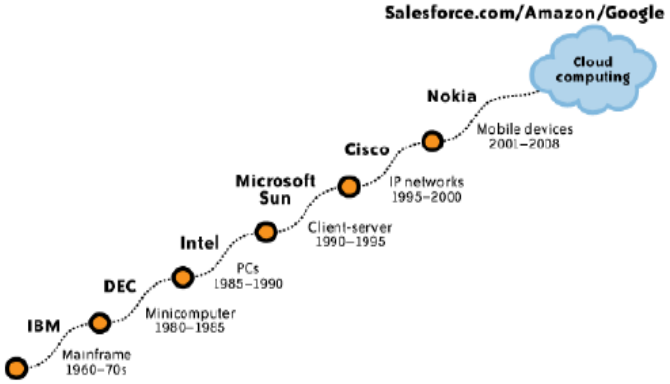

Figure 1. Evolution in Cloud Computing

II. CLOUD COMPUTING

The traditional computing paradigm prevailing today needs the application software, other programs and updates to be installed and run on our local machine. Upgrading the hardware and software as per the changing computational needs is a costlier affair. The issue is more obvious in the case of real-time and scientific applications, which demand high performance computing with large data centers to be set up and maintained. Recent advances in the Information and Communication Technologies have led to the evolution of an emerging computing model called cloud computing, which is considered as a paradigm shift from the traditional computing model. The basic idea of the cloud computing is to provide computing power as a utility like water, electricity, gas, telephony etc., in the form of services via the internet. Cloud computing facilitates the users to access scalable computing services on demand, from anywhere, using any internet enabled device.

A. Definition:

Regarding definition of cloud computing model, the most widely used one is made by NIST as "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models."

Definition of cloud computing [2] is based on five attributes: multitenancy (shared resources), massive scalability, elasticity, pay as you go, and self-provisioning of resources.

B. Architecture:

The cloud computing architecture of a cloud solution is the structure of the system, which comprises and cloud resource, services, middleware and software components, geo-location, the externally visible those [6]. It is achieved with the help of a hypervisor, a software or hardware that servers as a bridge between physical devices and virtual applications. This level manages the physical resources and allows sharing of their capacity among virtual instance of servers, which can be enabled or destroyed on demand and see the below Figure 2.

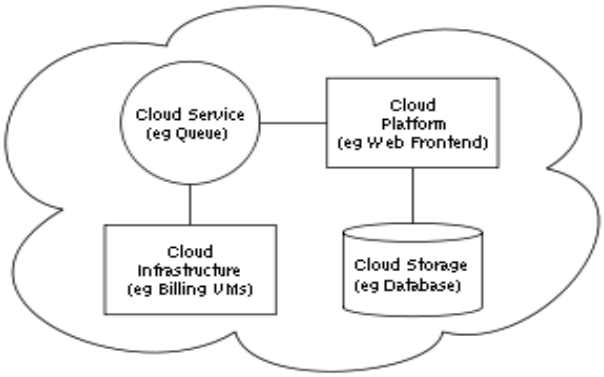

Figure 2. Cloud Computing Architecture

C. Characteristics:

Cloud computing is cost-effective. Here, cost is greatly reduced as initial expense and recurring expenses are much lower than traditional computing. Cloud is characterized by features such as platform, location and device independency, which make it easily adoptable for all sizes of businesses, in particular small and mid-sized. Cloud computing also brings an array of new features compared to any other computing paradigms there are Scalability and On-Demand Services, Quality of Service (QoS), User-Centric Interface, Autonomous System and Pricing.

Some of the most important five key characteristics are,

a. On-demand Self Service:

A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider.

b. Broad Network Access:

Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms.

c. Resource Pooling:

The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.

d. Measured Service:

Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service. Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

e. Selection of Provider:

A good service provider is the key to good service. So, it is imperative to select the right service provider. One must

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make sure that the provider is reliable, well-reputed for their customer service and should have a proven track record in IT- related ventures.

f. Rapid Elasticity:

Service can be rapidly and elastically provisioned.

