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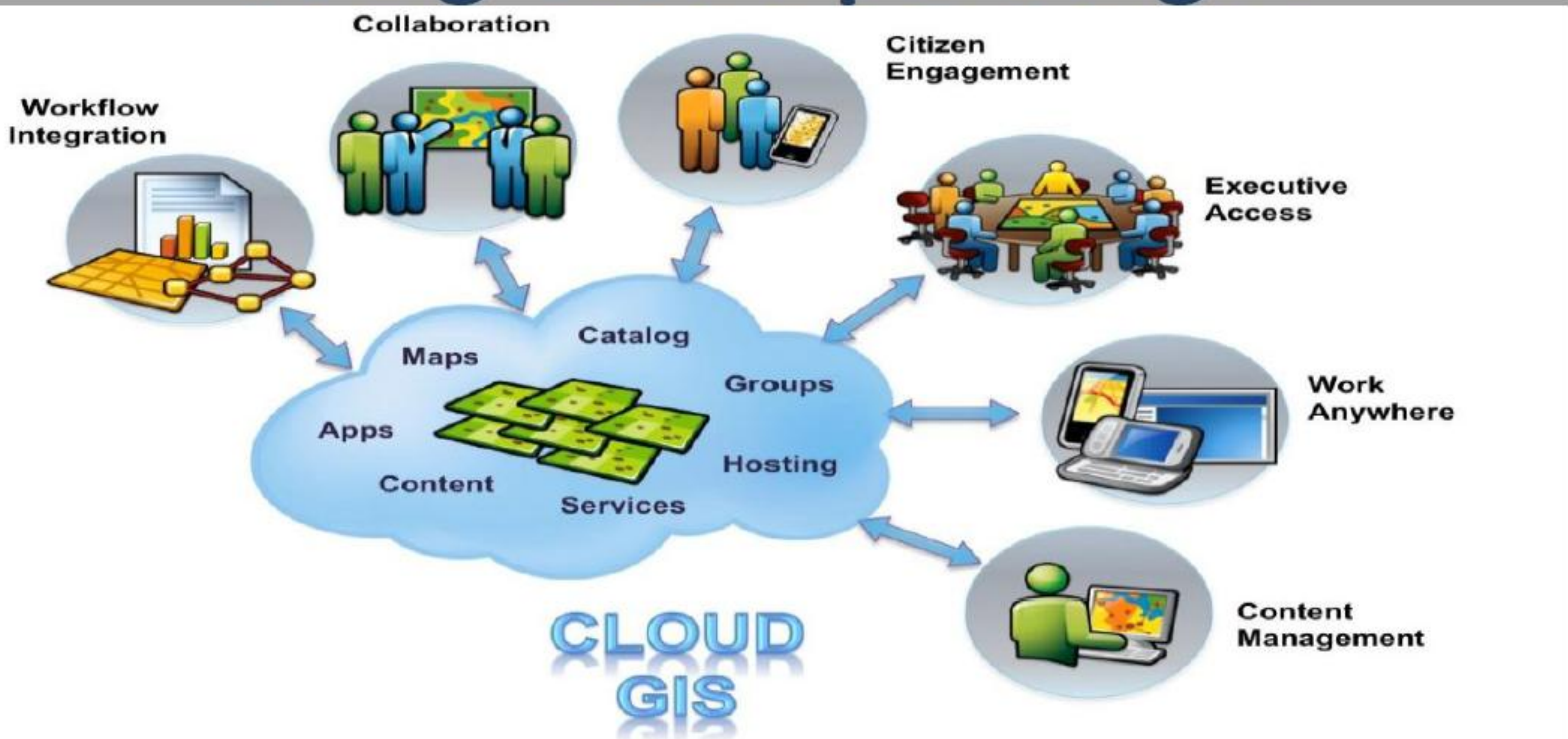
Implementation of GIS using Cloud paradigm



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Implementation of GIS using Cloud paradigm

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Abstract

Geographical Information Systems or Geospatial Information Systems (GIS) is a collection of tools that captures, stores, analyzes, manages, and presents data that are linked to geographical locations. GIS plays an essential role in wide range of areas and is extensively adopted nowadays. Over a few decades efforts are being made to upgrade the conventional GIS applications in order to provide broad spectrum services to the users across the globe. Cloud computing, a term which has become popular in recent years, has been described as the next natural step in the evolution of on-demand information technology services and products. Cloud Computing can be applied to solve and overcome the challenges in GIS applications. It also reduces the entry point to the high computing performance, allowing organizations to make use of the computing power they do not have the capital budget and operational experience to gain.

This paper discusses what cloud computing is, the advantages and challenges with cloud computing, and how does the GIS can make use of cloud computing paradigm.

