HPCCA: Is efficient in Mobile Cloud Environment (MCE)?

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Abstract—**Integrating cloud infrastructure and services into the Mobile Communication Environment (MCE) is an intensive research area nowadays. Mobile cloud computing provides interesting research opportunities to resolve the boundaries between mobile and cloud computing. Studies show that mobile devices are limited in resources: memory, network bandwidth, availability and specifically processing power. It does not meet the demand of high performance applications for mobile users. One obvious solution to this requirement is to get the processing power as a service from a resource-rich environment. Cloud computing is a service-based approach which provides the required computing resources to its subscribed users: on-demand, scaled elastically, and economically feasible in response to user's requirement. The cloud services which facilitate mobile environment describes as Mobile Cloud Computing (MC2). Existing advanced mobile devices can perform various multimedia applications (e.g., M-Commerce, Health Care, Games, Rich Media, etc.) and provide a number of utilities; they are not efficient for executing intensive computing applications such as advanced 3D Games, scientific calculations, result optimizer, high definition weather forecasting and many more. These applications require high processing power, intensive memory mapping and sufficient network support for efficient execution. Currently some IT giants like IBM, Rackspace, Penguin Computing, Sara, PureWeb and Sabalcore are providing High Performance Cloud Computing Applications (HPCCAs) over the cloud infrastructure. The HPCCAs shall be potential services for existing smart mobile device users. In this paper our focus is to analyze and present a comprehensive study to observe: Is utilization of HPCCA efficient in mobile environment? In our analysis, we considered different aspects and consequences of High Performance Computing (HPC) in mobile cloud environment. For example, High bandwidth, Signal quality, Mobility, Service availability and Security concerns. Through this analysis, we found HPCA is efficient in mobile cloud environment.**

Keywords- Mobile Cloud Computing; High Performance Cloud Computing Applications; High Performance Computing; Smartphones.

I. INTRODUCTION

More than decades of research on computational performance in traditional Information Technology (IT), the focus is now shifted towards the computation and communication resources as a service on-demand, over the internet, pay-on-usage. Availability is the vital metric for these resources; near 100% availability is becoming mandatory for both intensive users and service providers. Computational needs of users (desktop and mobile) increasing to the alarming stage. They need strong support of technology and its providers to meet their needs; particularly for High Performance Computing Applications (HPCAs). The conventional computing technology does not have enough potential in mobile environment with resource limited devices. Technology evolves and new integrated service-centric technologies emerged to offer high quality services specifically for HPCA in mobile environment.

Cloud computing has been emerged as a new service-centric technology. Offers service on-demand, elastic provisioning, reliability, security and pay-per-uses economic model. Cloud computing exists if tasks and data are kept on the internet rather than on individual devices, providing on-demand access. Data is provided and managed by the service providers. Applications run on a remote server and then sent to the user [1]. According to NIST cloud offered services in the form of Software as service (SaaS), Platform as a service (PaaS) and Infrastructure as Service (IaaS). Cloud users may access the server resources using a computer, netbook, tablet, pad computer, smart phone, or other device. In cloud computing, applications are provided and managed by the cloud server and data is also stored remotely in the cloud configuration [2]. Cloud subscriber need not to invest on high configuration hardware and expensive licensed software. Processing and storage maintained by the cloud service provider with the integration of local service provider on economically feasible model. Cloud extends its service domain with the integration of mobile computing technology. This integrated technology refers as Mobile

Mobile Cloud Computing (MC2), becomes a convenient alternative to personal computers by integrating mobility, communication, software functionality, and entertainment [3]. It offers mobile users great opportunities and turns from resource limited device into a resource-rich environment. It enables mobile cloud users to execute high computing application in potential and flexible environment such as 3D games, scientific calculations, result optimizer, high definition weather forecasting, and many more. With the influential growth of intensive mobile applications,

developers are shifting from desktop computing to mobile cloud computing environment.

