OPERATIONS RESEARCH AS A SERVICE

Mehdi Sheikhalishahi, Demetrio Laganà and Lucio Grandinetti
Department of Electronics, Computer and System Sciences, University of Calabria, Rende (CS), Italy

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Abstract: In this paper, we propose cloud solutions to provide Operations Research services to scientists. Currently, users must install Operations Research software tools or develop algorithms in order to tackle their problems.

1 INTRODUCTION

Cloud computing is outsourcing of IT resources such as software, hardware, etc. in which dynamically scalable and often virtualized resources are provided as a service over the Internet. The main concept in the cloud is an infrastructure that provides on-demand, instant and elastic resources or services over the Internet, usually at the scale and reliability of a data center. The future of software is in the cloud. It is our vision that by combining Operations Research(OR) and cloud computing technologies, OR cloud will make a wider audience able to easily access and benefit from the increasing number of OR services. Researchers are familiar with OR tools, but with OR cloud we can offer a much simpler and faster method for doing Operations Research.

Our OR cloud mission is similar to Globus Online that is a hosted service to automate the tasks associated with moving files between sites. It does not require custom infrastructure, Globus Online is software-as-a-service that can be used today without building these features yourself. However, Operations Research is a much more complex science than file transfer, thus to develop a general-purpose and complete solution, PaaS and IaaS cloud models should be exploited.

Obtaining, configuring, and maintaining solvers for numerous optimization classes is an expensive and time consuming proposition. Additionally, optimization problems often require significant computing time. Running multiple problem instances, each requiring substantial CPU resources, on a client machine such as a laptop, is not practical. The ability to solve optimization problems in a distributed environment is an ideal solution. Lack of standards in OR world, makes the development of OR as a service difficult. In OR world, there are numerous modeling languages with their own format, diverse problem instances with their own representation, various solvers with different APIs, results, etc. With OR in the cloud, scientists would benefit from the following advantages: No IT Required: requires no software installs or complex IT infrastructures, Give users a tool that simplifies dealing with OR, Automates the time-consuming and error-prone activity of doing OR such as manual tasks, so users can stay focused on what is most important: their research, Provide users with direct access to a wide variety of OR tools and services without the need to install, configure, or upgrade software on her computer., Enable better collaboration among users, Get the service up and running in minutes, Handling and managing of users' dataset such as Graph, Matrix, Network, etc., Validating and converting users' dataset into other data structures With OR cloud, users simply specify their OR problem and some other information e.g. which math programming model they would like to use, which methods. They will do this through a few questions. Then the OR cloud will provision the best OR environment for that OR problem. Next parts of this paper are organized as follows. Section 2 presents some background information on the topic. Then, Section 3 goes over related work. Section 4 discusses operations research cloud solution.

2 BACKGROUND

Currently, if a researcher wants to solve an specific problem of her research area, she would need to pass

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through the following steps: (1) developing or finding the right and the most efficient model, algorithm, tool and software; (2) installation; (3) configuration; (4) deployment; (5) test (6) usage. In this paper, we consider operations research and we provide cloud solutions to address the aforementioned challenges in solving OR problems for OR community.

The first and the main obstacle in usage of software, tools, and source code repositories is their installation and then their configuration management. Users need to install and deploy them in order to use them. This is a big challenge for user community of any scientific field. The second difficulty of scientists is the usage of a software and a service. In addition, some questions such as whether a software is a good one for a problem, whether a software is optimized for a problem, etc. are very important for scientists in order to solve their problems with the most efficient and optimal methods. In addition, installation, configuration, and deployment of these OR tools, software and services is a time-consuming task. By transforming all these bundles in the cloud we can instantiate them faster and users will get rid of all the difficult tasks. As a result, time to solutions will be faster than before.

There are many tools, software and services in the market and open source software in free software to offer appropriate solutions for various OR community. We have diverse set of OR problems, diverse set of models, methods, etc., etc. One solution, one piece of software, one interface, one tools, one math programming model does not suit the needs of all operations research users. Thus, if for an OR department we only use one OR software tool such as CPLEX, we cannot say that all OR users will be able to use it to solve their problems, also in the future perhaps will be more problems which cannot be solved by CPLEX. Therefore, we need to provide to an OR user a suitable and customized OR environment in order to model their problems with the most appropriate and optimized math programming model (e.g. algebraic lang.), and then select the best and the most efficient method to solve their problems. This OR environment depends on the focus of research activity. In sum, the OR cloud should be general-purpose and rich enough in order to address the needs of all OR user community or a large part of them.

In order to provide customized OR environment to a user according to its need, problem, and so on, we need to develop an OR-aware interface as an abstraction layer over OR tools, software, mathematical programming models, methods, algorithms, etc. An OR-aware interface at the highest level of cloud will determine the user needs based on a few questions and then will prepare the most efficient OR environment for that user. In cases that there are more than an option, this interface will suggest to user the best possible options. This abstraction layer will be implemented as part of SaaS solution of OR.

