Computers and Electrical Engineering 67 (2018) 145–158

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

A framework for integrating geospatial information systems and hybrid cloud computing[☆]

Abdelrahman M. Helmi[a,*], Marwa S. Farhan[b], Mona M. Nasr[b]

[a] Canadian International College, Cairo, Egypt
[b] Faculty of Computers and Information, Helwan University, Cairo, Egypt

ARTICLE INFO

Keywords:
Cloud computing
Geospatial information systems
Hybrid cloud
Deployment models

ABSTRACT

Many decisions are made daily based on the simple mental processing. This way of decision making is suitable for the simple personal daily issues. But when decisions are concerned with general and sensitive sectors, this way of decision making is unacceptable. Nowadays, Geospatial Information Systems help in making more accurate decisions in a lot of sections that would be built on accurate information by way of drawing maps and visualizing data to clearly judge which option is the best for that particular situation. This paper raises a framework that integrates the Geospatial Information Systems with the Hybrid Cloud Computing to let them work together and get greater powerful benefits via applying the concept of cloud computing to overcome the flaws related to the desktop GIS including the huge startup cost and the storage capacity and to provide the feature of location independence accessibility where the GIS can be accessed from anywhere and anytime. The hybrid cloud computing was picked to be integrated with the GIS to gain the elasticity and security of dealing with different types of data; private and public data. This integration is presented in three dimensions. The first one is architecture with seven segments that illustrate the main structure for the Hybrid Cloud GIS within a mix of private environment and public environment. The second one is the types of the participants and their workflow within the two environments. The last dimension is a case study for applying this integration in the health sector in Egypt.

1. Introduction

Recently, Cloud Computing (CC) was raised to help in solving a lot of problems in a wide range of different sectors. By using (CC), it became much easier to handle a large amount of data and services with a less cost using the utility of pay-as-you-go (PAYG) which is a computing billing method implemented in cloud computing. It allows the user to scale, customize and provision computing resources, including software, storage and development platforms where the resource charges are based on the used services. Cloud computing also gives access to these data and services without time or location dependency.

As it's one of the cloud deployment models, hybrid cloud is a cloud computing environment which uses a mix of private cloud and public cloud services with orchestration between the two platforms. By letting workloads to shift between public and private clouds as computing costs and needs change, hybrid cloud gives greater flexibility and more data deployment options. While (GIS) is playing an important role in a lot of sectors, its value would be much bigger by getting the access to its services 24/7 regardless the location and the time where an internet connection is all you need.

☆ Reviews processed and recommended for publication to the Editor-in-chief by associate editor Dr. L. Bittencourt.

* Corresponding author.
E-mail addresses: abdelrahman_helmi@cic-cairo.com (A.M. Helmi), marwa.salah@fci.helwan.edu.eg (M.S. Farhan), drmona_nasr@fci.helwan.edu.eg (M.M. Nasr).

https://doi.org/10.1016/j.compeleceng.2018.03.027
Received 15 June 2017; Received in revised form 16 March 2018; Accepted 19 March 2018
0045-7906/

This paper presents a Hybrid Cloud GIS framework with three dimensions. The first dimension is a seven segments' architecture for integrating the hybrid cloud computing with the GIS. Those seven segments are designed to cover the whole integration between the GIS and the two environments of the Hybrid cloud. The second dimension is the participants' workflow where the users in this framework are categorized to insiders and outsiders dealing with two different environments; public and private. The third dimension is an applied case study on one of the most important sectors which are the health sector to clarify the importance of the Hybrid Cloud GIS framework in solving the most common problems related to this sector and improving its services.

The Paper is divided into six sections. The first section gives the introduction. While section two gives a brief explanation of the concepts used in this research including the Cloud Computing definition, characteristics, deployment models and services and the GIS. The third section explains the related work that has been done by other researchers in the field of Cloud GIS. The fourth section demonstrates the suitable CC deployment model used in this research by explaining its advantages, disadvantages, and requirements. The fifth section elucidates the framework with its different dimensions. The last section gives a summarized conclusion for the gained results.

2. Background

This section gives a brief explanation of the concepts used in this paper including the Cloud Computing and the GIS where Cloud explains the use of a compilation of applications, services, information, and infrastructure composed of pools of computers, information, and network and storage resources. Cloud computing alludes to the use of networked infrastructure software and capacity to offer resources to users on-demand environment. With cloud computing, information is cached temporarily on clients that can include PCs, notebooks, and other devices and stored in centralized servers [1]. According to (NIST) National Institute of Standards and Technology, Cloud Computing was presented as a model for offering suitable on-demand network access to a shared pool of computing resources including servers, storage, applications, network, and services that can be quickly released and provisioned with minimal service provider interaction or management effort [2].

The cloud computing characteristics are five main characteristics. The first characteristic is that cloud computing is considered as on-demand service which means getting computing capabilities as needed automatically. The second one is the broad network access where the services are available over the network using PCs, Laptops…etc. The third one is the resource pooling where the provider resources pooled to serve multiple clients. The fourth one is the rapid elasticity which gives the ability to quickly scale in and out of services. The fifth one is the measured service where controlling and optimizing the services is based on metering [3].

The cloud computing deployment models are four different models. The first model is the public deployment model where it's owned and operated by one organization and its services offered to the general public. The second model is the private model where it's owned and operated by one organization but its services offered to their internal users only. The third model is the community model where it's owned and operated by organizations of a specific community. The fourth model is the hybrid one which is a composition of two or more clouds (Public, Private, and Community) [4].

Hybrid Cloud consists of at least one public cloud and at least one private cloud. It's regularly offered in one of two ways: a dealer has a private cloud and makes a partnership with a public cloud provider, or a public cloud supplier makes a partnership with a dealer that offers private cloud platforms. Its infrastructure is well presented as an integration of two or more different clouds that leap together by proprietary technology that enables application and data portability. In a hybrid cloud, an organization manages and provides some of the resources out-house and some in-house. It gives the scale and cost benefits of public clouds, while also it gives the control and security of private clouds. The hybrid cloud has an extra data privacy and security than the public cloud where the data is spread between at least two zones. Also, it has lesser establish cost than the private cloud. According to the distribution of data through different zones, important data would be stored in the private district to be only accessed by the allowed users while other data would be stored in the public district to be accessed by public users [5].

The services of the Cloud Computing are mainly categorized into three categories. The first one is the software as a service (SaaS) where the applications are running in the cloud. It presents an architecture that can run several instances of itself regardless of location. The second one is the platform as a service (Paas) where it's a platform that enables the developers to write applications to run on the cloud. It would usually have several application services available for quick deployment. The third one is the infrastructure as a service where it's a highly scaled redundant that shares the computing infrastructure to let it be accessible by internet technologies. It consists of servers, storage, security, databases, and other peripherals [6].

As a computer-based tool, Geospatial Information System (GIS) is used for storing, collecting, retrieving, transforming and displaying spatial data. GIS offers facilities for data management, data manipulation, data capture, analysis, and presentation [7]. GIS is the combination of cartography, statistical analysis, software, hardware, and data. GIS is usually used as a supporting system for decision making by offering best possible decisions through non-spatial and spatial data relations, processing, and visualization [2]. With GIS it is easy to draw maps and visualize spatial distributions. Also, it allows editing and altering existing data and accurately measure distances and areas. The uses of GIS in the health sector are extremely valuable including preparing and viewing diseases maps to easily track diseases and control it over time. It also helps in mapping populations at risks to make accurate saving plans. In addition to identifying accurately the healthcare areas and determine the shortage areas [8].