D. Service Models:

There are three cloud service models and these three fundamental classifications are often referred to as "SPI Model" i.e. software, platform and infrastructure as a service as shown in below Figure 3.

- ***a. Infrastructure as a Service (IaaS)-*** **T**his is the base layer of cloud service model. It can be used to deliver the computer hardware as a service. It enables the provider to offer unlimited virtual server to customer and make cost effective use of hosting hardware. Eg. Amazon, Rackspace etc.,
- ***b. Platform as a Service (PaaS)*** - This is the middle layer of cloud service model. It provides an executive environment for software development for developers over the internet. Developers write the code and the Paas provider provides a way to upload the code into the internet. Eg. Google App Engine, Microsoft Azure
- ***c. Software as a Service (SaaS)*** - This is the highest layer of the cloud stack. It is designed to simply rent out the software to the user. Eg. Facebook, twitter, gmail, yahoo etc
- ***d. Monitoring-as-a-Service (MaaS)*** – It is the outsourced provisioning of security, primarily on business platforms that leverages the Internet to conduct business. MaaS has become increasingly popular over the last decade.

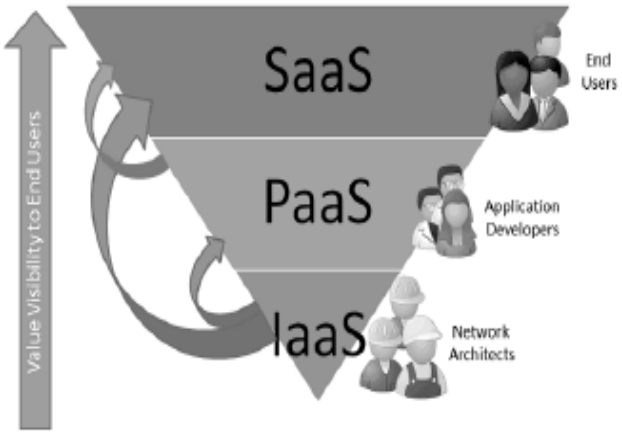

Figure 3. Cloud Computing Services

E. Deployment Models:

There are six types of cloud available in cloud computing i.e. private cloud, public cloud, hybrid cloud, distributed cloud and community cloud as shown in Figure 4. These deployment models describe who owns, manages and is responsible for the services. The detail types of different type cloud are as follows:

- ***a. Public Cloud (External Cloud):*** Public cloud infrastructure is owned by an organization selling cloud services to the general public or to a large industry group. Two examples are Amazon Web Services (AWS) and Microsoft Azure.
- ***b. Community Cloud:*** Community cloud infrastructure is shared by several organizations and supports a specific community that has a shared mission and shared goals, security requirements, policies, and compliance considerations. An example is Google Gov.
- ***c. Private Cloud (Internal Cloud):*** Private cloud infrastructure is owned or leased by a single organization and it is operated solely for that organization. Intel, Hewlett Packard (HP) and Microsoft have their own internal private clouds.
- ***d. Hybrid Cloud (Mixed Cloud):*** Hybrid cloud infrastructure consists of two or more clouds (public, community, or private) that remain unique entities but are bound together by standardized or proprietary technology that enables data or application portability.
- ***e. Federated Cloud:*** A federated cloud (also called cloud federation) is the deployment and management of multiple external and internal cloud computing services to match business needs..
- ***f. Personal Cloud:*** A small server in a home or small business network that can be accessed over the Internet.