The remaining structure of this paper as follows: In Section II, we explain existing infrastructure of HPCAs, in both fixed/static and mobile cloud environment. Section III discusses the importance of offloading for HPCCAs in desired environment. Section IV describes the required service-architecture of HPCCA in mobile environment. Section V presents HPCAs offerings by different service providers. In Section VI, we also discuss HPCCA economics. In Section VII, we discuss the much needed security and challenges issues and best suited solutions; result analysis. Finally, we conclude with our findings and future work.
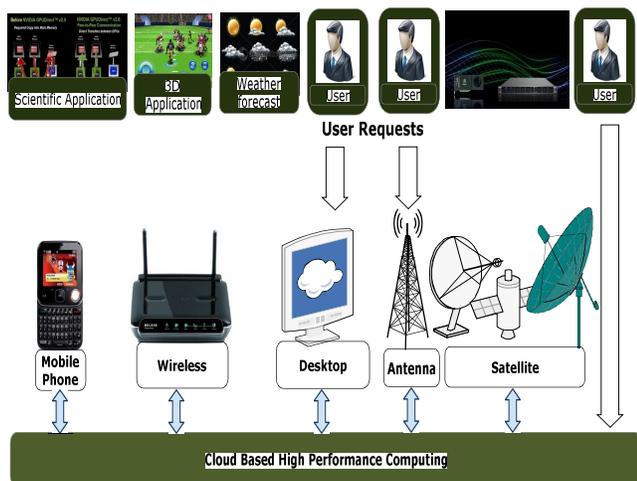

Figure 1. A software system that integrates mobile and cloud computing services.

II. EXISTING INFRASTRUCTURE FOR HPCA

HPCA basically needs intensive computing, accelerations, efficient parallel computing algorithms, and

bridge between software and hardware; includes a primary HPC and a backup HPC connected by a robust communications and secured IT infrastructure. In the early age of computing, the high performance computing is done by supper computers. It requires a large amount of electrical power for its infrastructure and need significant cost to maintain. In general, scientific and commercial organizations handle the HPCAs by the operating system in powerful computers or by the cluster-servers. High-performance analytics enable organizations to quickly and confidently seize new opportunities in order to make better choices ahead of competitors and create new value from big data. It enables organizations to handle their most difficult challenges, quickly generate high-impact insights and transform their operations [4]. With the computing technology evolution, the infrastructure keeps on changing. Large organizations like IBM releases technically configured powerful systems to meet the increasing demand of HPC. The world increasingly global and highly interconnected planet; needs communication and computation technology on move, anywhere, any time. In the present information age, acceleration of data processing is growing dynamically and influenced markets to deploy HPC for their applications.

The HPC architecture requires intensive applications to rum on multiple processors, rather than on single, to achieve the desired performance. Virtualization, parallel and vector processing, multi and co-processing are the fundamentals of HPC. Applications such as, 3D- imaging processing, financial commerce, medical imaging, data compression, seismic data interpretation, search, security, and many more have been efficient in desktop environment. Shall be the same in mobile environment? Today, many service providers offer HPCA as a service, available for enterprise users, community users, and individual subscribers in mobile cloud environment.
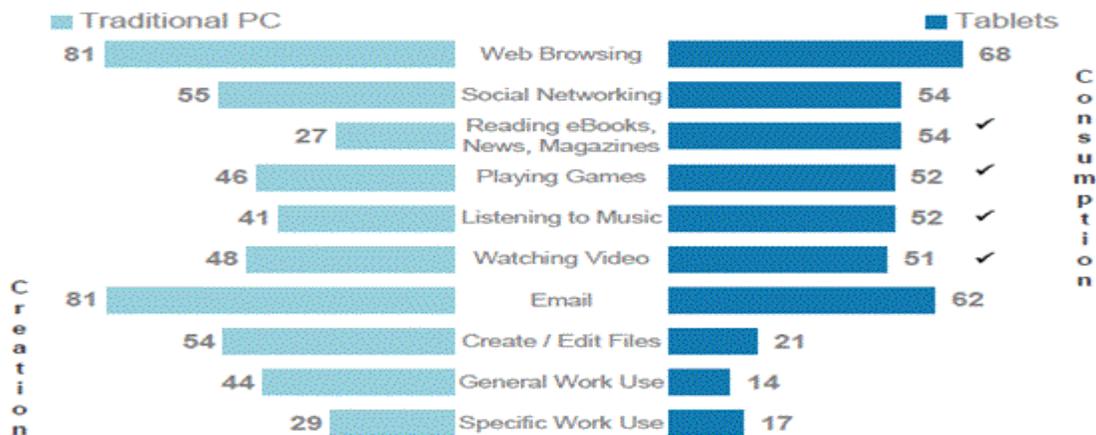

