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An Exploratory Study of Cloud and Ubiquitous Computing Systems

Stephen O OLABIYISI [1], Temitayo M FAGBOLA [2], Ronke S BABATUNDE [3]

ABSTRACT [ENGLISH/ANGLAIS]

To investigate the similarities and differences between cloud and ubiquitous computing systems, we carried out an exploratory study on the two computing paradigms. Cloud computing provides the next generation of internet based, highly scalable distributed computing systems in which computational resources are offered as a service. It is a new computational model that enables 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. However, ubiquitous computing refers to a scenario in which computing is omnipresent, and particularly in which devices that do not look like computers are endowed with computing capabilities. The idea behind ubiquitous computing is to surround ourselves with computers and software that are carefully tuned to offer us unobtrusive assistance as we navigate through work and personal lives. Emerging computing paradigms including cluster computing, grid computing, ubiquitous computing and cloud computing, amongst others have being misunderstood by most users of these services and researchers as meaning the same. To provide a well-articulated understanding of cloud and ubiquitous computing, certain comparative measures of these computing paradigms are reviewed. The comparative evaluation metrics used include cost, scalability, security/data protection, storage/speed, mobility and context-awareness. The findings of the study revealed that cloud and ubiquitous systems vary based on these comparative metrics

Keywords: Cloud Computing, ubiquitous computing, comparative evaluation metrics

RÉSUMÉ [FRANÇAIS/FRENCH]

Pour enquêter sur les similitudes et les différences entre les nuages et les systèmes informatiques ubiquitaires, nous avons réalisé une étude exploratoire sur les deux paradigmes informatiques. Le cloud computing offre la prochaine génération de l'Internet sur la base, hautement évolutive des systèmes informatiques distribués, dans lequel les ressources de calcul sont offerts en tant que service. Il s'agit d'un nouveau modèle de calcul qui permet un accès pratique et réseau à la demande à une piscine partagée des ressources informatiques configurables (par exemple, les réseaux, serveurs, stockage, applications et services) qui peuvent être rapidement approvisionné et libéré avec un effort minimum de gestion ou de prestataire de services l'interaction. Toutefois, l'informatique ubiquitaire se réfère à un scénario dans lequel l'informatique est omniprésente, et en particulier dans lequel les périphériques qui ne ressemblent pas à des ordinateurs sont dotés de capacités de calcul. L'idée derrière l'informatique omniprésente est de nous entourer avec des ordinateurs et des logiciels qui sont soigneusement réglées pour nous offrir une assistance discrète alors que nous naviguons par le travail et vie personnelle. Paradigmes informatiques émergentes, y compris l'informatique en grappe, le grid computing, l'informatique ubiquitaire et le cloud computing, entre autres, ont été mal compris par la plupart des utilisateurs de ces services et les chercheurs comme ayant le même sens. Pour permettre une compréhension bien articulée de nuages et de l'informatique omniprésente, certaines mesures comparatives de ces paradigmes informatiques sont passés en revue. Les paramètres d'évaluation comparatives utilisées comprennent le coût, l'évolutivité, la sécurité / protection des données, le stockage / la vitesse, la mobilité et la sensibilité au contexte. Les conclusions de l'étude a révélé que les systèmes nuageux et omniprésent varient en fonction de ces paramètres comparatifs

Mots-clés: Cloud Computing, informatique omniprésente, les paramètres d'évaluation comparative

Affiliations:

[1] Department of Computer Science & Engineering, Ladoke Akintola University of Technology, Ogbomoso. P.M.B. 4000, Ogbomoso, Oyo State, NIGERIA

[2] Department of Computer Science & Engineering, Ladoke Akintola University of Technology, Ogbomoso. P.M.B. 4000, Ogbomoso, Oyo State, NIGERIA

[3] Department of Computer, Library and Information Science, College of Information and Communication Technology, Kwara State University, Malete, NIGERIA

Address for Correspondence/ Adresse pour la Correspondance: cometoty@yahoo.com

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INTRODUCTION

Cloud computing is a model for enabling ubiquitous, 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 [1].

Instead of both owning and managing IT services for themselves, or using an outsourcing approach built around dedicated hardware, software and support services, organizations can use cloud computing to meet their IT requirements using a flexible, on-demand, and rapidly scalable model that requires neither ownership on their part, nor provision of dedicated resources [2].