Keywords— *GIS, Cloud Computing, GIS Cloud.*

1. Introduction

Cloud computing is a technology which can serve every industry that provides or consumes software, hardware, and infrastructure[1]. The technology and architecture that cloud computing provides, is current and future solutions of GIS products. There are several variations on the definition of cloud computing[1] [2], "Cloud computing provides technological capabilities that are delivered on demand as a service via the Internet". But The definition of the cloud computing is recently disputed . As we will see in the literature Review how it is defined. The customers of this services do not own the assets of the cloud computing, In other word, they are renting the software, hardware, or Infrastructure from shared architecture[2]. Main differences between clouding computing and Traditional computing services are scalability and Elasticity in clouding computing [3]. Instead of a static system architecture, Cloud computing supports the ability to rapidly scale the capacity of the provided service up or down, and also supports multitenancy, which provides the ability of the system to be shared by many organizations or individuals. Virtualization technology is also used in cloud computing. This allows the vendors of the cloud to divide one machine to virtual machines.

1.1 Objective:

The objective of this paper is to Designate the cloud computing and explain it as a paradigm that can be used in GIS. This paper will also explain what cloud computing is, what differences between cloud computing and web service are, and how the GIS can use this "the cloud" and takes the advantages of it.

1.2 Methodology:

In this paper, I will try to review the literature of cloud computing, its structure, and how GIS can be implemented using Cloud Paradigm as well as the advantages of using cloud computing in GIS. This paper will also include two case studies where GIS Cloud is implemented.

2. Literature Review

2.1 Cloud Computing

Cloud computing is not considered as a whole new technology but it is a result of collaboration of several existing technologies. The definition of the cloud computing is recently disputed. According to [3], the one that all will accept of any model of computing to considered as a cloud computing must contain the following aspects:

2.1.1 Elasticity

Cloud computing is Characterized by its ability to ability to dynamically scale up and quickly scale down, offering cloud consumers high reliability, quick response times, and the flexibility to handle traffic fluctuations and demand with little to no interaction from the consumer .This property, known as the elasticity (flexibility), is the key to cloud computing. and in some models of delivery of cloud computing, making it easier and often flexibility through virtualization, although cloud computing does not require virtualization.

2.1.2 Multi-tenancy

Clouds are inherently multitenanted, and even special clouds, which extends the workload of one company have multiple tenants , whether their workload or individual users. This multi-tenancy and multi-tenant consumption of computing resources is a common part of the reason behind the economic benefits of cloud computing.

2.1.3 Economics

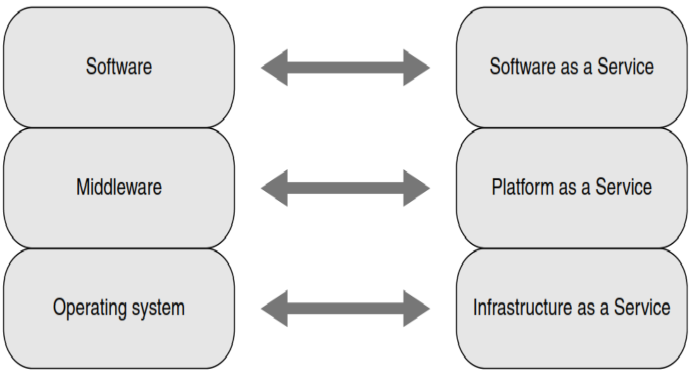
With cloud computing services, it is expected to be charging the consumer for the amount of time using the resources [3]. Cloud computing changes the barrier to entry for high performance computing resources, by allowing consumers to use only what they need at a time when they need it. On the other hand, has allowed these organizations to respond effectively to the requirements of peak demand without the need for surplus resource sits idle during periods of deep sleep. This can be achieved through distribution of the load across multiple shared resources and relying on economies of scale.

2.1.4 Abstraction

Determining cloud computing and the most important change with cloud computing is that of abstraction. most cloud providers provide one or more service layers to consumers. Isolation in the operational aspect of the layers supporting service of the customer . Therefore, software as a service (SaaS)as an example, the interactions of the user is with the application itself, but not with the operating system or hardware of the cloud . This fundamental difference allows organizations that do not have the necessary management system skills or the compute facilities of the enterprise applications hosted by others. Several technologies, which help to provide these capabilities present for many years. Virtualization and autonomic response are the areas of computing that have been well understood for several decades, also the Internet. The cloud computing providers are able to compile these different techniques in the capacities of the above, in the end determine the cloud computing.

