

Compute and servers

IT infrastructure

What is virtualization?



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What is virtualization?

Virtualization is a technology that enables the creation of virtual environments from a single physical machine, allowing for more efficient use of resources by distributing them across computing environments.

Using software, virtualization creates an abstraction layer over computer hardware, dividing a single system's components such as processors, memory, [networks](#) and storage into multiple [virtual machines \(VMs\)](#). Each VM runs its own [operating system \(OS\)](#) and behaves like a separate physical computer, despite sharing the same underlying hardware.

Today, virtualization is a fundamental practice in enterprise IT architecture and a key enabler of [cloud computing](#). It allows cloud service providers (CSPs) such as IBM Cloud®, Microsoft Azure, Google Cloud and Amazon Web Services (AWS), to optimally utilize their [IT infrastructure](#) to deliver scalable resources. For businesses, this means they only purchase the computing resources they need and then scale them cost-effectively as their [workloads](#) grow, maximizing their investment.

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The evolution of virtualization

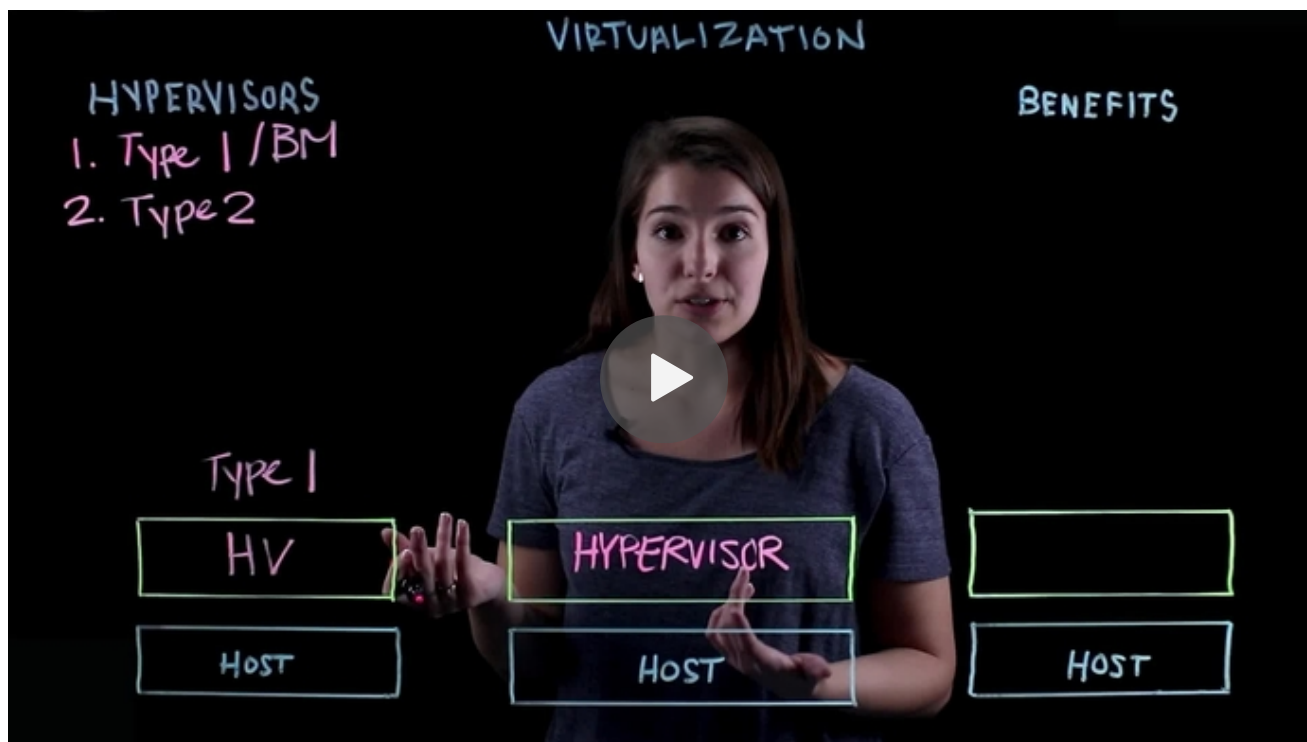
The emergence of virtualization technology dates back to 1964 when IBM launched CP-40, a time-sharing research project for the [IBM System/360](#). CP-40 later evolved into CP-67, which ultimately influenced Unix, one of the first multi-user, time-sharing operating systems that set the stage for modern virtualization technologies like virtual machines. In 1972, IBM announced its first official virtual machine product, [VM/370](#), for the System/370.