A conceptual overview of Cloud Computing is shown in Figure 1.Ubiquitous computing (often abbreviated to "ubicomp") refers to a new genre of computing in which the computer completely permeates the life of the user. In ubiquitous computing, computers become a helpful but invisible force, assisting the user in meeting his or her needs without getting in the way [4].

From a technical perspective, ubiquitous computing refers to a coordinated array of task-oriented computing devices that operate semi-independently in net-centric environments enabled by wireless and mobile technologies. The idea driving ubiquitous computing is to make computers unseen by their users and create a service environment in which devices are so embedded, natural, ergonomic, friendly, and so fitting, such that users use them without even noticing [5].

Two of the discontinuous shift that have a large impact on users of IT resources around the world, and as well misunderstood to mean the same thing are Ubiquitous computing system and cloud computing [6].

The purpose of this paper is to carry out an exploratory studyof ubiquitous and cloud computing technologies with specific interest on issues relating to cost, scalability, security/data protection, storage/speed, mobility, context-awareness and privacy. Using these metrics of comparison will go a long way in helping users of IT resources to understand the similarities and differences, benefits and challenges of cloud and ubiquitous computing from information technology point of view as well as making the best choice on which of the technologies to adopt for use.

MATERIALS AND METHODS

Comparative Evaluation Metrics for Cloud and Ubiquitous Computing Systems

The following metrics are used for comparative evaluation of Cloud and Ubiquitous Computing Paradigms.

i. Cost
ii. Storage/Speed
iii. Mobility
iv. Scalability
v. Context-awareness.
vi. Privacy
vii. Security/Data Protection

Cost: Cost can be used to evaluate a number of models. A cost-effective model that is functional in nature can be preferred over an expensive one. A model which does not require infrastructure purchase will lower maintenance.

Storage/Speed: A system to be used for global operations needs high storage capacity and faster response time, which is achieved by distributing workload requests among sophisticated computing environment.

A computational system with highly large number of hardware and software components, coupled with a high processor core count promotes a transition to high speed mechanism for network connection. This implementation will enable operational consistency between users as well as facilities on a network.

Security: When resources in a system come from different, possibly competing, vendors, the openness of the system implies that the level of trustworthiness of information obtained through interactive environment would be low and strong security measures have to be in place to protect devices from one another. Complex system interactions might substantially complicate tracing the information flows to its origin, thus preventing users to judge the reliability of acquired information. Security can be used to measure how reliable and acceptable a system will be.

Scalability: Today, internet is carrying us through an era of widespread distributed computing characterized by deeply imbedding computation in the world. A scalable communication network is one which is able to manage future loads with increase in the amount of users on a network. A model with high number of participants in a communication network and providing limited response time is preferred. Scalability is therefore an important metric to measure the effectiveness of a system.

Context-awareness: This is a scenario that suggests that applications should adapt themselves based on the knowledge of location. It allows users to personalize computing services. A context-aware system provides maximum flexibility of computational service due to mobility. This implies that the resources accessible to a device, which define its context, frequently change in such a system. Hence, every participating resource needs to be able to discover and adapt to its changing contexts to efficiently participate in the system.

Mobility: User mobility refers to the freedom the user has to move about when interacting with the system. Object mobility is required to move services around a network for better load balancing, fault tolerance and high-availability.

Privacy: A system should offer privacy in terms of confidentiality, integrity and availability to authorized entities. A computational system that ensures privacy for both users and applications in term of intrusion prevention is preferred.

Approaches

Evaluation of Cloud Computing Based on the Metrics

Cost: The emergence of cloud computing has enabled inexpensive processing of massive datasets by Internet user, lowering the institutional capacity required for participating in research. It has helped today's researchers by cutting the total cost of scientific computing. Reduced cost is a clear benefit of cloud computing, both in terms of capacity and operation. The reduction in capacity is obvious because an organization can spend increments of required capacity and does not need to build infrastructure for maximum (or burst) capacity. For most enterprises, operation constitutes the majority of spending, therefore, by utilizing a cloud provider or adopting cloud paradigms internally, organizations can save operational and maintenance budgets [3].