2.2CLOUD COMPUTING SERVICES LAYERS

Cloud computing providers provide different kinds of services to cloud computing consumers. In order to understand the different layers of service, it’s important to understand how they would relate in a noncloud computing scenario. See figure 1.1[2]



2.2.1 Software as a Service:

Application as a Service, or Software as a Service (SaaS) providers as they are more commonly known, typically provide a rich web-based interface to their customers. The customer, in most cases, is completely abstracted from the nuances of the application running behind the scenes. Tenant separation is often done at the application layer, leaving a common application, platform, and infrastructure layer underneath. Popular examples of SaaS include Google Apps and Salesforce.com. SaaS providers typically increase the capacity of their systems through scale up or scale out methods—depending on the characteristics of the application. SaaS applications that scale up are usually moved to larger platforms as their capacity requirements grow. SaaS applications that scale out are typically run on large clusters of servers. As additional capacity is required, the provider adds additional machines to the cluster. As there is a significant amount of shared resources used between tenants in an SaaS environment, the ability of one tenant to affect the quality of service of other tenants is always a concern. The ability for an SaaS provider to adequately fence or insulate one tenant from another is key to maintainain quality of service.

2.2.2 Platform as a Service:

Platform as a Service (PaaS) providers extend the software stack provided by IaaS to include middleware. Middleware generically refers to software such as a DB2 database, or runtime environments such as a Java Runtime Environment (JRE) or a Websphere application server. This middleware is a prerequisite to running more sophisticated applications, and provides a rich operating environment for the application to exploit. PaaS providers have two methods in which they facilitate the extra capacity needed for a large multitenant system. In some cases, they provide IaaS style virtual machines to the consumer. In other cases they provide an interface through which applications in the case of a runtime environment, or data in the case of a database, can be uploaded. A popular example of a PaaS is Microsoft's Windows Azure platform. Each method has its advantages and challenges. With an IaaS style approach, the provider typically has more control and stronger separation between tenants. This approach is less efficient, however, as common overhead such as the operating system and the virtual machine itself are duplicated across multiple tenants. In the second case, the underlying infrastructure is addressed in a much more efficient manner, with a single system image and middleware overhead amortized amongst multiple clients. Conversely, the main challenge with this approach lies in the degree of separation that can be provided between tenants. A runtime environment that is not robust or a misconfigured database can allow one user to adversely affect the quality of service of other users.

2.2.3 Infrastructure as a Service

Infrastructure as a Service (IaaS) providers allow their customers access to different kinds of infrastructure. The provider typically provides this service by dividing a very large physical infrastructure resource into smaller virtual resources for access by the consumer. Sometimes the service provided is a complete virtual machine with an operating system. In other instances the service provided is simply for storage, or perhaps a bare virtual machine with no operating system. In cases where the operating system or other software is included, the cost of the required license is either amalgamated into the cost for the service, or included as an additional surcharge. IaaS providers are often service providers to other cloud providers (see Integrator). Many current Platform as a Service providers leverage IaaS providers for extra capacity on demand. One of the more popular IaaS providers is Amazon, who provides their EC2 IaaS.

2.3 Cloud Deployment Models:

Cloud computing has a number of different deployment models. A deployment model is a particular method of delivering a service. In the case of cloud computing, these are unique methods of deploying a cloud computing service. Deployment models often have particular characteristics that suit them to appropriate workloads. The most commonly used deployment models are as follows:

2.3.1 Private cloud

In a private cloud, the cloud computing services are provided by an internal organization for use by other internal organizations. The provider in this case is most often the internal Information Technology (IT) or Information Systems (IS) department .

Consumers vary, but typically these consumers are consumers of other IT services. As both the consumer and provider are internal organizations, private clouds allow the consumer greater control over quality of service provided by the cloud. For instance, an internal customer can more easily assert the relative priority of a particular workload. In another instance, the internal consumer might assert specific characteristics regarding how critical the workload is, and therefore, the availability requirements of the cloud.

Private clouds generally provide the most control, as both provider andconsumer are part of the same organization. This control comes at a price, as

the organization ultimately bears the full cost of the cloud infrastructure.

2.3.2 Community cloud

Community clouds have membership in one or more organizations. Community

clouds are often groups of individuals and organizations collaborating for

the purpose of a particular mission or concern. This might be an industry consortium, an awareness group, or another group altogether. In some instances the community cloud is a shared responsibility, either financially or from a compute resource perspective. In other instances, one member of the community provides all the funding and resources with other members contributing as appropriate. The defining factor for the community cloud is that the different constituents are all assembled for a common cause. As community clouds are provided and supported by consortia with a common cause, there is some influence that members have over the quality of service.

The ultimate decision usually applies to the majority and/or veto members.

2.3.3Public cloud

Public clouds are clouds where the provider delivers a cloud service to any customer who wishes to access it. Unlike a private or community cloud, there are no stipulations regarding the consumer's ownership or cause in using the cloud; it is simply provided for any customer who wishes to support the payment model. One challenge of public clouds is the assurances regarding quality of service. In many instances, today's cloud providers offer little in compensation for missed service level agreements (SLAs). Most often, the only compensation offered is the reimbursement of fees paid by the consumer.

