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# VIRTUALIZATION SOLUTIONS

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A nowadays must

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The technological revolution we experimented during the last years has lead us to the need of creating new techniques and improving older ones to better face the problems of the nowadays computing world. One of those techniques is virtualization, and we will cover that topic along this work. First we will describe briefly the concept of virtualization, its definition and some examples. Then, a list of the different uses that virtualization has, and the benefits we can obtain by applying this technique in modern hardware, as well as other special uses of it. Following this topic we will describe the different type of virtualization: CPU, Memory and other advanced virtualization types like the one applied to OS, server, networks, etc. Obviously, there are some disadvantages, that we will contrast with the benefits in another section of this report. Finally, we will refer to the different firms and solutions for virtualization techniques, as well as some history, since 1960' to nowadays.

## 1 The concept of virtualization

Virtualization is one of the most known techniques of operating systems. It consists in the act of taking a physical resource, and divide it in order to create different simulated versions of itself that can work at the same time adding some improvements. Because of that, we sometimes refer to the OS as a virtual machine or a resource manager as it handles all input that goes into the hardware traducing the OS instructions to machine ones. It can be applied to different areas, apart from the operating systems, such that application-servers, networks, hardware, storage...

We could take a very simple example form a hard disk that is 'divided' in two, by means of virtualization, or a CPU that is shared among the different processes that are running.

This technique began in the early 1960s, with the goal of logically divide the system resources of the primitive computers, but that will be covered widely in next sections.

## 2 Usefulness of virtualization

Virtualization is a very useful technique that improves our system in many different ways, here are some aspects that represent modern virtualization usefulness.

### 2.1 Uses of virtualization

- **Resource optimization:** By virtualizing the hardware, the computing power, the storage, network bandwidth and other properties that computers offer to users, can be more effectively used.
- **Consolidation:** A server can run multiple virtual environments to take advantage of the small amount of power that some applications use, and not to dedicate individual computers to a single application. Many companies can save a lot of money with this solution.
- **Maximizing Uptime:** Virtualization also allows to Speedy recover for some failures, guaranteed uptime of servers and applications and in general, response quickly and in a flexible way to changing requirements.
- **Automatically Protect Applications from Server Failure:** Server virtualization allows to implement redundancy without purchasing other hardware. This redundancy is useful if a server fails, and another server running the same application, have to minimize the interruption of the service.
- **Easily Migrate Workloads as Needs Change:** With most virtualization solutions it is possible to move a virtual machine from one physical machine in the environment to another. This technique is typically used to improve reliability and availability.
- **Protect Investment in Existing, Legacy Systems:** Server hardware will eventually become obsolete, and switching from one system to another can be difficult. In order to continue offering the services provided by these legacy systems, you can run it as a virtual machine on new, modern hardware.

### 2.2 Special uses of virtualization

- **Run old apps:** If we want to run an application that has a better performance in a different operating system than the one we run, we could thanks to virtualization and the correct software solution (like Virtual Box, for example) run another operating system compatible with the app we desire to handle. We can also use these software solutions to do something not so professional like emulating old videogames.

- **Access risky data:** Many virtualization software allows to create an snapshot of the operating system in a given moment, so that we could recover that state in the moment we want. This serves for example if we want to open a file that may content malware, but its content is important for us. If we want not to risk our system, we can use that snapshot as a 'backup' copy of it.
- **Test software and new configurations:** Before using a new software into our actual operating system, it is advisable to test it in another one. This could be another utility of having two different operating system running in the same machine, and also having the option to restore the previous state of the machine.

At this point, it is obvious that virtualization offers us plenty of resources to take advantage of, apart from the work of the operating system with the different resources of the computer.

## 3 Types of virtualization

First of all, we will cover the 2 basic virtualization types over which any common computer system works, CPU and Memory virtualization. Those 2 types of virtualization are carried out by the OS system.

### 3.1 CPU Virtualization

CPU is one of the most important components in a computer. In the central processor unit are taken the operations to execute the different instructions of a program, so it is very important that not only one process occupies the whole processor.

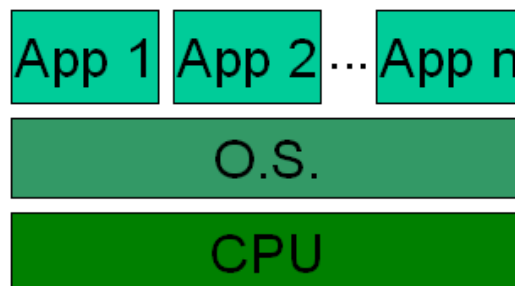
Let's develop a bit more this concept with an example. If we had three different processes in a system with a virtualized CPU, the three process seem to be executed at the same time. How this is possible if we only have a processor?