In order to implement an OR cloud system with the aforementioned features, IaaS and SaaS cloud paradigms should be exploited as well.

3 RELATED WORK

Globus Online (Online,) is among the first cloud solutions for scientists, it makes robust file transfer capabilities accessible to any researcher with an Internet connection and a laptop. Globus manages the entire file transfer operation: monitoring performance, retrying failed transfers, recovering from faults automatically whenever possible, and reporting status. Users cite Globus Online as their preferred service since it is Easy, Fast, Secure, Reliable and Research-focused.

NEOS (Czyzyk et al., 1998) is an Online optimization service which has been widely used by the OR community for over a decade. A central server maintains and queues job submissions for solvers that run on a variety of workstations scattered around the Internet. The main drawback of NEOS is its central server paradigm.

At first, submissions were MPS-format files for linear problems and C or Fortran programs for nonlinear ones, but now the great majority of submissions are in high-level modeling languages, predominantly AMPL (AMP,) and GAMS (GAM,). Submissions through the NEOS web portal (neos.mcs.anl.gov/neos/solvers) remain popular, and they can also be made by sending XML text files through email. The latest NEOS release features a NEOS API that permits all server functions to be accessed through remote function calls using the XML-RPC protocols (www.xmlrpc.com). This has brought NEOS more in line with the precepts of SOA and has made it much easier to integrate into optimization modeling environments. Nevertheless, its design still adheres in many respect to the central server paradigm. Also NEOS employs whatever file formats are supported by the various solvers; the over 40 solvers in the NEOS lineup require instance inputs of about a dozen different kinds. Similarly there is no NEOS standard format for communicating options to solvers or communicating results from solvers.

In (Fourer et al., 2010), authors present a distributed optimization environment (Optimization Services or OS) in which solvers, modeling languages,

Table 1: Traditional OR solution vs. its corresponding OR cloud solution.

Traditional OR solution	Provisioning actions and time	Cloud OR solution	Provisioning actions and time
Developer tools	I.C.D.T.B long	IaaS, SaaS	B short
Documentation	B short	SaaS:OR-aware cloud interface	B short
Graphs	I.C.D.T.B long	IaaS, PaaS	B short
Interfaces	I.C.D.T.B long	IaaS, PaaS, SaaS	B short
Modeling systems	I.C.D.T.B long	IaaS, PaaS	B short
Metaheuristics	I.C.D.T.B long	IaaS, PaaS	B short
Optimization utility	I.C.D.T.B long	IaaS, PaaS	B short

registries, analyzers, and simulation engines are implemented as services. It defines standards for decentralized optimization on the Internet: representation of optimization instances, results, and solver options; communication between clients and solvers; and discovery and registration of optimization-related software using Web Services. The OS project addresses NEOS weaknesses.

In all, while OS provides online distributed optimization services as a SaaS cloud, but it is not a complete cloud solution. Users will not be able to build their own OR applications if they cannot be offered by SaaS solution. In order to approach a more complete solution, IaaS and PaaS cloud paradigms are suggested to be used in this paper.

4 OPERATIONS RESEARCH CLOUD SOLUTIONS

In the previous section we enumerated various OR projects, tools, software packages, libraries, etc. in OR world. We would like to reuse and to exploit already available solutions in OR world with the help of IaaS, PaaS and SaaS cloud paradigms to build OR cloud solutions. SaaS paradigm suits to reuse software without significant changes such as tuning configuration parameters, while when we want to build new OR applications based on available OR solutions and our development, IaaS and PaaS paradigms are the right choice, for example to link a model to an interface and exploit our specific OR algorithm for an specific OR problem.

Table 1 provides some information on the corresponding cloud solution for each category of the aforementioned OR projects in the previous section, and compare the provisioning time and actions of traditional OR projects vs. OR cloud solutions.

In addition to free software resources, there are many enterprise OR tools such as CPLEX that can be hosted in the cloud. With these rich set of OR resources that are hosted in the cloud, OR cloud will be able to intelligently offer OR services for OR community. In the provisioning column we use the first letter of provisioning actions to represent them i.e. I. for installation, C. for configuration, D. for deployment, T. for test, and B. for boot. This table 1 demonstrates applicability of cloud paradigms to OR world. Unlike traditional OR solution with this, OR world would be available online without significant attempt to provision OR environment.

