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# A Review on Cloud Computing and Internet of Things

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***Abstract*—**Cloud Computing is a convenient model for on-demand networks that uses shared pools of virtual configurable computing resources, such as servers, networks, storage devices, applications, etc. The cloud serves as an environment for companies and organizations to use infrastructure resources without making any purchases and they can access such resources wherever and whenever they need. Cloud computing is useful to overcome a number of problems in various Information Technology (IT) domains such as Geographical Information Systems (GIS), Scientific Research, e-Governance Systems, Decision Support Systems, ERP, Web Application Development, Mobile Technology, etc. Companies can use Cloud Computing services to store large amounts of data that can be accessed from anywhere on Earth and also at any time. Such services are rented by the client companies where the actual rent depends upon the amount of data stored on the cloud and also the amount of processing power used in a given time period. The resources offered by the cloud service companies are flexible in the sense that the user companies can increase or decrease their storage requirements or the processing power requirements at any time, thus minimizing the overall rental cost of the service they receive. In addition, the Cloud Computing service providers offer fast processors and applications software that can be shared by their clients. This is especially important for small companies with limited budgets which cannot afford to purchase their own expensive hardware and software. This paper is an overview of the Cloud Computing, giving its types, principles, advantages, and disadvantages. In addition, the paper gives some example engineering applications of Cloud Computing and makes suggestions for possible future applications in the field of engineering.

***Keywords*—**Cloud computing, cloud services, IaaS, PaaS, SaaS, IoT.

## I. Introduction

OVER the last several decades, the pace of progress of Internet technology has undergone rapid developments in various aspects. Recent advancements in the field of IT have changed the way people live, including Cloud Computing, which enables internet users to access virtually infinite amount of hardware and software resources, wherever and whenever they want. The internet has become an inseparable element of people's daily lives and Cloud Computing is the most important subject to be considered in this area.

In recent years, Cloud Computing has shifted towards the IT sector. It reduces the costs significantly and introduces new possibilities for ways of doing businesses [1]. Less hardware and software, no license requirements, low maintenance costs, worldwide accessibility, high flexibility, etc. are some of the major advantages of Cloud Computing [1], [2]. The deployment of Cloud Computing is visible in industry in general and particularly in mega organizations such as Google (App Engine), Microsoft (office cloud version), IBM (Blue Cloud infrastructure), and Amazon (Amazon Cloud) [3]-[5]. The cloud is capable of providing facilities that enable their services to be accessed by users anytime and anywhere by renting instead of purchasing the required services, such as web services and applications [6]. It can therefore be said that the virtualization of resources is a paramount concept of Cloud Computing [7]. In fact, Cloud Computing is the combination of IT and web-based storage platform services [8]. Cloud Computing deploys, allocates or reallocates resources dynamically through a capacity to continuously monitor their performance [9]. User-location independence is one of the main strategies of the cloud [10], [11]. Cloud models are classified into two main categories: Service oriented models with three sub-models, and deployment oriented models with four sub-models.

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## II. Service Oriented Models for Cloud Computing

Generally, as seen in Fig. 1, cloud service oriented models can be categorized into three groups [12]-[14]: Software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS).

### *A. Software-as-a-Service (SaaS)*

SaaS is referred to as "Software on Demand" [6]. It means that the SaaS model provides facilities for users to purchase or download a software application on demand in various environments. In addition, this service offers facilities to users to control and execute purchased or downloaded applications [12]. Microsoft Office 365, Google Apps, GT Nexus, OnLive, Marketo, Trade Card [16], Gmail, NetSuite and SalesForce [12] are some examples that use the SaaS model. Because the SaaS applications are hosted mainly in the cloud and are usually far away from the real users, a natural latency is introduced into the applications usage and as a result of this latency, SaaS model is not suitable in real-time applications where fast response time is important and can be highly critical. In addition, organizations that adopt SaaS may find that they are forced into accepting new versions of the software, which might result in unexpected delays and problems, causing the users to be trained and thus increasing the overall costs. Additionally, there is the risk of making

errors as a result of possible bugs might be present in the new versions of the software.