If we want to run different programs at the same time, we would need a way to share the processor among them, and not monopolizing it with only one process. By means of virtualization, the operating system creates the illusion that each process has its own CPU, and all of them can be executed at once (See figure 2 and 3). But this is not applied only to small processes. One of the most common uses of virtualizing the CPU is for example, to run two different operating systems at the same time in the same machine.

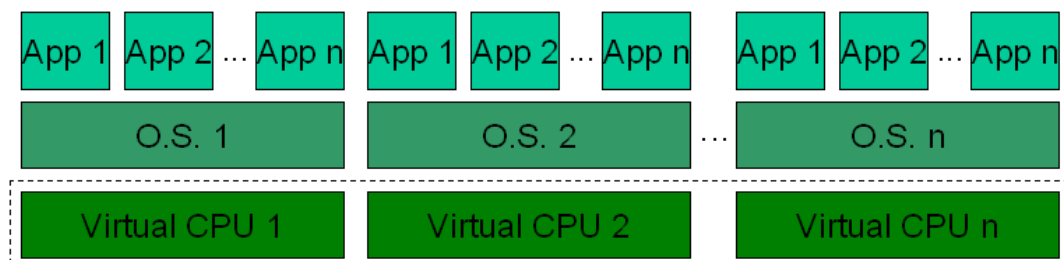


*Figure 1*

In this case, the CPU is **multiplexed in time**, employing a determined time for each program. The graph shows the three process running in the CPU in a given moment. Each of them is executed for some time. The arrows point to the moments in which the operating system, by means of different mechanisms, switches the execution from one process to another. The system takes the decision of switching thanks to the policies. Policies grant the different process a level of privilege, making them more likely to be executed than other.



*Figure 2: Multitasking*



*Figure 3: Virtualization*

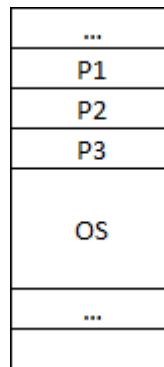
## 3.2 Memory Virtualization

Memory is an array of bytes that contains all the data of the computer from code to instructions going through the operative system, as you can imagine it is very important to preserve the security and the accessibility while we try to make the most of it.

For example, we have different programs executing at the same time, and accessing to same memory address, 0xABC123. Because of virtualization, they access to its own 'private' memory, 0xABC123, as if each process has its own address space. That is precisely which virtualization does, create individual memory for each process with their own address space each, memory is **multiplexed in space** (See figure 4).

The reality is that although each process has its own private address space, there is only one physical set of addresses which are referenced to the virtual ones.

Let's take look with an example. If we have three different processes P1, P2 and P3, we could represent the memory addresses space like the following scheme:



*Figure 4: Main memory multiplexing*

The three process are loaded into memory, with a reserved space for each of them. The benefits of this virtualization are many. For example, the process does not interfere with data of other processes, due to each one has its own space, by contrast if we want we can share the access to some critical memory positions, like the code sections that every program needs to read.

On the other hand, they cannot access to the address space of the operating system or any other critical section we want to protect from overwriting, thus the system gains in security, because the processes will never be able to access to the operating system address space, nor operations reserved exclusively for it. There is also a great performance improvement due to data sharing in our main memory.

### 3.3 Advanced Virtualization Types

As we have seen before, virtualization is a very useful and powerful tool nowadays and it has a lot of different uses, like for example, if you were to partition a basic hard disk in order to create two hard drives, then they would be two “virtualized hard disks”, as the hardware is a single hard disk that was digitally separated into two. The usual goal of virtualization is to centralize administrative tasks while improving scalability and overall hardware-resource utilization. In this report we will cover the 6 primary types of virtualization. Each one of them differs from the others according to both, the element it is used on, and the different effect on network security each of them have.

#### 3.3.1 OS virtualization

Consists of putting a second or multiple instances of an operating system, like Windows or Linux, on a single machine. The main advantage of this method is that empowers businesses to reduce the amount of hardware required to run their programs by reducing the number of physical machines. It also saves companies a lot of money on energy, cabling, hardware and more, while allowing them to run the same quantity of software. But, although this technique offers a lot of advantages, it might lead to some failures while using it. OS Virtualization has a high risk in physical fault. For example, if you are hosting 5 virtual OS on a single machine and it fails, every different operating system running on it will fail too. Another disadvantage would be that performance might suffer when running some type of really demanding software, and, finally, not all applications support OS Virtualization. Sometimes your applications or Operating System may face issues and act differently on virtual environment without giving any clues.