In 1998, [VMware](#) developed a x86 operating system that enabled a single machine to be segmented into several virtual machines, each running its own operating system. In 1999, VMware launched Workstation 1.0, the first commercial product that allowed users to run multiple operating systems as virtual machines on a single PC. This product became popular among software developers due to its ability to easily test and develop applications in different OS environments.

According to a forecast from The Business Research Company, the virtualization software market will grow from USD 85.83 billion in 2024 to USD 100.19 billion in 2025 at a compound annual growth rate (CAGR) of 16.7%.¹

Advancements in [edge computing](#), [containerization](#), [hybrid cloud](#) and [multicloud](#) adoption, increasing focus on security, and compliance are driving this growth. Other emerging trends contributing to the virtualization marketplace include the integration of the [Internet of Things \(IoT\)](#), [artificial intelligence \(AI\)](#) and [machine learning \(ML\)](#).





Virtualization Explained (5:20 min)

Benefits of virtualization

Virtualization offers numerous benefits to both on-premises and cloud-based [data centers](#) that support IT operations, including the following:

- Resource efficiency
- Easier management
- Minimal downtime
- Faster provisioning
- Disaster recovery (DR)
- Cost-effectiveness

Resource efficiency

Before virtualization, each application server, setting up a separate server for every application. This approach,

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ff allocated a dedicated physical [central processing unit](#) (C

which favored one application and one operating system per computer, was adopted for its reliability. However, each physical server would often be underutilized.

In contrast, server virtualization allows you to run multiple applications, each with its own VM and OS on a single [physical server](#) (typically an x86 server) without sacrificing reliability. This capability maximizes the use of the physical hardware's computing capacity and optimizes resource utilization.

Easier management

Replacing physical computers with software-defined VMs makes managing and enforcing policies via software easier. This enables the creation of automated IT service management workflows. For example, automated deployment and configuration tools allow administrators to define virtual machines and applications as services in software templates, which they can consistently deploy without manual setup.

Additionally, virtualization security policies can enforce security configurations based on the role of the virtual machine. These policies can also increase resource efficiency by decommissioning unused virtual machines, saving space and computing power.

Minimal downtime

OS and application crashes can result in downtime, disrupting user productivity. Virtualization allows administrators to run multiple redundant VMs alongside each other and failover between them when problems occur. Running multiple redundant physical servers would be far more costly.

Faster provisioning

Setting up hardware for each application can be time-consuming. However, if the hardware is already in place, [provisioning](#) virtual machines to run applications is significantly faster. VM management software can now automate this process, streamlining workflows.

Disaster recovery (DR)

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Virtualization optimizes [disaster recovery](#) by enabling quick restoration of services with

