Cloud Computing: A solution to Geographical Information Systems (GIS)

Cloud Computing and GIS

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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. In the simplest terms, GIS is the merging of cartography, statistical analysis, hardware, software and data. GIS is commonly used as a supporting system for making best possible decisions through spatial and non-spatial data relations, visualization and processing. 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. 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. This paper presents a brief evaluation of Cloud Computing approach to GIS and proposes a multi-tiered architecture for GIS Cloud System.

Keywords- Cloud Computing, High Performance Computing, Microsoft's Windows Azure, Elastic Computing Platform, Geographical Information Systems.

I. INTRODUCTION

Geographical Information System [1] plays a pivotal role in wide range of areas of interest and is extensively used by Businesses, Governments, Educators and Scientists, Environmental and Conservation Organizations, Natural Resource Groups, Researchers etc. 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.

Cloud Computing is evolving as a key computing platform for sharing resources that include infrastructures, software, applications, and business processes. Virtualization is a core technology for enabling cloud resource sharing [5].

Cloud computing [7], [14] is an emerging trend to deploy and maintain software and is being adopted by the industry such as Google, IBM, Microsoft, and Amazon. Several prototype applications and platforms, such as

the IBM "Blue Cloud" infrastructure, the Google App Engine, the Amazon Cloud, and the Elastic Computing Platform [13]. Cloud Computing can prove to be a future computing paradigm for Information Support Systems [8].

This paper briefly discusses the application of Cloud Computing as a computing paradigm to Geographical Information Systems (GIS). In section 2 we have provided a brief introduction of Cloud Computing, in section 3 & 4 we have characterized GIS Cloud System and in section 5 we have proposed a multi-tiered architecture for GIS Cloud System which is a consolidated, elastic pool of compute and storage system to gather, manipulate, analyze, and display spatial data.

II. WHAT IS CLOUD COMPUTING ?

According to NIST, National Institute of Standards and Technology, Cloud Computing is:

"Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

Cloud Computing is often equated with the concept of a utility, in which an organization can "plug-in" to this virtual computing environment and use the computing resources available on an as-required basis [6]. Applications running on such a platform can be accessed via web clients, while the application software and data are kept at the (virtual) server side. A scenario is that components of an application are dynamically selected from a pool of services, and their coordination and computation are carried out at the client side, in the cloud, or both. Consistency in using various intellectual property (IP) rights, private data, ownerships of data of different clients and components intermix with the "distributed" program executions, which may be deeply embedded all over the cloud [12].

Conceptually Cloud Computing can be perceived as having five key characteristics (on-demand self-service; ubiquitous network access; location-independent resource pooling; rapid elasticity; and pay-per-use), three delivery models (SaaS – software as a service, PaaS – platform as a service, IaaS – infrastructure as a service), and four deployment models (private, community, public, hybrid) [4].

Cloud Computing implementation in the Information Support Systems like GIS has opened new dimensions for researchers in general and IT Organizations in particular.

III. 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.

According to the Buyya et al. [9], Cloud Computing is: "a type of parallel and distributed 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". This definition reflects the fact that both compute and data exhaustive applications, such as GIS applications, can with good grace be moved to Clouds.

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. 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.

IV. WHY GIS CLOUD ?

GIS Cloud provides authoritative tools which can help many businesses, especially, when optimization and cost reduction are critical. Some basic principles which characterize GIS Cloud to be accepted as the serious contender for next generation GIS computing paradigm are:

A. 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.

B. 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.

C. 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.

D. 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.

E. 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.

F. 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.

G. 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.

V. 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. IT leaders look at cloud as an infrastructure architecture alternative that can reduce costs. End users, the media and financial analysts have still other perspectives on

what Cloud Computing represents [3]. For GIS applications the GIS Cloud can prove to be an approach to provide compute or storage capacity as a service, provisioned from a parallel, on-demand processing platform that leverages economies of scale to varied shade of users and organizations requiring GIS application services. Having said much about the GIS Cloud capabilities, it becomes very imperative to understand the underlying architecture of GIS Cloud system. Figure 1 shows proposed GIS Cloud architecture which can be followed to develop a consolidated, elastic pool of compute and storage system to gather, manipulate, analyze, and display spatial data. We have followed a multi-tiered architecture approach which separates different logical components of GIS Cloud system to exploit the capabilities of each component at its best. The given system will be capable of providing flexible solution, heterogeneous platform, scalable (horizontally and vertically) infrastructure, secure and personalized environment, extensive business intelligent system and elastic platform to the GIS users.

The proposed GIS Cloud architecture can be broadly divided into two major components which are:

- **GIS Cloud Web-Interface.**
- **GIS Server.**

A. 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 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.

Allow the GIS team to analyze user behavior and all online properties like online map production to chart out a more robust future growth roadmap and allow users to view, edit and integrate maps in the system.

Integration of all elements, which allows interlinking of geospatial information in terms of text /audio /video /maps etc with each other across the spectrum.

