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Development Of A Cloud Computing Application For Water Resources Modelling And Optimization Based On Open Source Software

Blagoj Delipetrev

Andreja Jonoski

Dimitri P. Solomatine

DELOPMENT OF A CLOUD COMPUTING APPLICATION FOR WATER RESOURCES MODELING AND OPTIMIZATION BASED ON OPEN SOURCE SOFTWARE

BLAGOJ DELIPETREV (1), ANDREJA JONOSKI (2), DIMITRI SOLOMATINE (3)
(1): Faculty of Computer Sciences, University Goce Delcev, Krste Misirkov bb, Shtip, 2000, Macedonia
(2,3): UNESCO IHE Institute for water education, Westvest , Delft, 2611 AX, the Netherlands

The cloud computing application for water resources modeling and optimization based on open source software is a continuation of a previous research presented in [1]. This article presents further research that is focused on distributing the web application on two separate virtual machines (VM) and upgrading it to a cloud computing application. The cloud application was deployed and tested in a distributed computer environment running on two virtual machines (VM-1 and VM-2). The application is upgraded with an additional web service for user management, while still having the previous three services for: (1) support for water resources modelling (2) spatial data infrastructure (SDI) and (3) water resources optimization, as reported in [1] from the previous research. The web services for support of water resources modelling and user management are deployed on VM-1 while the SDI and water resources optimization web services are deployed on VM-2. The web services communicate with web feature service transactional (WFS-T), which is an XML asynchronous messaging protocol. This research demonstrates the capability to scale and distribute the cloud application between several VMs. The article discusses the main cloud application capabilities and its future upgrades.

INTRODUCTION

With the explosive growth of the Internet and the enabled web access through diverse devices (computers, mobile phones, tablets) many organizations are shifting their software solutions to this platform. The software solutions are offered mainly as services accessible via the web rather than as products to be obtained, installed and run as stand-alone applications. There are examples of migrating the water related applications to the web [2-5] and development of web GIS application based on web services [6], cloud computing platform [7] and mobile application that depend critically on the same web orientation [8].

The cloud computing application for water resources modeling and optimization is upgrade of a previos web application described in [1]. The main idea behind this research is distributing the previously build application between two independent VM. The newly developed system has all advantages of the previous one, and the new advancements are in the cloud computing capabilities that are discussed later.

The cloud application is operational and can be used as a foundation for a modern cloud based software solution. It is important to highlight that the presented system is prototype software. The cloud application's URL is www.delipetrov.com/his/. The cloud application has a help page that contains web links with video presentations of the system components, guides about how to use the web services, etc.

CLOUD APPLICATION ARCHITECTURE

The cloud application architecture is presented in Figure 1. In the figure arrows represent the data communication links between the web services. The data communication is asynchronous or "on demand". The system has four web services:

1. for support of water resources modelling (WRM).
2. for user management.
3. for SDI.
4. for water resources optimization.