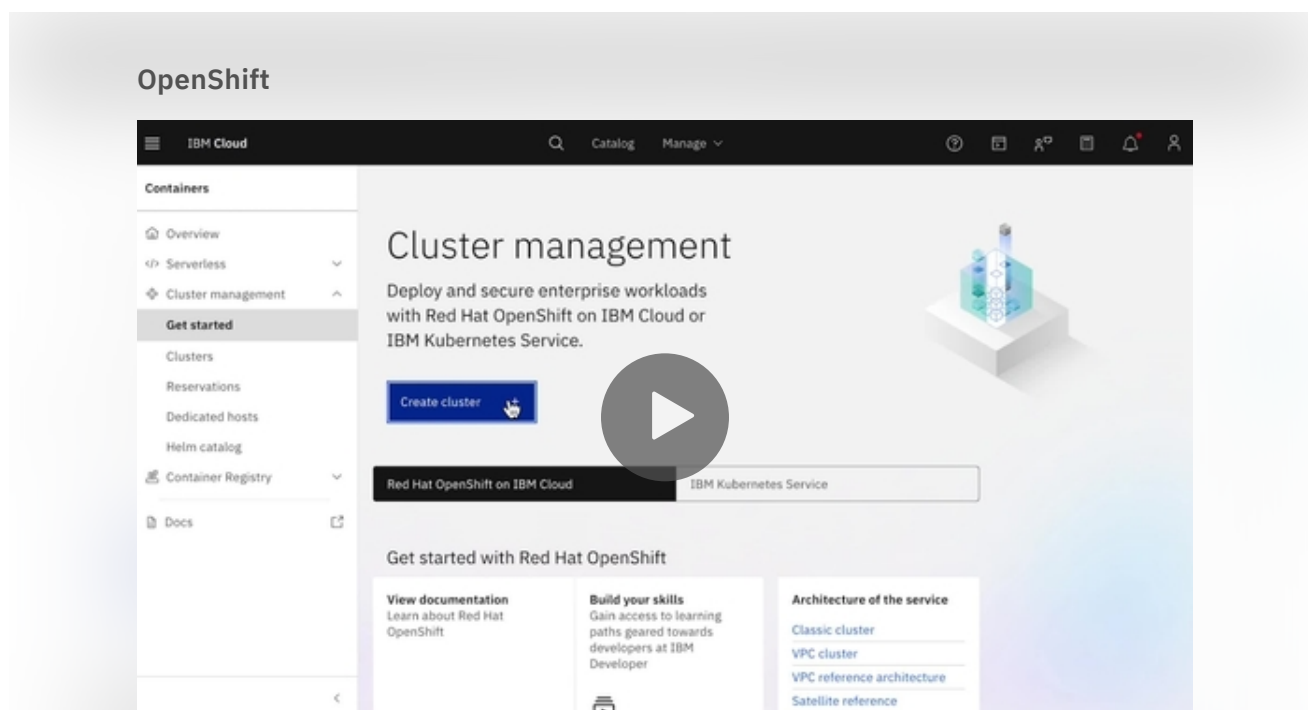


minimal downtime. Since virtual machines can be easily moved, replicated or backed up, restoring systems to operational status is faster and more efficient compared to traditional physical servers.

Cost-effectiveness

Virtualization helps reduce hardware acquisition, maintenance and energy consumption costs. Consolidating physical servers into virtual machines reduces the need for additional hardware, saving both capital and operational expenses.

For a more in-depth look at the benefits of virtualization, see “[5 Benefits of Virtualization.](#)”



Modern Virtualization with Red Hat OpenShift on IBM Cloud

Learn how Red Hat OpenShift on IBM Cloud empowers developers to securely deploy, manage and scale containerized applications on cloud. This video gives an overview of its integration to IBM Cloud.

[Explore OpenShift on IBM Cloud](#) →

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The main components of virtualization

Virtualization relies on several key components to create and manage virtual environments. Each plays a vital role in ensuring the effective allocation of resources so multiple VMs can run simultaneously without interference.

- Physical machine (server/computer)
- Virtual machine (VMs)
- Hypervisor

Physical machine (server/computer)

The physical machine, also referred to as the “host machine” is the hardware (e.g., server or computer) that provides CPU, memory, storage and network resources for the virtual machines.

Virtual machine

A virtual machine (VM) is a virtual environment that simulates a physical computer in software form. VMs are usually referred to as guests, with one or more “guest” machines running on a host machine.

Virtual machines typically consist of several files, including the configuration, storage for the virtual hard drive and other dependencies. By sharing system resources among virtual machines, virtualization offers on-demand scalability, efficiency and cost savings.

Hypervisors

A [hypervisor](#) is the software layer that coordinates VMs. It serves as an interface between the VM and the underlying physical hardware, ensuring that each has access to the physical resources it needs to execute. It also makes sure that the VMs don't interfere with each other by impinging on each other's memory space or compute cycles.

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There are two types of hypervisors:



- **Type 1 hypervisors:** Type 1 or “bare-metal” hypervisors interact with the underlying physical resources, replacing the traditional operating system altogether. They most commonly appear in [virtual server](#) scenarios in which a software-based server is created by partitioning a physical server into smaller, self-contained segments, each capable of running its own operating system and applications.
- **Type 2 hypervisors:** Type 2 hypervisors run as an application on an existing OS. Most commonly used on endpoint devices to run guest operating systems, they carry a performance overhead because they must use the host OS to access and coordinate the underlying hardware resources.

