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Research paper

Towards using cloud computing technology in Egyptian governmental organizations

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Abstract

Although Cloud Computing Technologies "CCT" and their benefits have been recognized for decades, there are still fears at Egyptian Governmental Organizations "EGO" to migrate to them. The paper addresses developing & enhancing IT capabilities & business model at EGOs by adopting CCT from a national planning viewpoint. It starts by explaining **Cloud Computing** "CC" definition, concept, characteristics, types, models, benefits and challenges. Then introduces survey results as a guide model for EGO, as done in a previous study supervised by the author, surveying their awareness of CCT, standards, and factors impacting the migration. It contributed with a **"Proposed Generic Cloud Computing Architectural Framework for EGO"** to be adopted nationally. It **concludes that adopting CCT has a positive impact on IT from a financial & Performance viewpoints that raise its IT capabilities.**

Keywords: *Cloud Computing; Cloud Computing Architectural Framework; Cloud Computing Models, Information Technology*

1. Introduction

With the international rise of digitalization of governance tools many EGO turned to modern IT. ICT infrastructure has grown to meet the increasing demand for automation of government processes, storage, data management and online services. From one side it led to improved efficiency and quality of work, however, from the other it resulted in increasing costs, data and digital infrastructure, which placed a heavy burden on organizations' resources; software, applications, devices. This hindered the government's ability for upgrading and scale up to address the increasing demands nationally.

In parallel, developed countries, business technology economies rapidly changed, which led to the rise of a new market of cloud computing- software, systems and services with a total global public cloud market expected to exceed $178 B in 2018 predicting CC applications dominance[1].

Cloud model is one of the most attractive and useful models for developing governments. It offers an opportunity to deliver efficient, cost-effective public services and create a paradigm shift by delivering hosted services through the internet with recognized cost benefits and business innovation eliminating redundancy, increases agility, and provides ICT services as a utility.

Problem Definition: This paper argues that in order for Egypt to realize its official ICT national strategy to establish digital economy & society; develop ICT Industry; and make Egypt a Digital Hub, it must use cloud-computing technologies. Additionally, it explores how the model to be adopted by Egypt on the national level should look like. The papers main **objectives** starts by highlighting and displaying the importance of using CCT, it's applications, methods, platforms at EGO to perceive its benefits and maximize IT capabilities in terms of reducing IT resources and infrastructure cost, utilizing available governmental servers capacity, providing flexibility methods of remote working and distance resource accessing, avoiding knowledge and data repositories loss, providing better equipped facilities to address power problems and network interruptions. The paper further briefly presents the experience of Central Agency for Public Mobilization and Statistics in Egypt "CAPMAS", a leading EGO which started a serious initiative towards adopting CCT, however faced the obvious barrier of deploying a costly IT solutions that could pose risks to safety and security. Through the case the paper examines CC standards and factors affecting governmental decision of cloud adoption and migration. Finally, it develops a "Proposed Generic Cloud Computing Architectural Framework for EGO" to be adopted by Egypt.

Methodology: The paper follows different approaches; descriptive analytical method depending on observing and evaluating existing IT status at EGO; cloud-based model-building approach depending on CC standards resulted from previous study.

2. Cloud computing

Since 2009 "Cloud Computing" turned to become a technological hype attracting different IT officials, companies, industries etc. Although there isn't a one specific definition of the term "Cloud Computing", still in its simplest sense, it represents, a network, more specifically the global internet through which computational resources are hosted remotely and delivered [2] that refers to transferring computing processes and storage space from the computers to the cloud through web-based services and software that promise reliable services delivery using next-generation data centres that are built on compute and storage virtualization technologies, where consumers will be able to access applications and data from a "Cloud" anywhere in the world on demand"[3] [4].

