Cloud application for water resources modeling

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ABSTRACT

Cloud computing is one of the most promising solutions for present and future water related problems. Planning and management of both urban water systems and basin-scale water resources systems are increasingly becoming multidisciplinary collaborative tasks that will rely on development of internet based systems based on web services that combine water related data, weather forecasts, climate variations, urbanization, population and economic growth, etc. These heterogeneous data sources (frequently provided by different institutions) may be integrated 'on demand' for water management tasks via cloud computing applications as the one demonstrated here. Cloud computing advantages over previous technologies are in the scalable computation power, internet based collaboration platform, transparency in the decision making processes and dissemination of valuable information between stakeholders and general public.

The architecture of prototype cloud application for water resources modeling is based on the latest advancement in computer science and technology: Cloud Computing, Service Oriented Architecture and web Geographic Information Systems. The prototype cloud application integrate three web services: (1) web service for managing of geospatial data (2) web service for support of water resources modeling. The components and software packages used in the development of the system are open source. The overall architecture and system components are flexible for adding new or upgrading existing web services. The system is scalable, interoperable and can work in distributed computer environment.

Keywords: Cloud, GIS, hydro information system, water resource modeling.

INTRODUCTION

Population growth, climate change, increasing food production, expansion of industry and other development-related driving forces are creating pressure on existing water resources, potentially leading to conflicts. Water resources will be increasingly important in our future cities where population growth and water usage are rapidly increasing. Providing water for all water users, general population, industry and agriculture is a challenging and complex task. On the other side climate change together with urbanization is increasing the floods risks. It is already recognised that these complex issues must be analysed and modelled together, which highlights the importance of creating an integrated water management system. The foundation of integrated water management is a hydro information system. Hydro information system is a computer based system that stores all relevant data and information regarding water (rivers, canals, users, water demands, water infrastructure, population, climate and others) and creates a platform for development of specialized applications (simulation models, optimization, decision support systems, etc.). Such specialized applications will give solutions for different aspects of the water management in question, concerning economic, ecological, social and other factors. Architecture of the cloud application for water resources modelling presented in this paper is starting point for development of integrated water management software. The cloud application is build using three latest ICT (Information Communication Technologies) concepts: Cloud Computing, Service Oriented Architecture (SOA) and web GIS (Geographic Information system). These concepts enable the development of a state of the art application and platform for integrated water management.

These systems are commonly built using several components [1] like relational databases, GIS applications, water modeling software and others. Geographic Information Systems (GIS) are preferred integration framework for modeling of water resources [2] and a platform for development of specialized water application and services. There are examples of powerful geospatial solutions [3] based on different open source components. Other systems are combination of open source and commercial software components creating web services for a distributed and interoperable hydro information system [4]. This article reviews several software components which are suitable for the development a cloud water modeling tool.

There are several major advantages of the presented prototype cloud application over previous technologies and software. The cloud application is internet based, available at any time and accessible from everywhere i.e. only web browser and internet connection is needed to use the application. This is one of the major objectives in development of the presented system. The architecture of the cloud application is based on n-tier SOA which is flexible for adding new services or upgrading the existing ones. The architecture and software components of the cloud application are scalable, interoperable and distributed. The cloud application can add or subtract additional software and hardware resources based on the workload and number of users. Most of the software components can work on different operating systems on distributed servers. Data portability and software versioning are no longer an issue because the cloud application is the same for all users and data, models and results are stored on the cloud with standardized formats. The database system of the cloud application can store all data concerning water resources (rivers, precipitation, lakes, towns, users etc.) and provide them to the developed services. The presented cloud application creates platform for development of various services and working environments. It gives possibilities for development of different working environments for groups of users, like stakeholders, manages and general public based on the same platform. Another great advantage is that the whole system can be built from open source software components and there is no need to deal with issues such as licensing, versions, updates, etc., which are common for stand-alone applications.

The presented prototype cloud application for the hydro information system is composed of two web services: (1) web service for managing of geospatial data (2) web service for support of water resources modeling. The cloud application is developed using several programming languages (AJAX, PhP, JavaScript, Java), relational database (PostgreSQL and PostGIS), additional components (GeoServer, ESRI ArcGIS) and others.