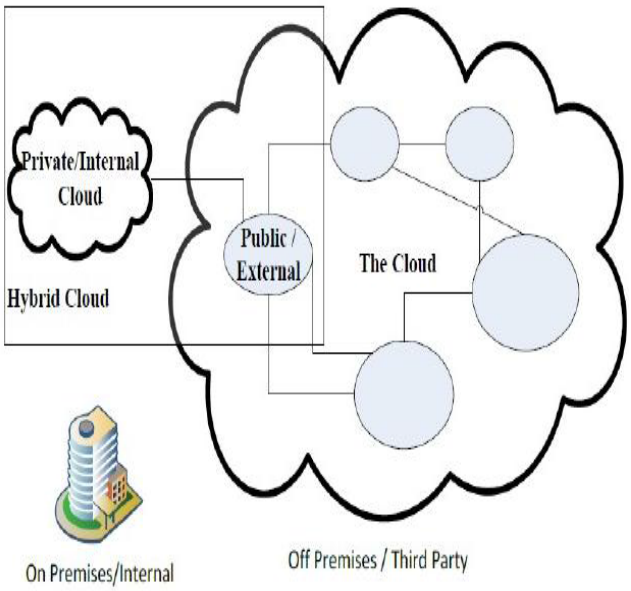

Figure 4. Cloud Computing Deployment Models

F. Benefits:

As cloud computing has taken hold, there are six major benefits that have become clear,

- ***a. Anywhere/anytime access*** - It promises "universal" access to high-powered computing and storage resources for anyone with a network access device.
- ***b. Collaboration among users*** - cloud represents an environment in which users can develop software based services and from which they can deliver them.
- ***c. Storage as a universal service*** - The cloud represents a remote but scalable storage resource for users anywhere and everywhere.
- ***d. Cost benefits-*** the cloud promises to deliver computing power and services at a lower cost. "ONLY PAY FOR WHAT YOU USE", Flexible scaling of resources (resource optimization) Rapid, request-driven provisioning.

G. Applications:

Cloud computing is Internet-based computing, whereby shared resources, software and information are provided to computers and other devices on-demand, like a public utility. Cloud computing is a technology that uses the internet and central remote servers to maintain data and applications. Internet has been a driving force towards the various technologies that have been developed since its inception. Arguably, one of the most discussed among all of them is *Cloud Computing*.

H. Advantages:

The advantages of using cloud computing include:

a. Reduced hardware and maintenance cost.
b. Accessibility around the globe.
c. Flexibility and highly automated processes wherein the customer need not worry about mundane concerns like software up-gradation.

The main advantage of cloud is cost savings.

I. Disadvantages:

The prime disadvantage is security like data security, data locality and data integrity etc.

III. CHALLENGES

The new paradigm of cloud computing provides an array of benefits and advantages over the previous computing paradigms and many organizations are migrating and adopting it. However, there are still a number of challenges, which are currently addressed by researchers, academicians and practitioners in the field.

Performance, Security and Privacy, Control, Bandwidth Costs Reliability.

IV. OPEN RESEARCH ISSUES IN CLOUD COMPUTING

Threats and opportunities of the cloud, Privacy, Privacy solutions, Compliance, Legal, Vendor lock-in, Open source, Open standards, Security, Sustainability, Abuse, IT governance, Consumer end storage, Ambiguity of terminology, Performance interference and noisy neighbors and Monopolies and privatization of cyberspace.

V. MOBILE COMPUTING

A computer network is collection of several homogeneous/heterogeneous systems, commonly used for resource sharing. Computer networks can be classified in many ways like Area wise: LAN, MAN, WAN and PAN. And As per medium it used like Wired Computer Network and Wireless Computer Network.

A. Wireless Computer Network:

Wireless refers to the method of transferring information between a computing device, such as a personal data assistant (PDA), and a data source, such as an agency database server, without a physical connection. Not all wireless communications technologies are mobile.

It also defines like which works without wires. Systems transmit data through radio waves. Users are mobile; they can access information within the range.