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While Cloud is defined "a type of parallel and distributed computing system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA)established through negotiation between the service provider and consumers [5]. The National Institute of Standards and Technology, NIST defined CC "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources; networks, servers, storage applications & services that can be rapidly provisioned and released with minimal management effort or service provider interaction [6]". Evolution of CCT is associated with emergence of some CC interrelated and similar technologies; Virtualization, Service-Oriented Architecture, Web 2.0, Grid Computing [1]. CC applications usually are composed of essential characteristics, service& deployment models [5, 7].

2.1. Cloud computing characteristics, service models, deployment models

Essential Characteristics; **On-demand self-service**; customers' provision computing capabilities, server time, network storage automatically on time without technical support. **Broad network access;** access cloud services & capabilities easily over the internet through standard mechanisms using heterogeneous client platforms; mobiles, tablets, laptops, workstations **Resource pooling**; computing resources (storage, processing, memory, and network bandwidth) in the virtual environment are pooled to create many virtual systems. They serve multiple consumers with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. **Rapid elasticity & flexibility;** describes cloud environment easy expansion. **Measured service;** cloud services should be measurable quantitatively using various parameters such as time, bandwidth, and data used. Resource usage can be monitored, controlled, and reported, providing transparency for provider & consumer of utilized service.

CC Services Models; Software as a Service (SaaS); cloud providers install application software easily accessed by consumer devices through cloud client software; web browsers or a program interface without consumers having waste time installing, running, managing or controlling the application, underlying cloud infrastructure including network, servers, operating systems, storage. **Platform as a Service (PaaS);** cloud provider offer computing platform & infrastructure including operating system, software development kit for developers to deploy onto the cloud infrastructure their applications using programming languages, libraries, services, and tools supported by the provider to run over the internet without managing, controlling underlying infrastructure but just deployed applications & possibly configuration settings for the application-hosting environment. Users pay what they use. **Infrastructure as a Service (IaaS);** cloud provider offer virtualized resources; computing, storage, servers, networks, operating systems as a service on demand. Consumers, infrastructure providers and systems administrators, are responsible for patching and maintaining the operating systems and application software. Files are saved in a virtual host assuring for a safe retrieval through the internet. Fig. 1 shows the management of resources in cloud computing service models.

CC Deployment Models; Regardless of services utilized, there are four main deployment models for cloud services as follows [5, 8]; **Public cloud;** "cloud infrastructure & computing resources provisioned for open use by general public over a public network. It's owned, managed, and operated by business, academic, or governments selling cloud services, serving a diverse pool of clients. It's cheaper using shared infrastructure and exists on provider premise. **Private cloud;** cloud infrastructure is provisioned for exclusive use by single organization comprising multiple consumers, business units. Is owned, managed, and operated by the organization, a third party, or combination of them. It can be hosted on organization premises (on-site private cloud; on -premise) or outsourced to a hosting company (outsourced private cloud; off-premise). **Community cloud;** cloud infrastructure provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community may exist on or off premises". **Hybrid cloud;** cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability.

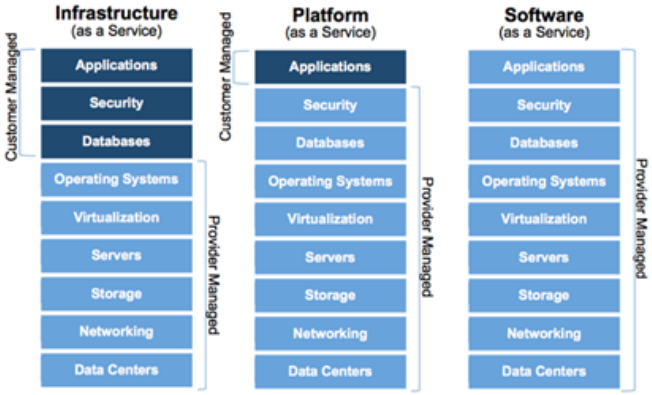


Fig. 1: Management of resources in different cloud computing service models [7]