Figure 2. Percentage of users who uses wearable devices for each activity and shows content consumption [5].

A. HPCAs in Mobile Cloud Environment

In present scenario, the usage of mobile phone applications is potentially increased, due to the integration of mobile technologies with the cloud. Cloud delivers services to its remote users over the IP network often through a web browser without referring to the boundaries. Mobile computing technology whereas connects its users in mobile or non-static environment across the network(s). This is accomplished by connecting mobile computing activities wirelessly through the internet or a private network. This connection ties the mobile device to centrally located information and application software by using battery powered, portable, and wireless computing and communication devices. This encourages manufactures, vendors, and service provides to develop an efficient mobile environment for intensive computations and quality-communications. Present mobile phones are heavily used for executing high performance applications such as 3D applications and scientific calculations. However the limitations exist in resources are the basic obstacles to execute these applications efficiently. These limitations can be removed or minimized with the integration of resource-rich, reliable, service-centric cloud technology.

The integrated (mobile and cloud) technology describes as MC2 deploys in heterogeneous radio access environment such as WiFi, 3G, WLAN, WiMax, GPRS. It is implemented through wireless connectivity. The prime features are access 24X7, on-demand, energy efficient, and economically feasible even for low data rate cloud controlling signals. Mobile applications can be launched on the device or cloud, and can be migrated between them according to dynamic changes of the computing context or user preferences [6]. Smartphone and tablets are quickly becoming the information worker's most valuable tools. Young workers and their strong affinity for go-anywhere technology is changing the shape of the enterprise right here, right now!! Enterprise Mobility is becoming more and more Anytime, Anywhere service in a true sense!! Smart-phones [7].
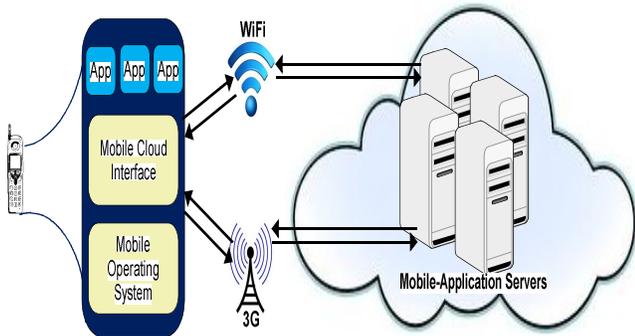

Figure 3. Block Diagram for HPCCA Services.

The most frequent and intensive users of HPC systems are researchers from academic and research oriented business establishments, investigating and specific government agencies; whereas the common users heavily use HPCAs for communication, entertainment and such many more activities. All need effective, improved, convincing,

reliable and efficient performance in both, fixed/static and mobile cloud-based environment.
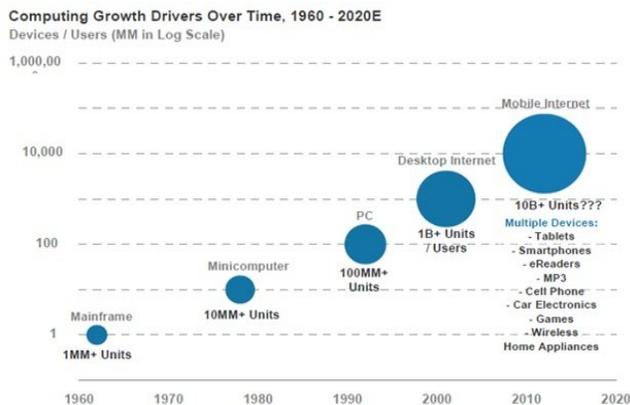

Figure 4. Expected growth of usage of mobile internet [8].