E.g. Wireless LAN i.e. ***"Wi-Fi"*** (Wireless Fidelity)

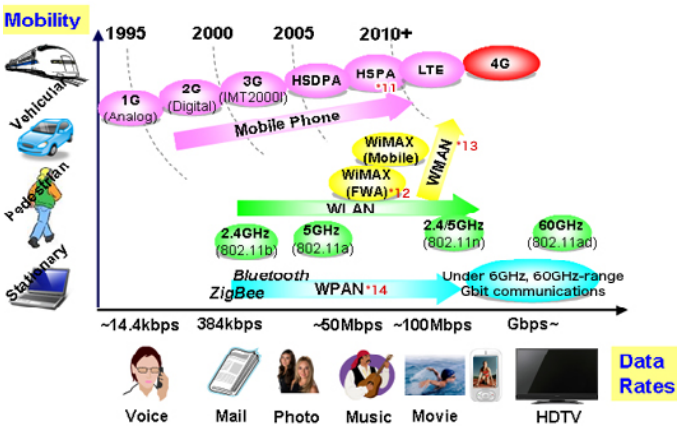

Figure 5. Evolution in Wireless Networks

Advances in wireless networking have prompted a new concept of computing, called mobile computing in which users carrying portable devices have access to a shared infrastructure, independent of their physical location. This provides flexible communication between people and (ideally) continuous access to networked services. Mobile computing is revolutionizing the way computers are used and in the coming years this will become even more perceptible although many of the devices themselves will become smaller or even invisible (such as sensors) to users as shown in above Figure 5.

A. Definition:

Mobile Computing is "taking a computer and all necessary files and software out into the field." "mobile computing" is type of computing which use intranet e.g. cell phone.

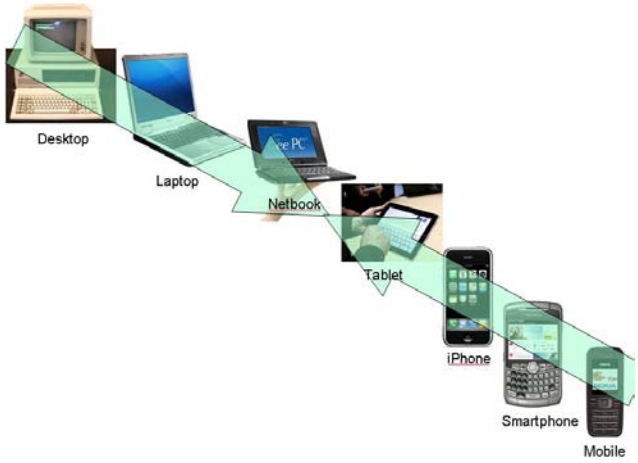

Figure 6. Evolution in Mobile Computing

Mobile computing and wireless technology usage has grown tremendously in recent years, to the extent where it is considered normal everyday technology in schools and many businesses *Mobile* simply describes a computing device that is not restricted to a desktop. A mobile device may be a PDA, a "smart" cell phone or Web phone, a laptop computer, a tablet PC or any one of numerous other devices that allow the user to complete computing tasks without being physically connected to a network. Mobile computing does not necessarily require wireless communication. In fact, it may not require communication between devices at all as shown in above Figure 6.

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B. Architecutre:

Mobile Computing for

a. Patient's clinical information available anytime, anywhere.
b. POC (Point of Care) information
c. Easy to use system for everybody
d. Prevent errors and promote efficiency

as shown in below Figure 7.

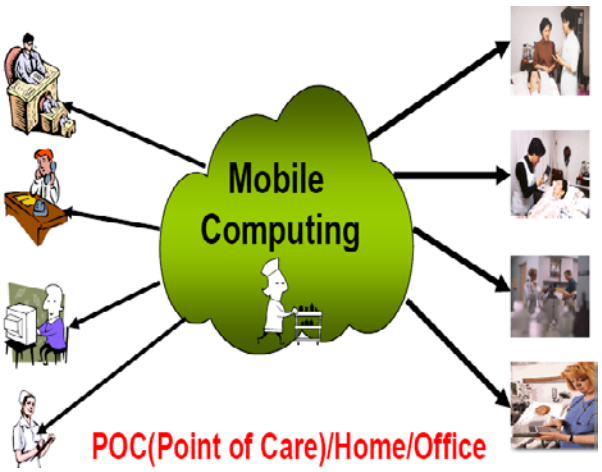

Figure 7. Mobile Computing Architecture

C. Characteristics:

We can define a computing environment as mobile if it supports one or more of the following characteristics:

a. ***User Mobility:*** User should be able to move from one physical location to another location and use the same service. The service could be in the home network or a remote network.