As a result of integrating the Geospatial Information systems with the concept of Cloud Computing, Cloud GIS was proposed as a valuable approach to give broad range services to the users across the world [3]. The widespread use of GIS over the decades has been put to a big question mark whether to move it to new better option i.e. Cloud Computing paradigm [4]. Geospatial Information Systems (GIS) applications have been moving into the cloud with an enlarged drive. International organizations like GIS Cloud Ltd, ESRI, etc. have taken the quantum jump and taken a technological move to Cloud Computing Paradigm and are dedicated to offering on-demand services to their wide shade of users. Amazon (Amazon EC2 & S3), IBM (IBM Cloud), and Microsoft (Microsoft Windows Azure, Windows Server Hyper-V) are the largest Cloud GIS infrastructure providers worldwide who provide secure and reliable cloud IT infrastructure to the user's on-demand [6].

3. Related work

Cloud GIS provides reliable tools which can add values for many sectors, especially when cost reduction and optimization are significant. Some essential principles which characterize Cloud GIS to be established as the serious contestant for the next generation of the GIS computing model are supporting the technology infrastructure, providing the application infrastructure, reducing the implementation cost, the data conversion and presentation, and the location independent resource pooling [2]. Some providers deal with Cloud Computing as a way to offer storage capacity or compute as a service, provisioned from a parallel, on-demand processing platform that enlarges economies of scale. Other providers may associate Cloud Computing with software as a service, a delivery model for letting applications available over the Internet. IT analysts see Cloud Computing from the viewpoint of variable pricing without long-term commitment and huge elastic scaling of services. IT leaders consider cloud as an infrastructure architecture option that can trim down costs. The media, end users, and financial analysts have at rest other perspectives on what Cloud Computing represents [9]. For GIS applications the Cloud GIS can show to be an approach to offering storage capacity or compute as a service, provisioned from a parallel, on-demand processing platform that enlarges economies of scale to a varied shade of users and organizations requiring GIS application services [2]. Therefore, Cloud GIS is well thought-out as an appropriate tool to upgrade and improve traditional GIS applications and offer a broad range of users across the world.

Spatial Cloud Computing (SCC) points to the computing paradigm that is operated by geospatial sciences and optimized by spatiotemporal principles for enabling geospatial and other scientific discoveries within a distributed computing environment. SCC is presented likely to be a good alternative versus traditional GIS. There are many reasons for this, first of all, results are same with Desktop GIS so there is no quality difference. Beside this SCC is advantageous in terms of economy, flexibility, and accessibility. SCC is economic because of initial costs of building an enterprise GIS system is too low. At first step, it can build a normal performance system and then increase system capabilities according to requirements. This makes SCC economic and flexible. Other side using system regardless of installing software makes SCC accessible. Just web browser and login info (username and password) is enough if an internet connection is available. After these, all GIS analyzes queries can be done quickly. If internet connection speeds will be better in future, strongly SCC will be more efficient with all of its capabilities. In SCC environment users can easily add base maps under their spatial datasets published from cloud vendors or public datasets which were shared by other users. This functionality removes barriers in front of interoperability and sustainable work model. Every user can easily share spatial data easy and fast. Permission control about self-data makes SCC more functional, nominate data, map or an application can be open to one person (Private Cloud), a group (Community Cloud) or the public. Access, edit, query and download controls can be manipulated cloud computing deployment models. SCC brings geospatial working ability for mobile devices [10].

Geosciences data are the main component operating geosciences advancement. Accepting the Earth as a system requires a mixture of observational data gathered by sensors and simulation data formed by numerical models. Within the last years human's ability to discover the Earth system has been enhanced with the appearance of new computing technologies. As the technological advancements speed up the gathering, simulating and distributing geo-data, they also make Big Data for geosciences. Successfully analyzing these data are necessary for geosciences fields. On the other hand, the tasks are challenging for geoscientists because processing and handling the huge amount of data is both data and computing intensive in that data analytics requires multiple tools and complex procedures. To handle these flaws, a scientific framework was proposed in 2015 for big geosciences data analytics. In this framework, techniques are proposed by leveraging cloud computing, MapReduce, and Service Oriented Architecture (SOA). Specifically, HBase is adapted for storing and managing big geosciences data across distributed computers. MapReduce-based algorithm framework was developed to support parallel processing of geosciences data. And service-oriented workflow architecture was built for supporting on-demand complex data analytics in the cloud environment. Results show that this innovative framework significantly improves the efficiency of big geosciences data analytics by reducing the data processing time as well as simplifying data analytical procedures for geoscientists [11].

In 2015, Cloud computing was proposed as a solution to enhance the Egyptian Higher Education. The Education sector in Egypt is the largest workforce in the Middle East and North Africa that full of investment opportunities. The higher education sector in Egypt has 2.5 million served by 20 public universities and 19 private universities while some students enrolled in private institutes reached 313,931 in June 2012, and about 63,000 staff members, 250,000 postgraduate students. No one can decline the necessary role that Cloud computing plays in the development of higher education newly. Using Cloud computing in the higher education can provides data storage, databases, educational resources, software and applications that can be accessed through Web browser of mobile devices, simply cloud computing provides services anytime anywhere but having in mind the user is not responsible for where the services or the application are located or how it maintained. Utilizing Cloud technology in providing multiple services; for example, e-learning environment will employ vital resource share which helps in solving the scalability. Thus, placing Egyptian Virtual University (EVU) services upper cloud technology considered the preferable solution to solve limitations of the current IT (e.g. Department of Information Systems). The general design for Egyptian University systems depends on the cloud computing technology that has an interface layer which controls the access of users to multiple services [12].

The proposed framework utilized the existing IT infrastructure for EVU which would adopt the framework based on cloud computing for (EVU-IS). Cloud computing consists of four deployment models such as Hybrid Cloud that merge public and private cloud together. This mixing process makes the user able to gather various services from various cloud service providers. Also, Hybrid cloud ensures data security for the users and also provides them with important applications to be used in universities by supplying them on the private cloud in spite that such important applications have been hosted by different cloud providers. Full control considered as the most remarkable feature of the Hybrid cloud, there for EVU can utilize this feature to control the system once it controlled a part of the infrastructure. Consequently, an open-source named Eucalyptus has been nominated to be used in the proposed framework aiming to manage the repetition of the disseminated data center such as managing a large number of connected virtual machines [12].

Also, GIS-based on cloud computing was proposed as a solution in 2013 in Egypt for earthquakes emergency management and earthquakes prediction based on (Microsoft Windows Azure) as a Cloud computing platform. The beneficial values of this model are the easy use and supervision of application and data, the lessening in establishing cost, and high security. Microsoft Windows Azure platform was selected as the public cloud computing environment for this model as a public deployment one. It consists of six layers including infrastructure and platform, storage, data management, application, and client layers. This model mainly used to apply earthquakes prediction application to give caution of potentially damaging earthquakes early enough to let suitable response to the disaster, enabling people to reduce the loss of life and property [17]. The enforcement of that integration between the Cloud Computing and GIS was presented as a solution for the emergency management based on public deployment model. Historical earthquakes data and GIS technology have been used to estimate the likelihood of future earthquakes in a cloud computing environment. In the proposed model, the user can upload the historical earthquake's data and geo-spatial data to the database. Then search for certain data by date and visualize the output layers on the map viewer for further analysis and queries to estimate the next earthquake time and position and generate useful reports [13].

In the previous work, different models and solutions built on cloud computing were presented and used in different sectors. In the educational sector, hybrid cloud computing was presented as a solution to gain the benefit of the data storage and to provide services anytime but it was only presented as a cloud solution with a platform layer for building applications to access resources of the public clouds without integration with a tool or a system to be used. In the emergency sector, cloud computing was integrated with the GIS as a solution to overcome the traditional GIS problems but based on public cloud deployment model that would deal only with public data without giving the flexibility to deal with different types of data (private and public).