2.2. Cloud computing related technologies

Evolution of CCT is associated with emergence of some interrelated technologies; Virtualization; abstracts physical Infrastructure & makes it available as easy manageable soft component, reduces cost, speeds up process, increase infrastructure utilization and minimizes human errors [8]. Service-Oriented Architecture; solves business problems, breaks them into integrated services, allows easy global access in a standardized way. Maximizes reusability, reduce effort needed to build new applications or modify existing programs [8]. Web 2.0; platform for web-based communities, facilitate user participation and collaboration. [1]. Grid Computing; uses interconnected computers to solve problems through highly parallel computation similar to CC involving large interconnected systems of computers, distributing workload [1].

2.3. Cloud computing benefits

There are a lot of benefits and privileges of using cloud computing services as follows [1] [8];

Cost Reduction; capital expenditure are converted to operational expenditure. **Scalability and Elasticity;** provides dynamic "on-demand" resources without users have to engineer peak loads on a self-service basis. It allows enterprise to match resources to demand without overpaying.

Flexibility and Agility; agility improves users ability to re-provision technological infrastructure resources while flexibility makes it easier to roll out new services.

Focus; through outsourcing IT services to cloud providers, IT experts and administrators can refocus on activities, opportunities and applications rather than IT.

Device & location independence; users access systems using a web browser regardless of the location or the device used.

Virtualization; allows servers and storage devices to be shared and utilization be increased. Applications easily migrate from physical server to another.
Performance; monitored and consistent.
Maintenance; easier as there is no need to be installed on user's computer and can be accessed from different places.

2.4. Cloud computing problems and challenges

Different challenges and threats should be considered as follows [1]; **Security and Risk;** service providers host sensitive data, usually in a multi-tenant environment. They should be trustworthy as they accesses, control, monitor information and communication between host company and end user with or without permission. Security concerns include loss of control over certain sensitive data, lack of security for stored kernels. Compared to traditional, it's better as providers devote resources to solve security issues which customers can't do.
Integration and Transition; it's not so easy to integrate the networks in a reliable, scalable and secure fashion. There could be uncontrollable sources of latency or data transfer and encryption problems. Interoperability, standardization and data integrity are of great concern.
Financial issues; significant migration costs.
Legal Issues legalities of CC is the problem of legal ownership of the data. [8].

3. Information technology statues in EGO, CAPMAS as a model

Many EGO still lack using effectively modern technologies, CAPMAS, as the basic official national data, information and statistics provider supporting ministries, authorities, decision makers over all sectors in the country, in an attempt to help the government extract indicators, draw policies, strategies and achieve national sustainable development goals for Egypt included in its strategical plan 20/30 has one of the most serious initiatives toward digital transformation, maximizing IT capabilities & infrastructure with limited funding. CCT, services & platforms are one of the most promising tools. Recently Egypt's IT infrastructure enlarged highly with physical components; hardware equipment; computers, laptops, portable devices, servers, network devices, switches, routers, firewalls, Software, Databases…etc. that represent main concern and burden on the government's budget. This section introduces surveying and analysis results done at CAPMAS and accomplished in a previous study [9] supervised by the author, choosing CAPMAS as a guide for EGO to be followed. It conducted two questionnaires surveying two groups of CAPMAS employees including IT staff members and various employees with different job titles to first measure and analyze the degree of awareness and understanding of CCT, its benefits and their motivation, willingness to really migrate. Then to survey the international CC standards & factors influencing the impact of adopting CCT in EGO based on CC benchmarking. Results should be realized as a trusted guide for other EGOs [9].

