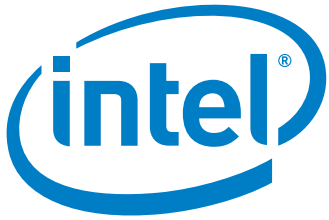

White Paper

Intel Information Technology

Computer Manufacturing

Client Virtualization

Developing an Enterprise Client Virtualization Strategy

Intel IT is investigating virtualization because it has the potential to transform client computing, reducing total cost of ownership (TCO) and increasing IT control while giving users more flexibility. However, because client virtualization embraces multiple rapidly evolving technologies, it can be difficult to identify the optimum long-term adoption strategy. Intel IT studies showed that OS and application streaming is the next evolutionary step for rich clients, OS virtualization is promising, new PC hardware can overcome performance concerns, and virtual containers are an important long-term direction. We are planning larger trials of streaming and continue to analyze developments in client virtualization.

John Dunlop, Intel Corporation

September 2008

IT@Intel

Executive Summary

Intel IT has identified virtualization as a way to potentially transform client computing by reducing total cost of ownership (TCO) and increasing control over the client environment while giving users more flexibility.

Virtualization is evolving rapidly and embraces multiple technologies at differing stages of maturity, including OS virtualization, streaming, and virtual containers. Because we cannot realize our ultimate vision today, we need to examine the capabilities available and select those that deliver immediate benefits while helping us move in the right direction.

Streaming is the next step for rich clients, providing centralized management without sacrificing end user productivity.

We conducted a series of studies to analyze the potential benefits of each technology and to begin to develop a targeted strategy for delivering client virtualization to our users. We found that:

- Application and OS streaming is the next step for rich clients, providing centralized management without sacrificing end user productivity. Application streaming also supports our mobile users.
- Client OS virtualization is promising and is well suited for some uses but needs to mature before mainstream deployment is feasible. Tests showed that new laptop PCs with Intel® Virtualization Technology (Intel® VT) can eliminate performance concerns.
- Virtual hosted desktop (VHD) is not a good fit because it does not support mobility, has problems with graphic- and compute-intensive applications, and requires infrastructure build-out.
- Virtual containers are important elements of our future vision and architectural direction, and could support new business models

Intel IT is enthusiastic about the potential of client virtualization and we will continue to analyze this rapidly evolving technology.

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Business Challenge

Like other IT organizations, Intel IT is trying to identify the optimum client computing strategy to satisfy many challenging and sometimes competing business requirements.

Cost pressures and security considerations are forcing IT to exert more control over the client platform; manageability has become a central focus of reducing total cost of ownership (TCO). At the same time, users and Intel business units are asking for more flexibility and choice, including the ability to run consumer applications and personalize the platform.

Historically, some of the most divisive client architecture debate has centered on the benefits of thick clients versus thin clients. In reality, we need the benefits of both models. We need a client that is robust enough to survive network connectivity and performance issues, support an increasingly mobile workforce, and satisfy growing user demand for flexibility and choice. At the same time, we need to reduce TCO and gain more control over the client.

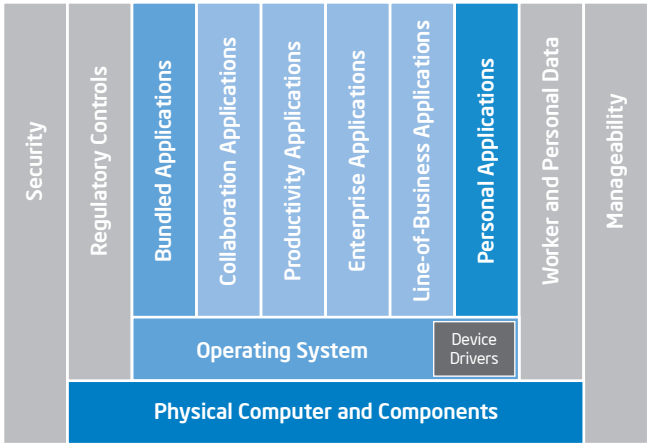

Figure 1. Traditional rich-client platform.