MOTIVATION

The cloud application is build using three latest ICT (Information Communication Technologies) concepts: Cloud Computing, Service Oriented Architecture (SOA) and web GIS (Geographic Information system).

The main idea behind cloud computing is that only a web browser and internet connection is needed to use the system, while everything else is in the cloud. Data, models, computation, software, are available "on demand" to users anytime and everywhere. Users don't care about infrastructure that provides the service. Similar to this concept is the electric grid where users just use electricity without knowing infrastructure behind. Cloud computing provides many advantages [5] for companies and users. That is why the biggest IT companies in the world like Google, Facebook, Microsoft, Amazon, Apple are heavily investing in cloud computing.

Service oriented architecture (SOA) [6] is a group of principles that redefine the phases of design, development, integration and implementation of an information system. The main idea in SOA is to develop components (services, applications) that are independent, reusable and modular and can communicate between each other in standardized way. Communication between different components is often done asynchronously or "on demand" with passing XML (eXtended Markup Language) messages. This enables integration of previously developed components, neutrality of programming languages, platform independence and integration of various application and services in one solution. Most important aspect is to rigorously define interface and communication among the components.

Third and crucial concept is web GIS. GIS provides an open integration framework for modeling of environmental systems described by elements with geographical coordinates, including water, climate, urban planning etc. Concerning water modeling almost all information have geographical component. Internet has a profound impact of development of the GIS. At the begging web based GIS were used to disseminate geospatial data, while today it is possible to create fully functional distributed web-based GIS solutions where internet is the new media [7]. The presented cloud application is a successful example of developing water related software using the latest web GIS technologies. There are two important organizations for geospatial data standards and promotion of open source software that are important for this research: (1) The Open Geospatial Consortium (OGC) and (2) Open Source Geospatial Foundation (OSGeo). OGC is a consortium of leading GIS companies, academy and national governments that collaborate in defining and proposing new internet standards for geospatial services. OSGeo is a non-profit organization with mission to support and promote open source geospatial software that is free and accessible under OSI-certified open source license.

ARCHITECTURE OF THE CLOUD APPLICATION

Software components, technologies and programing languages are carefully selected to support further upgrade, scalability and system interoperability. The general architecture and components of the system are shown on Figure 1. Arrows in the figure represent communication between the web services that is encoded in XML messages. The cloud application is composed on two services:

1. Web service for managing of geospatial data.
2. Web service for support of water resources modeling.

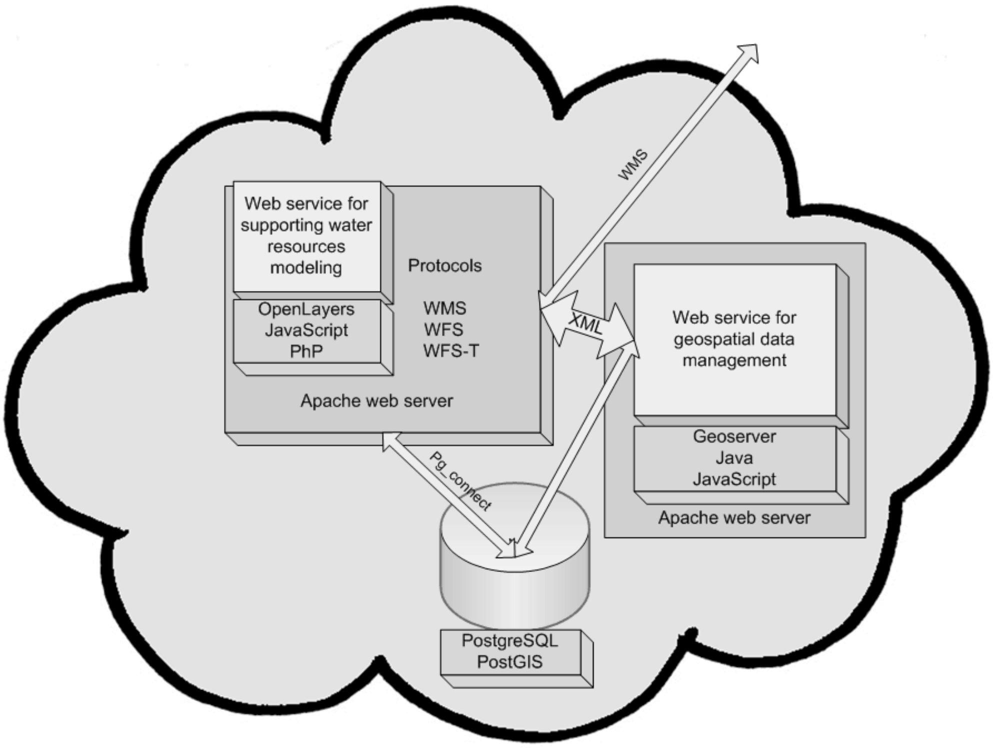

Figure 1. Architecture of the cloud application for the hydro information system

1. Web service for managing of geospatial data.

Web service for managing of geospatial data is composed of two main components: web application GeoServer and relational database HMak created in PostgreSQL and PostGIS. The relational database HMak stores relevant water related data (river network, canals, towns, population, etc.) of the Republic of Macedonia. This data can be used by other tiers, or web services for development of various solutions. Except this data, HMak stores data for the web service for support of water resources modeling. The web service for support of water resources modeling has six vector geospatial data layers: rivers, canals, reservoirs, users, inflows and agriculture lands.

GeoServer is the middle tier component that can connect to more data sources. On the other side GeoServer provides data access using OGC protocols (WMS, WFS, WFS-T) for the other tiers, in this case the web services. In the current implementation of the system the web service for support of water resources modeling is connected over WFS-T to GeoServer and indirectly to the data from the HMak database. Communication between the web service for support of water resources modeling and GeoServer is asynchronous or "on demand" using WFS-T protocol based on XML messages.