b. ***Network Mobility:*** User should be able to move from one network to another network and use the same service.

c. ***Bearer Mobility:*** User should be able to move from one bearer to another and use the same service.

d. ***Device Mobility:*** User should be able to move from one device to another and use the same service.

e. ***Session Mobility:*** A user session should be able to move from one user-agent environment to another.

f. ***Service Mobility:*** User should be able to move from one service to another.

g. ***Host Mobility:*** The user device can be either a client or server. When it is a server or host, some of the complexities change. In case of host mobility the mobility of **IP** needs to be taken care of.

D. Service Models:

Models are mainly concerned with the characteristics of mobile units such as the unit of mobility (who is allowed to move), its location (where a mobile unit is positioned in space) and its context (determined by the current location of mobile units). There are many existing models and many more are still in research:

a. Random mobility model(s)
b. Markovian model
c. Exponential Correlated Random Model
d. Nomadic Community Model

E. Deployment Models

The mobile computing functions can be logically divided into following major segments as shown in below Figure 8.

a. ***User with device:*** The user device, this could be a fixed device like desktop computer in office or a portable device like mobile phone

b. ***Network:*** Whenever a user is mobile, he will be using different networks at different places at different time. Example: GSM, CDMA, iMode, Ethernet, Wireless LAN, Bluetooth etc.

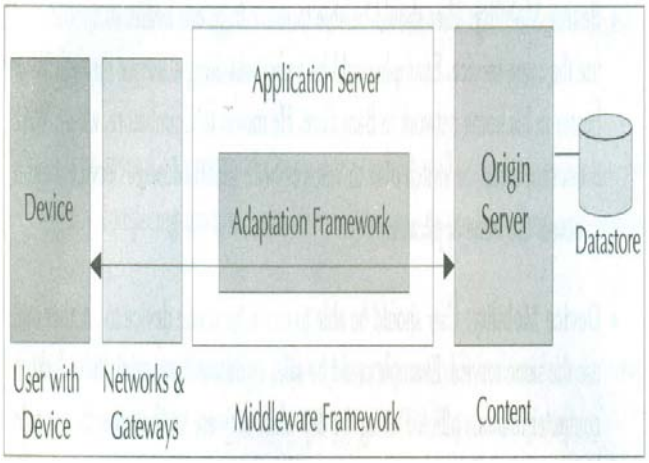

Figure 8. Mobile Computing Functions

c. ***Gateway:*** This is required to interface different transport bearers. These gateways convert one specific transport bearer to another transport bearer.

d. ***Middleware:*** This is more of a function rather than a separate visible node. In the present context middleware handles the presentation and rendering of the content on a particular device. It will also handle the security and personalization for different users

e. ***Content:*** This is the domain where the origin server and content is. This could be an application, system, or even an aggregation of systems. The content can be mass market, personal or corporate content. Origin server will have some means to accessing the database and the storage devices

F. Benefits:

a. Save costs:

(a). Reduces costs from paper forms and filing.
(b). Less checking required for insurance
(c). Decrease incomplete charts.

b. Enhance workflows:

(a). Improve efficiencies & Productivities
(b). Doctor can manage own schedules
(c). Faster response times
(d). Increased patient contact times reduce patient waiting times.

c. Prevents errors:

(a). Eliminates mistakes from poor handwriting.
(b). Verification of Patient, Drug & Delivery System information.
(c). Interruptions will not produce errors.