Storage/Speed: Cloud computing basically offers three service models. These are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). The IaaS model provides basic storage and computing capabilities as standardized services over the network. Servers, storage systems, networking equipment, data centre space etc. are pooled and made available to handle workloads. The customer would typically deploy his own software on the infrastructure [7]. With the massive Infrastructure that is offered by cloud providers today, storage & maintenance of large volumes of data is a reality. Sudden workload spikes are also managed effectively & efficiently, since the cloud can scale dynamically [8]. Through leveraging economies of scale and the capacity to manage assets more efficiently, cloud computing consumes far less energy and other resources than a traditional IT data center [3]. Cloud data centers are a natural repository for public information goods like shared data sets, so that users in any location or institution can instantly access, analyze and interpret data without the need to move it to their own facilities. This reduces the need for high-speed or high capacity network connections, since much less data moves between the users and the source of the data. A researcher with a moderate-speed connection to the Internet can work with data as well as other researchers regardless of location. In addition, researchers will normally leave the results of a cloud analysis at the cloud data center, allowing potential re-use by others. Properly managed, this can enable new kinds of collaboration and project organization [5].

Security: Cloud computing comes with several benefits that address data security including centralized data and incident response. Centralized data refers to the approach of placing all eggs in one basket. It might be dangerous to think that if the cloud goes down, so does the service they provide, but at the same time, it is easier to monitor. Storing data in the cloud voids many issues related to losing laptops or flash drives, which has been the most common way of loosing data for large enterprises or government organizations. The laptop would only store a small cache to interface with the thin client, but the authentication is done through the network, in the cloud. In addition to this, when a laptop is known to be stolen, administrators can block its attempted access based on its identifier or MAC address [9]. Moreover, it is easier and cheaper to store data encrypted in the cloud than to perform disk encryption on every piece of hardware or backup tape. Incident Response refers to the ability to procure a resource such as a database server or supercomputing power or use a testing environment whenever needed. From a security standpoint, cloud providers already provide algorithms for generating hashes or checksums whenever a file is stored in the cloud, which bypasses the local/client need for encrypting. This does not imply that clients should not encrypt the data before sending it, but merely that the service is already in place for them [5].

Scalability in cloud computing: The unified fabric now enables a fully virtualized cloud data center with pools of computing, network, and storage resources through the

Unified Computing System (UCS). The UCS bridges the silos in the classic data center, enabling better utilization of infrastructure in a fully virtualized environment, and creates a unified architecture using industry-standard technologies that provide interoperability and investment protection. UCS unites computing, network, storage access, and virtualization resources into a scalable, modular design that is managed as a single energy-efficient system. This system is managed through an embedded management framework, in the UCS platform. It also helps increase cloud data center staff productivity, enabling better management of storage, networking, computing, and applications to collaborate on defining service profiles for applications. So, at any given time, a machine could be running operating systems X, and then the next minute, it could be rebooted and it could be running a hypervisor Y. Hence, the compute node is just an execution engine with CPU, memory, disk, flash, or hard drive. Cloud computing provides a holistic way to address configuration management, rapid provisioning, upgrades/downgrades, scalability, policy enforcement, and auditing. UCS provides support for a unified fabric over 10-Gbps Ethernet foundation. This network foundation consolidates today's separate networks: LANs, SANs, and high-performance computing networks. Network consolidation lowers costs by reducing the number of network adapters, switches, and cables and thus decreasing power and cooling requirements. UCS also allows consolidated access to both SANs and network attached storage (NAS). With its unified fabric, the UCS can access storage over Ethernet and Fibre Channel, providing enterprises with choices and investment protection [4].

Privacy in Cloud computing: The compliance and Service Level Agreement (SLA) aspects of cloud data center security architecture are multifaceted. First, users need to understand the different components of a cloud data center that need to be compliant. These components may include physical data center facilities, infrastructure systems, and data itself. In the case of data and systems compliance, not only do classification requirements need to be addressed, but also the location (both source and copies of source) needs to be considered. Auditing and assessments requirements (both for risk and privacy), as mandated by the regulation, also need to be addressed. In a cloud data center, SLA contracts should be treated as a mechanism to map SLAs to architecture and service delivery. Some examples of SLA contracts-driven compliance in a cloud data center architecture could include understanding the secondary uses of consumer data and related systems, the prohibition of this use, if necessary, and the identification of the potential for cross-classification of data transfers, and its prohibition, if necessary. The above considerations lead to increased security, performance, and availability metrics for the consumers and an increased quality of the overall cloud data center security architecture [4].

Context-Awareness in Cloud Computing: Cloud Computing is device and location independent. This enables users to access systems using a web browser regardless of their location or what device they are using (e.g., PC, mobile phone). As infrastructure is off-site (typically provided by a third-party) and accessed via the Internet, users can connect from anywhere [10].