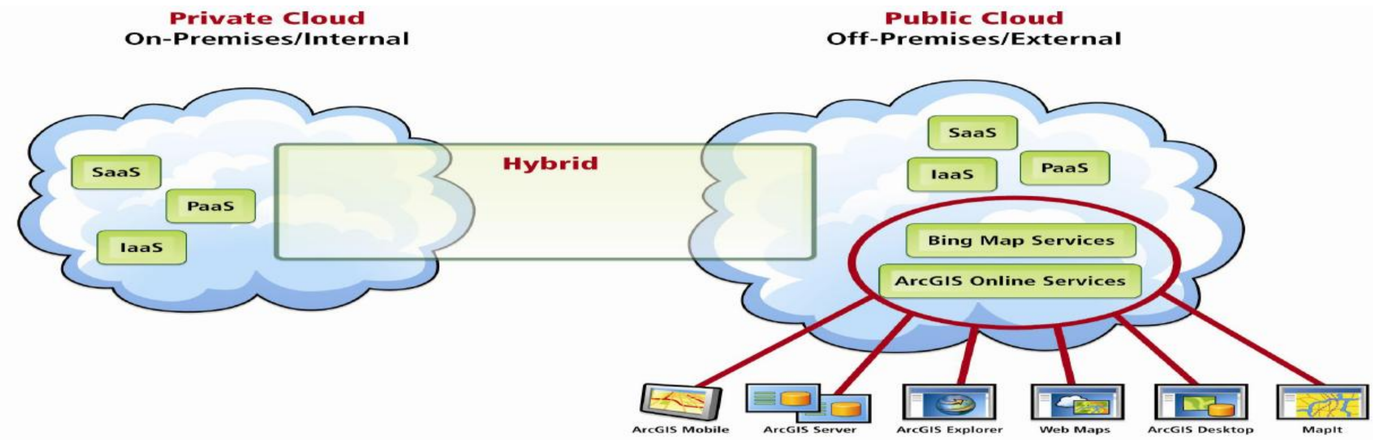
For many organizations, the business impact of application downtime can be magnitudes above the cost of the cloud service. Consider the extreme example of a stock exchange where downtime is measured in millions of dollars per hour versus a cloud service measured in cents per hour. This has caused many organizations to avoid using public clouds for their mission-critical workloads, and instead to relegate their usage to noncritical assets.

Further concerns regarding security issues, such as data residency requirements, have prevented the adoption of public cloud computing across some countries. When leveraging public clouds, consumers should exercise due diligence to ensure that their use of the cloud does not violate legislative, regulatory, or industry requirements.

2.3.4 Hybrid cloud

Hybrid clouds are not a separate deployment model, but rather an intersection of two or more—for example, a private SaaS application that is based on a public IaaS. Hybrid clouds are usually focused on leveraging the economies of scale present in public cloud offerings, but also on driving workloads that have more stringent quality of service requirements. For this reason, in many cases hybrid clouds are internal clouds, which turn to the capacity of public clouds for peak demand.

Fig2: hybrid cloud(public& private cloud) http://www.esri.com/news/arcwatch/0110/feature.html



3. GIS CLOUD

GIS is an Integrated System of Computer Hardware, Software and Spatial Data (topographic, demographic, tabular, graphic image, digitally summarized), performs manipulative and analytical operations on this data to produce reports, graphics and statistics and controls geographic data processing workflows [4].

GIS Cloud has been a suggestive approach to upgrade the conventional GIS applications in order to provide broad spectrum services to the users across the globe [4], [5]. The extensive use of GIS over the decades has been put to a question mark whether to shift it to more superior alternative i.e. Cloud Computing Paradigm. Geographic Information Systems (GIS) applications have been moving into the cloud with increased drive, Global organizations like ESRI, GIS Cloud Ltd etc have already taken the quantum leap and taken a technological shift to Cloud Computing Paradigm and are committed to provide on-demand services to their extensive shades of users. World's largest GIS Cloud infrastructure providers are Amazon (Amazon EC2 & S3), Microsoft (Microsoft Windows Azure, Windows Server Hyper-V), and IBM (IBM Cloud) which provide reliable and secure cloud IT infrastructure to the customers on-demand [6]

3.1 Characteristics of GIS CLOUD

GIS Cloud provides authoritative tools which can help many businesses. The next subsections are the main characteristics of GIS cloud. These characteristics can gain benefits/advantages of using GIS cloud [4], [6], [7], [8] :

3.1.1 Providing Application Infrastructure

GIS Cloud provides the dedicated framework for geo-enabling business data and systems. For organizations previously invested in GIS, GIS Cloud resources can be exploited to increase the assistance, making the organizations business and geographic data easier to be analyzed, authored, and managed. GIS Cloud provides web-services and application hosting for the organizations to make the organizational geographic data to be easily accessed, published and consumed.