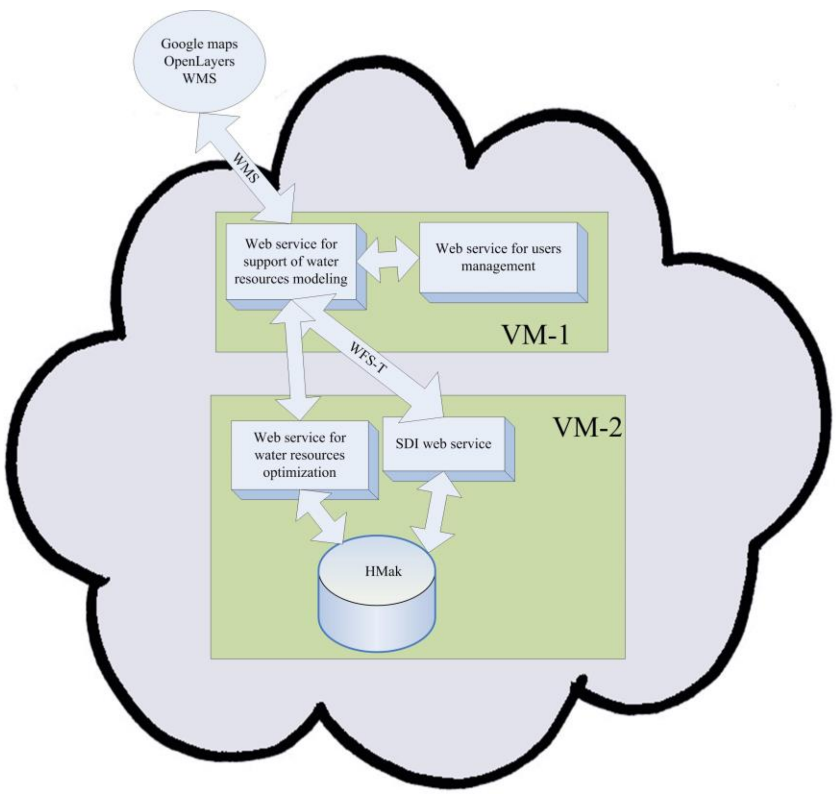

Figure 1. The cloud application architecture

Web service for support of Water Resources Modeling (WRM)

The web service for support of WRM originate from the web service explained in [1]. The difference is that this service is deployed on the VM-1 running as a micro instance on Amazon web services (AWS) using Ubunty 12 as an operating system. The web interface shown in Figure 4, provides tools to manage objects of the six vector geospatial layers (rivers, canals, reservoirs, towns, agricultural areas and inflows) that represent the water resources components and infrastructure. The web service allows only specific type of geospatial object to be inserted in the layers corresponding to the intended elements, e.g. points for users, inflows, and reservoirs, polylines for canals and rivers, and regions (polygons) for agricultural areas.

The web service for support of WRM is built using JQuery, OpenLayers library and additionally developed prototype source code written in PHP, Ajax and JavaScript programming languages.

Web service for user management

The user management web service is also deployed on the VM-1. The current implementation is fairly simple with managing user access to the cloud application. The user management web service contains an administrator panel for managing users, adding new users, control users usage time of the cloud application, delete existing users, etc. When the user logs in the cloud application, it activates a PHP session that measure the user usage time. The usage time is saved in the user profile on the web services. Further development of this service will include users computer power and storage usage. Using these information, the administrator can effectively manage the cloud application users.

SDI web service

The SDI [9] web service describes the service for managing, presenting and storing geospatial data that is explained in detail in [1]. The SDI web service stores geospatial data used by the web service for support of WRM. The web service SDI runs on VM-2. The VM-2 is based on Xen cloud platform with Fedora 12 as an operating system. The Xen cloud platform runs on physical server based in the Faculty of Computer Science in Shtip, Republic of Macedonia.

The SDI web service consists of two components: (1) the data repository built from the relational database HMak created in PostgreSQL and PostGIS, (2) and the web application GeoServer. The HMak stores the six vector geospatial data layers (used by the web service for support of WRM), the time series data, and the storage discretization data which is used by the web service for water resources optimization.

GeoServer is a powerful open source web application that manages, stores and presents geospatial data on the internet. The primary function of the GeoServer as a middle tier application is to connect the relational database HMak on one side with the developed web services on the other. In the web application implementation, the GeoServer provides WFS-T (Web Feature Service – Transactional) interface connections for the web service for supporting WRM.

Web service for water resources optimization

The web service for water resources optimization is the same as the one described in [1]. The web service is built from several components: web form, prototype PHP and Ajax code for uploading data into HMak database, application for optimization based on dynamic programming coded in Java, and a web interface for presenting results. The input data is uploaded using the “Time series data” tab web form and the DP application is executed using “Optimization” tab shown on Figure 2. The input data are: reservoir storage discretization, and timeseries of reservoir inflow, reservoir demand, reservoir recreation storage target and reservoir flood target with it’s corresponding demands. The DP application is coded using the example presented in[10]. The DP application connects to HMak to reads the input data, processes the input data and saves the results data back to HMak. The screen shot of a result is presented in Figure 2. The web service for water resources optimization was tested using monlty data from 1991 till 2001 from the study [11] of the Zletovica river basin.

