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Usage of Virtualization Technologies in Long-Term Preservation of Integrity and Accessibility of Digital Data

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Summary

The concept of virtualization making a transition from expensive hardware systems over to the affordable software field, capabilities that modern virtualization environments allow are becoming multidimensional and not many software designers can allow their applications not to include some type of virtualization system compatibility. Many applications allow virtualization systems to utilize them in such a manner that the performance is increased rather than hindered, and the level of collaboration among the users to be increased. Distribution of information, resources as well as entire operating environments can be very successfully and appropriately applied and used in systems for maintaining authenticity and preserving long term usability of data. The authors analyse requirements and suggest some initial high-level architectural solutions for the users of virtualization in the long term preservation process.

Key words: data preservation, virtualization

Introduction

Archival institutions, as well as all institutions requiring long-term preservation of digital data, whether in the form of documents, images, sound, moving images or 3D objects, are faced with the problem of hardware and software obsolescence. Those institutions, more often than before, have large scale datacenters implemented as the supporting facilities for their mandate operations. Accessibility and integrity of the data they preserve are obligatory requirements, sometimes followed by the requirements for authenticity, reliability and usability.[1] Although those requirements may seem easy to fulfill, it is not the case if long-term preservation perspective is taken into account. During the next 10, 30, 50 or more years of preservation of digital records, the underlying technology, upon which relies the possibility of fulfilling the mentioned set of requirements, will have to be changed several times. The question is how to achieve that as seamlessly as possible? The best solution would be that one can change the underlying technology, i.e. the lower layer, without affecting the data on the top layer. The technology which is far from a perfect preservation technology, yet offering good results, is the virtualization technology. The idea is to use virtual machines, i.e. software solutions for creation of virtual (software-based) computer(s) on one physical, modern computer. This would allow data-preserving institutions to change the actual hardware as needed to keep up with recent developments still having the obsolete systems installed and working on a virtual machine.

Emulation, to which virtualization is in some way similar, is an approach which "does not focus on the digital object, but on the hardware and software environment in which the object is rendered. It aims at (re)creating an environment in which the digital object can be rendered in its authentic form"[2]. In that sense emulators are mainly software solutions that can be installed on the current operating systems and emulate older hardware and/or software. On the positive side it is possible to run obsolete programs or read data in obsolete formats on the current hardware and software, but on the negative side emulators are written for specific hardware and software systems and can become obsolete too. Contrary to this, virtualization on the positive side:

- eliminates the influence of system upgrades on the preserved data,
- eliminates the compatibility problems of running old software on the new hardware,
- makes possible to install more than one virtual machine on a single physical machine thus enabling the possibility of having a parallel networked virtual computers environment,
- makes possible to export data from the preserved data format to other, possibly more stable, format or format which was supported by the original application and which has proved, during a period of preservation time, easier to migrate to a newer format. Such capabilities enhance the use of virtualized solutions in the environments where hybrid preservation approaches are applied.

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[1] As in: *ISO 15489-1 – Information and documentation – Records management*, 2001., 7.2.2., http://www.iso.org.

[2] Hoeven, Jeffrey van der, Wijngaarden, Hilde van, *Modular emulation as a long-term preservation strategy for digital objects*, 5th International Web Archiving Workshop (IWAW05), 23-23 September 2005, Vieanna, http://iwaw.europarchive.org/05/papers/iwaw05-hoeven.pdf (01. 09. 2011)

On the negative side this approach has similar drawbacks as the approach of maintaining original technology:

- requires trained personnel for operating obsolete systems and helping users
- as Thibodeau (2002) says, having in mind a wider problem of digital preservation, "it would cut users off from the possibility of using more advanced technologies for discovery, delivery, and analysis".

Why virtualization?

Modern datacenters and information technology systems are becoming increasingly reliant on techniques of masking physical characteristics of computing resources from the way in which other systems, applications or users access and utilize those resources. This includes a form of morphing of one physical resource (server, operating system, application or storage systems) into apparently functioning as multiple logical resources or vice versa – making physical resources appear and function as a single logical one.

Virtualization can therefore be defined as an abstraction of computing resources with the goal of simpler, more efficient and more thorough usage of information systems hardware as well as providing advanced functionalities such as high availability, automated resource distribution and organization etc.

Such virtualization systems, besides being used for server consolidation, simpler datacenter management etc., present a solid foundation for long-term data preservation systems although this is not their intended or primary purpose.

