Development of a monitoring module for physical and virtual servers: Advanced computing center case of the Universidad Pontificia Bolivariana, Bucaramanga, Colombia

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Abstract. The management and administration of physical and virtual servers requires a series of periodic activities that allow to show the optimal operation and the fulfillment of its objective of providing computational services. The work of monitoring servers allows the allocation and use of adequate resources, as well as assertive decision making in strategies for projection and scalability of resources. This article presents the results found in the process of development and implementation of the monitoring module of physical and virtual servers of the Advanced Computing Center of the Universidad Pontificia Bolivariana, Bucaramanga, Colombia, in which through the generation and display of reports in real time offer the coordinator of the center information of the current state of resources leading to the right decisions to improve the service provided at the level of efficiency, performance, among others. The results of the project were the design of the graphical interface, the development of the information system which was programmed with PHP language, the connection in real time with physical and virtual server made via SSH; the scripts programmed in platforms such as XenServer, Windows Server and Linux for CentOS, Debian and Ubuntu distributions.

1. Introduction
Cyberspace, defined as the virtual environment in which technological infrastructures connected to the Internet converge [1], there is a constant increase in threats that put business continuity at risk. These technological infrastructures have a set of physical or virtual resources associated with them, which require permanent management and monitoring.

The activities associated with the management and administration of resources lead to the analysis of the different variables that are interrelated and affected. That task becomes complex when it is performed manually [2]. The physical and virtual servers of a technological infrastructure are concentrated in what are commonly called data centers. There are currently several commercial tools for monitoring and managing data centers, such as ManageEngine applications manager, Device42, DataDeck, among others.

Since 2013, the Universidad Pontificia Bolivariana, Bucaramanga, Colombia has had an Advanced Computing Center (ACC) in which data processing and storage services are provided for academic and research activities. This document presents the process of developing a module for monitoring the ACC's physical and virtual servers. This module is part of an information system developed in a web environment that facilitates the ACC coordinator's management and administration of processes, documents, virtualization services requests and physical and logical resources of the center. This system
also allows the generation of different types of reports that allow decision making; it also allows the generation of alerts as reminders to perform maintenance of physical resources, replacement of resources, security analysis, among others. This will provide the coordinator an overview of the status and use of ACC resources and thus will have a tool that allows the management and administration of resources.

2. Related work

A variety of software solutions are currently available for data centers management. Those solutions have their own approach to data center analysis, such as the data network, computing resources, or the environment in which they are located. Some research has been focused to use different strategies for data centers management [3]. Moreover, related works for the management and monitoring of data center infrastructures will be presented.

In 2015, in the project entitled "Physical security monitoring system on a platform free of electronic components to ensure the management of continuity levels of computer services in the USAT Data Center", a software was implemented for environmental monitoring of hardware devices in a data center in order to provide access to information on factors such as temperature, humidity, liquids, among others. In this way the administrator of the center has control over these factors taking into account the need to preserve optimal environmental conditions for the proper and continuous operation of IT resources [4].

In the degree project "Analysis, design and implementation of a data center monitoring and control tool based on open source tools applied to the bank of Guayaquil" carried out in 2015, two free tools (NAGIOS and CACTI) were chosen to provide reports on the use of the network, CPU and equipment memory to the data center administrator of the bank of Guayaquil [5].

In the project "Definition and implementation of a logical security monitoring and reporting system in a Data Center" a data network monitoring system based on intrusion detection was developed in order to take pertinent measures when detecting threats or attacks to the center's security [6].

In the article published in 2017 "On the benefits of resource disaggregation for virtual data center provisioning in optical data centers" a comparison between traditional data centers and virtual data centers is presented, highlighting the advantages and maximum use of the resources with the implementation of the last. In addition, a set of techniques are proposed to allow for the dynamic allocation of available resources according to demand [7].

In the article entitled "A dynamic and interactive monitoring system of data center resources", the ResourceView monitoring system for data centers is presented, characterized by real-time monitoring, the generation of reports on factors such as energy, cooling, use of hardware resources of virtual servers, among others. The reports provided by this system are generated from different views and with descriptive graphics that allow administrators to make decisions. Its development focuses on data mining from which information is obtained and then presented with 3D animations. In addition, two solutions that did not offer the necessary functionalities for the management of a data center are mentioned, highlighting the absence of results in real time that contribute to make an efficient and optimal use of resources. Between the mentioned tools [8], Ganglia is a system which "provides near real-time monitoring and performance metrics data for computer networks" [9]; although it is an attractive solution for management, it is only focused on host organized in clusters. The open source tool CloudStack is also cited as outstanding for its scalability with an approach to data center configuration, however, it also lacks runtime monitoring [10].

