The future is *virtually* here

Image credit: NASA Ames Research Center (Donald E. Davis)

Visions of the future have often included some virtual experience or other. In *The Matrix* Neo grapples with an immense virtual reality computer. The crew of *Star Trek's USS Enterprise* dine on virtual food from a replicator. A police officer receives a virtual personality in *RoboCop*. Arnold is provided with virtual memories in *Total Recall*.

But much of that virtual future is already here. *Virtual* is associated with shopping, signatures, networks, keyboards, call centers, computers, software, documents, communities, guitars, libraries—even pets.

So what does it mean to be "virtual"? This question has confounded philosophers for centuries. Where does reality end and virtuality begin? Today, technology has provided new ways to blur the distinction, with marketers adopting the word *virtual* as if it were synonymous with *new*.

The language of the virtual often folds in upon itself, meaning one thing from a certain perspective and something else from another. With that in mind, let's take a closer look at how the modern world is going *virtual*.

Virtual memory

The move to virtualization in cyberspace may have started in the early 1960s with the introduction of virtual memory. Until then, computers relied on physical memory, where data resides with its own contiguous address. With virtual address space (VAS) an application thinks it has a dedicated address, when in fact it can be fragmented across the hard drive and even partly in disk storage.

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The Burroughs B5000, released in 1961, was the first commercial computer to use virtual memory. Today, general purpose operating systems all rely on virtual memory techniques to run most applications.

Virtual machines

For the software engineers and programmers who are crafting much of the virtual future, the virtual machine (VM) lies at the core of their creations. Just as the term *virtual machine* implies, a VM works like a physical machine, but without the physical machine hardware.

VMs can be used to run multiple operating systems on a single computer. A software application such as Microsoft Word or Adobe Photoshop needs an operating system (OS) to serve as interpreter for the computer hardware it's running on. Typically a computer can run only one OS at a time. But by directing traffic through a virtual machine monitor (VMM), or *hypervisor*, an operating system such as VMware or Virtual PC creates *virtual machines* on the same computer. Each VM can trick an operating system into thinking it's running on dedicated hardware.

IBM launched VM technology in 1972 with the VM/370. The first virtual machines were designed for mainframe computers to test operating systems for hardware that had not yet been developed. Later, mainframe VMs were also used for partitioning resources and running legacy software on newer hardware versions. Over the years, the technologies behind computer virtualization have grown increasingly sophisticated, extending VM capabilities to personal computers (PCs) and servers.

Virtual PCs

At the PC level, virtualization can boost productivity and reduce overhead. VMs running on a single workstation provide access to a suite of different software applications and devices that would otherwise require dedicated hardware.

Working from a virtualized desktop can also be handy. For example, a computer user can instantly switch between Linux-based applications and Mac OS software. Or different versions of Windows can be run simultaneously for testing software.

Virtual servers

A virtual private server (VPS) does for a network server what a virtual machine does for a PC. Each VPS, sometimes referred to as a virtual dedicated server (VDS), can run its own operating system, and each server can be independently rebooted.

By using VPS software such as Xen or OpenVZ, the server administrator can partition a single physical server into hundreds of virtual environments. Consolidating servers on a single VPS platform can cost less than maintaining multiple dedicated servers due to less hardware and support, fewer software licenses, reduced cooling requirements, and lower power consumption. For many organizations these cost benefits more than offset any accompanying performance loss.