3.1.2 Support Technology Infrastructure

GIS Cloud as a computing paradigm for geographical data provides subscribers' leverage of virtualized sophisticated hardware and software resources and full
access to data creation, analysis, editing and visualization. Simple collaborative utilities further enhance the spread of GIS across an office or across the globe.

3.1.3 Plummeting Support and Maintenance

Implementation of in-house geographic information system (GIS) within an organization requires people with specialized skills and elevated technical capabilities. GIS Cloud eliminates the need for in-house GIS potential for basic geo-information access capabilities. For organizations that already have GIS capability, it will be complimentary for highly skilled in-house staff from having to take care of basic information requirements, and letting them deal with more complex responsibilities and services. For customers, this means no bigger straight implementation investments and significant ongoing reductions in their in-house IT support and maintenance burden.

3.1.4 Reducing Implementation Cost

GIS Cloud has a tremendous capability of providing its consumers the advanced geo-technology infrastructure, the services and the geo-spatial data. There is no huge initial investment in time and cost, or partial maintenance. This is most significant because the cost of an enterprise geographic information system can be quite large. Cost becomes the basic reason why many organizations don't provide any GIS solutions to their customers. With GIS Cloud, that threshold to entry is eliminated to a larger extent.

3.1.5 Leveraging Data Command

The essence of GIS is to provide Imagery and Topographic mapping, which acts as a foundation against which other spatial data are encrusted. For

GIS application providers it costs a considerable amount of money to obtain and process from a spatial data vendor. The GIS Cloud has capabilities to provide the underlying data as component of the core services made available through standard Internet-enabled devices. The rapid elastic nature of GIS Cloud makes it sure that users can increase or decrease capacity at will. GIS Cloud provides the users capabilities to input, analyse and manipulate Spatial Information. In addition to that GIS Cloud advanced services for Storage and Management of Spatial Information prove to be supportive for users.

3.1.6 Location Independent Resource- Pooling

GIS Cloud has the tremendous capability of providing location independent resource pooling; processing and storage demands are balanced across a common infrastructure with no particular resource assigned to any individual user. The pay-per-use property of GIS cloud provides the leverage that consumers are charged based on their usage of a combination of computing power, bandwidth use and/or storage.

3.1.7 Data Conversion and Presentation

A data conversion service implies the transformation and importing from one format into a new database. For any GIS it is utmost importance and requires dedicated in-house technical resources which include infrastructure, software services and skilled man power. GIS Cloud provides its users the spatial data conversion services without any requirement of in-house resource capabilities and that too on demand. The advanced features like 3D presentation of spatial information in GIS Cloud removes the traditional "pancake perspective" that flatten all of the interesting details into force-fitted plane geometry.

3.2 GIS CLOUD ARCHITECTURE

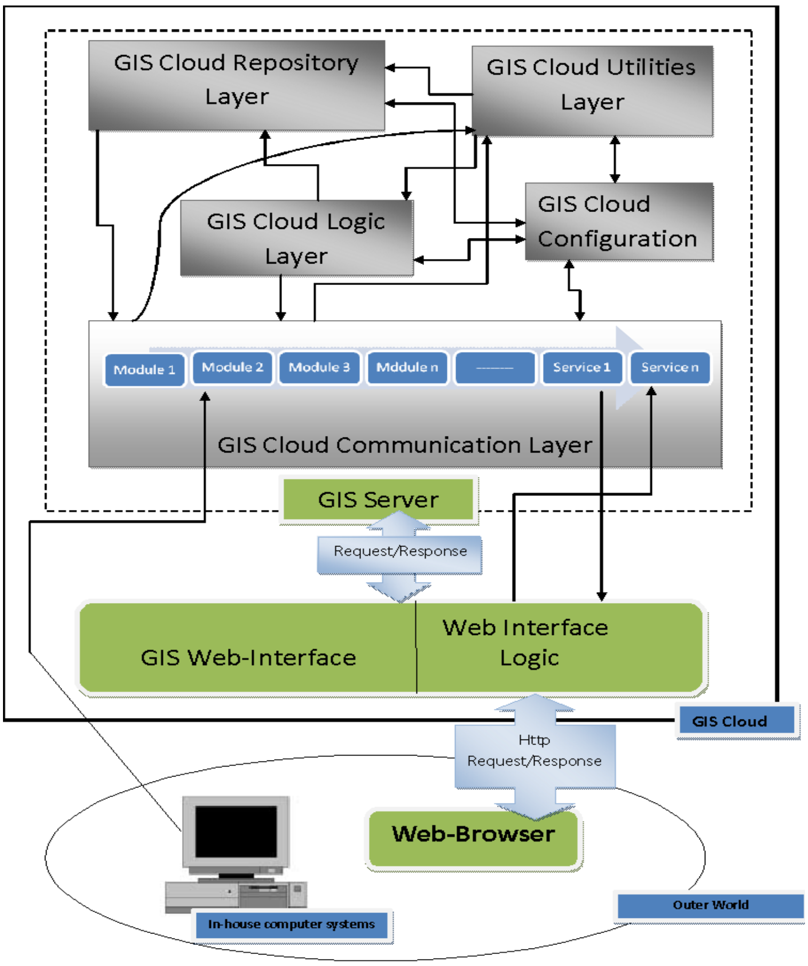
Some providers look at Cloud Computing as way to provide compute or storage capacity as a service, provisioned from a parallel, on-demand processing platform that leverages economies of scale. Others may equate Cloud Computing with software as a service, a delivery model for making applications available over the Internet. IT analysts view Cloud Computing from the perspective of variable pricing without long-term commitments and massive elastic scaling of services.