### B. Platform-as-a-Service (PaaS)

This model provides facilities for users to access the scalable computing and embedded data structure environments in order to develop, create and deploy their own applications [6], [12]. AWS Elastic Beanstalk, Cloud Foundry, Heroku, Force.com, Engine Yard, Mendix, Google App Engine, Windows Azure Compute, OrangeScape [16], Ruby on Rails, Java, or LAMP [12] are some examples that are included in the PaaS model.

### C. Infrastructure-as-a-Service (IaaS)

IaaS is the basic infrastructure of Cloud Computing. The IaaS provides virtual resources such as hardware, networks, machines and data storage. By using this service, users can assemble their own virtual clusters. In addition to supply the hardware, the cloud service providers also have the tasks of maintaining and upgrading the existing hardware as new models become available. The resources can easily be scaled up or down depending upon the actual demand and this has the effect of minimizing the costs. The main advantage of IaaS is that the client companies avoid the costs of purchasing and maintaining their own hardware and software. This is especially important for small companies with limited budgets that cannot afford to purchase expensive equipment and software. Table I explains briefly the relationship between cloud consumer activities and cloud provider activities for these services.

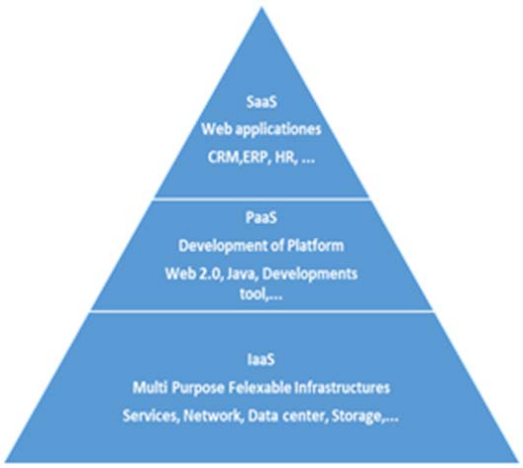


Fig. 1 Service Oriented model of Cloud Computing [15]

## III. Deployment Oriented Models for Cloud Computing

Based on Cloud Computing's deployment and environments, these models can be categorized into four main models [18]. The deployment models show how users can access the cloud service/services [19]. The existing cloud models in the real world are public, private, community and hybrid, which are named based on their specifications and may have negative and positive aspects [20].

### A. Public Cloud Model

The public model refers to the traditional concept of the cloud; it means that users have the opportunity to freely access the virtual resources of the cloud [19]. Google, Amazon, Microsoft, Azure and Google App Engine [15] are some examples of public cloud models. Normally, the public models are accessible to everyone via an Internet connection, wherever and whenever users need it [12]. Management, education and government sectors have taken advantage of the public model benefits, such as cost effectiveness, flexibility, reliability, location independence, high scalability and utility style costing [12], [15], [19]. However, it should be mentioned that there are some limitations, such as reduced customizability and security issues, that exist in this model [12], [15], [19].

TABLE I
The Cloud Consumers and the Cloud Providers [17]

| S.M | Cloud consumer activities | Cloud provider activities |
|---|---|---|
| SaaS | It uses an application service for operations regarding business processes. | It installs, manages and assures maintenance and support for software applications from the Cloud infrastructure. |
| *PaaS* | It develops tests, applies and manages hosted applications in a Cloud system. | It provisions and manages the Cloud infrastructure and the middleware for the consumers of the platform. It offers development, application and management tools for consumers. |
| *IaaS* | Creates installs, manages and monitors services for operations within the IT infrastructure | It provisions and manages physical processing, data storage, network connection, hosting environment and Cloud infrastructure for IaaS consumers |

### B. Private Cloud Model

The private cloud is an isolated form of cloud, which is only accessible and modifiable from inside an organization or company [18]; in other words, private or internal clouds model are controlled and operated by the relevant organizations [18]. Organizations can use this cloud model in order to provide higher efficiency from low cost hardware and improve average server utilization [22]. Furthermore, reducing the costs of administrative overheads and operation automation are other advantages of the private cloud model. However, there are still some limitations that exist in this model, particularly the initial investment required for building and managing the clouds [18], [22]. Eucalyptus Systems is one of the best examples of private cloud model [21].