A VPS platform can also be used to safeguard network resources. For example, the system administrator can set up a sandbox on an isolated copy of the

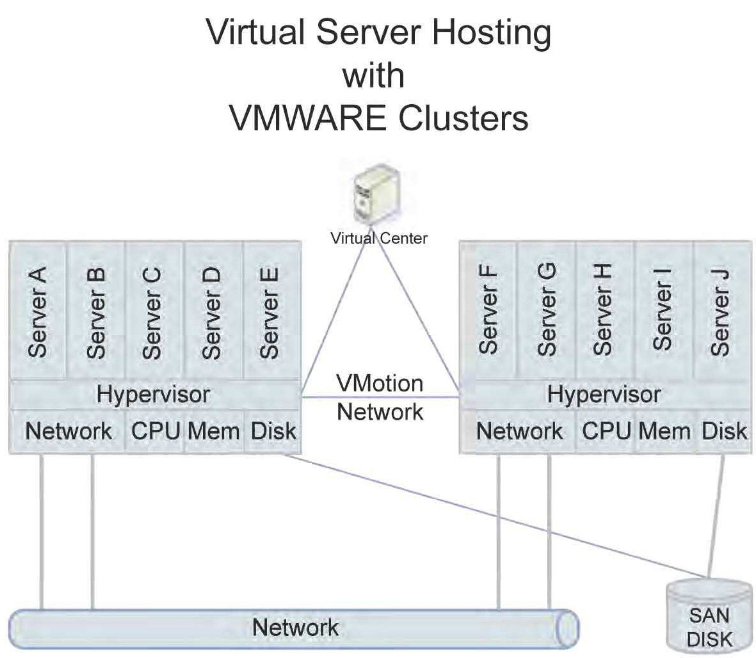


Image credit: *Washington State Department of Information Services* operating system, running on a VPS, to test software updates before deploying them. A VPS can also be turned into a *honeypot*, designed to attract and identify users with malicious intentions.

Java Virtual Machine

Sun Microsystems developed the Java Virtual Machine (JVM) as a way to make Java a "universal language." The product slogans *Write once, run anywhere* (WORA) and *Write once, run everywhere* (WORE) sum up the intended benefits of Java Language.

A JVM creates a virtual machine in a run-time environment to execute Java-based computer programs and scripts. The JVM, which is the instance of the Java Runtime Environment (JRE), comes into action when a Java program is executed. The instance is then deleted after the code has executed.

Virtual networks

Virtual networks offer more configuration options than physically wired networks. Virtualization software such as VMware and Microsoft's Virtual Server replace physical switches and network adapters with software equivalents.

By using a virtual network, virtual machines can access the host operating system, local network resources, external network resources such as the Internet, and other virtual machines. Virtual networks make it possible for departments in an organization to share documents, international teams of engineers to collaborate on projects, and employees to work from home.

Departments in an organization can be assigned separate logical networks on a single server through a virtual local area network (VLAN). The IEEE 802.1Q standard sets guidelines for creating multiple bridged networks to share the same physical network link without risk of leaking information between networks.

