Spatial Services in Cloud Environment

Sašo Pečnik, and Borut Žalik

***Abstract*—**Cloud Computing is an approach that provides computation and storage services on-demand to clients over the network, independent of device and location. In the last few years, cloud computing became a trend in information technology with many companies that transfer their business processes and applications in the cloud. Cloud computing with service oriented architecture has contributed to rapid development of Geographic Information Systems. Open Geospatial Consortium with its standards provides the interfaces for hosted spatial data and GIS functionality to integrated GIS applications. Furthermore, with the enormous processing power, clouds provide efficient environment for data intensive applications that can be performed efficiently, with higher precision, and greater reliability. This paper presents our work on the geospatial data services within the cloud computing environment and its technology. A cloud computing environment with the strengths and weaknesses of the geographic information system will be introduced. The OGC standards that solve our application interoperability are highlighted. Finally, we outline our system architecture with utilities for requesting and invoking our developed data intensive applications as a web service.

***Keywords*—**Cloud Computing, Geographic Information System, Open Geospatial Consortium, Interoperability, Spatial data, Web-Services.

I. Introduction

CLOUD computing became a trend in the information technology (IT) in the last few years. With the promise to do more with less, the cloud computing is a valid option to conventional computing [1]. Therefore, many companies have already moved their business to the cloud, and the number is increasing. Not only companies, research and governmental organizations as well have recognized the great opportunity of cloud computing. With the Pay-Per-Use service mode, companies and organizations can access shared IT resources trough internet. In this way, the physical infrastructure is rented and paid only when it is used. This dramatically reduces the upfront investments, as there is no need to invest in expensive physical resources nor employ system administrators. The users get on-demand access to high performance, dynamical scalable, inexpensive, rapidly elastic IT resources. Many cloud platforms are already offering their services in internet-accessible data centers owned by Amazon, Google, Microsoft, IBM and others.

With on-going advances in technology for obtaining spatial data, Geographic Information Systems (GIS) are becoming increasingly widespread [2]. Huge quantities of spatial data and data obtained by remote sensing are gaining in size and complexity. This data has contributed to rapid development of Geographic Information Systems into a complex distributed computer system with several problems [3]. Such modern GIS can benefit from the service oriented architecture of cloud computing. With the enormous processing power and storage capacity that the clouds provide, spatial calculations on huge amount of GIS data can be performed efficiently, with higher precision, and greater reliability. Furthermore, data acquired from different providers may cause interoperability conflicts because of the incompatible assumptions. Because of this, Open Geospatial Consortium (OGC) standards are used to provide the hosted spatial data and GIS functionality to integrated GIS applications. In this way, the combination of cloud computing and modern GIS leads to deliver better GIS services faster, more reliably, and at a lower cost than with traditional data center models. Improved technology provides increased efficiencies, cost reductions, and faster processes that can overcome challenges and take advantage of opportunities in GIS. Also it has an important application prospect in the GIS tools development and application for cloud computing.

In this paper we present our work on geospatial data services within the cloud computing environment and its technology. First, a cloud computing environment with the strengths and weaknesses regarding GIS is introduced in Section 2. In Section 3, we highlight the OGC standards that guarantee interoperability of GIS applications. And finally, we outline our system architecture with utilities for requesting and invoking our developed data intensive applications as a WEB service in Section 4. The paper is concluded in Section 5.

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II. Cloud Computing

Cloud computing is an information technology where hardware and software resources are provided as services over a network independent of device and location [4], [5]. The idea of cloud computing is new, but the concept behind is not. It is a combination of several different computing technologies such as grid computing [6], distributed computing [7], autonomic computing [8], and ubiquitous computing [9]. It also uses the advantages of virtualization, utility computing and service oriented architecture (SOA). With all of these technologies, clouds offer numerous IT services ranging from storage to software applications anytime, anywhere, and with any device.

One of the main concepts of cloud computing is virtualization. Virtualization enables a server to act as multiple virtual machines (VM) in order to better utilize limited and costly hardware resources. Virtual machines behave like independent systems, but unlike a physical system, VM can be configured on demand, maintained and replicated in real time.

That give clouds the ability to dynamically redistribute computer resources to supply users with the amount of computing power they require. This happens fully automatically without any changes to the physical infrastructure of data centers.

In order to utilize resources more effectively, traditional computing is transformed into a model consisting of services that are commoditized and delivered in a manner similar to traditional utilities such as water, electricity and gas. With such resource utilizing of cloud computing, users access IT services based on their requirements without concern to where the services are hosted or how they are delivered and the cost reflects the amount of resources allocated and consumed.