#### 3.3.2 Application-Server Virtualization

It is often referred to as ‘advanced load balancing’, as it spreads applications across serves and servers across applications. This enables IT departments to balance the workload of specific software in an agile way that does not overload a specific server or underload a specific application. In addition, it also allows easier management of servers and applications, since you can manage them as a single instance instead of having to install a copy of the applications on every client machine. Finally, it gives greater network security, as only one server is visible to the public while the rest are hidden behind a reverse proxy network security appliance. But, if the application server goes down, then clients cannot access the application in any way. Moreover, it can be expensive to set up, so it is not useful in a network with only a few client computers.

#### 3.3.3 Administrative Virtualization

This is one of the least-known forms of virtualization, likely due to the fact that it is used in data centers. The concept of administration, or “management”, virtualization means segmented admin roles through group and user policies. For example, certain groups may have access to read specific servers, infrastructure, application files and rules, but not to change them.



### 3.3.4 Network Virtualization

The network virtualization evolves into virtually managing IPs, and is accomplished through tools like routing tables, NICs, switches and VLAN tags. It is the process of combining hardware and software network resources and functionality into a single, software based administrative entity, a virtual network. This method offers several advantages. The first one, as it is for all the virtualization techniques, is that it takes less time, effort and money spent on hardware, that is one of the most expensive costs associated with running an IT department, just after the price of your workforce. Network virtualization makes development, testing and deployment of new apps a lot faster, which will lead to more productivity and better performance of the company in the market. And finally, as well as improving the security of the system, as we explained in the first type, network virtualization also improves recovery times if a hardware failure occurs. A virtualized network helps get your systems and applications back up faster because cloud services have an extraordinary record when it comes to providing solid uptime. On the other hand, there are some disadvantages. For example, this virtualization might not be compatible with other servers and applications and it needs training to network administrators in the companies, because maybe not all personnel are ready to learn new computer skills in order to manage a virtualized system.

### 3.3.5 Hardware Virtualization

Is one of the rarest forms of virtualization. It is similar to OS virtualization and, in fact, often required for it. The only difference is, that instead of putting multiple instances on a single machine, chunks of the machine are partitioned off to perform specific tasks. This is the case of Memory and CPU virtualization.

### 3.3.6 Storage Virtualization

This type uses virtualization to enable better functionality and more advanced features in computer data storage systems. These storage systems use special hardware and software along with disk drives in order to provide very fast and reliable storage for computing and data processing. Within the context of storage system, there are two primary types of virtualization that can occur: blocky virtualization, that refers to the separation of logical storage from physical storage, allowing the administrators of the system greater flexibility in how they manage storage for users; and file virtualization, which eliminates the dependencies between the data accessed at the file level and the location where the files are physically stored, providing opportunities to optimize storage use and server consolidation.

## 4 General Advantages and Disadvantages

To sum up, virtualization is a very useful technique which offers a lot of advantages to the companies like reducing the spending on hardware, an easier backup and disaster recovery system, a better business continuity, as it offers access to software, files and communications anywhere, as well as enable multiple people to access the same information at a time; and more efficient IT operations, as it offers an easier route for technicians to install and maintain software, distribute updates and maintain a more secure network. On the other hand, virtualization also has some disadvantages, for example, setting up a virtualized environment in a company is not cheap, because of the initial investment in software and hardware, depending on the existing network; or possible learning curve, as implementing and managing a virtualized environment will require staff with expertise in the field. In conclusion, for many businesses, comparing the advantages to the disadvantages, moving to a virtual environment is typically pretty straight-forward.

## 5 Virtualization Firms and Solutions

We will talk now about some of the most important virtualization companies, both for the products and for the impact they had in this industry.

- **VMware:** as one of the first virtualization providers it is still one of the most important company in this sector as it provides services to cloud computing, network, security, data storage and of course basic virtualization. They are remarkable in desktop and application virtualization but also provide for free some hypervisors. Some examples of products are vCloud Suite for cloud management and Virtual SAN that creates clusters for disk in order to offer a higher performance in data centers.
- **Microsoft:** as one of the biggest tech companies Microsoft also works on some features of Virtualization. They have focused on Windows Server, and also Azure their cloud service, where they provide Hyper-V (its hypervisor) to control all the services in the server, which is compatible with Linux.
- **Citrix:** Citrix was one of the very first developers of application virtualization. Specialized in server virtualization, network connection, and SaaS, nowadays owns one of the most powerful virtualization software: Xen, which is in fact used by Amazon cloud system. Offers some more interesting options like XenApp and XenDesktop and also Intel and NVIDIA are using it and doing some improvements in order to add better performance.
- **Oracle:** on important virtual machine of oracle is Java Virtual Machine (JVM), that will be explained in the **Nowadays** section. Since sun microsystems was bought by oracle in 2010. Oracle has some functionalities specially in the case of Server and Desktop virtualization. Also provides a widely used program, Virtual Box. With Virtual Box you can create your own virtual machine assigning the

desired components of your computer to run that system, it is very useful when you are working on a desktop windows system and you need access to use a Linux one or in case you are a MAC user and need access to a program which only exists on windows.