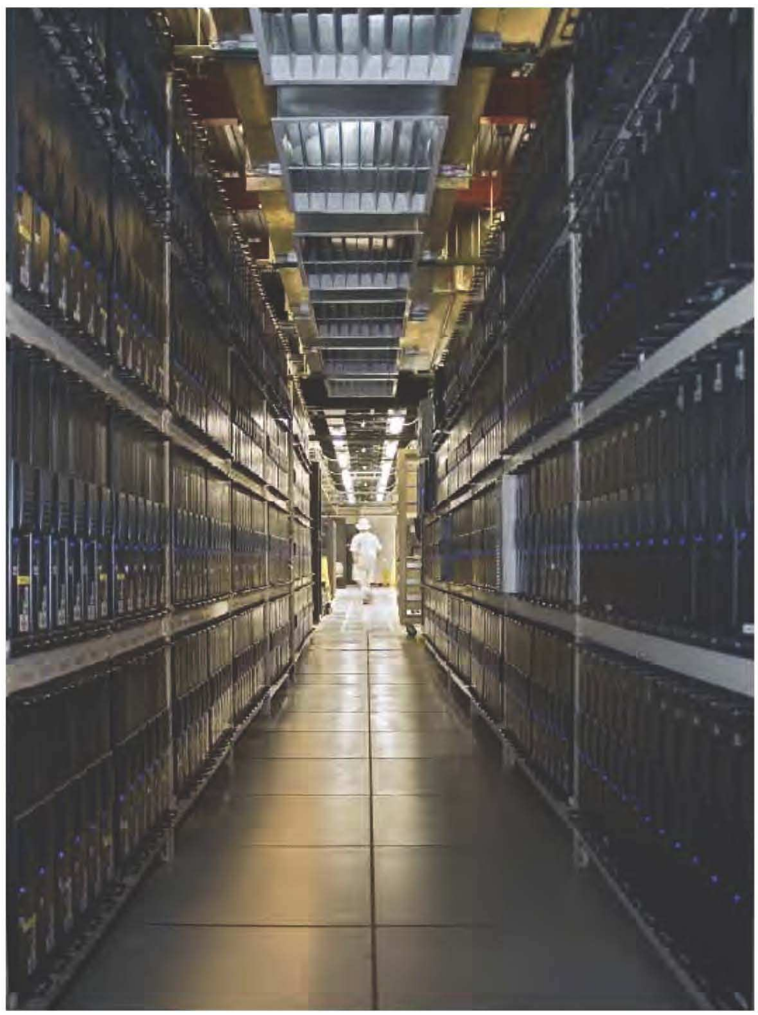
VC describes another way to look at virtual networks for computing and telecommunications. The "V" in VC, of course, stands for "virtual." The "C," on the other hand, can represent the word *circuit, connection,* or *channel* while still meaning the same thing.

A virtual circuit typically is set up when a call is initiated and then terminated after data has been passed from one user to another. A VC can be provided at the transport layer, as with Transmission Control Protocol (TCP). At the network layer and datalink layer where data always is delivered over the same path, a VC can be set up permanently for a dedicated link.

A permanent virtual circuit is also called a *virtual private network*, or VPN. With a VPN users communicating with each other have what appears to be an exclusive VC, even though other users may be sharing the same circuit at the same time. The VPN uses link-layer protocols to *tunnel* through other larger networks such as the Internet. A VPN uses encryption to assure secure communications across the network.

Virtual supercomputers

Cluster computing and multiprocessor computing evolved out of the need for



The "Kaon" virtual supercomputer in the Fermilab Lattice Computing Center runs on a cluster of 600 units connected by a high-speed network. Kaon is used to help physicists better understand particle behavior.
Image credit: *Fermilab*

more computing power and the ability to make resources work in parallel. Packet switching networks, designed to meet this need, led to the development of the ARPANet. By linking four computer centers in 1969, ARPANet established the design model for future computer clusters, and ultimately the Internet.

Computer clusters are inherently harder to program than individual computers. The breakthrough for cluster computing came with the release of PVM (parallel virtual machine) open-source software in 1989. PVM software, based on TC/PIP communications, made it possible to instantly link individual computers to form a virtual supercomputer.

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NASA attempted to use PVM parallel processing libraries for its Beowulf high-performance computer, built in 1994. Beowulf clusters have come to describe any group of commodity computers networked into small TCP/IP networks and running a Free and Open Source Software (FOSS) Unix-like operating system such as BSD, Linux, or Solaris.

Free-form heterogeneous clusters of inexpensive computers quickly rivaled expensive mainframe supercomputers on standard throughput, measured in floating operations per second (FLOPS). Such "virtual supercomputers" show up consistently on the Top500 list of supercomputers. In the November 2008 Top500 rankings, cluster architecture accounted for 82 percent of the winners.

Cluster architectures were quickly adapted to create networks of personal computers located anywhere in the world. Distributed computing, otherwise known as *grid computing*, is powering projects that are able to enlist the computing power of tens of thousands of personal computers worldwide to create virtual supercomputers. Global grid computing efforts are now underway to simulate protein folding (Folding@home), sift through data from the Large Hadron Collider (WLCG), study how diseases spread through the body (BRaTS@home), and search for extraterrestrial intelligence (SETI@home).