3.1. Results and analysis of CAPMAS surveys, titled "Towards Cloud Computing"

Q1: main reasons behind the desire to use CC and its applications in CAPMAS; answers ordered from the highest; avoidance of spending on IT components and support; removal of economical obstacles &lack of experiences; increasing computing capacity, business performance, flexibility &scalability of technological resources; ensuring business continuity & ease of disaster recovery. Q2: reason of fearing transformation/migration to CCT; answers as follows were confidentiality, privacy & unreliability problems of service provider ; cost of accessing CCT; data integration & availability; lack of clear pricing policy. Q3: most appropriate cloud types to be used at CAPMAS, the results showed 45 % for private, 40 % for hybrid, 15% for public cloud. The very similar results for private and hybrid cloud raise a question about how much workers there realize the real difference. Q4: concerning CC deployment models and to which extent each one is preferred, results showed highest for IaaS then PaaS then SaaS, which implies the uncertainty towards the new technology. In addition to other questions, results implying general divergence towards CCT (negatively) while positive implying awareness of the staff to CCTs importance

3.2. Analysis of a proposed checklist of international cloud computing standards in CAPMAS

International CC standards ensure that clouds can easily interoperate based on open standard interfaces. Cloud standardization deals with finding common representations of user identity, workload (virtual machine images), cloud-storage APIs, and cloud management API's. As vendors influence many standards, there should be an agreement on a number of standards that enable the creation of abstract APIs to reduce efforts, improve performance and reduce costs in the company rather than each one having its single standard. Standardization, also allows workloads services easy transfer from cloud to cloud, reducing redundant code writing with an advantage of making transparent code available and suited for any interoperable environment [10]. Accordingly CC standards include six main layers; IEEE P2301, IEEE P2302, Open Cloud Business Initiative, Open Cloud Initiative, Open Virtualization Format and Open Cloud Computing Interface which are explained thoroughly in many references [10]. While CC Performance Standards focuses on Cloud Metrics (CM) depending on SaaS, PaaS, IaaS, Cloud Metric basics are Availability, Concurrency, Dynamic load balancing, Intensiveness, Security and independent running application. As well as the Total Cost of Ownership TCO, which is important to estimate direct and indirect costs of a product or system helping in estimating the financial impact of deploying CCT [11]. After presenting International CC standards, a checklist has been applied to CAPMAS employers and analyzed through following steps;

• Surveying existed literature on CC standards deciding most used via the ordinal scale for ranking that resulted in seven main standards in this order**, Performance, Management, Accountability, Assurance, Agility, Usability & Security**.

• Constructing a proposed checklist of these standards and their different attributes that reached 21 attribute.

•Evaluating constructed checklist of CC standards via IT experts at CAPMAS. They generally agreed on list as they knew the benefits of the new technology.

•Distributing evaluated proposed checklist to CAPMAS IT managers, decision makers who filled the checklist according to arranged interviews

• Analysing received responses of the evaluated checklists. Most important CC standards were; accountability, agility, assurance and management, which include cost reduction, performance, ease of use and security. Confidentiality, risk, flexibility, support, innovation & efficiency standards can be very important to EGO as it results in cost reduction & enhanced performance. Hence, one can easily adopt the same view & steps to be applied to other

EGOs jut to assure the general direction and agreement towards migrating.

4. Proposed generic cloud computing architectural framework for EGO

Problem Statement: The aim of this section is to explore how a generic cloud computing architectural framework for EGO, based on the NIST definition revealing characteristics, delivery & service models explained thoroughly earlier can look like. Therefore, it is important to ask, what are the relationship and dependencies of different models? What are the cloud types and deployment models to be used in the different EGOs?

IaaS is the foundation of all cloud services, with PaaS building upon IaaS, and SaaS in turn building upon PaaS and by that information security issues and risk will be inherited like capabilities are inherited. IaaS layer provides physical and logical connectivity of hardware resources including entire infrastructure resource stack, facilities in the hardware platforms and a set of APIs allowing consumer-infrastructure management &interaction. PaaS layer allow developers to build applications upon to the platform in a programing environment; using programming languages and tools supported by the stack. It provides middleware capabilities; functions as database, messaging, and queuing while SaaS layer provides application level capabilities to users including functions for presentation, application. It is built upon the underlying IaaS and PaaS stacks. Adjustments to each model can exist in terms of integrated features [12, 13].