With adequate planning and appropriately defined information object for long term preservation, any of the currently available virtualization systems and infrastructures with adequate hardware background can be successfully adapted for this purpose.

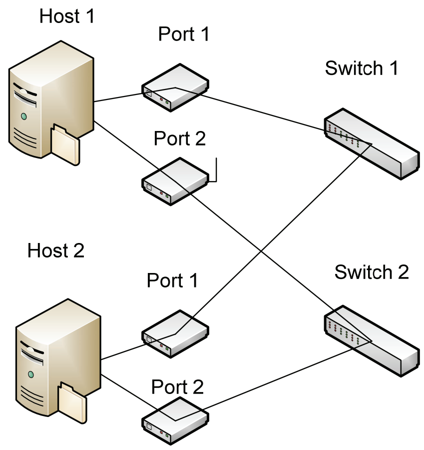
Virtualization systems in this model are only indirectly capable of preserving individual files and formats (e.g. pdf, doc, xls, zip, mp3) via "information blocks" that can include complete operating environments, virtual disks, data storage systems and similar, which are then directly accessed by the users and which offer the ability to not only access and view the data but also provide the tools necessary for their usage and manipulation.

Hardware requirements

Initially it is necessary to define the hardware requirements in which such a model can operate. Let's consider a virtual machine on a standalone virtual host. In this case, the virtual machine with all of its accompanying virtual disks and data is the information block which is intended for preservation.

Virtualization host should be equipped with redundant hard drives in order to ensure security of data in a hardware failure scenario as well as multiple failo-

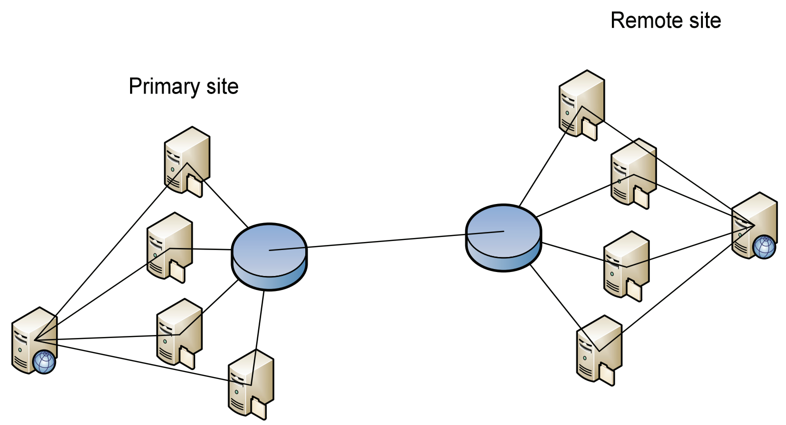
ver paths to the network interfaces and the storage system. All the connections should be interlaced as shown in Picture 1.
Such an approach allows both high availability schemes to be implemented, as well as safety mechanisms from data corruption due to hardware malfunction.



A standalone virtualization host implemented in this manner allows for the identically configured host to be added into the system, therefore allowing instantaneous transfer of all operations, managed by the virtualization software, in case of a catastrophic hardware malfunction. In order to expand the capabilities further, both hosts must have access to a central storage repository which in itself provides a hardware level redundancy on the virtual disk layer.

Picture 1: Redundancy and failover paths

All the data of the aforementioned information block, virtual machine or disk, with all the accompanying data should, in this case, be stored on the shared storage system while the virtual hosts’ internal disks should be used only for virtualization software requirements. Ability of the system to transfer the entire running operating environment from one physical hardware to another in real-time can be further expanded using the true high availability systems. They allow uninterrupted sharing of active data, thus creating a clone of the virtual environment capable of uninterrupted “takeover” of shared data access and processing.
Since recommendations regarding virtualization systems are stating that the load of each individual host within the virtualization system and all of its components should optimally be under 50% (due to the failover requirements), now that a clone of the original system has been created, a fully clustered system needs to be established. This brings the minimum required number of virtualization hosts per cluster to 4, including a shared storage system.
Implementation of any of the virtualization tools on the specified hardware and addition of a remote safety copy of the virtualization component as well as replication of the storage component is shown as a system diagram in Picture 2.



Picture 2: Fully redundant virtualization cluster with replicated storage

The key here is replication of the storage system so that, in an emergency situation, the remote location can independently take over all the operating components of the primary.