The power of cluster computing is also available from "the cloud," where virtualization has taken on new meaning. Amazon's Elastic Compute Cloud (EC2) makes it possible for subscribers to harness the raw computation and mathematical processing power of as many machines as the company has available.

Virtual services

Cloud computing, also called *utility computing*, is steadily gaining market share as a way to access computing services. Analysts at Gartner, Inc. project that by 2011, 30 percent of consulting and systems integration revenue will be delivered via cloud computing. Cloud technology can provide solutions for hardware as a service (HaaS), software as a service (SaaS), and platform as a service (PaaS).

At the hardware level, cloud computing refers to the virtualization of the data center. A user who goes to the cloud for HaaS doesn't know which physical machines are used to host applications or store data. For managed service, HaaS transfers ownership and maintenance costs from a business to the managed service provider (MSP). In a grid computing context, HaaS allows access to the infrastructure and CPU of a single provider to concentrate the resources of many commodity computers.

Some users are turning to SaaS for software applications, doing away with the need for owing licenses to many of the various products they use. Cloud vendors such as Salesforce.com also let users purchase and add frequently used third-party applications to the cloud.

Vendors that offer PaaS provide an integrated platform to build, test, and deploy custom applications. For example, Amazon gives developers root privileges for any development technology that runs in the Amazon Machine Image (AMI).

Other services are available through the cloud, as well. These include providers of data as a service and storage as a service.

The *aaS family of services seems virtually limitless.

NASA's 2008 Future Forum used Second Life for off-site attendees to participate virtually.
Image credit: *NASA Ames Research Center / Dominic Hart*

Virtual communities

People in increasing numbers are turning to the Internet to form relationships based on common interests instead of proximity. Cloud computing is making it easier to establish virtual communities for business and education, but social networks are leading the way.

The rapid rise in popularity of social networks such as YouTube, Facebook, and MySpace took many sociologists by surprise. According to a 2008 Harris survey of people who were recently married, more of them met online—19 percent—than at work or through friends. Online matchmaking services now attract over 20 million visitors a month. Personal photographs also abound, with five thousand images loaded on Flickr every minute. People are freely sharing their opinions online, as well. Blogs now accompany almost every major web site and have become a central feature of many news services.

The momentum in the direction of virtual social networks is steadily increasing. Virtual translation services have helped to extend the reach of many social networks by improving the accuracy of real-time translations for a growing number of languages. As language barriers fall, virtual communities are crossing national boundaries to reach global audiences.

Virtual worlds

Science fiction fans have been anticipating the arrival of virtual worlds since the 1970s. A forerunner of the holodeck, a playroom for interacting with virtual actors in a virtual setting, was introduced in *Star Trek: The Animated Series* in 1974. That was the same year *Maze War* was first played on ARPANET, launching the virtual world genre of video games.

Millions of gamers around the world are intimately familiar with the virtual worlds of *Everquest, World of Warcraft*,

The Berkeley Lower Extremity Exoskeleton (BLEEX) helps lighten the load for the human user.
Image credit: *UC Berkeley*

and *SimCity*. As processing power increases and graphics engines improve, these interactive environments are becoming indistinguishable from *real* settings.

The *metaverse*, a term coined in Neil Stephenson's 1992 cyberclassic *Snow Crash*, may have come of age in 2003 with the launch of *Second Life*. Parent company Linden Lab made the *Second Life* client open source in January 2007, paving the way for more virtual world development by organizations that have been especially wary of security issues.