B. Performance Parameters for efficient Mobile Cloud Environment

Advancing the efficient HPC architecture is a big challenge, particularly in mobile cloud environment. It includes processing, managing, using existing architecture, mobility, and offering services anywhere anytime from individual user to enterprise subscription locally and globally. The following features are most desirable for efficient HPCCA:

Availability: HPC system needs to be clock-driven; highly available (99.9%), network, data centers, and at much lower cost.

Scalability: It needs to have an infrastructure that provides expandable resources to accommodate heavier load, high throughput, scalable storage, and reliable communication.

Intensive-scale computing: It is the ability to run massively parallel code of instructions with the simulation of data.

Life cycle management: The efforts to maximize the efficiency of the transition operations throughout the processing cycle.

Software configuration and management: Updates and adopt the software standards that accommodate sharing of code internally and externally with other partners.

According to Lawrence Berkeley National Laboratory, the following features are vital in mobile cloud environment:

- A global shared memory abstraction
- Support dynamic updates
- A high-bandwidth, low-latency network
- Ability to exploit fine-grained parallelism
- Support for light-weight synchronization
- Massively Multithreaded architectures

Symmetric multiprocessors

III. OFFLOADING ESSENTIAL FOR HPCCA IN MOBILE ENVIRONMENT

Offloading is the process of using complementary devices which are resource-rich, for accelerating the processing originally targeted for resource-limited mobile devices. Offloading technology must be an essential tool in the desired environment. Offloading of a mobile computing

task is a tradeoff between the energy used for local processing and the energy required for offloading the task, uploading its data, and downloading the result, if necessary. One can express the offloading energy trade-off with the formula $E_{trade} = E_{local} - E_{delegate} > 0$, where E_{local} is the energy used for complete local execution, and $E_{delegate}$ is the energy used from the perspective of the mobile device if the task is offloaded. If E_{trade} is greater than zero, then there is an energy benefit for delegating the task to the cloud [9].

A. Factors affecting offloading

Network traffic: High bandwidth is required for fast connection to the cloud through internet.

Security Aspects: Secured service access mechanism should be ensured.

Business Models: Business models need to be modified to adopt the cloud computing standards.

Accessibility: Robust Infrastructure needs to be placed for providing high accessibility to the services.

B. Parameters for offloading decision

Power Consumption: Power consumption can be a vital parameter for offloading decision as battery life time is the major concern for mobile devices.

Processing Requirement: Processing requirement is an important parameter for offloading decision. The applications requiring intensive processing shall be offloaded.

Storage and memory requirement: Memory and storage requirement is a major parameter. Applications requiring huge memory and storage cannot be executed on mobile devices as they are generally poor in the resources; these applications need to be offloaded.

Latency and bandwidth: Latency also plays an important role in offloading decision. The interactive applications cannot support high latency. Offloading decision shall be taken on the available bandwidth.