This paper presents a GIS solution built on cloud computing but mainly the hybrid cloud computing to gain the flexibility and security of dealing with different types of data; private and public data by merging the GIS with the hybrid cloud computing and let them work together to gain the most benefits. This solution would deal with two different environments for the public and the private data through different seven segments (7S) starts with the client segment and ends with the infrastructure segment. It also presents the workflow of the two main types of users that would deal with that solution including the insider users and the outsider users.

4. CC deployment model

Which cloud computing deployment model would be suitable to be integrated with the GIS? The answer depends on the types of data related to sector using the Cloud GIS solution which can be divided into two main types; public data and private data. The public data is the data related to the general information about the sector that can be accessed by anyone. While the private data is the critical data related to sensitive departments and partitions that must be accessed only by the authorized ones. Due to these two types of data, the proposed framework depends on the Hybrid Cloud deployment model to obtain the beneficial values of the mixture between the private cloud and the public cloud where some of the resources are provisioned and managed by the allowed partners and in private cloud environments are hosted while other resources through the public cloud services are delivered. Hybrid cloud model provides security to user data and also used for storing large amounts of data.

The advantages of the hybrid cloud include reducing the capital expenses as part of the organization's infrastructure where the needs are outsourced to cloud providers. Also, it improves the resource allowance for impermanent projects at an infinitely cheap cost because the use of public cloud eliminates the call for investments to handle out these projects. It helps to optimize the infrastructure spending during different stages of the application lifecycle where public clouds can be used for testing and development while private clouds can be tapped for production. Also, it offers both the controls available in a private cloud deployment along with the ability to rapidly scale using the public cloud. Hybrid Cloud also provides drastic improvements in the overall organizational agility, because of the ability to leverage public clouds, leading to increased opportunities [14].

As a hybrid cloud expands the IT edge outer the organizational borders, it opens a bigger surface area for attacks where the hybrid cloud infrastructure is managed by the service provider. While hybrid cloud makes the data-flow from a private zone to a public zone much easier, there are integrity and privacy concerns related to such data movement because the privacy controls in the public cloud differ considerably from the private cloud. There are risks linked with the security policies across the hybrid cloud zone such as issues with how encryption keys are controlled in a public cloud compared to a private cloud zone [15].

The requirements for the hybrid cloud computing includes the interoperability and openness across on-premise and public cloud environments. Also, the extensible architecture that is easy to integrate with existing systems, tools, and applications. In addition to the on-premise control of sharing and composition of services and sharing of information and the ability to select cloud services from a variety of providers and create secure compositions. It also needs a high degree of automation and availability across multiple data center environments. In Hybrid cloud computing the security and policy-based isolation in a multi-tenancy environment. It needs the ability to integrate with existing on-premise middleware and application and ability to integrate cloud services with existing data sources [16].

5. 3D-7S-2E framework

The internet at the present plays a main function in the process of most geospatial tasks. Cloud solutions build on the internet's base of interaction and connectivity. In addition to moving information, remote servers can give powerful computing capabilities. It's possible to bring sophisticated data processing to more users and locations by tying leading to cloud services, As a result, cloud-based systems for geospatial information management and analysis are poised to provide new flexibility in enterprise operations.

There are now cloud-based platforms for software, data, and services to serve the geospatial community. Focused on applications in surveying, engineering, and GIS, the cloud is used to support work in geospatial data management, field data collection and transfer, equipment management and spatial data catalogs. By combining cloud services with technologies for positioning, communications and data analysis, companies can leverage point-of-work delivery of information needed by geospatial professionals in the field and office.

Data is the cornerstone of any geospatial workflow. By enabling professionals to easily discover access and utilize different types of data, the cloud became an essential part of the daily processes of data collection, processing, modeling, and analysis.

Cloud Computing is presented as a solution for the traditional desktop GIS to overcome most of the local desktop GIS flaws including:

☐ The weak computing power when dealing with a large scale of spatial data
☐ The resources limitation - limited to be accessed only by the local users.
☐ The waste of money and time when it comes to software upgrading and maintenance.

Some basic characteristics of Cloud GIS to be accepted as the serious contender for next-generation GIS computing paradigm are:

☐ Results are same with Desktop GIS so there is no quality difference.
☐ Advantageous in terms of economy and accessibility.
☐ Using system regardless of installing software makes Cloud GIS accessible.
☐ Cloud GIS brings the geospatial working ability to mobile devices.
☐ Mobile clients can apply GIS analyzes with browsers or small applications on cloud servers.
☐ The location independent resource pooling

According to these features that give preference for the Cloud GIS, the proposed framework is built upon it. The proposed framework deals with the hybridization of the private and the public cloud for a more prominent working of clouds. This framework is composed of three dimensions “3D Framework”:

5.1. Hybrid Cloud GIS Architecture:

This architecture consists of seven segments (7S) through two environments; public and private.

5.2. Participants:

This dimension is divided into two main types of users; insiders and outsiders.

5.3. Applied Case Study:

The last dimension is the one related to an applied case study on the health sector in Egypt.

5.1. Hybrid cloud GIS architecture

According to Fig. 1 this architecture is made of seven segments (7S) including the client segment, hybrid management segment “portal,” application segment, GIS segment, data management segment, storage segment, and infrastructure segment. This architecture is built upon a hybrid cloud where these seven segments are distributed and running in two different environments (2E). The first environment is related to the public cloud computing, and it's called the off-premise environment while another environment is the one related to the private cloud computing and it's called the on-premise.

5.1.1. S1 - Client Segment

It is the first segment in this architecture where it's the segment that refers to the web-based interface where the user can interact with in order to start dealing with the different types of data including the spatial data and the non-spatial data. This segment would be called the front segment where it's the only segment seen by the users to deal with. The whole processes would start and end at this segment where the user requests would be sent from this segment and the data retrieved would be viewed on this segment back. Due to this, the client segment should be as simple as possible in order to let the different types of users deal with it smoothly especially the non-expert users who will deal with it.

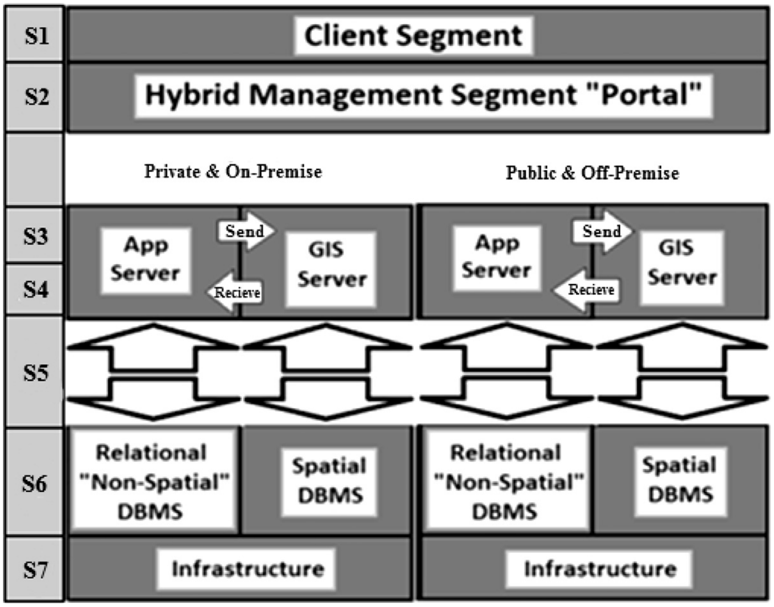

Fig. 1. Hybrid cloud GIS architecture 7S-2E.

5.1.2. S2 - Hybrid Management segment

The second segment is the hybrid management segment and would be called the portal segment. It would be considered as the most important segment in this architecture where its main task is to organize the different types of users and connects them with the appropriate content and capabilities based on their role and privileges. The portal uses to deliver the right content to the right person at the right time and provides access controls, content management capabilities. While all the users will deal with the client segment, the portal or the hybrid management segment is the one who will determine which content to view to which user according to the users different classifications and privileges where some of the users will deal with both environments (public and private) while others will deal only with the public environment.