Type 2 hypervisors

Type 2 hypervisors run as an application on an existing OS. Most commonly used on endpoint devices to run alternative operating systems, they carry a performance overhead because they must use the host OS to access and coordinate the underlying hardware resources.

Types of virtualization

Beyond server virtualization, many different types of IT infrastructure can be virtualized to deliver significant advantages to IT managers in particular and the enterprise as a whole. These types of virtualization include the following:

- Desktop virtualization
- Network virtualization
- Storage virtualization
- Data virtualization
- Application virtualization
- Data center virtualization

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- GPU virtualization
- Linux virtualization
- Cloud virtualization

Desktop virtualization

[Desktop virtualization](#) lets you run multiple desktop operating systems, each in its own VM on the same computer.

There are two types of desktop virtualization:

- **Virtual desktop infrastructure:** [Virtual desktop infrastructure \(VDI\)](#) runs multiple desktops in VMs on a central server and streams them to users who log in on thin client devices. In this way, VDI lets an organization provide its users access to various operating systems from any device (e.g., laptop, desktop computer), without needing to install the OS locally on each device.
- **Local desktop virtualization:** Local desktop virtualization runs a hypervisor on a local computer, enabling the user to run one or more additional operating systems on that computer and switch from one OS to another as needed without changing anything about the primary OS.

For more information on virtual desktops, check out “[What is desktop as a service \(DaaS\)?](#)”

Network virtualization

Network virtualization uses software to create a “view” of the network that an administrator can use to manage the network from a single console. It abstracts hardware elements and functions (e.g., connections, switches, routers) and abstracts them into software running on a hypervisor. The virtual network administrator can modify and control these elements without touching the underlying physical components, which dramatically simplifies [network management](#).

Types of network virtualization include:
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- **Software-defined networking (SDN):** The network architecture approach [software-defined networking](#) virtualizes the hardware that controls network traffic routing. It does this through a centralized platform called the control plane, which helps manage IT infrastructure and direct network traffic.
- **Network function virtualization:** Network function virtualization virtualizes one or more hardware appliances that provide a specific network function (e.g., firewall, [load balancer](#), traffic analyzer), making those components easier to configure, provision and manage.

Storage virtualization

Storage virtualization enables all the storage devices on the network, whether they're installed on individual servers or stand-alone storage units, to be accessed and managed as a single storage device. Specifically, storage virtualization consolidates all blocks of storage into a single shared pool from which they can be assigned to any VM on the network as needed. Storage virtualization makes it easier to provision storage for VMs and makes maximum use of all available storage on the network.

Cloud service providers rely on storage virtualization to offer [cloud storage](#) services, including [block storage](#), [object storage](#) and [file storage](#).

Data virtualization

Modern enterprises store data from multiple applications by using multiple file formats in numerous locations, ranging from the cloud to on-premises hardware and software systems. Data virtualization lets any application access all that data, irrespective of source, format or location.

Data virtualization tools create a software layer between the applications accessing the data and the systems storing it. The layer translates an application's data request or query as needed and returns results that can span multiple systems. Data virtualization can help break down data silos when other types of integration aren't feasible, desirable or affordable.

Application **virtualization**

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Application virtualization runs application software without installing it directly on the user's OS. This technology differs from complete desktop virtualization because only the application runs in a virtual environment, the OS on the end user's device runs as usual.

There are three types of application virtualization:

- **Local application virtualization:** In this case, the entire application runs on the endpoint device, however it runs in a runtime environment instead of on the native hardware.
- **Application streaming:** With application streaming, the app lives on a server that sends small software components to run on the end user's device when needed.
- **Server-based application virtualization:** Here, the application runs entirely on a server that sends only its user interface to the client device.

Data center virtualization

[Data center](#) virtualization abstracts most of a data center's hardware into software, effectively enabling an administrator to divide a single physical data center into multiple virtual data centers for different clients.

Each client can access its own infrastructure as a service (IaaS), which would run on the same underlying physical hardware. Virtual data centers offer an easy on-ramp into cloud-based computing, letting a company quickly set up a complete data center environment without purchasing infrastructure hardware.

CPU virtualization

Central processing unit (CPU) virtualization is the fundamental technology that makes hypervisors, virtual machines and different operating systems possible. It allows a single CPU to be divided into multiple virtual CPUs for use by multiple VMs.