d. Medical information at Point of Care:

(a). Can keep latest patient information always at hand and with increased access.
(b). Provides easy access to reference information.
(c). Clinical decision support

e. Is more efficient saving time:

(a). Reduces telephone interactions for checking
(b). Decreased chart access times
(c). Saves time looking for chart and patient information

G. Applications:

The popular applications are Airline and Railway Industries
Transportation Industry, Manufacturing & Mining Industries Distribution Industry, Banking and Financial Institutions Insurance & Financial Planning, Hospitality Industry, Emergency Services.

H. Advantages:

The Popular advantages of Mobile Computing are Location flexibility, Saves Time, Enhanced Productivity Ease of research, Entertainment, Streamlining of Business Processes, Easy to operate, Handy, Touch Screen ,Wireless Light Weight, Easy to Carry , Anywhere access facility

I. Disadvantages:

Range & Bandwidth, Security standards, Power consumption, Transmission interferences, Potential health hazards, Human interface with device.

J. Challenges:

a. Hardware (Memory, CPU) – Capacity of hardware, limits the applications that can be developed.
b. Battery Life – No matter the device, Battery life is an issue. With devices shared by many users no one takes responsibility for charging or even if battery is not working. For PDAs if battery goes flat then lose applications
c. Networking – incorrectly configured wireless LAN's can cause signal gaps, or signal drop out as users roam. This can cause problems with data transfer.
d. Security– Sensitive patient information on unprotected device. Misplaced device. Interfacing with legacy systems – All the data is obtained from the legacy system which may not be easy to interface to. Difficult to use mobile device as stand alone.
e. User interface, Ease of Use - different use age from desktop. Screen usually smaller, no mouse or keyboard. Makes the device difficult to use.

VI. MOBILE CLOUD COMPUTING

Mobile devices (e.g., smart phone and tablet PC) are increasingly becoming an essential part of human life as the most effective and convenient communication tools not bounded by time and place. Mobile users accumulate rich experience of various services from mobile applications (e.g., iPhone apps and Google apps), which run on the devices and/or on remote servers via wireless networks. The rapid progress of mobile computing (MC) [1] becomes a powerful trend in the development of IT technology as well as commerce and industry fields. However, the mobile devices are facing many challenges in their resources (e.g., battery life, storage, and bandwidth) and communications (e.g., mobility and security) [2].In addition, CC enables users to elastically utilize resources in an on-demand fashion. As a result, mobile applications can be rapidly provisioned and released with the minimal management efforts or service provider's interactions. With the explosion of mobile applications and the support of CC for a variety of services for mobile users, mobile cloud computing (MCC) is introduced as an integration of CC into the mobile environment. MCC brings new types of services and facilities mobile users to take full advantages of CC.

A. Definition:

Mobile Cloud Computing is a new paradigm for mobile applications whereby most of the processing and data storage associated with the applications is moved off the mobile device to powerful, centralized computing platforms located in the Cloud. These centralized applications are then accessed over the mobile Internet, using either a thin native client or web browser on the device

The Mobile Cloud Computing Forum [8] defines MCC as "Mobile Cloud computing at its simplest refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and mobile computing to not just smart phone users but a much broader range of mobile subscribers".

B. Architecture:

The general architecture of MCC proposed by [20] can be shown in Figure 9. Mobile devices are connected to the mobile networks via base stations (e.g., base transceiver station (BTS), access point, or satellite) that establish and control the connections (air links) and functional interfaces between the networks and mobile devices. Mobile user's requests and information (e.g., ID and location) are transmitted to the central processors that are connected to servers providing mobile network services. Here, Mobile network operators can provide services to mobile users as AAA (Authentication, Authorization, and Accounting) based on the home agent (HA) and subscriber's data stored in databases.