5.1.3. S3 - Application Segment

This segment acts as the middleware between the GIS server, DBMS and the end-user (client segment). This segment is responsible for providing the different applications and services that can be executed in- the Cloud GIS by the end-users where the request moves from the client segment passing by the portal to determine the user privileges and upon this it will pass or refuse the request. After passing the request to the application server it would be sent to the GIS segment to deal with it by retrieving data from the data management segment and start processing this data in order to send it back to the first segment to be viewed to the appropriate user.

5.1.4. S4 - GIS Segment

This segment provides the basic GIS functions and services including map services, spatial analysis, spatial quires, geo-processing and hosts GIS resources including the maps and locations coordinates. In this segment different utility used to support the optimization and seamless functioning of the GIS Cloud as a whole focused GIS utility for address lookup, mapping, routing, geo-coding, and navigation. It provides these services and resources to the application segment in order to move it to the client segment to be viewed it after processing as an information to the end user on the client segment.

5.1.5. S5 - Data Management segment

This segment is responsible for all the mechanisms and procedures used to store and retrieve different types of data within the two environments. This segment handles the movement of the spatial data coming from the GIS segment to be stored in the spatial database management systems in the storage segment and the non-spatial data coming from the application segment to be stored in the relational database management systems. Also, it handles the retrieval of all of this data back to the previous segments for using and processing.

5.1.6. S6 - Storage Segment

Because data is not stored in the user's computer; this segment is developed to use the cloud storage services to store the different types of data within the two environments by storing the spatial and non-spatial private data in database management systems on the private cloud while storing the spatial and non-spatial public data on the public cloud.

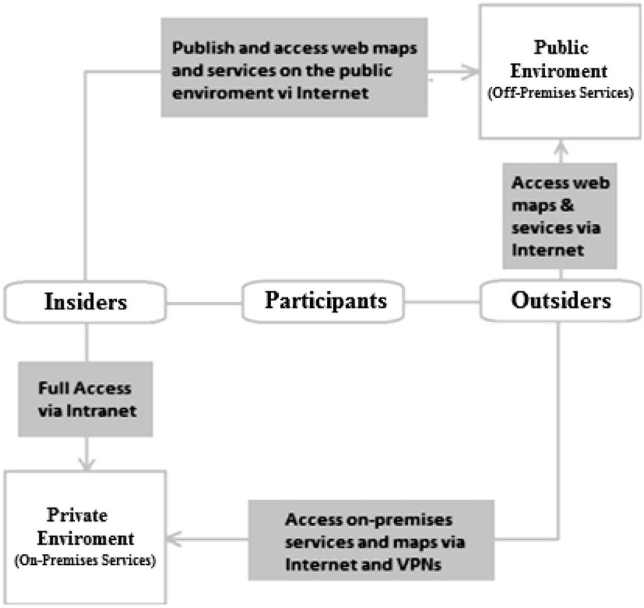

Fig. 2. Cloud GIS participant's workflow.

5.1.7. S7 - Infrastructure segment

This segment is considered the last segment within this architecture. The value of this segment comes in giving the flexibility of dealing with infrastructure service level to let the GIS Cloud uses the cloud infrastructure (IAAS) to create virtual machines and control the data centers. Ending with this segment gives the ability to build a full controlled cloud GIS that covers the infrastructure controlling.

The architecture consists of seven segments that start with the client segment which represents the user interface and end with the infrastructure segment to cover the whole process for any system that would be built upon it by giving the flexibility to deal with any cloud service level. The (7S) gives the elasticity to deal with different cloud services models that would begin with the software as a service that would deal with the client and the hybrid management segments while the platform as a service would deal in addition with the application & GIS segments to build applications. It also gives the chance for the last service model which is the infrastructure as a service to deal with the remaining segments including the storage segment and the infrastructure segment to control the datacenters and the virtual machines.

5.2. Participants

According to Fig. 2, the participants that would deal with Hybrid Cloud GIS solution are mainly divided into two main types of users; insider users and outsider users.

5.2.1. Insiders

Insiders are the users who have the full access to the on-premises services and maps “Private Environment” through the Intranet and also have access to the web maps & services on the Public Environment through the Internet. This type of users would be mainly exampled by the sector office users.

5.2.2. Outsiders

Outsiders are all the outside stakeholders who have access to the off-premises services and maps “Public Environment” through the Internet and also some can access the Private Environment (on-premises) services and maps through the Internet and the virtual private network according to their privileges. This type of users would be mainly exampled by public citizens and users from related sectors.

5.3. APPLIED case study

This section deals with the third dimension of the framework which is applying the hybrid cloud GIS solution in the health sector in Egypt with its different types of participants to gain the benefits of the cloud GIS on the hospital's distribution and the disease's tracking.

The current situation for the health sector in Egypt now is well described in two words “Separate Islands” where all the partners play individual roles due to the lack of the common indicators and the benchmarking for any process. Also, the bad distribution of the resources is the most common flaw where no fixed numbers for the hospitals, patients, and diseases so as a result the resources are distributed without the accurate analysis needed for the process success. The Cause of this problem is the late, inaccurate and unclear information used by the decision makers. Also, the dimensions related to the shortage of health services in the areas with population density and the poor areas that are hard to be solved based on numeric data, but it may be much easier to be solved using the graphical presentation. On the other side, health providers and stakeholders in Egypt could not access the information needed for making right decisions. Also, no published standards for the health sector in Egypt where no unique health platform found to gather all health and spatial information in one pool based on cloud computing techniques to support all decision makers in Egypt to enhance health services. Applying such a solution in the Health sector in Egypt will help in making a full integration for all the related partners to let them all work on a common platform using common data resources that will help in making a full strategic plan for the whole sector. Also, it will help in categorizing hospitals, making a networked street path, mapping medical drugs, and making regions with full health services [13].

The Hybrid Cloud GIS picked to be applied as a solution for the health sector in Egypt due to two critical parameters. The first one is the participants related to the health sector and the second one is the data types related to the health sector that would be accessed by those participants. In this case study, Google Maps and ArcGIS online were used as a Cloud GIS solution.

The solution implementation is based upon a web-based cloud GIS that offers different services concerning the hospital's distribution and the diseases tracking. These services would be accessed by different types of users through two environments according to the privileges and the workflow of each user. The implementation applies the seven segments architecture where it first starts with the user-interface that represents the first segment which is the client segment. According to the 7S-2E architecture, it's a hybrid cloud solution where the user goes through the client segment to access either the services on the public environment or the services on the private environment according to the access privileges. Here comes the role of the second segment which built to cover the hybrid management segment that connects the users with the appropriate content and capabilities according to their privileges for accessing the different cloud environments. After that, it moves to the application segment and the GIS segment to access the implemented services including the GIS services for the hospital's distribution and the diseases tracking. The data used within this service including the spatial and non-spatial data are stored on the cloud DBMSs. The processes of the data movement and the data storage run through the data management segment and the storage segment. The last segment is the infrastructure segment that is responsible for controlling the virtual machines to run the application on the cloud servers and also for controlling the datacenters on the cloud DBMSs.

5.3.1. *Health sector participants*

As it is one of the most important and sensitive sectors, many users would deal with the health sector seeking different goals. Those users as mentioned in the participants' section are separated into two main categories; insiders and outsiders. In this case study the insiders are well represented by the ministry of health and population office users who have the full access to deal with all types of data including private and public data while the outsiders are well represented by the public citizens who have only the access to view the public data as the hospitals distribution on maps.