The GIS Cloud architecture can be broadly divided into two major components which are: 1) GIS Cloud Web-Interface, and 2) GIS Server [9] shown in Fig3.

3.2.1 GIS Cloud Web-Interface

The idea behind GIS Cloud Web-Interface is to provide flexible, robust and cost-effective web-based interface to the users by taking advantages of Web 2.0 and associated technologies. The GIS Cloud Web Interface will be one of the core components of GIS Cloud which will be actually a zero downtime web application with real-time content updates. The main aim will be to provide

Fig.3 GIS Cloud Architecture & server layers[8]



users a better experience by downloading it in less than 10 sec. Allows user personalization and complete interactivity. Make content available using varied technologies like broadband, mobile, RSS etc. and enhance employee productivity by creating a CMS which executes the workflow (from accessing raw content and delivering the processed copy) for publishing content in 3-5 minutes in routine situations and have exceptions to the process to take care of Emergency scenarios

3.2.2 GIS Server

The idea behind GIS Server is to have scalable computing resources for GIS Cloud that manages shared resources such as databases, configuration, server logic, server side utilities, communication interfaces and high powered processing infrastructure.

3.3 Layers of GIS Cloud server

The proposed GIS Cloud Server will be composed of five tiers or Layers shown in *fig3* which are:

1- GIS Cloud Communication Layer
2- GIS Cloud Repository Layer
3- GIS Cloud Utilities Layer
4- GIS Cloud Logic Layer
5- GIS Cloud Configuration Layer

3.3.1 GIS Cloud Communication Layer

It will be a communication interface of the GIS Server composed of logical components (Module1, Module2 … Module (n) and Service1, Service2 … Service (n)).This layer will be responsible for managing and controlling all the communication processes within the GIS Cloud System.

3.3.2GIS Cloud Logic Layer

This layer will act as the 'Heart' of GIS Cloud System and will contain all the logic forming the basis of the System. This layer will contain logic for complex processing tasks, presentation logic, business logic and data access logic of GIS Cloud System.

3.3.3GIS Cloud Repository Layer

This layer will be an application programming interface (API) based data repository layer which unify the communication between a GIS Cloud System and the spatial DBMS used for the system such as DB2, Post GIS, Oracle Spatial, SQL Server 2008 etc for maintaining spatial databases in the system. This will govern all the processes, mechanisms and procedures used to store and access of spatial, non-spatial data in the GIS Cloud System. This layer will also hold spatial metadata which should be stored as part of the spatial databases, and treated as decision aid to assist data users.

3.3.4 GIS Cloud Configuration Layer

This will be a system configuration management and storage component of the GIS Cloud System. Any change in the GIS Cloud System will result to a change in the configuration of the system as a whole and the GIS Cloud Configuration Layer will maintain the system configuration in terms of its consistency and performance.