In the cloud computing environment, the services provide the core functionality. Through the service oriented architecture, the underlying platform is abstracted without revealing the cloud architecture to the users. Thus cloud users have no need for expertise in cloud technology for accessing cloud services. In that way, users consume all the cloud capacity over well-defined user interfaces (UI). According to the offered services as seen in Fig. 1, cloud computing is divided into three basic layers: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Each layer offers a different level of user flexibility and control.

Infrastructure as a Service is a provisioning model where IT infrastructure based on physical resources such as the capacity of processing, storage and network is delivered as a service. IaaS allows whatever applications to be run on clouds provider's hardware. In that way, users can migrate or set up their own system that is hosted and managed in datacenters. The objective of IaaS is to provide an appropriate runtime environment to exploit the physical resources at best. An example of IaaS is the Amazon Elastic Cloud.

Platform as a Service provides an environment for developing and deploying of cloud applications. Cloud developers are supported with a programing language environment and a set of tools that makes the designing of custom applications much easier, faster, and more manageable at lower cost. In that way, PaaS eliminates the cost and complexity of buying and managing the underlying hardware and software. The most known PaaS are Microsoft Azure and Google App Engine.

Software as a Service delivers end-user applications as web services that run on the cloud infrastructure. SaaS allows users to run existing online applications accessed over thin client interfaces such as browsers. SaaS eliminates the need to install and run the applications on a personal computer (PC) as well as the maintaining the applications, and so reduces the costs. The best examples of SaaS are Salesforce, Facebook and Google Apps like Gmail, Google Docs, Google Maps, etc.

In terms of deployment, cloud platforms can be divided into three categories: public cloud, private cloud and hybrid cloud. Public clouds provide IT services to everyone in the public who needs computational resources. The owner of a public cloud is the service provider who maintains and sells the services to customers. On the other hand, private clouds provide IT services to group of people like an organization. The organization is the owner and it maintains the whole cloud infrastructure. The hybrid cloud is a combination of both public and private clouds. The hybrid cloud consists of a private cloud that contains external cloud services available to the public.

The concept of cloud computing embraces the idea of green computing, since data centers can be located in areas that have access to cheap electricity while their IT resources can be accessed over the internet [10], [11]. But cloud computing also has issues, such as limited bandwidth and presenting a problem with large amounts of data. However, the major concern with the use of cloud computing is still security [12].

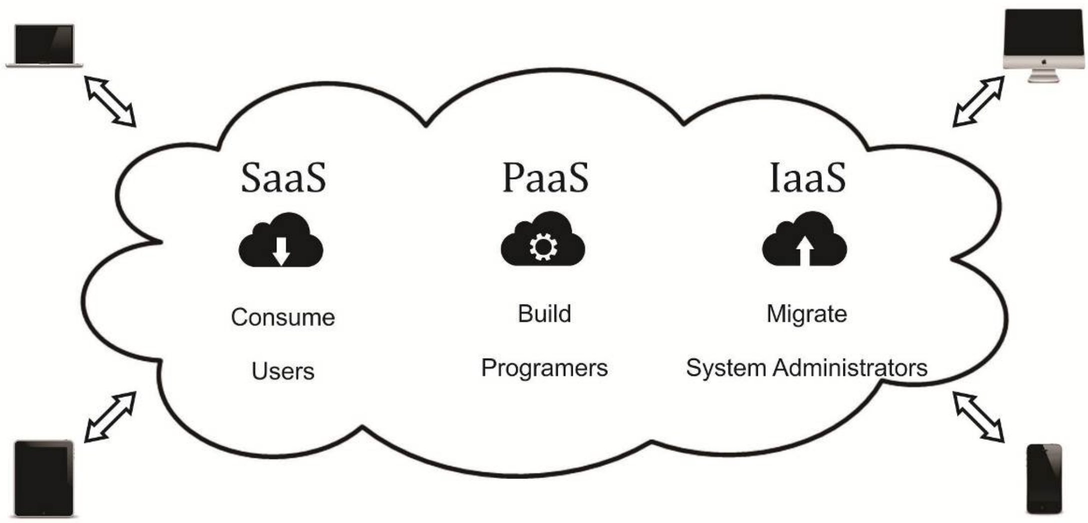

Fig. 1 Cloud Computing

The services are available outside and inside a cloud through Simple Object Access Protocol (SOAP) and Representational State Transfer (REST) interfaces [13]. SOAP is a platform independent communication protocol based on XML and is commonly used in the implementation of Web Services [14]. REST is a client-server architecture built for the transfer of representations of resources. A resource can be essentially any coherent and meaningful concept that may be addressed [14].

III. Geographic Information System

GIS is widely known for the ability to capture, store, manipulate, analyze and represent all kinds of geographic data and its attributes, so called geospatial data. These abilities helped to develop a number of GIS with specialized function for specific data. Because of the enormous diversity of spatial data and the specific operations in GIS, the data dissemination between different GIS is difficult to be achieved. In the field of GIS, Open Geospatial Consortium is dealing with the interoperability problem.