5.3.2. *Health sector data types*

The types of data related to the health sector are mainly categorized into public data and private data where the public data is the one that would be stored in the public cloud environment and accessed by all users including insiders and outsiders through the internet. While the private data (diseases and patients data) is the one that would be stored in a private cloud environment and accessed only by the insiders who are mainly represented by the ministry office users and the authorized users who have the privileges to access this data.

As shown in Fig. 3, it's the web-based user interface that the user can go through to reach the services and data offered either on the public cloud or the private cloud according to the roles and privileges assigned to each user. The whole process would start and end at this segment where the user requests would be sent from this segment and the data retrieved would be viewed on this segment back. Due to this, the client segment (user-interface) should be as simple as possible in order to let the different types of users deal with it smoothly especially the non-expert users who will deal with it. The user-interface gives the ability to log in either as a private user or a public one. Each user will match with the appropriate cloud GIS services according to the logged environment; public or private.

As shown in Fig. 4, it's a public user access to the services and the data hosted on the public cloud that is exampled as shown in the figure with the health services locations. This figure shows the role of the client segment and the hybrid management segment in moving the appropriate user to access the right content. The public user, in this case, would be represented by the public citizens who need to use such a solution for determining the suitable health services locations including the hospital's locations within different regions.

According to Table 1, it's a dataset that represents the first type of the data which is the public data. This dataset is related to some hospitals "10 hospitals" filtered by region "Mansoura." including seven different attributes; serial, Geospatial Coordinates, Name, Address, Phone, Type, and Region. This data would be stored in a public cloud environment and spatially presented on a map as below in Fig. 5 to be viewed by all public and private users.

According to Fig. 5, the dataset in Table 1 was presented as a spatial distribution on a map using Google map as a cloud solution. This map would be viewed by all users seeking different purposes. This distribution would mainly help in making more accurate decisions by measuring distances and finding the shortage areas with the feature of 24/7 accessibility regardless of the time and location due to the cloud solution. This type of maps would be mainly accessed on the public cloud by different users, for example, it

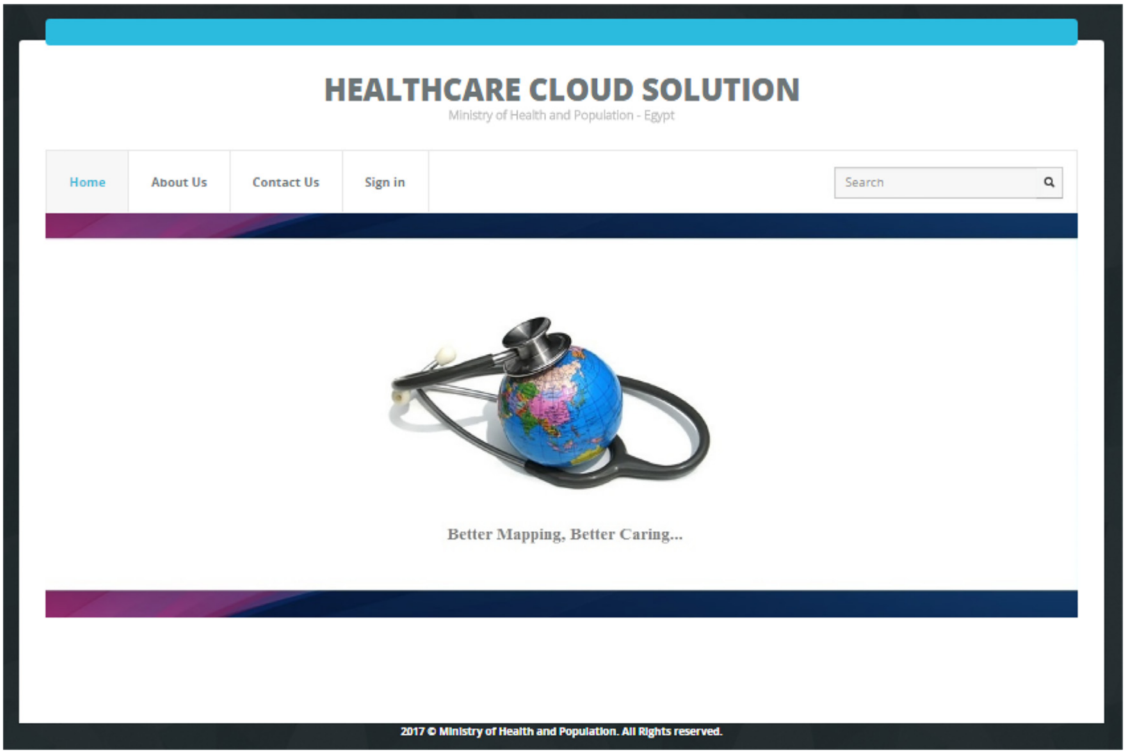

Fig. 3. Web-based user interface.

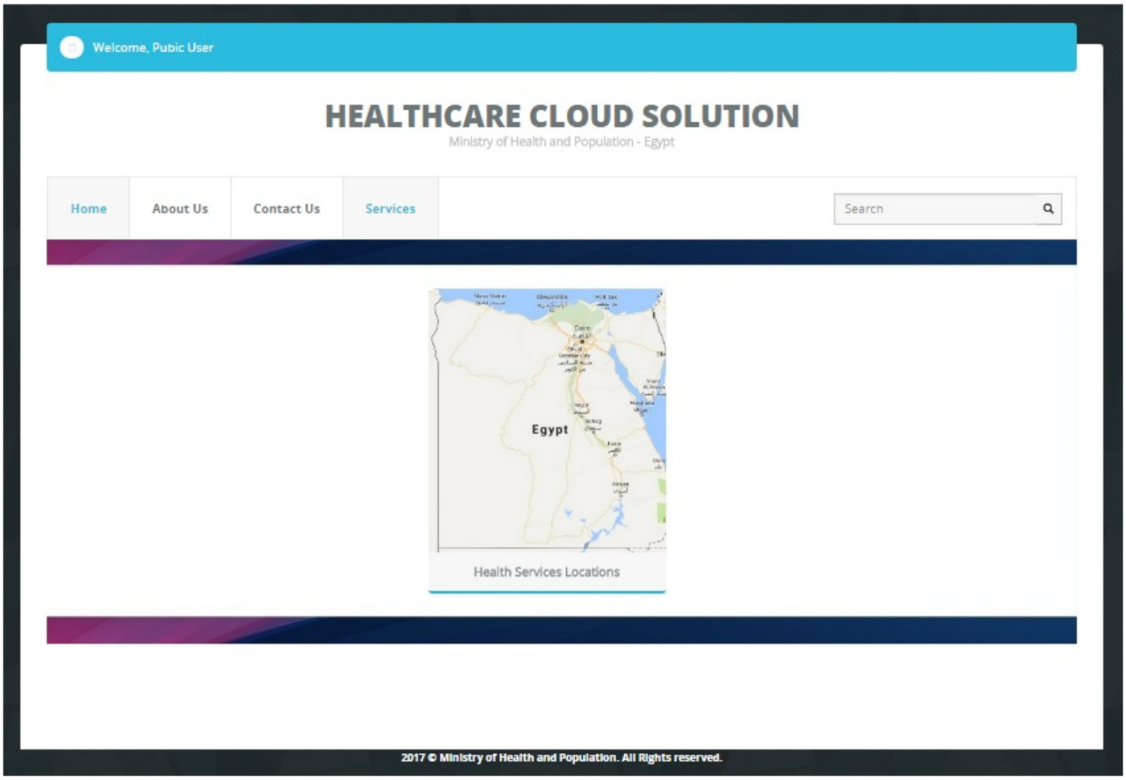

Fig. 4. Public user access.

Table 1
Hospitals within specific Region “Mansoura”.