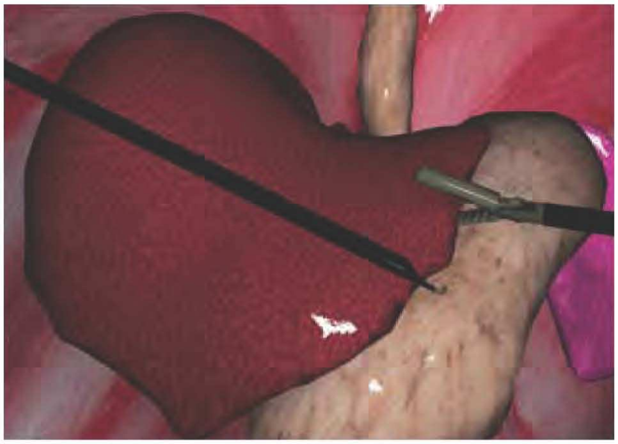
The metaverse is home to virtual shopping malls, lecture halls, corporate offices, and social clubs. *Second Life* already boasts over 16 million residents. Over the next few years, Web 3.0 is expected to usher in the wide-spread adoption of virtual 3D worlds in the next generation of the Internet.

Virtual humans

From the earliest cave drawing of a hunter and the first stick doll, virtual humans have been a part of culture. Today, CGI (computer generated image) animation is creating virtual humans that can pass as real on the silver screen. Virtual actors have already landed leading roles in feature films such as *Beowulf* and *Tomb Raider*, delivering disturbingly convincing performances.

Avatars, the characters that represent players in a game, make it possible to interact in real time within a virtual world. Many avatars can be customized with amazing detail. Non-player characters (NPCs), those generated by the computer, also take part in the game. As artificial intelligence (AI) improves, it is becoming increasingly difficult to distinguish NPCs from player avatars. With the addition of mature holographic technologies, it may one day be hard to tell 3D avatars apart from flesh-and-blood creatures!

People and technology are also converging in what some futurists have called *transhumanism*. Already, mind-controlled joysticks and neural implants are available as computer input devices, and living brain tissue is being used to build logic circuits and drive self-learning systems. The time may not be far off that guidelines will be needed for classifying "cyborgs"—mechanically enhanced people—as either machine or human.



Virtual laparoscopic instruments controlled by the surgeon move the liver, allowing the surgeon to practice the procedure with limited visibility and, perhaps, changing tissue response.
Image credit: *National Institute of Health*

"FutureFlight Central" is a full-scale virtual airport control tower at NASA Ames Research Center, Moffett Field, CA. The facility is designed to test - under realistic airport conditions and configurations - ways to solve potential air and ground traffic problems at commercial airports.
Image credit: *NASA Ames Research Center*

Virtual reality

The virtual world is finding its place in the physical world—literally. The global positioning system (GPS) makes it possible to precisely identify on a map the location of a feature or a person. Google Earth is providing a "street view" of nearly every city in the United States, and other countries are quickly being added to the list. By "driving" through a neighborhood, it is possible to see what model car is parked in front of someone's house or if the newspaper had been picked up.

Virtual reality games are already using GPS information to merge the physical world with virtual images. In Human Pacman players don special headsets that project images of Pac-Man figures on a visor. A GPS device tracks the player's location while a combination of Bluetooth, WiFi, infrared, and other technologies are linked by a central computer system to manage the game. When the player enters a target zone, the system displays the appropriate characters superimposed on the physical landscape.

Similar technologies are used for military combat training, where soldiers walking through a mock village encounter projected images that only they and their teammates can see and interact with.

Plans are underway in several cities to make entire neighborhoods WiFi enabled. By coupling WiFi connectivity with strategically place RFID (radio frequency identification) devices, for someone wearing headup display goggles a stroll down main street could resemble a walk through Roger Rabbit's Toontown.

The *virtual* future—the *real* present

Virtual technologies are changing how we work, how we communicate, how we socialize, and how we live. They are also changing how we view reality. As the virtual and the real grow ever closer together, new possibilities present themselves in ways we haven't even imagined.

The answer to the age-old question, "What is real?" has changed numerous times over human history. And that answer is certain to change again when we confront the future. As the cutting-edge of technology is blunted by familiarity, the new grows old and the virtual becomes more real.