B. 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. The proposed GIS Cloud Server will be composed of five tiers or layers which are:

- **GIS Cloud Communication Layer**
- **GIS Cloud Repository Layer**
- **GIS Cloud Utilities Layer**
- **GIS Cloud Logic Layer**
- **GIS Cloud Configuration Layer**

1) GIS Cloud Communication Layer

GIS Cloud Communication Layer 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 (Inter-Layer Communication) and communication between GIS Cloud System and the outside world. Figure 1, shows that the In-House Computer Systems located at the GIS-Service provider organizations will communicate with the GIS Cloud system via GIS Cloud Communication Layer. There will be dedicated logical modules ranging from (Module1 – Module (n)) which will serve for all the requirements for GIS Service provider organizations mainly for Paradigm Shift (Adoption of Cloud Technology). The dedicated logical modules will be responsible for providing enhanced capabilities to the GIS service provider organizations like creating and importing spatial, non-spatial and temporal (the evolution of both spatial and non-spatial data over time) data into the GIS cloud system. The authentication and authorization mechanisms will also be handled at the same level to enforce data security and privacy constraints.

There will also be present a standardized XML Service Oriented Messaging System [11] for manageable approach to distributed computing, broad interoperability, and direct support for service orientation in the form of Web-Services (Sevice1 – Service (n)) at the GIS Cloud Communication Layer. The GIS Cloud Web-Interface will consume these services based upon the user requirements so that enterprises can integrate spatial, non-spatial and temporal data and business processes with the GIS Cloud system using GIS Cloud Web-Interface.

2) GIS 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) GIS 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, PostGIS, 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 [2].

4) GIS Cloud Utilities Layer

This layer will be a collection of software utilities to support the optimization and seamless functioning of the GIS Cloud System as a whole. The utilities will include system profilers, schedulers, system logging, data conversion, data compression and other focused GIS utilities for address lookup, mapping, routing, reverse geocoding, and navigation.

5) 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. There will be thread based logical modules which will be monitoring the system performance, consistency and change of state.

The above discussed GIS Cloud System can be placed on any of the reliable and secure cloud infrastructure like Amazon EC2 & S3, Microsoft Windows Azure, Windows Server Hyper-V and IBM Cloud etc.

Since one of the core characteristics of Cloud Computing is ubiquitous network access i.e. accessing cloud services through standard internet-enabled devices eliminating the bottlenecks for information access. The GIS Cloud System will be accessed either by GIS Cloud Web Interface or by the In-House computer systems located at the GIS-Service provider organizations.