As shown in figure 5, percentage of total mobile data traffic from handsets and tablets, mobile offload will be 31 percent (3.1 Exabyte/month) in 2016.
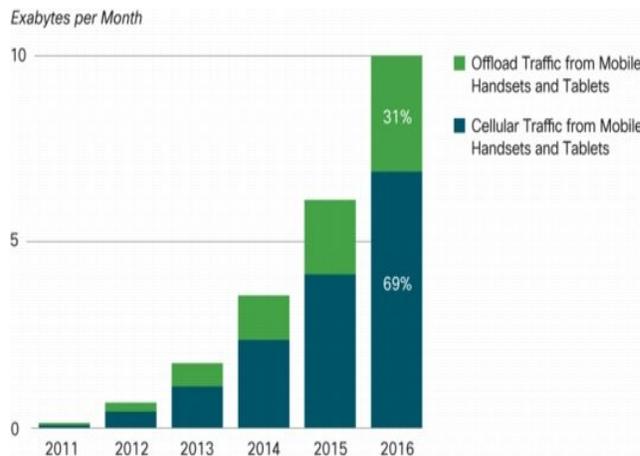
Figure 5. Offloading trend in mobile cloud environment [10].

IV. HPCCA SERVICE ARCHITECTURE

The service architecture shown in Figure 5 describes how the cloud resources can be utilized by mobile devices for executing high performance applications.
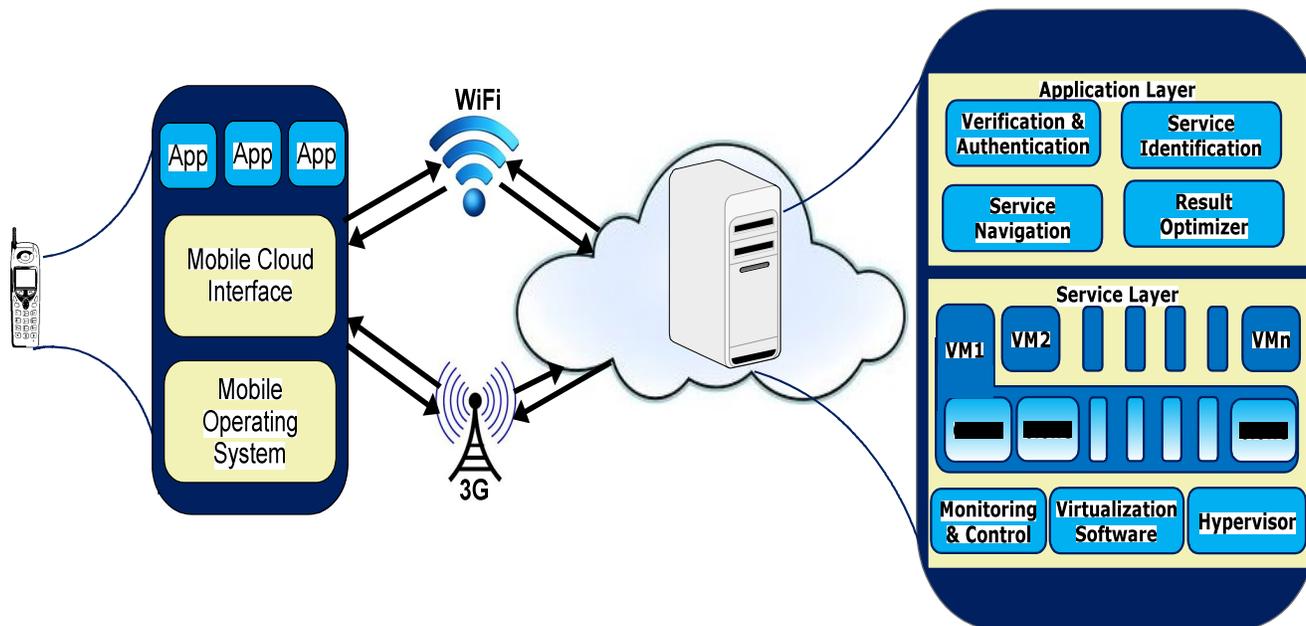

Figure 6. Service Architecture in Mobile Cloud Environment.