### C. Hybrid Cloud Model

Amazon Web Services (AWS) is a good example of a hybrid model [15], [23]. The hybrid model falls somewhere between the Private and Public models [18] as shown in Fig. 2.

In hybrid cloud model, organizations can control their crucial resources, activities and services via using the private capabilities of a hybrid model, while non-crucial resources, activities and services are performed using the public cloud [15], [24]. The major advantages of the hybrid model are flexibility, high scalability and cost efficiency. Network and

security issues and dependency problems in the infrastructure are some weak points of this model [12].

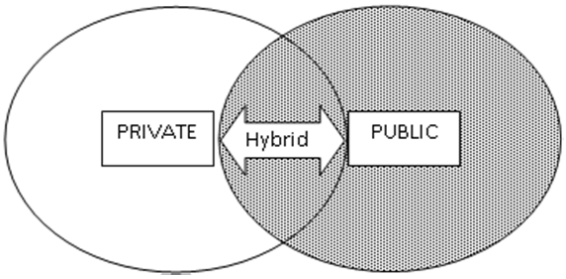


Fig. 2 Hybrid deployment model of Cloud Computing

### *D. Community Cloud Model*

Facebook is used by millions of people around the world and it is a Cloud example [15]. The Community Cloud model provides facilities to groups or organizations to access services and systems [19]. In addition, management of this model is carried out by one of the shared organizations or third-party services [15], [18]. Sharing data, resources and information among the organizations increase the cost effectiveness in this model. On the other hand, because all data are stored in one location and may be accessible by others who are not members of the organization(s), users must be careful about storing data in this model [15]. Fig. 3 explains the relationship between the services oriented models and deployment models of Cloud Computing.

## IV. Advantages and Disadvantages of Cloud Computing

### *A. Advantages*

Literature reviews reveal that Cloud Computing has various important advantages [25]. Some of the major advantages are summarized in this section. The first important advantage is the economic achievements, which are obtained through enhancing the output volume and efficiency, using fewer specialist human resources. For example, since the data backup operations are handled by the cloud operating companies, the clients do not have to employ computer operators for this purpose. The second important advantage of Cloud Computing is the low price globalization of the workforce, with via Internet connection and cloud usage. Reducing the costs of capital; it means that the organizations are not required to investigate and spend their budgets on preparing specific hardware, software, licenses or network instruments. Improving accessibility is another advantage of Cloud Computing which makes it easier for users to access data wherever and whenever they want. For example, a salesman can easily access his company resources such as the sales databases from anywhere on Earth and at any time of the day and any day of the year. Another advantage of the Cloud Computing is providing project monitoring facilities more effectively. Lastly, perhaps another less important advantage is improving flexibility without serious dependency on "financial" or "people" issues [15], [18], [26].

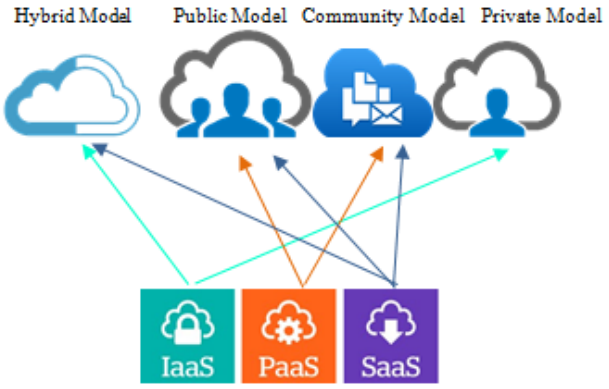


Fig. 3 Deployment and Service Models Relations

### *B. Disadvantages*

Cloud Computing has some disadvantages. Since the cloud services are entirely owned, managed, and controlled by the service providers, it gives no control over to the customers. The customers can only control and manage their own applications. As a result of this, the installation of new updates is entirely under the control of the service providers and customers may have to wait for new updates to be available. Storing data in all deployment models decreases the security of the stored data; this means that a third party can change, delete or modify stored data without users' knowledge or consent [27]. An Internet connection is vital for Cloud Computing; for example, if the Internet connection fails in a safety critical application which may require the Internet all the time, the results could be life threatening. Another important issue is the speed of the Internet. Cloud Computing does not work efficiently with low-speed Internet connections. As will be discussed in a later section in this paper, lack of proper security is another important disadvantage of the Cloud Computing.