Between the existing development solutions are available Manage Engine OpManager as a network monitoring tool; on the other hand, for the management of resources, their monitoring in terms of cost, security and operations, Microsoft proposes the software Microsoft Secure and Manage Resources. For factors such as temperature and energy consumption and even real-time monitoring, Intel Data Center Manager is a tentative tool [8,11].
3. Development
When server monitoring is performed, the management and administration system becomes one more component of a distributed system that meets the challenges that characterize one, such as heterogeneity, extensibility, security, scalability, fault handling, concurrency, and transparency. The components of the distributed system are platform-independent and communicate with each other through the passage of messages [9,12].

3.1. Monitoring module design
Figure 1 presents the architectural design of the monitoring module of the physical and virtual servers of the ACC, which shows three main components, the first refers to the user's equipment, the second is the virtual server where the information system is running, and the third refers to the servers that are monitored. Table 1 describes the characteristics of each component.

![Figure 1. Architectural model of the server monitoring module.](image)

| Table 1. Components of server’s monitoring module. |
|---------------------------------|---------------------------------|
| Component | Description |
| 1 | Process executed on the user's computer through which requests are made to the management and administration system. |
| 2 | Management and administration system hosted on a virtual server, with the functionality of exchanging messages with the servers to be managed (Component 3) and the generation of reports of hardware characteristics of the physical and virtual servers in response to user requests (Component 1). |
| 3 | Processes executed on physical and virtual servers to respond to requests from the administration and management system (Component 2) with the information required for monitoring. |

3.2. Implementation of the monitoring module
For the implementation of the monitoring module, a development was made in each component. The virtual server where the information system is hosted (Component 2) was configured to communicate via SSH with the other servers; in addition, PHP modules were implemented in the management and administration system hosted in it. Scripts were programmed for the XenServer, Windows Server and Linux operating systems for Centos, Debian and Ubuntu distributions of each server (Component 3).
Finally, the graphical interface was designed that allows the user interaction for the generation of requests to the system (Component 1).

### 3.2.1. Configuration of component 2 for remote access to servers via SSH protocol using a public key.

The following steps were taken to establish communication between the management and administration system and the physical or virtual servers with Linux or XenServer operating system:

- Step 1. Generate the public key for the virtual or physical server.
- Step 2. Add the generated public key to the known_host file.
- Step 3. Create the .ssh directory.
- Step 4. Copy the public key generated in step 1 to the authorized_keys file located in the .ssh directory created in step 2.
- Step 5. Change permissions for the .ssh directory and the authorized_keys file.
- Step 6. Verify ssh connection with the public key.
- For servers with Windows Server operating system, the FreeSSHd tool was used to connect via ssh to the management and administration system.

### 3.2.2. Report generation.

A PHP module was developed for the generation of each report. The activity diagrams presenting in Figure 2 describes the behavior of each one will be exposed.

![Activity diagram of the servers’ overview report.](image)

Figure 2 shows the activity diagram defined for the generation of the overview report of the physical and virtual servers. The user makes the request to the management and administration system for the
generation of the report with the information of the servers, this query is processed by the management and administration system in the following way: performs a query in the database of the list of existing servers in the ACC, for each record found reviews the information for the establishment of server connection, then verifies whether the server is available, so that if this is carried out the connection via SSH, if not available proceed to continue with the server that follows in the list of servers; If successful authentication is achieved via SSH, the remote script is executed in which the server information is consulted (hardware characteristics, available capacity and in use, among others); the results are stored in an arrangement for the generation of the response to the user through a report displayed in the user interface; if the successful connection to the server is not achieved, the information for the next server continues to be consulted in the list of found servers.

3.2.3. Coded scripts. Several scripts were coded to generate server reports, each of them executing commands specific to the operating systems. Scripts are executed to obtain the information from which the PHP module generates a report in an interface of the management and administration system.

4. Results

The management and administration system allow to generate a report of the physical servers, virtual servers, an individual report per server or a general report that groups the virtual and physical servers. All reports presented can be downloaded in Word format.