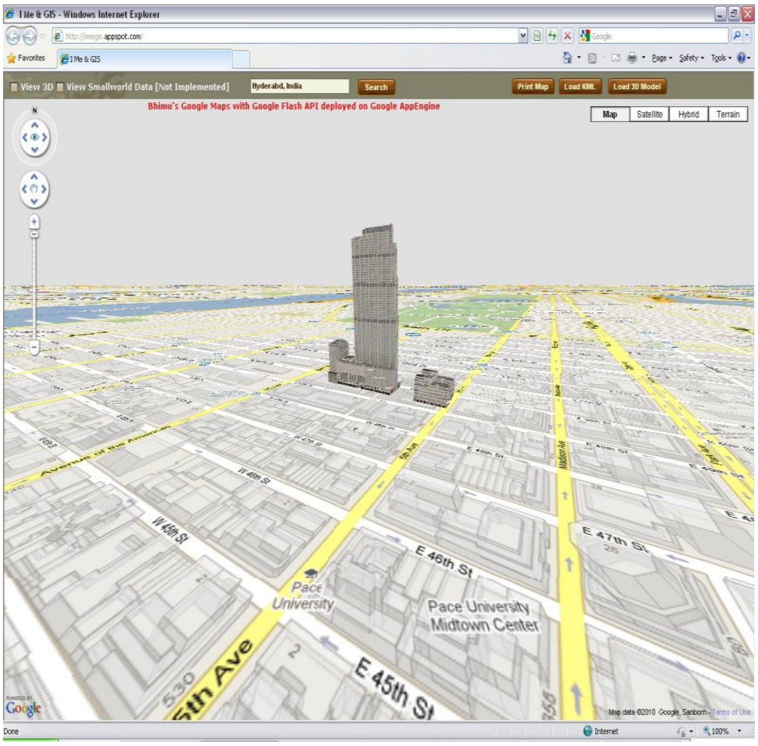
4. CASE STUDY #1: THE GOOGLE APP ENGINE (GAE) (PLATFORM AS A SERVICE)

This case study is an implementation of GIS cloud by Google corporation [10].

In GAE, applications are sandboxed and run across multiple servers [10]. App Engine offers automatic scaling for web applications—as the number of requests increases for an application, App Engine automatically allocates more resources for the web application to handle the additional demand. The Google App Engine (GAE) different from many cloud environments (http://tinyurl.com/dlbllz). Instead of providing a virtualized operating system into which any software can be installed, GAE provides a custom hosting environment, for which applications have to be specially developed. Once an application is deployed in GAE, many concerns of scalability are handled automatically by the infrastructure: new service instances are dynamically provisioned as demanded by the current load. Furthermore, there is no charge for using this environment, provided that an application does not exceed certain quotas. although service providers can expand these quotas by enabling billing. The low cost and automated scalability make GAE an attractive target for investigation. From a GIS perspective an example would be renting Arcgis server images on the Amazon platform), Platform as a Service (e.g. Google AppEngine which provides its own webserver, datastore and other platform apis and we develop software using these APIs and deploy on Google's platform) or Software as a Service (where we rent usage on a software and the same software is used by many users a prime example being Gmail).

A critical part of the adaptation of the Google AppEngine to provide support for GIS is that GAE supports Geohashing [10]. Geohash is a latitude/longitude geocode system invented by Gustavo Niemeyer when writing the web service at geohash.org, and put into the public domain. It is a hierarchical spatial data structure which subdivides space into buckets of grid shape. Geohashes offer properties like arbitrary precision and the possibility of gradually removing characters from the end of the code to reduce its size (and gradually lose precision).As a consequence of the gradual precision degradation, nearby places will often (but not always) present similar prefixes. On the other side, the longer a shared prefix is, the closer the two places are.

Fig4 GIS application using GAE(http://magikfun.blogspot.com/2010/07/gss-google-flash-maps-as-cloud-in.html)



5. Case study 2#: ArchGIS cloud:

Esri uses the cloud in in several ways:

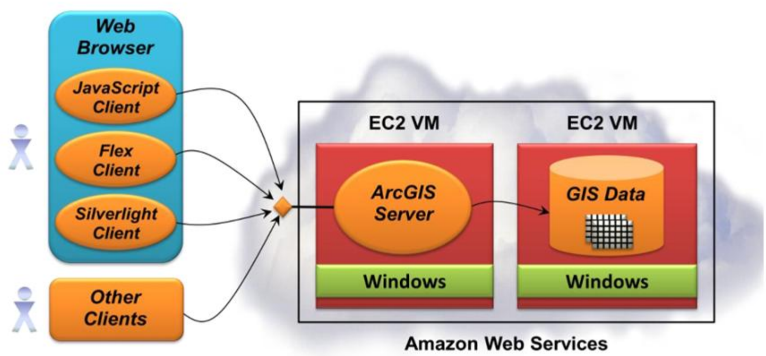
1- The ability to deploy ArcGIS server on Amazon shared cloud.

2- ArcGIS.com ,a web site offering tools and data for GIS application.