## V. Engineering Applications

Most of the current applications of cloud computing are in the field of data storage and data mining where many companies use the cloud as a large database to store their clients' data.

With the recent developments in the field of Internet of Things (IoT) we can nowadays see many companies investing heavily in this field. Cisco estimated that IoT has a potential value of $14 trillion over 10 years [28]. In addition, seminars and conferences are being organized [29] all over the world to increase the awareness of the IoT and to encourage more research in this field. An IoT system basically consists [30] of a low-power microcontroller with various sensors and actuators, all interconnected and communicating with each other using communications technology such as WiFi, Bluetooth, RF, ZigBee, and so on. In home based applications the cheapest option is to use the available Wi-Fi home system to establish communication between the various devices in the system. The use of Bluetooth is also possible in a home environment but one of the problems with Bluetooth is that the

power consumption is relatively high and the range of communication is limited.

Fig. 4 shows a typical IoT implementation in a future intelligent home. Here, all the appliances have built-in sensors and actuators and all are interconnected to each other using the WiFi router at home. For example, the fridge may have sensors to detect when an item such as a tin of coke has been taken out. One important requirement of all IoT systems is that it should be possible to monitor and control the system remotely using a mobile device, for example such as using a mobile phone, a tablet, or a laptop computer. This requirement can easily be met by using a cloud based approach, where the home WiFi system has access to a cloud. In addition, the mobile device which is to monitor or control the home appliances should also have access to the same cloud.

In a typical application, various parameters of interest at home, such as the temperature, humidity, state of the cooker, state of the microwave, dish washer and so on can be uploaded to the cloud at given intervals and they can be accessed remotely by the mobile devices. As suggested by Ibrahim [31], cloud is an integral part of any intelligent IoT system. Fig. 4 is an example of an IoT system where each device is attached to an independent processor with Wi-Fi capability. Here, each device can independently send and receive data from the cloud. It is also possible to directly combine a number of devices and control them from a single main processor where the processor has an interface to the cloud through a communication equipment. Such architecture has the advantage that it is cheaper to implement since only one processor and one communications device are required. Another advantage of such architecture is that the individual devices can communicate with each other through the main processor.

Other cloud usage applications in engineering systems are mainly in environmental monitoring and control, where for example the weather conditions such as the temperature, humidity, pressure, wind speed, and wind direction can be measured at remote locations and then uploaded to the Cloud so that the data can be accessed from anywhere on Earth and at any time of the day and any day of the year [32].

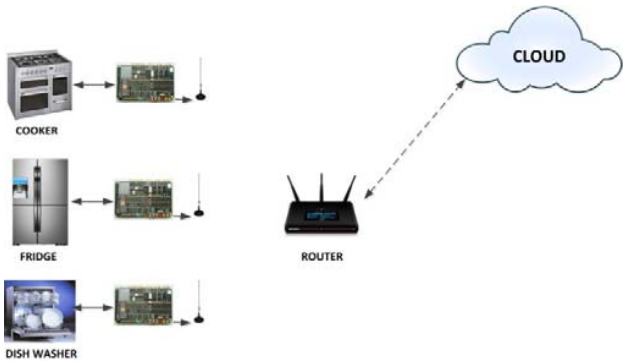


Fig. 4 A typical home IoT system

IoT is also shaping and transforming the healthcare by defining how the healthcare people and devices should interact with each other for the benefits of the patients. The major benefits of the IoT in healthcare can be summarized as:

- Improved disease management: Because the patients will be monitored continuously in real-time, healthcare personnel will be able to access their data quickly and improve the patients' conditions.
- Decreased costs: The healthcare costs will be decreased since the patients will be monitored remotely by the IoT devices and this will mean less physical visits by the doctors.
- Reduced errors: Errors will be reduced in healthcare since the patient data will be collected automatically.
- Speedy service: The speed of the services offered to patients will be quicker since any emergency conditions will be detected by the IoT devices at the instant the emergency occurs and the healthcare personnel will be notified quickly.
- Automatic drug management: With the help of the IoT devices most patients will be able to receive their drugs at the correct dosage and at the correct times.