After that, the subscriber's requests are delivered to a cloud through the Internet. In cloud, the cloud controllers process the requests to provide mobile users with the corresponding cloud services. These services are developed with the concepts of utility computing, virtualization, and service oriented architecture (eg.web application, and database servers).

a. Mobile devices are connected to the mobile networks via base stations that establish and control the connections and functional interfaces between the networks and mobile devices.
b. Mobile users' requests and information are transmitted to the central processors that are connected to servers providing mobile network services.

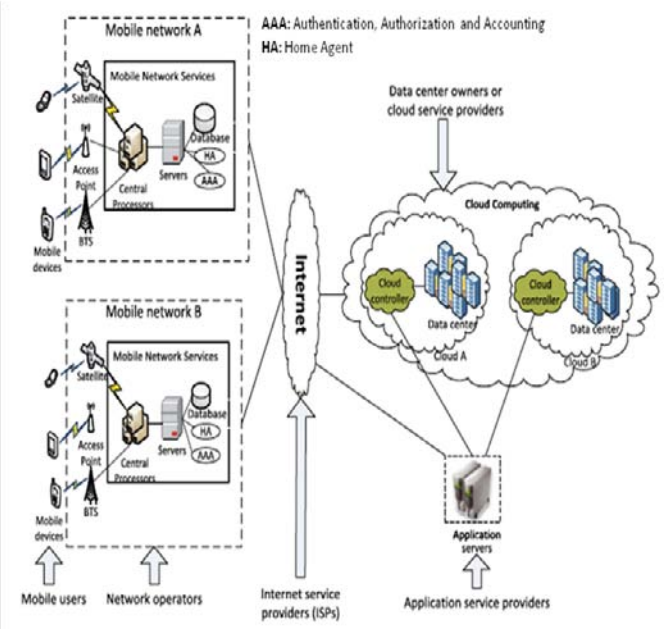

Figure 9. Mobile Cloud Computing Architecture

c. The subscribers' requests are delivered to a cloud through the Internet.
d. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services.

C. Characteristics:

The key characteristics of mobile cloud computing that make it possible to implement seamless service delivery in across the network environment. From the perspective of the enterprise solution provider or web/mobile application developer, the objectives of the Mobile Cloud Computing platform are Reliability, Scalability, Security, Agility, Device Independence, Reduced Cost, and Reduced Maintenance.

There are also some key features of Mobile Cloud Computing Simple APIs offering transparent access to mobile services, and requiring no specific knowledge of underlying network technologies.

D. Service Models:

MCC services can be classified in three major models: Mobile-as-a-Service-Consumer (MaaSC), Mobile-as-a-Service-Provider (MaaSP), and Mobile-as-a-Service-Broker (MaaSB).

MaaSC is originated from the traditional client-server model by introducing virtualization, fine-grained access control, and other cloud-based technologies at the initial stage. Mobile devices can outsource their computation and storage functions onto the cloud in order to achieve better performance and more application capabilities. In this architecture, the service is one-way from the cloud to mobile devices and mobile devices are service consumers. Most existing MCC services fall into this category.

MaaSP is different from MaaSC in that the role of a mobile device is shifted from a service consumer to a service provider.

MaaSB can be considered as an extension of MaaSP, where MaaSB provides networking and data forwarding services for other mobile devices or sensing nodes. MaaSB is desired under some circumstances because mobile devices usually have limited sensing capability compared to sensors that are dedicated for specially designed functionalities and sensing locations.

E. Deployment Models:

Mobile clouds (mobile community/private/public/ad-hoc clouds) similar to the deployment models of cloud computing.

F. Benefits:

MCC provides the software engine that fuels the convergence of open mobile networks, mobile cloud computing, on demand enterprise solutions, and web and mobile applications, opening up new low friction commercial channels between multiple diverse industries and vertical market segments. Our solution, when deployed either by Mobile Operators or cross-network Mobile Cloud Providers, makes it easy for enterprise solution providers and web or mobile application developers to turbo-charge a wide variety of applications and services, enriching them with powerful mobile network features and intelligence available on demand via the mobile cloud. The solutions deliver significant benefits to a range of organizations, including Mobile Cloud Providers, Network Operators, Enterprise Solution Providers, and Web or Mobile Application developers.