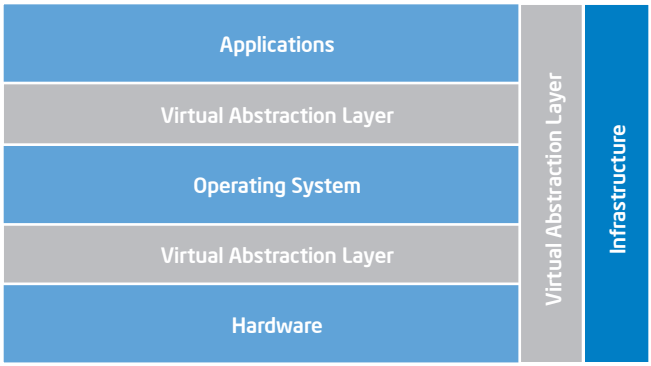

Figure 2. Virtualization abstraction layers.

In our ideal scenario:

- Applications and data are available across all of a user's computing devices—anytime, anywhere.
- Users can run any application, regardless of the underlying hardware or OS.
- Solutions are easier to manage, take less time to develop, and are less expensive to support.
- Users can select platforms and run personal applications.
- We can lock down IT services and manage them like appliances.

We have identified virtualization as a set of technologies that we believe can bring us closer to this vision.

Virtualization Technologies

Virtualization technologies are abstraction layers that reduce or eliminate the dependencies between the components of a system. This has broad implications for client computing. In our current rich-client model, the applications, OS, and hardware are tightly coupled, as shown in Figure 1. If we introduce a new hardware platform, we create a new build and qualify hundreds of applications to verify that they work on the new platform. Though we have greatly streamlined this process over the years, it still inhibits change and limits our choices.

Virtualization inserts abstraction layers so that the components of the client system are now loosely coupled, as shown in Figure 2. This means that we can upgrade or introduce individual capabilities more quickly, without affecting other components of the system.

Virtualization consists of a broad range of abstraction technologies that enable us to deliver OSs and applications to users without requiring a traditional local installation process. These technologies include:

- **Host/guest OS virtualization.** Host/guest OS virtualization uses a type-2 hypervisor that runs as a software process on a host OS. The hypervisor supports one or more guest OSs, or virtual machines (VMs), which are all dependent on the host OS and virtualization software.
- **Hardware OS virtualization.** Hardware OS virtualization uses a type-1 hypervisor called a virtual machine manager (VMM) that

runs directly on the hardware platform with no host OS and supports multiple independent VM systems.

- **OS streaming.** In this model, the client is essentially "bare-metal," with no OS or applications installed. At power-up, the OS and applications are streamed to the client over the network, where they execute locally using the client's own CPU, graphics, and so on. The client may be a PC with no hard drive, using main memory exclusively.
- **Application streaming.** The OS is locally installed on the client but applications are streamed on-demand from the data center to the client, where they execute locally. Streamed applications frequently do not install on the client OS, but instead interface with an abstraction layer and are never listed in the OS registry or system files. Streamed applications can be cached on a laptop and taken off the network.
- **Virtual hosted desktop (VHD).** This is a server-side compute model where all computation and storage are centralized and images of the application are pushed over the network to the client. VHD offers each user a complete VM and customized desktop, including the OS, applications, and settings.
- **Virtual containers.** In this model, VM images, including the OS and applications, are created and managed centrally by IT. But instead of running the VM on the server, as in the VHD model, the VM is streamed to the client for local execution on a client-based VMM. This provides centralized management of the image and, depending on storage policy settings, centralized security of application data. Since execution is on the client, even compute- or graphics-intensive applications are responsive, and users can enjoy off-network mobility.

These virtualization technologies could significantly change enterprise client computing. Virtualization can increase agility because we can introduce new capabilities and upgrade platforms more quickly. Virtualization can also reduce TCO. By abstracting the OS from the hardware platform, we can simplify provisioning, reducing build time and integration costs. We can stream applications and OSs over the network, allowing us to centralize configuration and application management. This software-as-a-service approach could finally make software license management practical, enabling us to pay for actual usage rather than buying enterprise licenses. Virtualization could also open the way to new models, such as delivering the IT environment as a managed VM while letting employees use a personal workspace on the same system.