An IoT network is not different from a conventional computer network. Therefore, most problems encountered in conventional networks such as security issues could also be found in IoT systems. Security is one of the concerns in cloud based systems, also in IoT systems [33]. The concerns about cloud security have become one of the barriers for cloud adoption by many organizations.

Because the cloud services are distributed and widely available, it is open to attacks, threats, viruses, and un-authorized access. Inside threats are also of concern in cloud systems. For example, a malicious insider working for a cloud service provider can easily cause damage to the system by giving the security passwords and related documents to un-authorized people.

In general, cloud service providers can guarantee the availability of their services, but they cannot guarantee that their system will not be attacked by un-authorized people. Cloud security is highly important especially in applications where personal data are stored, such as the storage of medical data or the bank details of people. As a result of this, currently the hospitals, healthcare homes, or financial institutions do not store the personal data of their clients on the cloud.

Securing reliable and efficient communication is really important in IoT systems, especially because the memory capacity of these systems is small and it is difficult to implement secure software with limited memory capacity. Unauthorized access to the cloud or to an IoT system is very important as such access can be very risky, for example, unauthorized people can monitor or control the appliances remotely without owners' knowledge and can easily cause unwanted damages.

Many organizations are developing sensors and special processors to be used in IoT based applications. Electronic IoT kits, special training videos, and books are available to teach the use of the IoT to interested people and make the general public aware of the technology, and to encourage the use of IoT devices in everyday life. However, most of these

companies are not considering the issue of IoT security and security seems to be low in their lists of priorities.

## VI. CONCLUSIONS

Cloud Computing is capable of being a pioneering virtual, secure and economic IT. Cloud Computing provides an expandable and cheap on-demand computing infrastructure, which offers three service levels, namely IaaS, PaaS, and SaaS. It implements and deploys four models of deployment, namely the Public, Private, Hybrid and Community Cloud models. The cloud is capable of providing facilities that enable users to access services anytime and anywhere by renting the required services, such as a web services and applications, instead of purchasing. Therefore, it can be said that virtualization of the resources is a paramount concept of Cloud Computing. Less hardware and software or licenses requirements, low maintenance costs, worldwide accessibility ease of use, flexibility, etc. are some major advantages of Cloud Computing. However, even though this new technology offers many benefits, it is faced with some challenges and issues, such as security and reliance on the quality of the Internet connection. Therefore, these problems should be considered and solved in the future.

Technology experts estimate that by 2020, most people will use and access online applications [34], and share information using remote network servers, rather than their personal devices, to do their work. They believe that in the next decade, the cloud will become more dominant than the desktop. Nowadays, some examples that reveal the increasing number of cloud users in recent years are: 400 million active Facebook users [35], Hotmail and Yahoo mail webmail services users, Twitter as a micro blogging service, YouTube for sharing video, Flickr for sharing pictures, Google Docs for documents, Delicious for social-bookmarking, eBay for business, and Yelp and Trip Advisor used for ranking, rating and commenting, and this will expand continually.

In the future, users will not be able to distinguish the difference between working with their local devices and working with the connected cloud. Thus, future Internet technologies will have a direct effect on research, which is considered to be the future of Cloud Computing. As the speed of the internet increases and also the cloud becomes more secure it is inevitable that more and more companies will join and use the cloud services.

Cloud computing is not only used by the companies interested in social media. The engineering applications of Cloud Computing are also growing, especially in the field of IoT at home and at commercial and industrial applications. The cost of the microcontroller based devices, memories, and sensors are falling all the time. At the same time the processors are becoming faster and also more reliable. As a result of this, it is apparent that the use of Cloud Computing in engineering based applications should see a big growth in the next few years as more and more companies are already investing heavily in this field.

IoT systems are also being used in many diverse fields such as in tourism, in transportation, in government offices, in restaurants, in hotels, and so on. It has been pointed out in this paper that security currently seems to be one of the major barriers to the acceptance of IoT by the general public. It is the authors' opinion that more research work is needed in this area to make the IoT systems fully secure before they can be universally accepted.

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