Components of virtualization systems

Virtualization systems are a collection of tools used in wide range virtualization of the information technology infrastructure which allow for a variety of advanced features in order to ensure high availability, automated resource management, monitoring, distribution and control over data usage within the system as well as many other functions.
Several virtualization tools (hypervisors) available today offer the required functionality:

1. VMWare – vSphere (ESX, ESXi), vmotion abilities in the commercial variant
2. Citrix – Xenserver 5.5+ freeware version
3. Microsoft – Hyper-V in MS Windows domain environment

The data object can now be defined as any format which can be interpreted, read, modified or acted upon in any manner allowed by the virtualization system functionalities. This can include:

- an entire virtual machine including operating system and/or desktop working environment,
- virtual disk in a format supported by the relevant hypervisor,
- data on the virtual disk via direct access to the storage system.

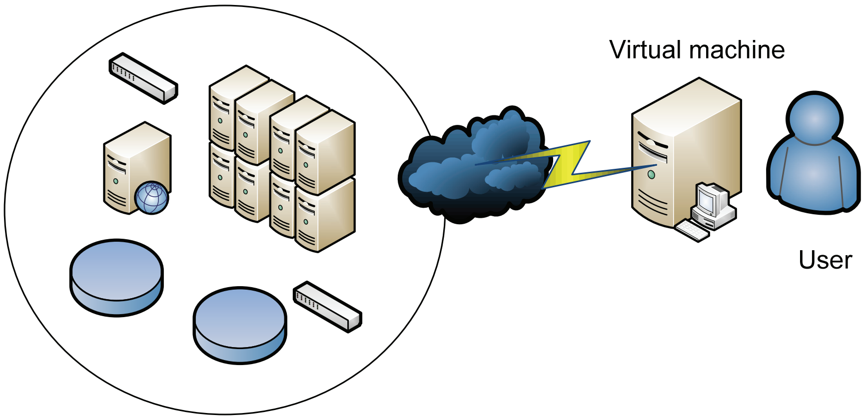
The entire virtual disk can be placed in an inactive state on the specified hardware, where, due to the multiple failover redundancy of each component, a practical indestructibility of stored data is ensured. Template or clone can contain and store such a "block", or it can be copied onto a storage system which prevents unwanted or unauthorized copying. Such a "safety" copy allows both verification of its integrity by comparing it to the identical data stored on the backup system and incorporation into a versioning system schema, where all the potential modifications are visible and directly tied to a specific user.

The most important aspect of such a model is the creation of a "infoterminal" type system where the virtual desktop environment, as well as all the data which is intended for long-term preservation, is stored with the tools and instructions necessary for viewing and operating such data. All of those elements are then grouped together into a single un-modifiable environment which utilizes all of the previously listed advantages of the virtualization cluster. In this way, the user is presented with a complete virtual interface, with all the necessary tools and physically (hardware-level) enforced integrity of the data within the central repository. The central repository allows the virtual environment to be copied but it subsequently manipulates and process the data on another location without compromising the original.

Due to the fact that the entire system is operating in a virtual environment, the number of users is theoretically indefinitely scalable. In case the number of users of a certain virtual "infosystem" is increased and the resource requirements exceed the resources allocated to a service in question, virtual environment allows for simple and even automatic resource redistribution without adverse effects on the guest virtual machine. Also, if there is a need to upgrade or format the existing system, virtualization makes it very simple to allow a parallel cohabitation of two systems. Therefore, usage of the old one can remain uninterrupted during migration to the new one. It is also possible to retain all the old formats and tools required to access legacy data in case the format migration process entails a loss of certain characteristics (e.g. forward migration from doc to docx).

Such a system, based on any of the currently available hypervisors, safeguards the data from the need of version changes or the format of the data within the virtual PC itself, since such a machine is independent from both hypervisor or hardware upgrades or any other external factors. So what is obtained is simultaneous preservation of data as well as tools required for manipulation of that data.

The user is now able to access the desired virtual environment from any location, where network access is granted to the virtualization management tools, and use personal access data through the necessary client software available for various operating environments. The background of the virtualization cloud (Picture 3) and its internal modifications, upgrades etc. do not affect the end user in any way.