Intel IT has been actively exploring these technologies to analyze how they can benefit Intel and the users we support. At the same time, we analyze how the technologies would fit into our existing environment. Table 1 summarizes some of our findings.

Intel's workforce is highly mobile. About 80 percent use laptop PCs, which provide them with a powerful client that can run a rich set of productivity and other business applications, even when they are working at home or traveling without reliable network access. We need to make sure that any new technology does not compromise our users' mobility needs or their expectations of client performance.

Each virtualization technology also has potential implications for our IT infrastructure in areas

such as security, manageability, and LAN and server capacity.

Virtualization is evolving rapidly, and the various virtualization technologies are at different stages of maturity. This rapid evolution makes it difficult to know when and how to take steps toward an architectural vision based on virtualization. To take advantage of virtualization in the short term, we need a targeted strategy that identifies the appropriate virtualization technology for specific uses.

To gain a better understanding of enterprise client virtualization and begin to develop our strategy, we conducted studies to assess each technology, its advantages and disadvantages, and potential uses at Intel.

Table 1. Virtualization Technologies

Technology	Advantages	Disadvantages	Potential uses at Intel	Supports Mobile Users?
OS Virtualization (Type-1 and Type-2 Hypervisors)	▪ Reduced total cost of ownership (TCO) through a streamlined build process ▪ Rapid system recovery and provisioning ▪ Potential to allow user choice of platform	▪ Security, manageability, and usability concerns ▪ Type-1 technology is less mature	▪ Design engineering ▪ Software development and QA testing ▪ Training rooms ▪ Eventual mainstream use	Yes
OS and Application Streaming	▪ Supports a full set of rich-client applications with good performance ▪ Reduced TCO through centralized manageability ▪ Improved license management ▪ On-demand software provisioning ▪ Leverages existing investment in client computing devices ▪ Consistent with data center consolidation and network investment strategies ▪ Decouples applications from OS, allowing separate and accelerated upgrade paths	▪ Implementation still requires several products and integration work ▪ Need to package applications for streaming	▪ Application streaming: all uses ▪ OS streaming: shared desktops ▪ Call centers ▪ Systems manufacturing ▪ Training rooms	With local caching
Virtual Hosted Desktop (VHD)	▪ Reduced TCO through centralized manageability	▪ Fully dependent on network connection: no support for mobility ▪ Significant investment in data center and network resources ▪ Not suitable for graphic- and compute-intensive applications	▪ Call centers ▪ Training rooms	No
Virtual Containers	▪ More control for IT; more flexibility for users ▪ Device-independent mobility ▪ Enables new provisioning and business models ▪ Decouples all components, allowing separate and accelerated upgrade paths	▪ Technology is not mature enough	▪ All uses could leverage this capability	Yes

Enterprise Client Virtualization Analysis

During 2007 and early 2008, we conducted a series of enterprise client virtualization studies focused on:

- **Client OS virtualization.** We studied PC OS virtualization in a PoC to determine whether we could reduce TCO by streamlining provisioning while offering users more choice and flexibility. We also conducted PC OS virtualization performance tests to determine whether we could refresh existing native-mode PCs with new laptops running a virtualized OS while continuing to provide users with good performance.
- **OS and application streaming.** We assessed OS and application streaming for Intel users in call centers and manufacturing.
- **Virtual hosted desktops.** We compared the impact of streamed and VHD computing models on server and network utilization.
- **Virtual containers.** We developed a prototype for a virtualized IT environment—a virtual container—that could run on any client hardware, enabling new service provisioning models and device-independent mobility.

Client OS Virtualization

Intel's traditional rich-client architecture delivers a full suite of powerful user applications to our mobile workforce. Over the years, we have reduced client TCO by streamlining the PC build process and standardizing hardware and software. However, the build process remains time-consuming, and the tight integration between applications, OS, and hardware inhibits change and user choice.

Cost pressures and security considerations are forcing Intel IT to exert even more control over the client platform. However, users want the same widely available capabilities, such as Internet phone applications, that they have on their home PCs.

Client OS Virtualization Proof of Concept

We set out to determine whether virtualizing client PC OSs could lower TCO by further streamlining the build process, while giving users more choice. Our goal in the PoC was to create a virtualized OS that would run the user's IT applications. Ideally, we would quickly deploy this within a VM onto any capable off-the-shelf client PC.