Mobility in Cloud Computing: Virtualization technology allows servers and storage devices to be shared and utilization is increased. Applications can be easily migrate from one physical server to another. This reduces physical mobility of users [10].

Evaluation of Ubiquitous Computing Based on the Metrics

Cost: Major barriers for adoption of ubiquitous computing are high investment expenditures and unclear benefits [1]. After employment of Ubiquitous systems, the flood of information has to be managed and that often requires well-planned process reengineering. Ubiquitous computing requires large capital, time and competencies to accomplish success and a great usefulness of it. Assigning consulting firms or service providers adds even more to the cost-side. Nevertheless, adoption of cost in ubiquitous system strongly depend on individual design choice and organizational factors [11].

Privacy in ubiquitous: Privacy is the most often-cited criticism of ubiquitous computing, and may be the greatest barrier to its long term success. However, developers currently have little support in designing software architectures and in creating useful and usable interactions that are effective in helping end-users manage their privacy [10]. The physical outreach of ubiquitous computing makes preserving users' privacy a much more difficult task. Augmenting active spaces with active sensors and actuators enables the construction of more intelligent spaces and computing capabilities that are truly omnipresent. Through various sensors and embedded devices, active spaces can automatically be tailored to users' preferences and can capture and utilize context information fully. Unfortunately, this very feature could threaten the privacy of users severely. For instance, this capability can be exploited by intruders, malicious insiders, or even curious system administrators to track or electronically stalk particular users. The entire system now becomes a distributed surveillance system that can capture too much information about users. In some environments, like homes and clinics, there is usually an abundance of sensitive and personal information that must be secured. Moreover, there are certain situations when people do not want to be tracked [12].

Security in ubiquitous: Access to and authenticity data, which users insert into the network, should be secured. In centralized systems security mechanism can easily be implemented through authorization of participants and control of data by the authoritative organization. On the other hand, the central authority may abuse its power, because it can take over control about data streams and network access. This is the situation in a ubiquitous system. Furthermore, it is an obvious target for attacks. In distributed systems other security means are feasible. Authorization can be realized by a public key infrastructure (PKI) and a trusted third party, which offers and validates certificates of participants [13].

Mobility in ubiquitous system: Increased user mobility is a defining dimension of ubiquitous computing, suggesting that applications should adapt themselves based on knowledge of location. This location can be position and orientation of a single person, many people, or even of a certain set of devices. Research in ubiquitous computing is toward the development of application environment able to deal with the mobility of both users and computing devices. The vision of ubiquitous computing relies on the presence of environments enriched by computers embedded in everyday objects and by sensors able to catch information from the context. This means that mobility is an important requirement for ubiquitous computing applications so as to provide a supportive environment in which specialized computing instruments can be accommodated and integrated into existing application contexts [14]. Users can carry devices with them from one active space to another or could take them out of the range of the system. Different active spaces can have different requirements and standards devices might need to be reconfigured as they move between different active spaces. Similarly, varying characteristics of wireless links and the possibility of network partitions warrant adaptation of system services and applications [15]. Ubiquitous systems need to interact with mobile users with or without wired infrastructure. This may generally involve some form of wireless communication - Bluetooth, wireless LAN, cellular, infra-red, reflecting lasers, amongst others. Mobile users may need to seamlessly switch between different modes of communication when they move from house to outdoors etc. Communication policies are needed to limit consumption of limited power sources. This implies that there is high degree of mobility in Ubiquitous computing environment [16].

Context-awareness in Ubiquitous Computing: Context-aware system face important security challenges related to the use of context information. The main issue is how to get secure and trusted context information. Context-awareness is a critical feature for a ubiquitous computing system because important context changes are more frequent. Due to the loose structure, mobility and scale of the system, devices in a ubiquitous system join, leave, move and fail more often. Devices are prone to network partitions and disconnection. Therefore the resources accessible to a device, which define its context, frequently change in such a system. Hence, every participating resource needs to be able to discover and adapt to its changing contexts to efficiently participate in the system [17].

Scalability in Ubiquitous System: One natural consequence of the growing complexity of the devices in ubiquitous system is the desire to connect them together in order to achieve greater functionality, flexibility and utility. Consumer devices usually have long life times. Therefore, they cannot be manufactured to interoperate with all the newer models of other devices that may become part of the ubiquitous system. Though economies of scale permit increasing computational capability to be embedded in consumer devices to allow additional software to be accommodated, they usually have no programming terminal attached that can be used to upgrade the software embedded in them. This limits their interoperability with newer devices in the system. Hence, it is desirable to utilize the network interface of a device to automatically upgrade its software to enable it to interoperate with newer devices in the system. Therefore, to enable ubiquitous interaction of devices, the fixed software embedded in the device ROM needs to be minimal to allow suitable extensions to be deployed, using the device network interface, to enable interaction of the device with other newer devices in the system [12].