4.1. Cloud architecture model

Before introducing main layers & components of the cloud architecture model that will be used in the proposed framework. One should know it includes the following;

"IaaS layer provides high-level core services at system level, physical machines present large-scale data centres consisting of many hosts which manage a set of virtual machines.

Virtualization; decoupling hardware, operating systems, data, applications. It gives a chance for better management and distribution of workloads across physical infrastructure. Virtualization layer migrates running virtual machines from one server to another without downtime. Hypervisor-based virtualization technologies enable a rich set of solution capabilities that can be utilized by automation and orchestration layers to manage the virtualization layer. Virtualization provides an abstraction of software from hardware that enables the majority of management and automation to move from manual human tasks to automate tasks that are executed by the management software.

Servers; are well published and managed. (e.g.; no. & speed of CPU cores, maximum amount and speed of RAM, no. & type of motherboard input/output ports. Ethernet & fibre Channel expansion cards provide multiport options

Storage; data is stored virtually through cloud storage services; Azure Virtual Machine.

Networking; Multi-tenant networking refers to using technologies such as virtual local area networks (VLANs) or Internet protocol security (IPsec) isolation techniques to provide dedicated networks that utilize a single network infrastructure or wire. It can use Active Directory, Domain Services (AD DS) and Group Policy to control, firewall settings across the hosts and guest, in addition to the IPsec policies controlling network communication.

PaaS Layer provides simple and reliable distributed programming, requires scheduling jobs based on the underlying resource, managing data. Therefore, there is no need for developers to worry about the resources, for the platform layer provides all the necessary platform resources for the operation and maintenance of the application programs. PaaS layer application developers only need to upload program code & data as explained earlier. PaaS will govern processes, mechanisms and procedures used to store and access data in the Cloud System such as SQL server Database. The SQL Database service enables organizations to rapidly create, scale and extend applications into the cloud with familiar tools such as windows server 2012 [13]. Fig.2 introduces management of resources in cloud computing service, while Fig.3 introduces the cloud architectural general model components.

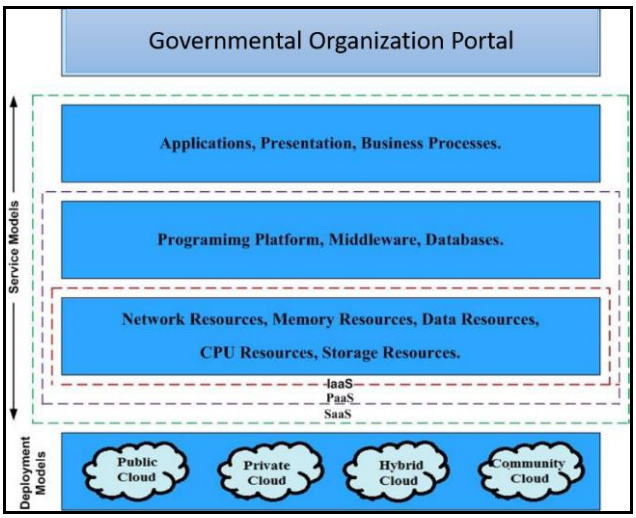


Fig. 2: Management of resources in cc service [6]

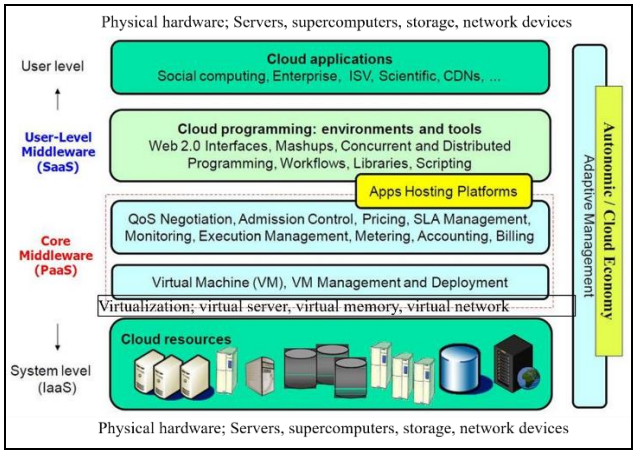


Fig. 3: Cloud Architecture Model [12]