OGC is an international consortium that develops standards and specifications to solve interoperability problems for geospatial content on the Web, wireless and location-based services (LBS)[15]. These standards allow complex spatial information and services accessible and useful with all kinds of applications. OGC is developing a number of specifications and standards such as Geographic Markup Language (GML), Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS) and others. Each service supports a certain GIS operation that allows application developers to integrate high-quality maps, driving directions, distance calculations, and proximity searches.

GML is XML grammar defined for the transport and storage of geographical information [16]. GML serves as an open exchanging format for geographical features on the internet. The key advantage of GML is the ability to integrate all forms of geographical information.

WMS is an international standard that produces maps of geographic information [17]. Generally, WMS produce georeferenced spatial data in pictorial format such as PNG, GIF, JPG or occasionally as a vector based graphic element. Each map server implements WMS as a common interaction protocol that specifies three operations: *getCapabilities*, *getMap* and *getFeatureInfo*. First operation, *getCapabilities,* provides service-level metadata, specifying its capabilities. The second operation, *getMap,* specifies an interface for image map requesting, and the operation *getFeatureInfo* is optional and provides information about features shown on a map.

WFS is OGC standard that specifies the behavior of a service that provides access to geographical features in a manner independent of the platform [18]. WFS returns requested geographic objects and vector data that cannot be displayed on a map. Returned data are typically in GML or some other vector formats like ESRI shape files [19]. The WFS standard defines eleven operations that are described in [18].

All mentioned OGC standards are accessible through Uniform Resource Locator (URL). With the full URL path to the services they are usable immediately after they are deployed. Through the standardized methods, parameters and properties, the service functionalities are easily exposed and fast accessible through different platforms. With the development of OGC standards, GIS services became more useful to the general public.

In cloud computing, WEB services provide the core functionality, which makes GIS services perfect for integration into the cloud environment. In that way, cloud computing concepts improve the functionality and solve some traditional GIS problems like weak computing power of large-scale spatial data, difficulties to get on-demand resources, expensive professional software, availability and reachable of geospatial data and services to the public anytime and anywhere. By applying cloud technology we obtain dynamical scalable geographic information platform with spatial data and spatial applications delivered as services.

IV. Cloud Assisted Services

Cloud Assisted Services (CLASS) is the project that includes the development of cloud computing as its supported services. In the project, we designed the cloud architecture with PaaS environment for location information and search data. We also integrated some services for spatial data processing.

A. Infrastructure

The CLASS architecture consists of three data centers on different locations across Slovenia as seen in Fig. 2. In that way, we ensure access to our services at any time, even in the event of failure in one of the data centers.

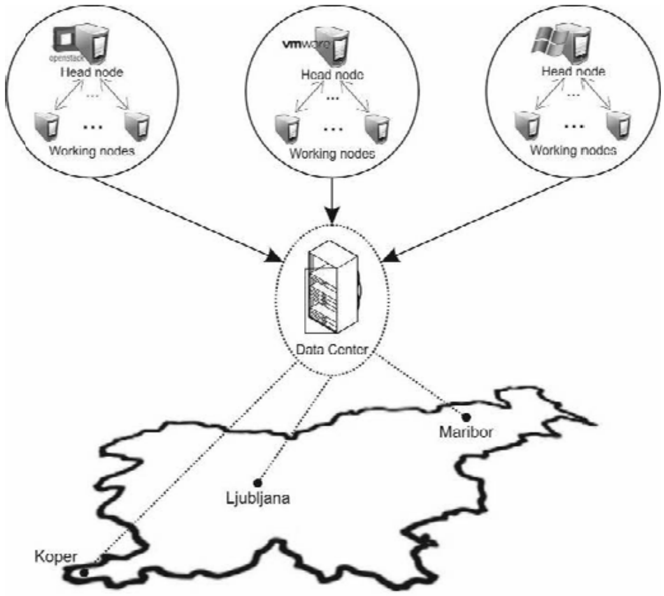

Fig. 2 CLASS infrastructure

Each data center contains 10 HP DL360 G6 servers with following specifications:

- Intel® Xeon® Processor E5540 (2.53 GHz, 8MB

L3 Cache, 80W, DDR3-1066, HT, Turbo 1/1/2/2),
- 32 GB DDR3 1066Mhz and 2 servers with 146 GB DDR3 1066Mhz of memory,
- 4 TB of storage on Nexenta systems.

To realize the project objectives, a hybrid IaaS infrastructure was established, in form of various IaaS on one physical infrastructure. Thus, we installed three IaaS clouds:

- OpenStack,
- VMware vCloud Director, and
- Microsoft Private Cloud.