Storage/Speed: Power sources for devices are one of the biggest problems in ubiquitous system. Since there exists a lot of devices per person, you cannot keep changing batteries. Use of solar cells, fuel cells, heat converters, motion converters may all be possible. The biggest challenge is to design very low powered devices, transmitters etc [15].

DISCUSSION

The summary of the findings obtained in the study is shown in table 1.

From the findings, reduced cost is a clear benefit of cloud computing as opposed to high investment expenditures in ubiquitous computing [3]. Ubiquitous computing requires large capital, time and competency to accomplish a great deal of success in it [1], [14]. Also, the study reveals through the Unified Computing System (UCS) that cloud computing is scalable by uniting computing, network, storage access, and virtualization resources into scalable modular design that is managed as a single energy-efficient system[4]. As for ubiquitous computing system, there is limitation in the interoperability of increasing computational capability with newer devices. Programming terminals to upgrade new software embedded are not available [12]. Furthermore, privacy is more guaranteed in cloud computing than in ubiquitous computing system [4]. On the other hand, privacy is the most often cited criticism of ubiquitous computing [2], [18].

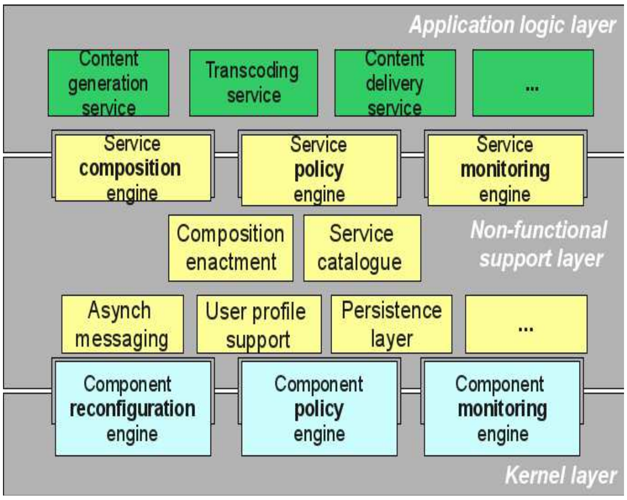
Also, from the study, it was revealed that cloud computing comes with several benefits that address data security [5]. These include centralized data and incident response [8]. In ubiquitous system, the centralized data centre may become the target for attacks and the central authority may abuse its power as well [7]. It is shown however from the study that context-awareness is a critical feature for ubiquitous computing systems [12]. There exists an independence of device and location-based cloud computing systems, making users to access resources regardless of their location [16]

Table 1: This table shows cloud & ubiquitous computing comparative evaluation summary

Evaluation Metrics	Cost	Storage/Speed	Mobility	Scalability	Context-awareness	Privacy	Security/Data Protection
Cloud Computing	Low	High	Low	High	Low	High	High
Ubiquitous Computing	High	Low/High	High	Low	High	Low	Low

This table presents a summary of the exploratory study carried out on cloud and ubiquitous computing systems based on some identified evaluation metrics.Figure 1: Conceptual view of cloud computing(Source: Harris [8])

Figure 2: This figure shows ubiquitous computing architecture



Source: Umar [11]

CONCLUSION

In this paper, an exhaustive review of ubiquitous computing and cloud computing was carried out. The study is designed to carry out a comparative evaluation of emerging technologies with a focus on cloud and ubiquitous computing paradigms. The comparative metrics used include cost, scalability, security/data protection, storage/speed, mobility, context-awareness and privacy. The results obtained indicated that cloud and ubiquitous computing are two different emerging technologies and should not be mistaken for each other. However, results obtained from the findings indicated that in this current economy where the expectations of efficiencies and cost savings are growing from IT organizations, enterprise private clouds has the potential of providing associated benefits of agility, cost savings and on-demand services while meeting the stringent enterprise security, performance and reliability requirements. Future research work should focus on the efficiency of service-specific applications of cloud and ubiquitous computings relatively to incurred time and space complexities. The universality, usage, acceptability and user versatility level of these computing paradigms can also be investigated.

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CONFLICT OF INTEREST

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