The mobile device sends request to the cloud through mobile cloud interface available in the device itself. The request is first verified and authenticated by the verification and authentication module then it passes to the service identification module. This module categorizes the request as per the nature of processing, if the request requires parallel processing then the parallel segments shall be assigned to individual virtual machines else it will be assigned to any of the available clone. Once the process is done, the individual results shall be forwarded to the result optimizer. It combines the individual results, formulates it, and sends back to the mobile client through the service navigation module. The virtual machines are created with the help of hypervisor and virtualization software; it is controlled and monitored by the monitoring and control unit. The clones can be created using any of the existing cloning technology shown in Figure 6.

V. HPCA SERVICES OFFERED IN MOBILE CLOUD ENVIRONMENT

In the technically advanced competent environment, many cloud service providers offer huge benefits for their users in response to their growing needs of HPCAs in mobile environment. Focus is gradually shifting, services offer on-demand, over the internet, through web-browser, pay-as-you-consume, at very low economic subscription. All most all the providers emphasis on HPC, software, infrastructures, data storage, networking, and special attention to privacy, integrity, and security of data, shown in the table1. In the table, column1 shows the services offered by the respective providers. A substantial number of providers have contributed to the development of this technology and many in the adoption process shown in Table 1.

TABLE 1. SERVICES OFFER BY THE RESPECTIVE PROVIDERS IN CLOUD-BASED MOBILE ENVIRONMENT

Services	Service Providers-HPCCAs in Mobile Environment					
	Sara	PureWeb	Rackspace	Sabalcore	BlueCoat	Penguin
Computation	HPC, Grid	HPC	HPC	HPC	HPC	HPC
Software	ADF, BLAS, HDF, BLACS, DMF, FFTW,	Software Transformation KITs	Software as a Service for Business	Open source software	Bespoke Service	Scyld ClusterWare
Infrastructures	Grid, CPU cluster, Lisa Huygens, System	Cyber Infrastructure	High Performance configuration	High Performance configuration	Proxy AB 1400-2400, AND, MACH5	POD, Hybrid, Private and dedicated Cloud
Data Storage	Grid Permanent, Data Services	Data Storage	Hosting Storage	Ample Permanent Storage	-	HPC Datacenter, POD
Networking	High Performance Networking	High Performance Networking	High Performance Networking	High Performance Networking	High Bandwidth 300X	High Performance Networking
Security	Data Security	Mobile Data Security	Data Security	-	ProxySG, web filtering solutions	Strong Security

A. Efficiency Parameters of HPCCAs in Mobile Environment

As we discussed earlier, the limitations of executing HPCAs in mobile environment shall be minimize significantly by implementing cloud service-model in turn maximize efficiency. The nature of cloud services is best suited for efficient processing of HPCAs in mobile cloud environment. The following are the most promising features need to be considered for an efficient mobile environment:

- High Data Rate
- Quality of Service (QoS)
- Scalability
- Availability
- Mobility
- Security

- Network latency

B. Service characteristics of HPCCAs in Mobile Environment

1) *HPC Ubiquitously:* By the subscription of HPCCA services, user can access intensive HPAs on their smart mobile devices in heterogeneous environment, without considering processing burden. During the process mobile devices act as interface, send the instructions, and request processing is done on cloud infrastructure. Users have full advantages of access these services from resource limited device to a resourceful environment conveniently.

2) *Right to use – anyplace, anytime:* Cloud computing with the integration of mobile computing provides services anywhere anytime with the application of adequate Service

Level Agreement (SLA). It includes flexible mechanism for delivering IT services at each level of the computing stack: from hardware level to application level [11]. Initially, HPCCA software was supporting desktop environment and users are free to work anywhere through the internet. With the amount of mobile applications increased, the developers extend its reach for mobile access with the devices like laptops, notepad, tablets and smartphones. In the present, era any software application can be execute by mobile cloud users anywhere anytime.

3) Platform Support: Another promising feature of cloud is HPCAs can execute irrespective of platform dependencies. PureWeb integrates directly into your existing Microsoft Foundation Class, C#, C++ or Java code, bringing the web to your application rather than your application to the web. Furthermore, adding support for the latest mobile touch-based devices such as an Apple iPad, iPhone or Google Android devices is seamless [12].