4.2. Proposed generic cloud computing architectural framework for GEO

All over this paper, the author presented first the CC concept, definition, types, service & deployment models, benefits and challenges. Then introduced important results of a previous study on CAPMAS as model for EGO with its great function regarding Egypt's main indicators, demographic data as well as data bases of many governmental ministries and institutions. Then introduced surveying methods, analysis and CC standards and their attributes in order to be a guide for various EGO towards adopting and deploying CCT. Based on literature, previous study and findings the author proposed a generic governmental CC architectural framework for EGO aiming from one side to cope with the new era of digitization all over the world and from the other side to gain from the many benefits and advantages of cloud computing on a national level by reducing TOC & maximizing IT capabilities in EGO. Fig.4 shows the whole proposed architectural framework including following entities & their relational dependencies, cloud types.

4.2.1. Central agency for public mobilization and statistics in Egypt

CAPMAS the official statistical agency of Egypt that collects, processes, analyzes, and disseminates statistical data and conducts the census. Its main role and function is as an official provider of data, statistics, and reports supporting state planning, decision-making, policy assessment and regulations. On a national level it cooperates with almost all official national ministries, organization and decision makers in all sectors to conduct their plans regards the sustainable development goals. As well as providing individuals and different stakeholders with required data. One of its main interest lately is to cope with the rapid international developments in the field of IT & Telecommunication to be able to communicate and cooperate efficiently with all citizens. Therefore it adopted different initiatives towards digitization with a last one during the Egypt Census 2017 process, which has been completely digitized. **As CAPMAS provides public &private sensitive data it was necessary to adopt a hybrid cloud model containing both.**

CAPMAS Hybrid Cloud; is composed of two clouds; **one public** and **one private on -premise** as unique entities that are bound together by standardized or proprietary technology that enables data and application portability. It allow CAPMAS to optimize its resources, so that critical applications & activities be run under control of the private component of the hybrid cloud while other tasks are outsourced to the public component as follows;

The Public cloud is easy accessible through the internet for customers, stakeholders and individuals via mobile, Internet gateways, call centres etc. It can be used for simple applications, services, e-mails, for organization's website to publish its products and services to everybody who acquire it. It will also offer services and applications to the end user on a pay-per-use basis.

The Private on – premise cloud designed to assure data protection on all the sensitive governmental data and information. It provides multiple packages of specialized software solutions for different business units in CAPMAS. The physical infrastructure will be owned and managed by CAPMAS with an extension of management and security control planes controlled by MCIT. The Private cloud is more secure since their users are trusted CAPMAS individuals.

4.2.2. Egyptian ministry of communication and information technology

MCIT is the government body responsible for communications and information technology (ICT) issues in Egypt. It is responsible for planning, implementation and operation of government ICT plans and strategies. MCIT itself adopt vision of digitization, cloud computing and predictive analytics for Egypt. In the proposed framework, the author suggest that MCIT will be the National cloud provider responsible for making a service available to all interested parties. It acquires and manages the computing infrastructure required for providing the services, runs the cloud software, and makes arrangement to deliver the cloud services to the Cloud Consumers through network access. Regardless if it will provide SaaS, PaaS or IaaS, it conducts its activities in the areas of service deployment, service orchestration, cloud service management, security, and privacy. The framework recommends that MCIT deploys an **outsourced Community Cloud** in which from one side the various and different governmental organizations and ministries can access together the same ICT facilities and services while from the other side the private cloud can deal with their critical and sensitive information and data.