We successfully created this virtualized client OS and delivered it to users, who then completed the installation themselves. We used off-the-shelf type-2 hypervisor software to create the virtual client builds and run each virtualized client. We added software to manage the virtualized environment and create an integrated user interface.

We analyzed whether client virtualization could substantially reduce TCO by streamlining build preparation and client provisioning. We calculated the potential TCO reduction using estimates from Intel engineering and PC services groups, based on the steps that we could eliminate from the build process by avoiding the need to customize and provision builds for each platform.

We estimated:

- A 33 percent reduction in engineering resources for each platform generation
- A 24 percent reduction in resources required for provisioning each client
- A 19 percent increase in cash flow over five years

Users were concerned about performance and data migration. Not all users liked integration of host and guest workspaces into a single desktop; some found it confusing. In addition, there were concerns about the security implications of deploying an IT environment on non IT-managed hardware.

Our conclusion was that client OS virtualization can significantly reduce TCO through streamlined provisioning processes but that the technology needs to mature before deployment to mainstream users becomes feasible.

Virtualization Performance Testing

There are concerns about the performance impact of running a virtualized OS. We conducted a series of tests to determine whether virtualization performance is adequate to meet our users' needs.

We focused our study on a fundamental Intel IT process: our three-year refresh cycle. We set out to determine what a user's perception would be if we replaced a three-year-old native-mode laptop with a new laptop running a virtualized OS. To make virtualization acceptable to users, we need to ensure that a new virtualized environment performs at least as well as the native-mode one it replaces.

We ran tests designed to represent typical Intel user workloads, using office productivity applications and industry-standard benchmarks. We ran these tests on a three-year-old native-mode system due for refresh and on newer laptops with a virtualized OS. The newer systems included Intel® Virtualization Technology (Intel® VT) to accelerate virtualization performance.

We found that a laptop based on Intel® Centrino®2 with vPro™ technology performed up to 125 percent faster than the three-year-old native system in standard office productivity tests, and 73 percent faster in application and e-Learning benchmarks. Across all the tests, an 11.5 percent performance improvement could be attributed to Intel VT.

In our tests, we used a type-2 hypervisor to run the virtualized OS. We anticipate that forthcoming type-1 hypervisors, which reduce overhead by running directly on the hardware, may result in even better virtualization performance.

We concluded that we can refresh older systems with new virtualized laptop PCs with Intel VT. This could deliver virtualization benefits such as reduced TCO and greater flexibility, while still providing significant performance improvements for users.

OS and Application Streaming

Streaming promises the benefits of the rich-client model together with the TCO benefits of centralized management. With streaming, we download software on demand to the client for local execution. Because the client is a PC, local execution and caching could preserve a user experience comparable to locally installed applications. With streaming, the OS and application software are stored and managed on centralized servers. The system can be configured so that users obtained a clean, consistent, current build each time they log on, although streaming can also be configured to save each user's state information between sessions.

Four-part OS and Application Streaming Study

We conducted a four-part study examining streaming performance, usability, IT operational impact, and TCO. Our study focused on streaming the OS and business applications to shared desktop PCs within Intel call centers, systems manufacturing, and core manufacturing groups.

We compared this test streaming environment with existing client platforms that use locally installed software.

We found that the test streaming platform performed remarkably well, with 85 percent of users reporting equal or better performance compared with their existing client system. Our analysis of operational impact indicated that centralized management would result in faster and easier software updates and more controlled security.

Our TCO analysis included IT planning, implementation, and management costs. We found that significant savings are achievable due to the operational benefits, and that further savings can be realized by using low-cost desktops.

We concluded that shared PCs are good candidates for on-demand software, and that a combination of OS and application streaming is preferred to maximize flexibility and control. Key challenges were software packaging and troubleshooting.

Our study showed that streaming was an effective model for the tested Intel use cases, and we are planning larger trials.

Virtual Hosted Desktops

In the VHD model, client software runs centrally in a VM on the server, with the user interface transmitted to the client. We conducted a study to compare the impact of streaming and VHD on server and network utilization.