In ArchGIS cloud [12], customers are able to add, delete, and edit items in the cloud. There are five basic kinds of items you can work with: maps, data layers, data files, applications, and tools. In Esri's cloud, you'll find hundreds of thousands of web maps, map layers, web applications, and other items published by the GIS community, including Esri and local governments and agencies around the world. Use this content to create maps and embed them in your own sites, download data files, and develop your own applications that use address locators and other tools. You can also share your items on the site and even web-enable your large feature collections and map tiles and have them securely hosted in Esri's cloud, choosing to share them only if you want. Items in can be static or dynamic. Static items do not change and need to be web-enabled before they can be viewed in a web browser. Dynamic items can be viewed in a web browser and change automatically when information is updated. For example, a dynamic traffic map might show different road hazards each time you view the map because the traffic information is updated every few minutes.

Here are some features supported in ArchGIS cloud[13]:

- Adding items
- Adding web maps
- Adding files from your computer
- Adding items from the web
- Adding applications



6. CASE STUDY3: MICROSOFT GIS CLOUD – AZURE:

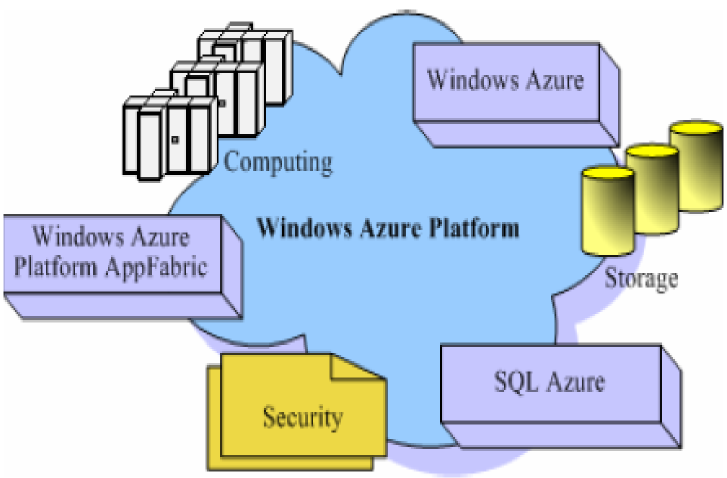
The Microsoft Azure platform [13] consists of the following components (Chappell, D., 2009) (Figure 6):

1- Windows Azure: Provides a platform for running Windows applications and storing their data in the cloud. Windows Azure runs on a large number of servers in Microsoft data centres, which are connected into a unified whole by Windows Azure Fabric. Windows-based compute and storage services for cloud applications are built on top of this fabric.

2- SQL Azure: Provides data services in the cloud based on SQL Server. Although the eventual goal of SQL Azure includes a range of data-oriented capabilities, including data synchronization and reporting, the first SQL Azure component to appear is SQL Azure Database, which provides a cloud-based database management system (DBMS).

3- Windows Azure platform AppFabric: Provides cloud services for connecting applications running in the cloud or on premises. The functions provided by AppFabric are called cloud-based infrastructure services including Service Bus and Access Control Service.

Fig6: Windows Azure Platform[13]



6.2 Azure Implementation:

The Windows Azure Tools for Microsoft Visual Studio 1.2 (June 2010 version) is used to develop geoprocessing services in Windows Azure. The tools is combined with Visual Studio 2010, SQL Server 2005 Express, and IIS 7.0 to provide a Windows Azure development environment including development fabric and storage utilities, which can simulate the Windows Azure compute and storage services in the desktop machines. Thus the tools allow the creation, building, debugging, and running of cloud applications in a simulated Windows Azure environment. Once these services pass the tests in the development environment and are ready to be used by public, they can be packaged and deployed on Windows Azure by using utilities in the tools. Since Windows Azure platform is a commercial product and does not have free offers, the implementation here is tested only in the Windows Azure development environment for academic purposes.

7. FINDINGS:

According to this paper and based on the observations on the three case studies, we found that GIS Cloud can upgrade the conventional GIS applications in order to provide broad spectrum services to the users across the globe. The three case studies showed how much implementing GIS using cloud computing can be very beneficial to both private and public organizations.

8. CONCLUSION & RECOMMENDINGS

Cloud Computing can be applied to solve and overcome the challenges in GIS applications. It also reduces the entry point to the high computing performance, allowing organizations to make use of the computing power they do not have the capital budget and operational experience to gain.In this paper, Cloud Computing is represented as an interesting solution paradigm in implementing GIS. Also, we discussed the Cloud Computing approach to GIS applications and the benefits of implementing GIS in Cloud Computing for GIS applications. We also showed two case studies where GIS is implemented in a cloud (GAE and ArchGIS cloud).

This Paper strongly recommends the use of Cloud Computing in implementing GIS since GIS is beneficial and works well when made available to as many people as possible everywhere and anytime at the expense of very less resources in terms of technology and expenditure and this can be easily achieved using Cloud Computing Paradigm.

9. Future Work

In future work, we will discuss the security aspects related to GIS cloud. We will review the main security issues and the possible solutions proposed to make GIS cloud more secure especially for private organizations

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