Serial	Geospatial Coordinates	Name	Type	Region
1	31.0434759, 31.3586862	El Mansoura university emergency hospital	Hospital	Mansoura
2	31.0427179, 31.3629369	El Delta hospital	Hospital	Mansoura
3	31.0441472, 31.3762372	El Shorouq hospital	Hospital	Mansoura
4	31.0454277, 31.3633894	Gezeera international hospital	Hospital	Mansoura
5	31.0398999, 31.3835341	Mogama Al Eman hospital	Hospital	Mansoura
6	31.0477816, 31.3863325	Al Hekma hospital	Hospital	Mansoura
7	31.0457522, 31.3922369	Tabarak hospital for children	Hospital	Mansoura
8	31.0540635, 31.3987889	Hawaa hospital	Hospital	Mansoura
9	31.0519364, 31.4048776	El Khair hospital	Hospital	Mansoura
10	31.0320306, 31.3887793	El Mansoura new general hospital	Hospital	Mansoura

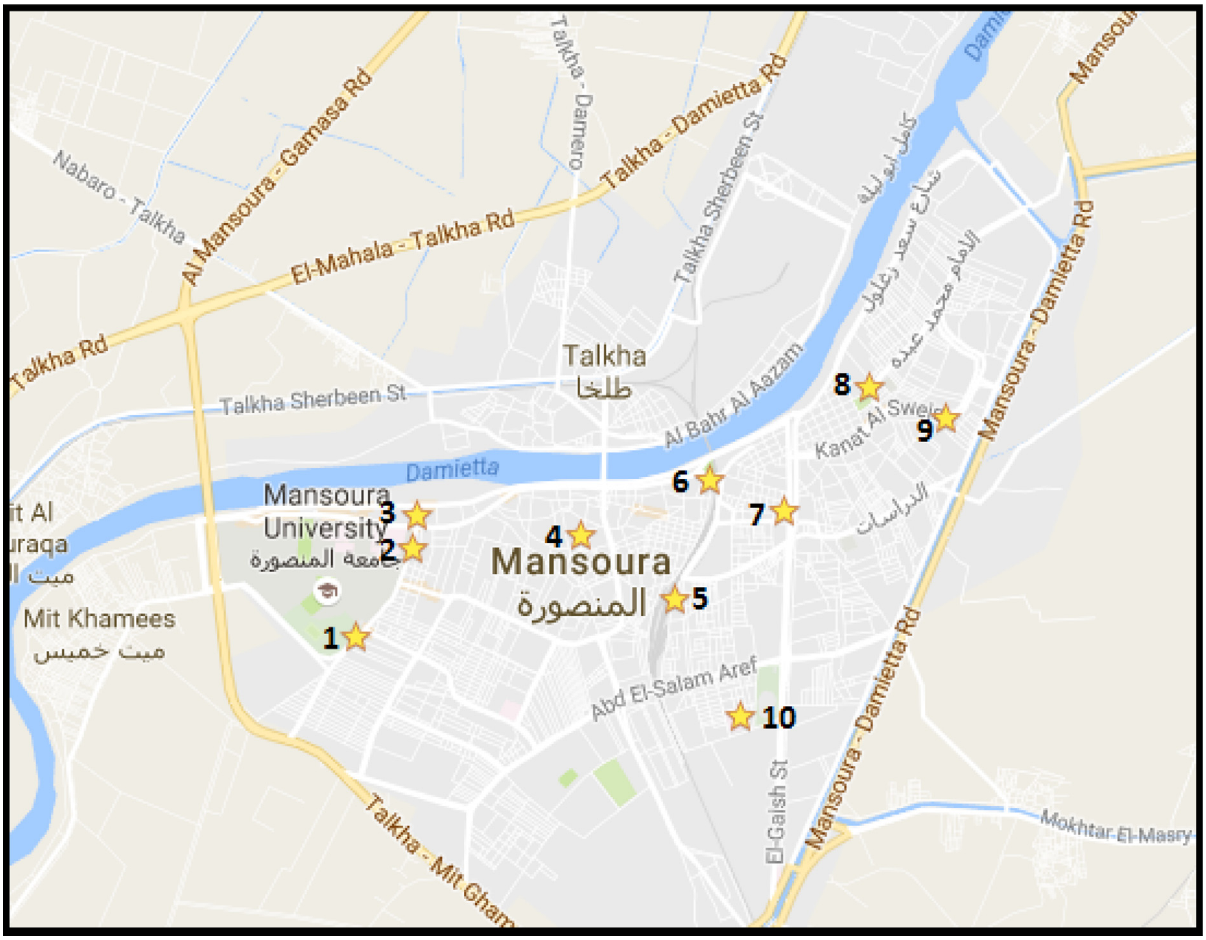

Fig. 5. Spatial distribution of the hospitals using the cloud solution.

would be accessed by anyone who needs to get the hospitals locations.

As shown in Fig. 6, it's a private user access for the services and the data hosted on the private cloud that is exampled as shown in the figure with the geography of healthcare systems and the geography of diseases. Here comes the value of the second segment which is the hybrid management segment that matches the users with the right content and capabilities according to their authentication and privileges.

According to Table 2, it's a dataset that represents the second type of the data which is the private data. This dataset is related to a number of medical cases infected with a specific disease in 3 different regions within a specific period “1 month”. This critical and sensitive data would be stored in a private cloud environment and spatially presented on a map as below in Fig. 4 to be viewed only by specific users who had the privileges to access the private environment.

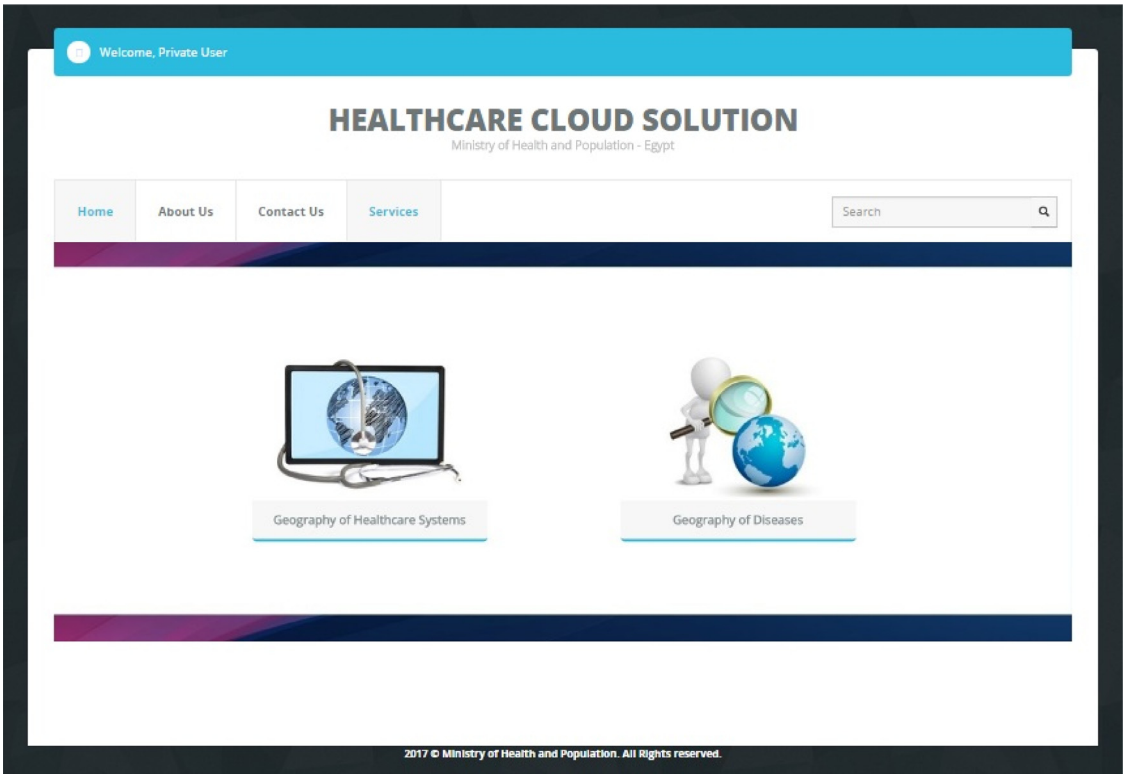

Fig. 6. Private user access.