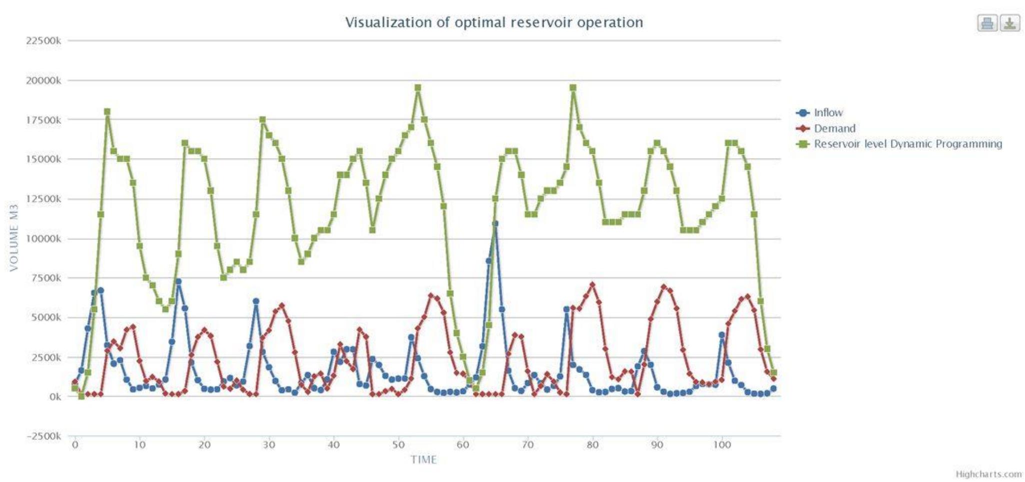

Figure 2. Visualization graph of the web service for optimal reservoir operation

DEMONSTRATION OF THE CLOUD APPLICATION

The system was tested on the same case study as in the previous research [1], the hydro system Zletovica of the Bregalnica river basin in the Republic of Macedonia. The main objective was to demonstrate the cloud application works as designed.

The important milestone that has been accomplished was to connect the web service for support of WRM and the SDI web service over the Internet using WFS-T. The WFS-T is an asynchronous two way XML communication message protocol. The committed user activity in web service for WRM creates a XML message that goes to the SDI web service. The SDI web service translates the message and act accordingly using the geospatial data stored in HMak database. With the user browser refresh, the web service for WRM sends a WFS request to the SDI web service. The SDI web service reads the data, creates an XML file and returns it to the web service for WRM, as shown on Figure 3. The difference from the previous system is that the WFS-T communication is over the internet and not on a single VM. This clearly demonstrates the possibilities to deploy many web services and connect them accordingly.

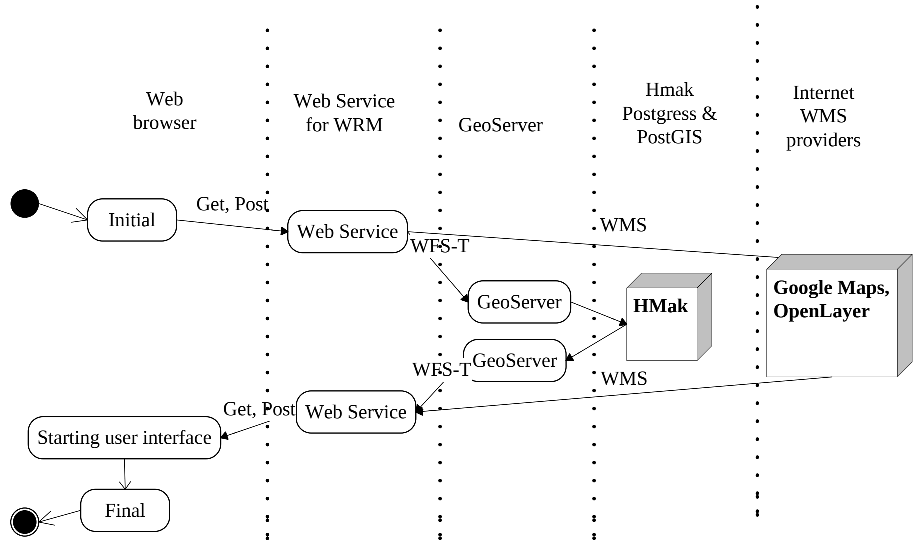

Figure 3. Activity diagram of web browser refresh

The hydro system Zletovica (shown on Figure 4) was modelled using the web service for support of WRM and uDIG geospatial software. The hydro system Zletovica basic model contains the river network, canal network, Knezevo reservoir, and agricultural areas and towns in the region as different users of water resources.