Figure 1 presents a high level architecture of OR cloud. OR-aware interface is an abstraction layer over OR tools, software, mathematical programming models, methods, algorithms, etc. An OR-aware interface at the highest level of cloud will determine the user needs based on a few questions and then will provide the most efficient OR environment for that user, like in (Fourer et al., 2010) that Optimization problems are solved automatically with minimal input from the user. Users only need a definition of the optimization problem; all additional information required by the optimization solver is determined automatically. In cases that there are more than an option, this interface will suggest to user the best possible options. This abstraction layer will be implemented as part of SaaS solution of OR. In (Fourer et al., 2010), if users are not sure of the type of optimization problem, they should consult the Optimization Tree of the NEOS Guide for information on optimization problems. However, we move this action to the cloud i.e. OR-aware interface layer. The choice of solver is then dictated by the language used to define the optimization problem.

At IaaS we have a number of Virtual Appliances abstracted as Virtual Machines (VM). IaaS VMs are developed by reusing available OR tools. They are prepared by OR experts of various fields of OR. These VMs contain customized OR environments for different OR problems. We reuse OR tools, softwares, services, open source software, etc. in order to build these VMs. With development environment (Platform-as-a-Service) on the cloud, users will be able to develop their own OR applications by exploiting already available OR tools, algorithms, methods in the cloud. Like any cloud effort, standardization at the interface and data levels are very important, for example open standards for data interchange.

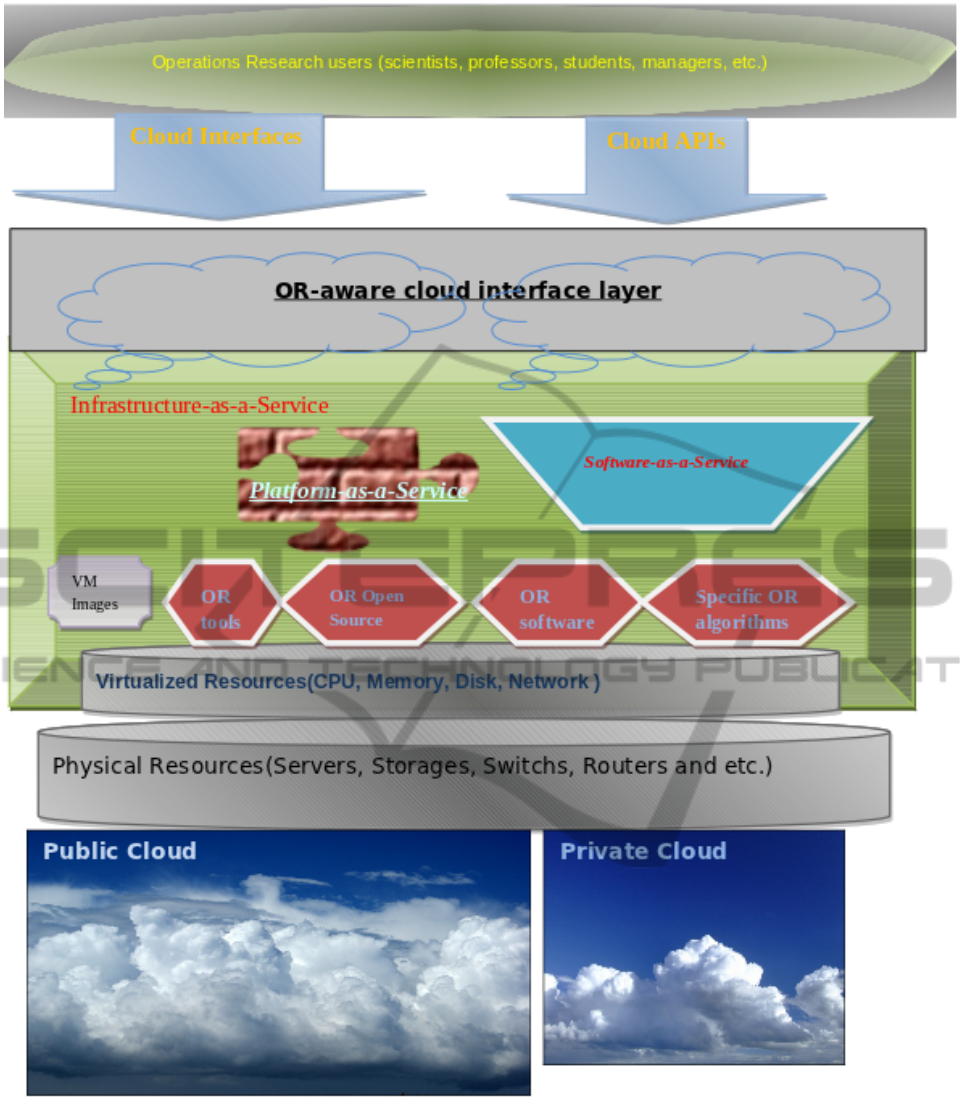

Figure 1: Operations Research cloud architecture.

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