4) Data Security and Compliance: Major concern of mobile cloud users is security; data is mostly secured in static environment and remains uncertain in mobile environment. Service providers do not comprise on any less secure system for securing and handling data.

VI. ECONOMICS FOR HPCCA

According to Microsoft, the overall cost of IT is determined not just by the cost of capacity, but also by the degree to which the capacity is efficiently utilized. It is needed to assess the impact that demand aggregation will have on costs of actually utilized resources (CPU, network, and storage) [13]. Many organizations realized the impact of low cost offering by the deployment of cloud services. Cloud Computing has been emerged as an economic service-centric technology; combines the best economic properties of mainframe and client/server computing, and shifting the economics of traditional IT. The architecture of cloud facilitates elastic consumption and pay-as-you-consume pricing model. Resource-intensive computing is offloaded to the cloud to leverage the cost advantages of massive data centers [14]. Efficient multi-tenancy is a major factor, increases number of tenants, maximize application processing, minimize the applications management and server cost. Recently, Microsoft joined Google and Amazon Web Services in cutting the cost of cloud services. Microsoft dropped the price on its Azure Storage Pay-as-you-Go service and lowered the price of its six-month storage plan. The cost to use Azure Extra Small Compute has dropped in half [15]. In cloud paradigm, resource-intensive computing is offloaded to the cloud to leverage the cost advantages of massive data centers. Researchers are working on different techniques that minimize the cost of using cloud resources, provide efficient and seamless environment while maintaining user satisfaction. According to PureWeb, the following activities slash down the cost significantly:

- HPCC will slash web migration cost
- The risk & expense of traditional migration
- Fast & straightforward with HPCC
- No need for expensive & risky rewrites

- No licensing fees or proprietary downloads
- Significant hardware saving
- High speed for any high performing application

VII. SECURITY CONCERNS

Security, privacy, and integrity, of data and applications are major concerns in mobile cloud environment. It is quit known fact, data is more secure in static rather than in mobility. To design an efficient HPCCA-service system in mobile environment, various challenges such as high computation, scalability, availability, mobility, and cost restrictions need to be addressed. Cloud computing fits well as an enabling technology in this scenario as it presents a flexible stack of computing, storage and software services at low cost [16]. These challenges can be tackled by leveraging various cloud services in HPCCA-service system. The major constraints, HPCAs require significant computing power, need to process from a limited energy source mobile device. It is essential to outsource intensive computing applications to cloud. Offloading seems to be simple solution; it is non-trivial, since wireless network bandwidth and latency are also big challenge need to be address. According to Alcatel-Lucent and Techzine, four key strategies should be considered to overcome the challenges of mobile cloud computing are 1) Processing time at the data center 2) Processing time on the device 3) Network latency 4) Data transport time.

VIII. EFFICIENCY RESULT ANALYSIS OF MOBILE VS FIXED DEVICES

Connectivity is almost guaranteed in fixed/static networks and potentially rich in resources; whereas mobile environment intensely depend on network bandwidth and latency. In processing of HPCAs, both mobile and fixed devices require intensive computation, significant amount of energy; and consume heavy resources. Efficiency exists in fixed/desktop environment and shall be improve for mobile environment also with the integration of mobile technology with cloud. Although the current generation mobile devices have significantly improved in technology and support Service Oriented Architecture (SOA), need for efficient performance in mobile cloud environment. Market updates, eying the users need and requirements, especially for HPCAs. A comparative study shown by Kyung Mun, of a Dell Inspiron 580 desktop with the iPhone 4 and iPad, for example, reveals the tradeoff cost of mobility. As compared to a fixed device, mobile devices in general have:

- 3 times less processing power
- 8 times less memory
- 5 times less storage capacity
- 10 times less network bandwidth