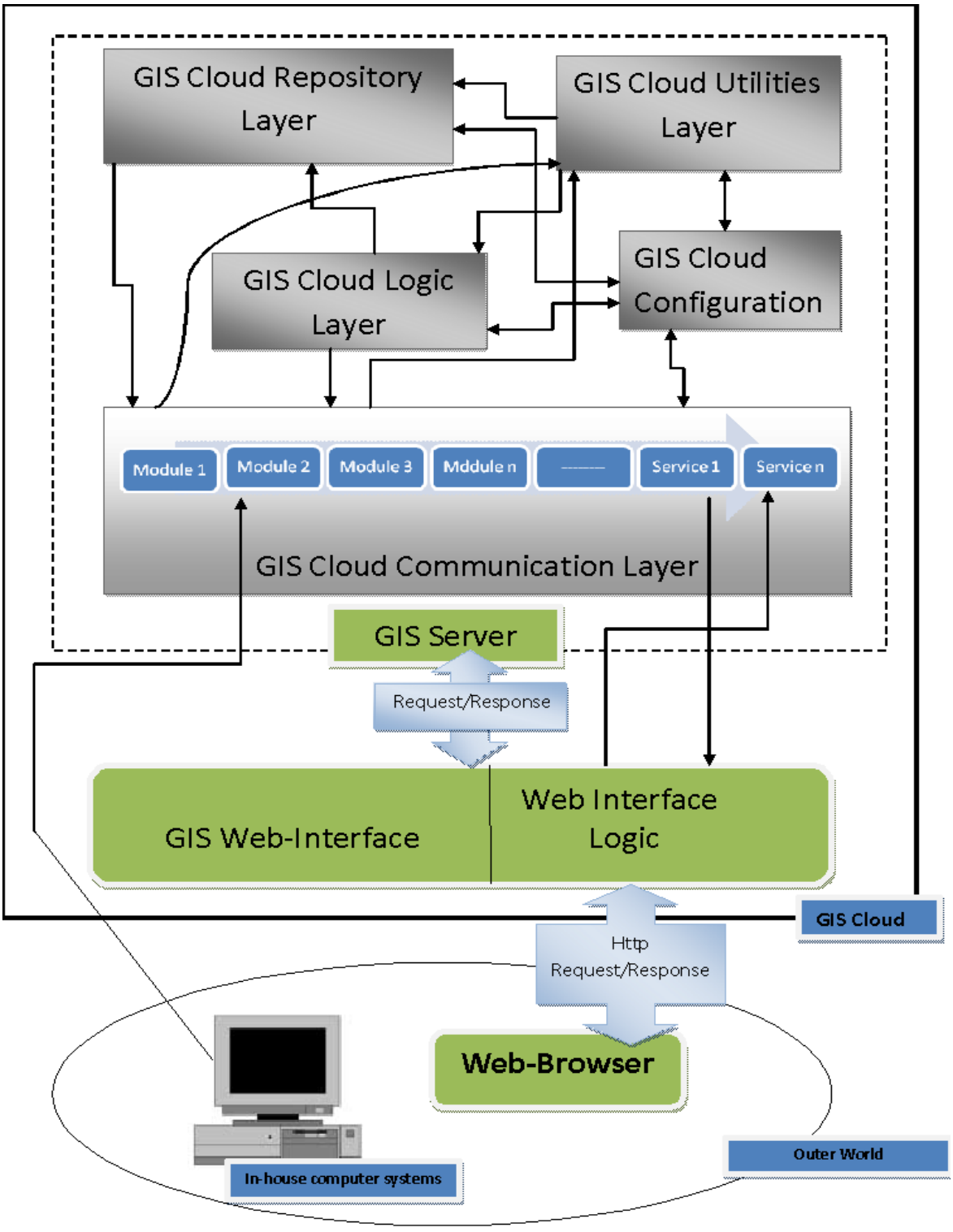

Figure 1: Proposed GIS Cloud Architecture

VI. CONCLUSION

The present research discusses the Cloud Computing approach to GIS applications and the benefits of implementing former for later applications. In addition, we tried to propose a multi-tiered architecture for GIS Cloud System which is a consolidated, elastic pool of compute and storage system to gather, manipulate, analyze, and display spatial data. Although this is a conceptual framework but is a strong contender for meeting the high level demands of GIS applications and a well engineered Cloud Architectures for such applications can potentially improve the scalability, accessibility and usability of GIS resources.

REFERENCES

[1] David W. S. Wong and C. Victor Wu, 1996, "Spatial Metadata and GIS for Decision Support,"Proceedings of the 29th Annual Hawaii International Conference on System Sciences - I996 IEEE.

[2] D. Oliveira, F. Baião, and M. Mattoso, 2010, "Towards Taxonomy for Cloud Computing from an e-Science Perspective," Cloud Computing: Principles, Systems and Applications (to be published), Heidelberg: Springer-Verlag.

[3] IBM Global Technology Services, "Defining a framework for cloud adoption ,"Thought Leadership White Paper May 2010..

[4] I. Foster, Y. Zhao, I. Raicu, and S. Lu, 2008, "Cloud Computing and Grid Computing 360-Degree Compared," In: Grid Computing Environments Workshop, 2008, GCE '08, p. 10, 1.

[5] Liang-Jie Zhang, Qun Zhou, "CCOA: Cloud Computing Open Architecture," IEEE International Conference on Web Services icws, 2009, 607-616.

[6] L.M. Vaquero, L. Rodero-Merino, J. Caceres, and M. Lindner, " A break in the clouds: towards a cloud definition," SIGCOMM Comput. Commun. 39(1), 50-55, 2009.

[7] L. Mei, W. K. Chan, and T. H. Tse, "A tale of clouds: Paradigm comparisons and some thoughts on research issues," Asia-Pacific Conference on Services Computing. 2006 IEEE, vol. 0, pp. 464–469, 2008.

[8] Muzafar Ahmad Bhat, Razeef Mohd Shah, Bashir Ahmad and Inayat Rasool Bhat, December 2010, "Cloud Computing: A Solution to Information Support Systems (ISS)," International Journal of Computer Applications 11(5), 5–9. 2010.

[9] Rajkumar Buyya, Chee Shin Yeo, and Srikumar Venugopal, "Market-Oriented Cloud Computing: Vision, Hype, and Reality for Delivering IT Services as Computing Utilities," Keynote Paper, Proceedings of the 10th IEEE International Conference on High Performance Computing and Communications (HPCC 2008, IEEE CS Press, Los Alamitos, CA, USA), Sept. 25-27, 2008, Dalian, China.

[10] Spatial Cloud Computing (SC2) White Paper 2009: "A New Paradigm for Geographic Information Services," Presented by: Hugh Williams, SKE Inc. August 2009.

[11] Thomas Eri, 2005, "Service-Oriented Architecture: Concepts, Technology, and Design," ©2005 ISBN: 0131858580.

[12] VOGELS, W., 2008, "A Head in the Clouds – The Power of Infrastructure as a Service," In First workshop on Cloud Computing and in Applications (CCA '08) (October 2008).

[13] W.K. Chan, Lijun Mei, and Zhenyu Zhang, "Modeling and testing of cloud applications," In: Proceedings of 2009 IEEE Asia-Pacific Services Computing Conference (APSCC 2009), (Singapore, December 7-11, 2009), IEEE Computer Society Press, Los Alamitos, CA, USA, 2009.

[14] Y. Zhao, I. Raicu, and I. Foster, 2008, "Scientific Workflow Systems for 21st Century, New Bottle or New Wine?," In: 2008 IEEE Congress on Services, p. 467-471.

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