Table 2
A number of cases infected within specific regions.

Governorate	Cairo	Giza	Qalubia
Malignant tumors	4	3	2

According to Fig. 7, the dataset in Table 2 was presented as a spatial distribution on a map using ArcGIS as a Cloud GIS solution. This map would be viewed only by the private cloud environment users who had access to the private sector. This distribution would mainly help in making more accurate decisions concerning the diseases tracking and controlling with also the feature of 24/7 accessibility regardless of the time and location due to the cloud solution. For example, it would make it easier to determine the red zones of a certain disease and its distribution to build prevention plans with more accuracy.

Also, the data related to diseases in Table 2 would be presented as statistical reports as shown in Fig. 8 as a percentage distribution of a specific disease through 3 different regions within a specific time. This type of charts would be accessed through the private cloud by specific users to help more in taking the right decisions concerning diseases tracking and controlling.

According to Table 3, it's a part of a dataset from attribute table for the hospitals within a specific area in Cairo which is “Masr El-Gdeda”. Each record in the table has an Id, shape to be represented as, area and name. This data would be hosted on the private side to be used by the authorized users concerning the hospital's distribution through the geography of healthcare systems.

According to Fig. 9, it's a location map for a specific area in Cairo which is Masr El-Gdeda presented using a Cloud-based GIS solution. As it's shown on the map, it's an empty map without distribution for any objects.

According to Fig. 10, it's a distribution map for the hospitals in Masr El-G-+deda presented on a map using Cloud-based GIS solution. As a result of presenting the data in Table 3 on the location map in Fig. 9, it was the output presented in Fig. 10 on a cloud-based solution. Using such maps with the cloud favor would help all the related partners in making more accurate decisions and building more integrated strategies. This distribution would mainly help in making more accurate decisions by measuring distances and finding the shortage areas and taking decision easily where to build new hospitals; with the feature of 24/7 accessibility regardless of the time and location due to the cloud solution.

Table 4 highlights the main differences between the previous researches and the 3D-7S-2E framework proposed in this research. It shows the main advantages of the 3D-7S-2E framework.

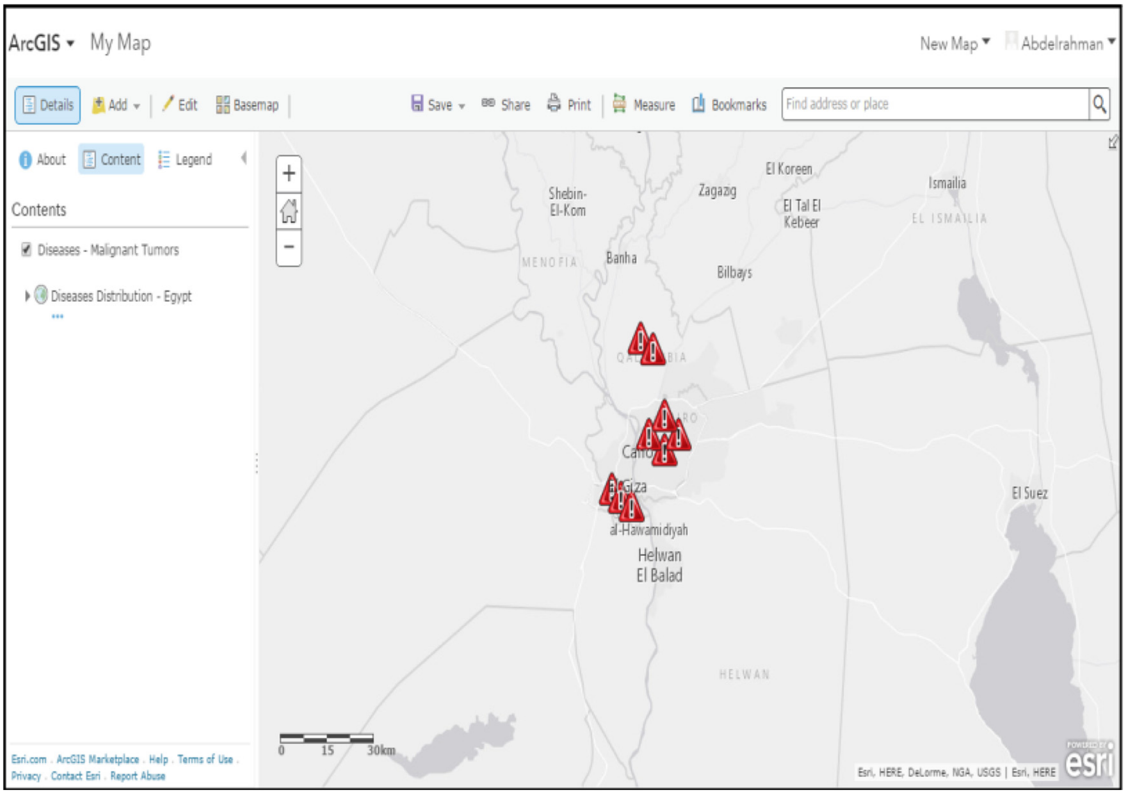

Fig. 7. Spatial distribution of specific disease using the cloud solution.

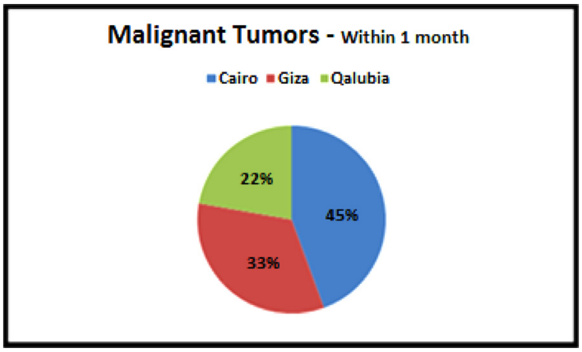

Fig. 8. Disease statistical report.

Table 3
Hospitals within Specific Area “Masr El-Gdeda”.

FID	Shape*	AREA	A_NAME1
1	Polygon	Masr El-Gdeda	Roxy hospital
2	Polygon	Masr El-Gdeda	El-Qahera hospital
3	Polygon	Masr El-Gdeda	Celiopatra hospital
4	Polygon	Masr El-Gdeda	El-Dorra hospital
5	Polygon	Masr El-Gdeda	Masr El-Gdeda hospital
6	Polygon	Masr El-Gdeda	Teriumph hospital
7	Polygon	Masr El-Gdeda	Heliopolis hospital
8	Polygon	Masr El-Gdeda	El Hegaz hospital
9	Polygon	Masr El-Gdeda	Sheraton hospital
10	Polygon	Masr El-Gdeda	El Nozha hospital