While mobile device performance will continue to improve in absolute terms (Figure 7), the disparity between the resource constraints of mobile and fixed devices will remain and must be accounted for in the types of application selected for mobile cloud computing [17].
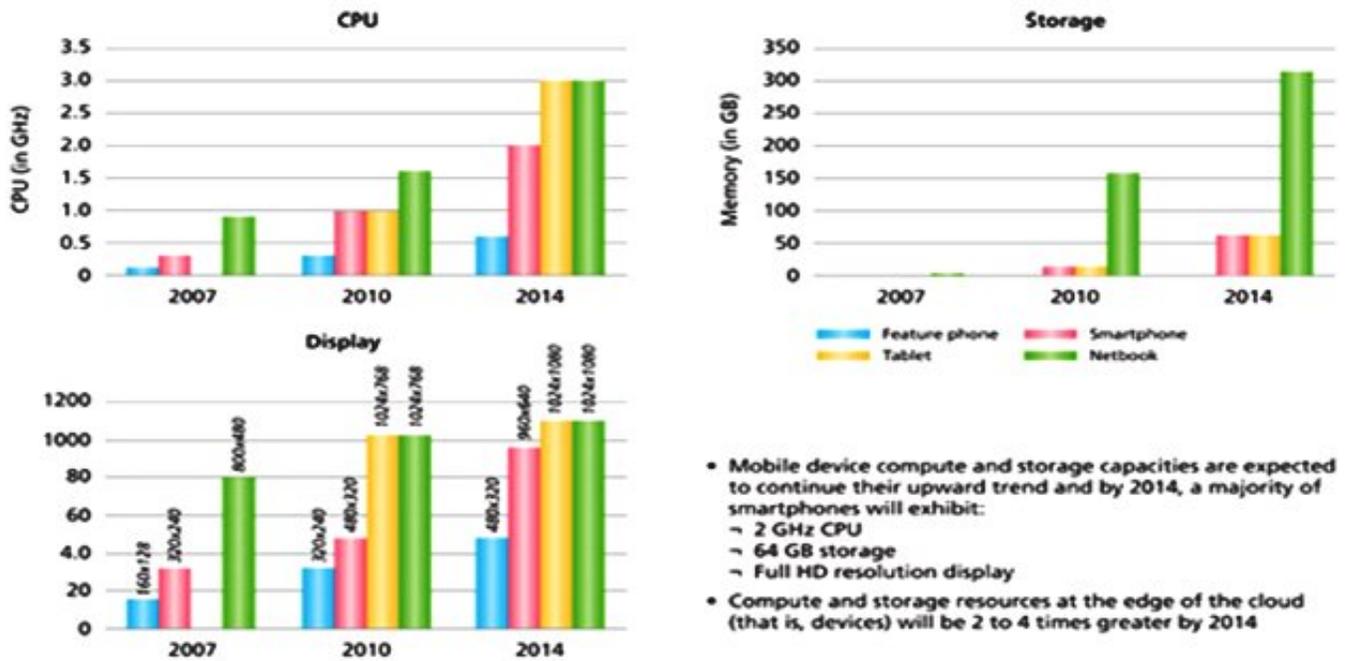
Figure 7. Mobile device computing storage and display trends [18].

CONCLUSION AND FUTURE FOCUS

In this work, our interest was to measure the processing performance of HPCAs on existing infrastructure in fixed/static and mobile environment. Compare the efficiency and investigate: shall HPCAs be potential for existing mobile device users in cloud-based environment. Accordingly, we presented HPCA architecture, resources consumption on both traditional PC and mobile platform. The efficiency shall be achieved on resource-limited devices for HPCAs with the integration of service-centric cloud technology. We presented service architecture for high performance computing applications in mobile cloud environment. Further we analyzed the HPCCA services offered by cloud providers and the characteristics in mobile environment. One of the common interests of HPCCAs mobile device users and providers is the business-economic, discussed in detail. We compared the efficiency performance in our result analysis and concluded with the concerns of security and challenges; common for both users and cloud service providers.

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