At first, CPU virtualization was entirely software-defined, but many of today's processors include extended instruction sets that support CPU virtualization, which improves VM performance.

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GPU virtualization

A [graphical processing unit \(GPU\)](#) is a special multi-core processor that improves overall computing performance by taking over heavy-duty graphic or mathematical processing. GPU virtualization lets multiple VMs use all or some of a single GPU's processing power for faster video, AI and other graphics- or math-intensive applications.

The two main types of GPUs in virtualized environments are:

- **Pass-through GPUs:** These GPUs make the entire GPU available to a single guest OS.
- **Shared vGPUs:** Shared vGPUs divide physical GPU cores among several virtual GPUs (vGPUs) for use by server-based VMs.

Linux virtualization

[Linux](#) includes its own hypervisor, the [kernel](#)-based virtual machine (KVM), which supports Intel and AMD's virtualization processor extensions to create x86-based VMs from within a Linux host OS.

As an [open source](#) OS, Linux is highly customizable. You can create VMs running versions of Linux tailored for specific workloads or security-hardened versions for more sensitive applications.

Cloud virtualization

By virtualizing servers, storage and other physical data center resources, cloud computing providers can offer a range of services to customers, including the following:

- **Infrastructure as a service (IaaS):** The delivery model [IaaS](#) provides a virtualized server, storage, and network resources you can configure based on their requirements.
- **Platform as a service (PaaS):** The [PaaS](#) service model offers virtualized development tools, databases and other cloud-based services that you can use to build your own cloud-based applications and solutions.

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– **Software as a service (SaaS):** [Software as a service](#) refers to applications hosted on the



cloud. SaaS is the most widely used cloud-based service.

To learn more about these cloud service models, check out our topics page: [“IaaS vs. PaaS vs. SaaS.”](#)

Virtualization versus containerization

Server virtualization reproduces an entire computer in hardware, which then runs an entire OS. The OS runs one application. That’s more efficient than no virtualization at all, but it still duplicates unnecessary code and services for each application you want to run.

Containers take an alternative approach. They share an underlying OS kernel, only running the application and its dependencies, such as software libraries and environment variables. This feature makes [containers](#) smaller and faster to deploy.

Check out the blog post [“Containers versus VMs: What’s the difference?”](#) for a closer comparison.

This video, “Containerization Explained”, breaks down the basics of containerization and how it compares to virtualization through VMs.



Virtualization and security

Virtualization offers numerous security benefits. For example, VMs infected with [malware](#) can be rolled back to a point in time (called a snapshot) when the VM was uninfected and stable; they can also be more easily deleted and re-created. You can't always disinfect a non-virtualized OS because malware is often deeply integrated into the core components of the OS, persisting beyond system rollbacks.

Security features for protecting VMs and their underlying physical hardware include access controls, regular updates, network segmentation and [encryption](#). Additionally, software-based security solutions provide virtual machine monitoring tools that address compliance, provide real-time threat detection and more.

Virtualization marketplace solutions

Numerous companies offer specialized virtualization solutions tailored to different use cases, including server, desktop and application virtualization. Below are some of the most prominent solutions in the marketplace:

- **VMware:** A leader in server, desktop, network and storage virtualization, VMware is renowned for its reliability and feature-rich tools. Its ESXi hypervisor, in particular, has been widely adopted in enterprise environments.
- **Oracle VirtualBox:** Oracle VirtualBox is an open-source desktop virtualization platform, a popular choice for individuals and small businesses looking to run multiple operating systems on a single machine.
- **Citrix:** Known for its strength in application virtualization, Citrix also offers server and virtual desktop solutions, providing a platform for organizations that need remote access and centralized app delivery.
- **Microsoft Hyper-V:** Built into Microsoft Windows, Hyper-V offers a cost-effective server and desktop virtualization product.
- **Red Hat Virtualization:** Built on KVM, Red Hat Virtualization provides an enterprise server and desktop virtualization with a focus on open-source platforms.





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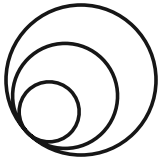


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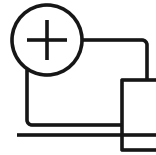




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