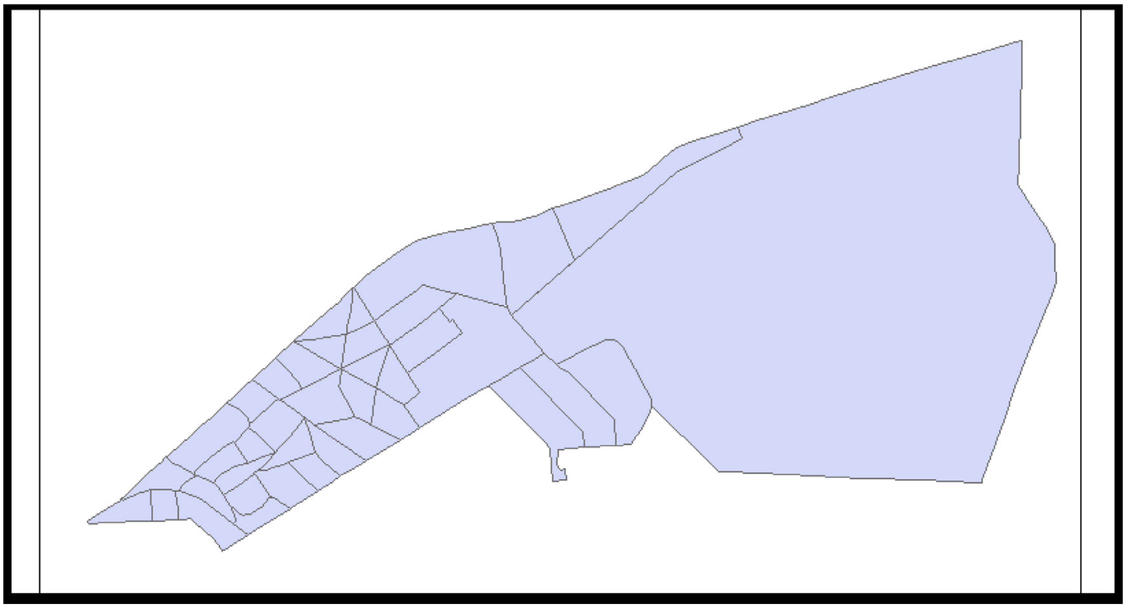

Fig. 9. A location map for Masr El-Gdeda.

Fig. 10. A distribution map for the hospitals in Masr El-Gdeda.

6. Conclusion and future work

This paper presented a framework for integrating the hybrid cloud computing with the GIS through three dimensions; (7S) Hybrid Cloud GIS architecture, (2E) participants' workflow and an applied case study in the health sector in Egypt. The value of this framework comes in the (7S) architecture that offers the integration process on all the phases related to the GIS and the Hybrid Cloud starting with the client and moving to end with the infrastructure. This framework would be applied to different sectors for gaining its valuable benefits especially when it comes to dealing with different types of data and users. Using such a solution for the health sector in Egypt would be much valuable in solving the most common flaws related to the resources bad distribution and the diseases tracking by helping in making more accurate and right decisions without looking for location accessibility or time barrier.

In the future work, some research areas are open for enhancing the integration reality through the review and the comparison for the cloud computing vendors (public & private) would be needed to evaluate the integration process through some important approaches including the cost and the data migration elasticity between the two environments and the security. Also by rebuilding the

Table 4
Comparison of Previous Work and 3D-7S-2E Framework.

Criteria	Related work	3D-7S-2E Framework
System integration	• Cloud Computing was presented as a solution for enhancing the performance in different sectors without integration with a tool or a system used.	• Cloud Computing integrated with GIS
Cloud GIS integration method	• Some Cloud GIS architectures were proposed depending on the CC services without addressing the deployment model • Others were proposed based on public deployment model where no flexibility to deal with different types of data.	• Depends on the hybrid cloud computing to gain the flexibility and security of dealing with different types of data. • This solution would deal with two different environments for the public and the private data through an architecture of seven segments (7S) • It presents the workflow of the two main types of users that would deal with that solution including the insider users and the outsider users. • An applied study is presented to evaluate the role and the importance of the Hybrid Cloud GIS.

architecture based on community deployment model to apply it to communities with common characteristics. In addition to applying and comparing the architecture performance within the scope of the cloud computing services with its different levels including the Software as a Service level, Platform as a Service level and Infrastructure as a service level. In addition to one more open area for research on how to deal with lots of geospatial data on the cloud in the terms of data storage, transmission, management, processing, integration, analysis, security and quality.

References

[1] Gurjar YS, Rathore VS. Cloud business intelligence–is what business need today. Int J Recent Technol Eng 2013;1(6):81–6.
[2] Bhat MA, Shah RM, Ahmad B. Cloud computing: a solution to geographical information systems (GIS). Int J Comput Sci Eng 2011;3(2):594–600.
[3] Chappell D. GIS in the Cloud-The ESRI example. David Chappell Assoc 2010.
[4] Mell, P, & Grance, T. The NIST definition of cloud computing (2011).
[5] Zhou Z, Zhang H, Du X, Li P, Yu X. Prometheus: privacy-aware data retrieval on hybrid cloud. INFOCOM, 2013 proceedings IEEE. 2013. p. 2643–51.
[6] Kouyoumjian V. Gis in the cloud: the new age of cloud computing and geographic information systems. Esri; 2011.
[7] Mahmoud E, Hegazy O, El-Dien MN. Integration of GIS and cloud computing for emergency system. Int J Eng Comput Sci 2013;2(10):2889–93.
[8] Lyseen AK, Nøhr C, Sørensen EM, Gudes O, Geraghty EM, Shaw NT, Bivona-Tellez C. A review and framework for categorizing current research and development in health related geographical information systems (GIS) studies. Yearb Med Inform 2014;9(1):110–24.
[9] De Oliveira LR, JulioMurlick A, Rafael Vicentin GVP. Adoption analysis of cloud computing services. Afr J Bus Manage 2013;7(24):2362.
[10] Bediroglu S, Yildirim V, Erbas S. Application of GIS analyzes with cloud computing. FIG congress 2014 engaging the challenges. 2014.
[11] Li Zhenlong, Yang Chaowei, Jin Baoxuan, Yu Manzhu, Liu Kai, Sun Min, Zhan Matthew. Enabling big geoscience data analytics with a cloud-based, MapReduce-enabled and service-oriented workflow framework. PloS One 2015;10(3). 2015.
[12] Mosbah MM, Sol H, El-Nasr MA. Cloud computing framework for solving Egyptian higher education. Advances in computing and communications (ICACC), 2014 fourth international conference on. 2014. p. 208–13.
[13] Helmi A, Nasr M, Farhan M. The pivotal role of geospatial information systems based on hybrid cloud computing for the health sector in Egypt. Int J Emerging Trends Technol Comput Sci 2015(4):99–103.
[14] Goyal S. Public vs. private vs. hybrid vs. community-cloud computing: a critical review. Int J Comput Netw Inf Secur 2014;6(3):20.
[15] Mell P, Grance T. Effectively and securely using the cloud computing paradigm. NIST Inf Technol Lab 2009:304–11.
[16] Lewis G, Echeverría S, Simanta S, Bradshaw B, Root J. Tactical cloudlets: moving cloud computing to the edge. 2014 IEEE military communications conference. 2014. p. 1440–6.
[17] Aly AG, Labib NM. Proposed model of gis-based cloud computing architecture for emergency system. Int J Comput Sci 2013;1(4).

Abdelrahman Mohammed Helmi is a Ph.D. candidate in Faculty of Computers and Information, Helwan university. He received the M.Sc. in information systems from Faculty of Computers and Information, Helwan University, Egypt, 2017. His research scopes on Cloud Computing, Geographical Infroomation Systems, Business Intellegince and Internet of things.

Marwa Salah Farhan holds a Ph.D. in Information Systems. She is a lecturer, information systems department, Faculty of Computers and information, Helwan University, Egypt. Her research interest focuses on Cloud Computing, Advanced Database Management, Big Data, Data Science, and Software Engineering.

Mona Mohamed Nasr is an Associate Professor and Ex-Vice Dean of Faculty of Computers and Information, Helwan University for Community Service and Environmental. Ex-Vice Dean at the Canadian International College, El Sheikh Zayed Campus. She received the M.Sc. in information systems from Faculty of Computers and Information, Helwan University, Egypt, 2000. Ph.D. in Information Systems from Faculty of Computers and Information, Helwan University, Egypt, 2006.