- **Google:** with the use of great amounts of servers for Google Apps and all its services it is obvious that Google had been interested in Virtualization services. In fact, uses a special implementation of the Citrix Xen to adapt it to its own necessities by means of the product Ganeti, a cluster solution, it is a wrapper around the hypervisors which makes convenient for administrators to set up a cluster.

## 6 Impact of Virtualization until Nowadays Datacenters

### 1960's

In the beginning, around 1960, IBM used to deal with a lot of different systems, those systems had very little in common from a performance point of view, that means that every time an update or a new requirement where needed the whole system with a different set of instructions per each process had to be loaded again in punched cards format, then as computers where monotask machines you will have to wait until a process finishes to introduce by hand another. With all these steps and leading to bad performance, IBM researchers started to work on a system that allowed to run Batch Jobs keeping the compatibility with the previous versions.

In that time, MIT started to research on computers and as they needed new hardware capable of more than one simultaneous user they contacted to IBM and GE in order to buy it, as IBM wasn't interested on it the hardware was bought to GE (the model GE-654 with several security levels and supporting virtual memory, developed in 1965). As IBM lost against GE, they started to consider the option to add the functionality of several users at a time, especially when Bell Labs was interested in a similar hardware to MIT.

In 1967 we can say the first IBM operative system with use of virtualization appeared, the CP-40 that was restricted to research. After the IBM CP-40 released in January, the model CP-67 appeared in April as the first commercial Main Frame to support virtualization.

### 1970

In the early 70s a model called CP- 370 was released, that model was a reimplementación of the previous model CP-67 that later will be modified by adding virtual memory system.

## 1999

After that years of great development in Virtualization techniques, the interest decreased until 1999 when VMware presented VMware Virtual Platform with x86-32 for Intel IA-32 architecture that covered all the basic virtualization functions.

## Nowadays

Nowadays virtualization is not a research or a theoretical topic and we can see it everywhere in computing world, from memory sharing and protection to multitasking systems and videogame emulators.

Since 2005 VMware has been providing for free the virtualization technology to everyone, and later the application virtualization was developed. Today VMware is still one of the most important researchers and developers of virtualization services, but that has been covered in the **Virtualization firms** section. In every today regular computer we can find the CPU and Memory virtualized, all of that regulated by other virtualization technique, the OS. The main virtualization application nowadays, we could say it is cloud, server and datacenters clusters, that is where application and desktop virtualization appears, as well as hypervisors.

Hypervisors are a new feature that allows to configure virtualization techniques to use at the same time different OSs. The hypervisor is an *evolution* of the supervisor that works in Kernel mode.

A very remarkable virtual machine of our time is JVM (Java Virtual Machine) which is a native abstract virtual machine which works with its own set of instructions (Java bytecode). No matter the system where the code is created or executed, when the code is compiled it is transformed to Java instructions and must be run in the JVM. That allows using programs in multiplatform instead of traducing programs to each system with its own architecture and machine code.

Another virtual machine use nowadays is the test of potential harmful programs, for instance if we want to test a program that will make a system crash we can create a virtual machine with the desired specifications and see what appends without damaging anything important. Some of this virtualized versions if they are not a command line are called Virtual Desktops.

Some remarkable benefits of datacenters virtualization are, the heat and physical space reduction, reduced cost and speed improvement. Some not so obvious aspects are the capability of perform easier backups, which improves a quicker system recovery in case a disaster happens and also makes testing purposes much efficient.

As we have seen during this report, virtualization is a very powerful and useful technique that, since its appearance in 1960, has changed the computing world by adding some important features such security, performance, cloud services and so on. Taking this into consideration, we have defined the basics concepts and we have seen how virtualization works with its internal mechanisms. On the other hand, we have also noticed some relevant drawbacks of this technique like expensive set up costs of regular size companies, worse performance and the possible learning curve of new employees that have never worked with virtualization environments. But, in conclusion, we have seen and shown that virtualization is really advisable and useful for great companies such as Amazon or Google.

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