Each IaaS consists of multiple nodes. These nodes are divided into two types: one head node and a large number of working nodes. The head node executes job scheduling (load balancing) to working nodes, which execute all functional services, like map displaying, data preparation and spatial calculations. The CLASS architecture is designed to work with petabytes of data.

B. Implementation

We developed our test application for location information and spatial search with OpenLayers v2.6 [20], [21]. For the intensive spatial calculations, the Geoserver v2.1.3 [20], [22] and PostGIS [20], [23] database for storing spatial data are used. Spatial data, map displaying and other functional services are distributed on computing nodes. All developed services are part of a PaaS environment that is available through the CLASS architecture.

With the use of WMS and WFS services from Geoserver we can calculate directions, find optimal paths and process location services. The WFS service is used to display paths and locations on a map. Fig. 3 shows the interface for location information and spatial search services.

Fig. 3 Location information and spatial search services

Terrain visibility service displays visibility areas that can be controlled if a sensor (camera, transmitters, etc.) is placed on a specific point on the terrain as seen in Fig. 4. The terrain height is derived from DTM (Digital Terrain Model) while the visualization is implemented in OpenGL [24] as a Java applet [25].

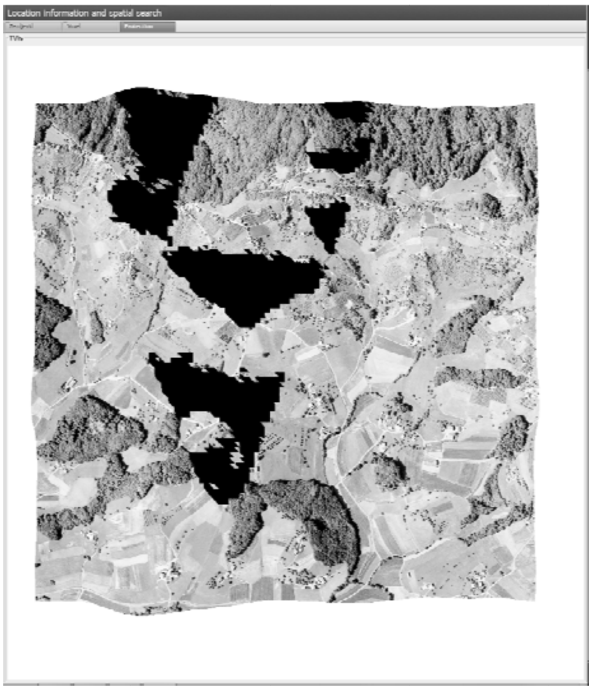

Fig. 4 Terrain visibility service

We also integrated services for processing, visualization and compressing of voxel data. The service is implemented in Java applet [25] as seen in Fig. 5 and is detailed explained in [26].

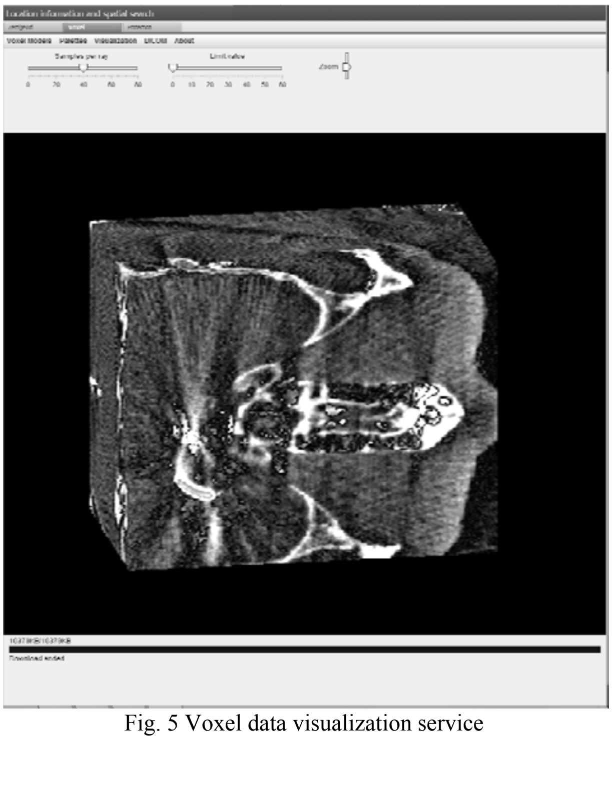

Fig. 5 Voxel data visualization service

V. Conclusion

We are living in an increasingly information rich society. GIS and spatial data related to urban regions will increasingly need to represent these complex environments over the internet. Cloud computing has dominant effect on GIS and is most likely the crucial candidate for advantages of Cloud Computing. In this paper, the PaaS layer for location information and spatial search in the CLASS project is presented. We provide implementation and deployment of geospatial applications based on OGC geospatial web services in the cloud environment. The provided PaaS layer solves key problems of geographic information services.

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