4.1. Physical servers report

This report presents general server information as well as individual information. The information shown is based on features such as RAM, disk storage; for the two features shown are: total amount, in use and available, reported in gigabytes (GB). In the results interface of the report two tabs are presented, one for the information of the physical servers in general, and one for the information of the physical servers individually.

Figure 3 shows an example of the general report generated for the physical servers, on the left are the results associated with RAM memory and on the right column the results associated with storage (disk capacity); for both cases the total amount in use and available is described, as well as a pie chart that facilitates the interpretation of these at a percentage level. This report allows evidencing the current capacities of the physical servers of the data center, with it to analyze issues of projection and decision making for the best rendering of services, as for example, for the case presented in Figure 3, it can be deduced that there is a low availability at RAM memory level in the physical servers of the ACC, which leads to project the growth of the same one after analyzing other variables such as the capacity in disk, the amount of cores in use, among others.

Table 2 shows an example of the individual physical servers’ report in which the list of the physical servers of the ACC to which the script could be executed after the request in each machine is shown.

As in Figure 3, Table 2 shows information regarding the server, its location, the total capacity in use and available RAM memory, as well as the total capacity, in use and available hard disk storage. This report allows, being crossed with the one presented in Figure 3, to analyze the real use of the servers, those that already present less available capacity, in order to project growth or scalability according to the requirements of use of the ACC.

| Name      | Total memory | Memory in use | Memory available | Total hard drive | Hard drive in use | Hard drive available |
|-----------|--------------|---------------|------------------|------------------|-------------------|---------------------|
| Server 1  | 64.0         | 54.1          | 9.8              | 1853.0           | 731.5             | 1121.5              |
| Server 2  | 64.0         | 63.3          | 0.7              | 2191.6           | 339.2             | 1792.4              |
| Server 3  | 63.9         | 52.6          | 11.3             | 1821.5           | 1026.0            | 795.5               |
| Server 4  | 8.0          | 0.7           | 7.3              | 2000.0           | 8.8               | 1991.2              |
4.2. Virtual server reporting
This report has the same schema of the physical servers report, only that it is directed to analyze the characteristics of the virtual servers lodged in the physical servers of the ACC, such as the capacity of RAM memory and storage (total, in use and available) in a graphical and descriptive way; it is also presented the general report of the virtual servers, as well as the individual report.

4.3. Report per physical server
For the individual report of physical servers, two graphical interfaces were designed for each of the operating systems that are currently installed in the ACC servers: XenServer and Debian. For the XenServer servers was designed a graphical interface that has 3 tabs; in the first one we list the virtual servers that have been created and stored in the server from which the report is being generated, from each one we present the processing capacity, storage and RAM memory.

In the second tab of the report for a XenServer server where it shows general information about it, including the number of domains on the server, the percentage of use and description of the CPU, the time of the system running, the users connected, the number of tasks and the description of the network interfaces of the same.

Finally, tab 3 shows information on RAM memory capacity and storage, for each one two graphs are made in which the percentage of use available and in use by the physical server in general (left) and by existing virtual servers within each physical server (right).

4.4. Report per virtual server
The management and administration system also allow the generation of virtual server reports. For distributions of the Linux operating system, a report is generated with general information about the server and percentage of RAM use and storage. In servers with Windows Server operating system, a report is generated with relevant information about memory and storage, but lacking data presented in the previous ones due to certain limitations of the commands that can be executed in the same.
4.5. General report

General report presents the use and availability of both RAM and storage of the ACC’s physical and virtual servers. It has two columns and graphs that represent the information on the use of the aforementioned hardware characteristics. Finally, a table reflects the history of the ACC, which indicates the number of physical and virtual servers acquired and created each year.

5. Conclusions and recommendations

Server monitoring provides the manager of a data center reports with information about the use and availability of the most relevant hardware characteristics of a server, processing capacity, storage and memory, thus facilitating decision-making regarding the acquisition and/or allocation of resources according to the needs of the projects stored in them. The generation of reports in real time with the hardware characteristics of a server allows those in charge of an ACC to have an updated perspective of the state of the resources.

The ssh protocol allowed communication between the server where the system that generates the reports is hosted and the physical and virtual servers located in the data center. On the other hand, the use of customized scripts for each operating system allowed to obtain information of the characteristics on real time.

Add a module for monitoring the ambient temperature of the ACC that displays each time the user wants the environmental conditions at that time and also alerts when a factor is not within the established in order to act before damage occurs.

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