G. Applications:

Mobile cloud computing is one of the mobile technology trends in the future since it combines the advantages of the integration of both mobile computing and cloud computing, thereby providing optimal services for mobile users. The applications supported by mobile cloud computing including mobile commerce, mobile learning, and mobile healthcare and other areas like mobile banking ,mobile game.

H. Advantages:

The advantages of Mobile Cloud Computing are Extending battery lifetime, Improving data storage capacity and processing power, Improving reliability, Dynamic provisioning.Scalability, Multitenancy, Ease of integration

I. Disadvantages:

a. Data security issues in the mobile cloud
b. Privacy and Confidentiality
c. Data Integrity
d. Data Location and Relocation
e. Data Availability

J. Challenges:

In the MCC landscape, an amalgam of mobile computing, cloud computing, and communication networks (to augment smart phones) creates several complex challenges such as Mobile Computation Offloading, Seamless Connectivity, Long WAN Latency, Mobility Management, Context-Processing, Energy Constraint, Vendor/data Lock-in, Security and Privacy, Elasticity that hinder MCC success and adoption.

K. Open Research Issues In Mobile Cloud Computing:

Although significant research and development in MCC is available in the literature, still efforts in the following domains lacking: Architectural issues, Energy efficiency,

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Security, Better service, Task division, Energy-efficient transmission, Context-awareness issues, Live VM migration issues, Mobile communication congestion issues, Trust, security, and privacy issues.

V. CONCLUSION

The emergence of Cloud Computing, and its extension into the mobile computing domain, has brought a new dimension to Network as a Service (NaaS): the vision of a global, interconnected "Mobile Cloud Computing" where application providers and enterprises will be able to access valuable network and billing capabilities across multiple networks, making it easy for them to enrich their services whether these applications run on a mobile device, in the web, in a SaaS Cloud, on the desktop or an enterprise server. The combination of cloud computing, wireless communication infrastructure, portable computing devices, location-based services, mobile Web etc has laid the foundation for the novel computing model. Mobile Cloud Computing will provide a full commercial environment for applications, providing an easy way for smaller developers to monetize their services as well as new routes to market. New programming languages such as HTML 5 already provide a solution by enabling data caching through a mobile device, and this allows a cloud application to continue working if connection has been momentarily lost. In this paper we have given an overview of Cloud computing, Mobile Computing and Mobile Cloud Computing that includes architecture, benefits, key challenges, service models and open issues.

VI. FUTURE WORK

Considering the importance of Mobile Cloud Computing from this discussion, which is poised to be the fifth utility in the future, we would like to explore further architectures that are plausible.

a. ***SMAC (Social, Mobile, Analytics and Cloud)*** technologies are the new change agents in enterprise IT. When implemented, these technologies serve as a synergetic solution for digitally transforming an organization to be better equipped for the future of business. The formula for the Future of Work is called SMAC - social, mobile, analytics and cloud on one integrated stack, where each function enables another to maximize their effect. This is the new enterprise IT model delivering an organization that is more connective, collaborative, real-time and productive.

b. ***The SMAC Effect:*** In all Industries across the business landscape, the SMAC Stack is eroding the century-old blue print of value chains and spawning new, highly distributed, virtualized business models. The power of this technology platform is in treating it as a stack, for its components have a multiplying effect when they work in combination.

c. *Technology in Perspective:* Today's SMAC Stack—'the fifth wave' of IT architecture—is happening faster than anything that's come before. By 2020, as many as 100 billion computing devices will be connected to the Web, and corporations will be managing 50 times the data they do currently. So SMAC will have a multiplying effect on businesses and increase productivity across the organization.

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