4.2.3. Ministry of defense

Use a private cloud for itself to be sure that it won't deal with privacy and security issues but at the same time it can access any public cloud.

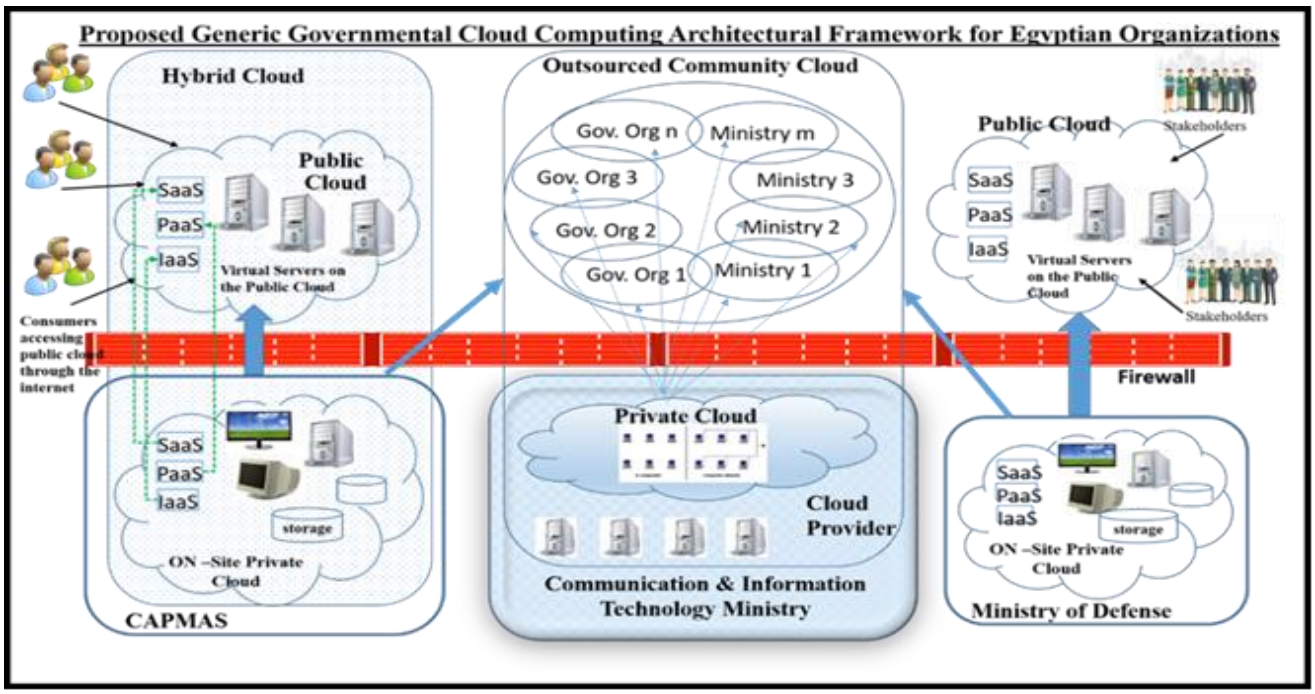


Fig. 4: Proposed generic governmental cloud computing architectural framework for EGO

4.2.4. Stakeholders

Generally normal users will access any public cloud through internet.

5. Conclusion

This paper presented the concept of Cloud Computing and clearly explained its benefits including IT cost reduction and improving government's IT capabilities. The results of a previous study outlining the initiative of CAPMAS to migrate to the cloud have been introduced as a model for EGOs. Finally **the paper's original contribution consists of a proposed Generic Governmental CC Architectural Framework for EGO with its different entities and components.** The paper recommended to adopt this framework for deployment nationally & to raise awareness concerning this technology on various levels. As a future work it is recommended to carry out an accurate economic feasibility study realizing the CC standards before adoption. In addition further research is needed to thoroughly address CC Challenges connectivity efficiency, culture change reluctance, shortage of qualified resources in EGO.

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