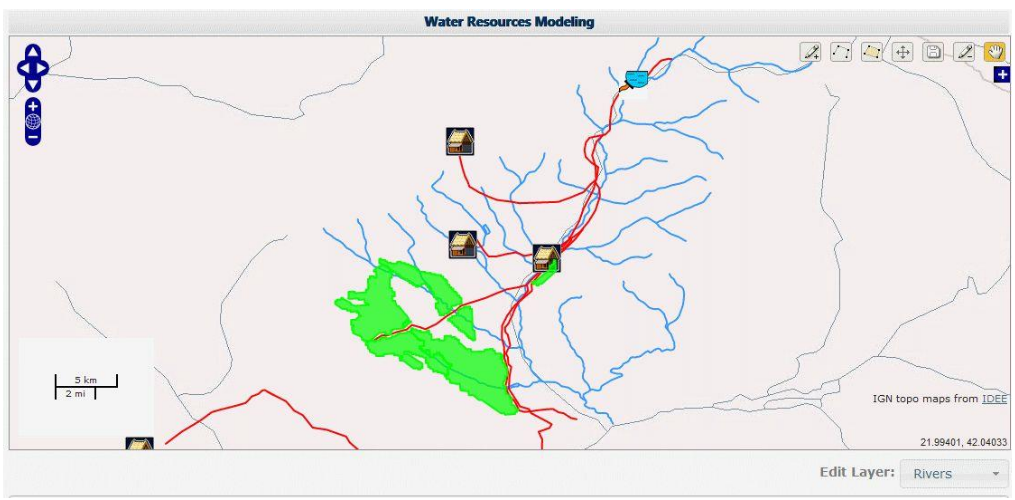

Figure 4. WRM of Zletovica river basin

DISCUSSION AND CONCLUSION

The main goal of the paper was to distribute web services between the two VMs and connect them appropriately, which was successfully accomplished. The general conclusion is that the cloud application and the four web services are working properly. The presented application demonstrates all cloud computing advantages, such as diminishing concerns about working platform, collaboration environment, software versions, data portability, and other implementation details.

Further we want to consider the NIST definition [12] of cloud computing with the proposed cloud application and explain the advantages, disadvantages and further development of the system. The first two essential characteristic of the cloud application are “on-demand self- service” and “broad network access.” The cloud application is available and accessible all the time and from anywhere and it only requires a web browser to access it and use it. Moreover, our interaction with the application is on-demand and driven by user needs. The web application is available on thick client platforms (e.g mobile phones, laptops and PDAs).

The third and fourth essential characteristics of the cloud application are its capability for “resources pooling” and “rapid elasticity.” The current web application is deployed on two physical servers running two separate VMs. The basic adjustment concerning the workload can be performed by increasing the current VMs computational power. The VMs workload can be monitored over AWS console and XenCenter and adjust appropriately. The cloud application components, standards and programming languages are interoperable and can be deployed on an unlimited number of servers. Issues concerning scalability and resource pooling can be resolved by adding and connecting additional VMs.

Concerning service models, the presented cloud computing application belong to SaaS. Users with a web browser access the cloud application and don’t care about underlying cloud infrastructure. The current deployment model is hybrid of public - private cloud because the VM-1 is running on Amazon web services which is a public cloud, while VM-2 is on Xen cloud platform which is a private cloud.

The last essential characteristic of cloud computing is “measured service” which is rudimentary supported by measuring the time of each user’s usage of the system. This satisfies cloud computing criteria, but needs to be vastly improved (e.g. with measuring processing power consumption, storage capacity utilization, etc.).

The most valuable characteristic of the cloud application is its real time collaboration platform capabilities. Multiple users using only a web browser can work jointly with the web services and collaborate in the same working environment in real time. An example is when a user saves the current work in the web service for supporting WRM. After that moment all other distributed users with just refreshing the web browser window can see the change (new/modified rivers, users etc.). All of the data and models are stored on the Internet and users do not have to be concerned about hardware and software support infrastructure.

The presented web application is based on open source software and custom prototype code. This increases the application value, because many software companies could use this approach and create various solutions without license fees. The application doesn’t exclude the possibility of adding additional commercial software components (data repositories, libraries, applications etc.).

The major drawback is that without internet access or due to a potential server downtime, the cloud application is not accessible. The first and second drawback can be solved by additional internet connection and backup servers, respectively.

Another important consideration is the cost. The development of the presented web application to the stage of fully operational solution would involve significant human and material resources.

The presented web application could be further upgraded into a solution intended for different user groups, such as policymakers, experts, other stakeholders and the general public. The cloud application has the capacity to create a collaborative platform that can be accessed by all users and provide new ways of communicating important information, potentially leading to more participative decision making processes regarding water resources management and planning.

Future applications, software and services will be cloud oriented. The presented application demonstrates that there are existing open source software and technologies to develop a robust and complex cloud application for supporting water resources modeling and optimization.

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