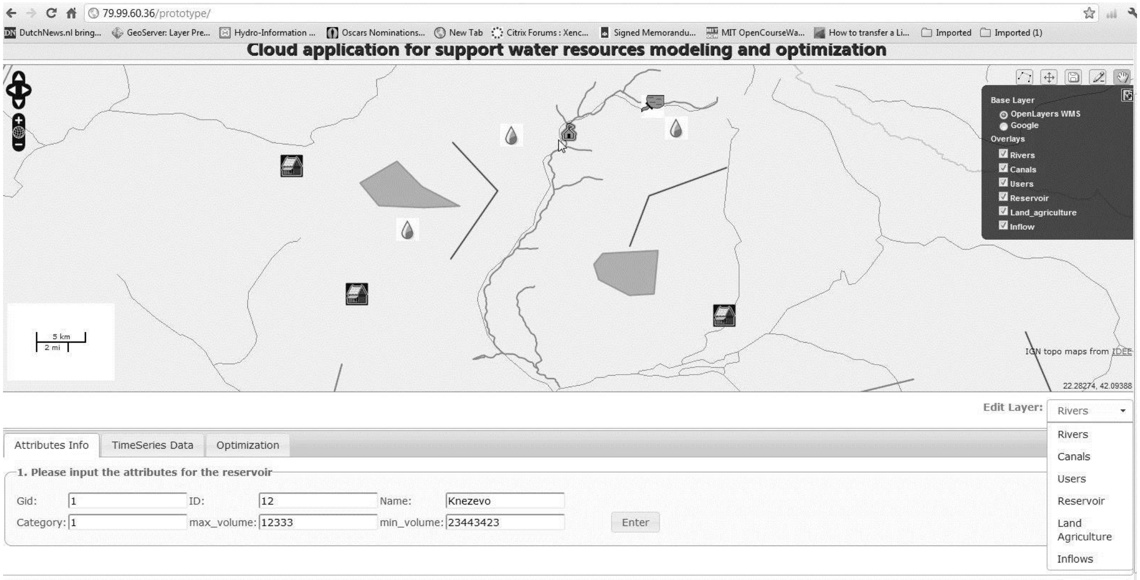

Figure 2. Prototype Cloud application for a hydro information system

2. Web service for support of water resources modeling.

The web service for support of water resources modeling is based on OpenLayers library that support OGC standards and additional custom developed source code written in programing languages PhP, AJAX, JavaScript. This web service connects to GeoServer and indirectly to the six data layers from HMak. Every data layer can have many geospatial objects e.g. layer: rivers can have many polylines - geospatial objects that will represent the rivers. The toolbar for working with the geospatial objects is build using OpenLayers library. The toolbar has buttons for creation of new objects, modifying existing objects, deleting objects, zoom and others. Every geospatial object has additional attributes that are stored together with geographic information. When an object is selected JavaScript code is executed and attributes of the object are presented on the bottom of the screen. Attributes can be modified and uploaded into the HMak database. The web service for support of water resources modeling is in fact web based GIS solution customized for water resources.

Using the web service for support of water resources modeling, the geographical representation of a river basin can be created, as shown on figure 2. This figure shows the river network, canals, users, reservoir and agriculture lands. All these geospatial objects are drawn using the toolbar of the web service. Together with the geographical representation additional information about every object is stored in the attribute table. Attributes used are fairly simple e.g. river attributes are Name, GID (unique identification), Id, Category, etc.

DISCUSSION

There are many ways for improvement and upgrading the presented web services. The web service for support of water resources modeling can be improved by creating more complex attribute structure for every object. One step further is to add new layers that are needed for subsequent water resources modeling. In the current implementation the objects are not connected in a network where water sources (e.g. reservoirs) would be connected to water users (e.g nodes with water demand). Such network with interconnected nodes is necessary input to computational engine that can simulate ware resources allocations. Such improvements are planned for the future. At this stage, the current development of the web services demonstrates the possibilities of the existing technology and software and it can be extended in many different directions. The main idea is to exemplify an integrative solution of heterogeneous components within one common platform.

Considerable advantages of this system over other solutions are availability and accessibility. One of the main goals “to use only a web browser while everything else in the cloud” is accomplished. Another important step towards integration is the possibility to deliver all geospatial and other data into one client application even if they are stored on distributed servers. The web service for managing geospatial data is presenting the possibility to contain all data concerning water resources into databases and with GeoServer provide common platform for development and delivery of web services.

The current cloud application for water resources modelling is composed of one relational database, one GeoServer instance, two web services and one user interface running on Apache server. All software works on one physical server. Because the components are flexible and operate in SOA, adding additional components and connecting them to the system is easy task. GeoServer is capable to connect to more relational databases. Relational databases can be distributed on different physical servers on the internet. In addition, the web services can communicate with more instances of GeoServer. Finally, the web services themselves be instanced on several web servers. The web service, GeoServer and relational database can also be deployed on different operating systems. The system depending of the workload can include/exclude software and hardware components. All these possibilities show the cloud application scalability, interoperability and support of distributed environment.

The current implementation of the system and services are fully open and allow everyone with internet connection to enter data, create elements of the water system model. Future development of the system will introduce different users and environments. Environments will provide same working window to geographically dispersed users and contain a group of web services available for the users. At the same time different users can use the service for support of water resources modeling and model the water resources e.g. one user can draw river network while in the same time other enters attribute data. This provides great collaboration environment where all users have access to the same web services and data. Additionally, separate collaboration environments can be developed for decision makers, water managers and general public. The difference between these environments will be in the selection of web services, access to data, etc. The presented solution allows development of various web services and different environments, all based on one common platform.

CONCLUSION

The shifting of desktop applications, information, and processing power to the cloud has already started. Future applications, software and services will be Cloud oriented. The developed cloud application for water resources modeling is a demonstrator of such future orientation. Advantages of the developed application are its flexibility, scalability, interoperability included in the design and software components. The prototype cloud application is just a first step in development of integrated water management platform. The software components and the web services presented in the article, show that there is software and technologies to develop a robust and complex cloud application for modeling of water resources. Further development of the application will include various water related data, population growth, urbanization, climate variations and others. Platform for development of application is created and future application will be additional services or modules on the existing cloud water resources modelling application.

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