Streaming versus Virtual Hosted Desktops Study

We generated typical Intel user workloads using standard office productivity, graphics, and multimedia applications, and tested the infrastructure impact when supporting up to 20 clients.

We found that server utilization was significantly lower—44 percent for the 20 clients—with streaming than with VHD. Compute-intensive and multimedia applications caused high server utilization with VHD, resulting in significant delays in user response time. We found that streaming more efficiently supported multimedia, graphics, and other interactive applications, including real-time collaboration. Streaming imposed an initial network overhead; however, as the clients cached the OS and applications, the load decreased until it was comparable to the traffic normally experienced with the traditional rich-client approach.

We concluded that while streaming is a good fit for certain users at Intel, VHD is not. Intel's users are accustomed to the mobility and responsiveness of a rich client that executes all applications locally, providing an enhanced user experience with graphical and compute-intensive applications. Implementing VHD would also require significant investments in building out server and network infrastructure. In contrast, Intel's strategy is to consolidate and reduce data centers.

Virtual Containers

Virtual containers are an evolving approach that would enable us to virtualize a user's entire IT environment and deliver it as a service. We set out to develop a prototype virtualized IT environment, called the Virtual User Environment (VUE), that we that could deliver to users as a virtual container.

The Virtual User Environment Prototype

Because the VUE is independent of the host OS, we could potentially run it on any device capable of supporting a hypervisor. This gives our users true device-independent mobility—the ability to access IT services from any device, wherever they happen to be.

We could manage the VUE according to IT policies and stream IT applications and data to it. The environment is protected because it runs within a VM.

This would open the door to radically new business models. We would manage only IT assets, not personal data and applications; employees could run their choice of personal applications outside the VUE. Employees could buy their client platform of choice instead of being restricted to a limited number of IT pre-qualified platforms.

We created an initial design based on technology available now or within the next 18 months. We built a working prototype and developed a vision of how the VUE may evolve in two years. We are working with Intel business groups, suppliers, and other IT organizations to further analyze and investigate the benefits of our approach.

Conclusion

Intel IT is enthusiastic about the potential for client virtualization technologies. Client virtualization could significantly reduce TCO, improve agility, and, ultimately, deliver a wide range of other benefits to Intel and our users.

We found that identifying the right virtualization technology requires careful analysis of the potential uses. We also found that to accurately assess potential TCO benefits, we need to include end-to-end computing costs, including the back-end infrastructure required to support virtualization.

Our studies showed that these technologies are at different stages of readiness and that there is great variation in the potential benefits, as was described in Table 1.

- Application streaming along with OS streaming for desktops is the next evolutionary step for rich clients. Streaming delivers the benefits of centralized application and license management without sacrificing end user productivity.
- Client OS virtualization is becoming more viable as the technology improves. Our tests showed that new hardware with Intel VT can eliminate performance concerns.
- Virtual containers are important elements of our future vision and architectural direction.
- VHD is not a good fit for Intel users. It lacks support for mobility, causes performance problems with graphical and other interactive applications, requires substantial investment in back-end infrastructure, and would disrupt our environment.

Virtualization is evolving rapidly, and we expect that our strategy may also evolve as we continue to analyze virtualization technologies.

Further Reading

The IT@Intel studies described in this paper can be found at www.intel.com/it.

"Streaming and Virtual Hosted Desktop Study." Catherine Spence and Christian Black. January 2008.

"Software On-Demand." Catherine Spence. February 2008

"Client Computing with a VUE." Ed Jimison, David Buchholz, and Jim Sutorka. May 2008.

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"Virtualizing the Client PC: A Proof of Concept." Julian Braham, John Dunlop, Michael Flores, Efi Kaufman, and Daniel Shukrun. July 2008.

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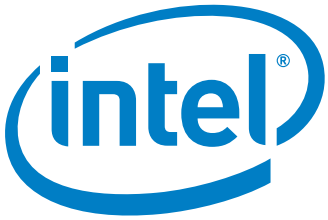
Acronyms

Intel® VT	Intel® Virtualization Technology
TCO	total cost of ownership
VHD	virtual hosted desktop
VM	virtual machine
VMM	virtual machine manager
VUE	Virtual User Environment



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