Picture 3: End-user view of the virtual infrastructure

Therefore we suggest usage of virtualized systems because of at least eight situations concerning the long-term preservation of integrity and accessibility of the data:

1. Hypervisor upgrades do not affect virtualized data or machines in any way, which ensures longevity of the data in case when virtualized systems need upgrades.
2. Modern storage systems, with implied regular maintenance, practically guarantee a 100% safety from data loss or corruption in long term-data preservation due to the fact that the data is not affected in the case of hardware component malfunction. Additionally, hardware can be upgraded and replaced without either disrupting normal operation of the entire system or the integrity of the data it preserves.
3. If upgrades of the storage system are required, hypervisors offer the ability for data migration from one storage unit to another while maintaining data integrity and real-time functionality of the entire infrastructure.
4. Incorporation of the solid state drives (SSD) in the system, which possess no movable components, will further increase safety of the stored data.
5. Virtualization methods of creating backup copies on the virtual disk layer, or having the entire dataset stored in the virtual machine offer a redundant mechanism for data loss prevention, thus fortifying the preservation process.
6. Hypervisors offer the ability of storing as well as using old formats and systems without the need of software upgrades and without adverse effects of hardware upgrades, while maintaining a low cost of upkeep for old or obsolete technologies.

7. Backwards compatibility is ensured because new versions of the hypervisor implicitly support all of the previously supported variants of operating systems.
8. The ability to create templates and store the entire operating environments as well as to ensure their integrity through authorization and authentication mechanisms of virtualization systems adds to the stability of the long-term preservation process.

It can appear that the described systems are expensive or inaccessible to smaller or financially weaker institutions. However, many modern datacenters are already, in one way or the other, moving towards being virtualization compatible, for the reasons of maintenance cost reduction as well as better utilization of existing resources and infrastructure, many of which can support the desired virtualization tools in freeware versions, therefore incurring no additional cost.

Furthermore, due to the extensive flexibility of such systems, with an adequate network infrastructure, it is possible to share resources between institutions or to host external services, thus making it unnecessary for all institutions to own all the components of the discussed model. Instead, the resources can be shared for financial compensation, decrease of the maintenance costs, or by some other arrangement. This is in accordance with the OAIS RM suggestion for technical level of interaction between OAIS archives, i.e. for creation of archives with shared functional areas. This means that "each archive can serve totally independent communities (...). However, for the common storage element to succeed, standards are needed at the internal Ingest-storage and Access-storage interfaces."[3]

Interchange of materials, as well as complete viewers of data between institutions is in this way reduced to the procedure of copying the virtual disk, or merely allowing access to the intended user.

Conclusion

Successful long-term preservation of digital data depends on the ability to safely store, maintain integrity over extended periods of time, and ultimately allow changes of underlying technology while retaining accessibility of the digital data which is being stored and preserved. With recent advances in virtualization technologies, tools have been developed that allow all of these goals to be achieved in relatively small or low-cost environments depending on the size and scope of the digital data in question.

Although primarily targeted at allowing the hardware consolidation, creation of affordable high-availability systems as well as easier-to-administer datacenter system, virtualization has brought with it the ability to logically detach com-

[3] *Rerefence Model for an Open Archival Information System (OAIS)*, Blue Book (CCSDS 650.0-B-1), Consultative Committee for Space Data Systems, NASA, Washington, DC, SAD, January 2002, pp. 6-7, http://public.ccsds.org/publications/archive/650x0b1.pdf (15. 03. 2011)

plete "self-sustained" software environments, which include operating systems, applications and the digital data of any format or type, from the hardware and/or software on which it depends.

Therefore we are suggesting the usage of the virtualization systems, and all their advanced functionalities, to collectively save the digital data intended for preservation, their operating environment, and all the tools needed for access, intended and allowed modification and usage of the data. The data will stay preserved regardless of the future changes of format, type, software capabilities and compatibilities as well as other problems present in the long-term preservation of digital data.

Furthermore, implicit high-availability and storage functionality of the virtualization systems both safeguards data integrity and ensures accessibility regardless of hardware failures and underlying technology modifications, upgrades and/or adjustments. Considering the fact that virtualization systems are increasingly becoming a common component of medium-scale or even small-scale datacenters, they are a logical and effective way of applying the existing technology mechanisms in achieving, often complex, long-term data preservation goals.

Further research

Taking into account long-term preservation of digital data, virtualization techniques prove to be good solution for the period of time longer than the expected life-span of the standard digital preservation media. Virtualization will prove efficient for the data frozen in time and for testing and making migration procedures easier and more transparent. Nevertheless, there are some data, e.g. results of certain experiments, measurements etc., that will need to be used for future analysis. In some cases emulators will be needed in order to achieve the original functionality since standards and protocols will eventually change. Further research is planned on the role and possibilities of using emulators along with virtualized systems for extension of the periods during the long-term preservation process in which both the preserving institutions and users could be sure that the integrity of the data is preserved and that the data are accessible, usable and reliable.

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