White Paper

Intel Information Technology

Computer Manufacturing

Client Management

Client Computing with a VUE

Intel IT is developing a Virtual User Environment (VUE), a new approach that could transform the way we deliver computing to users. It employs a managed, virtualized IT container that runs on any capable client hardware, with IT applications and data delivered by streaming. The VUE could enable radically new business models at Intel: Employees could buy their own client platforms of choice, and Intel IT would no longer have to build and support client PCs. Employees could then use a variety of different devices to access IT services while also running personal applications.

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IT@Intel

Executive Summary

Intel IT is developing a new computing approach that combines multiple emerging technologies, including client virtualization and streaming, to potentially transform the way we deliver computing to users.

Called the Virtual User Environment (VUE), it employs a virtualized IT container that could run on any client hardware capable of supporting virtualization. We manage the VUE according to IT policies and use streaming to deliver IT applications and data to it. The environment is protected because it runs within a virtual machine (VM), so employees can simultaneously use the client for personal applications and data without affecting the IT environment.

The VUE could enable radically new business models with substantial benefits for IT and for employees.

This could enable radically new business models with substantial benefits for IT and for employees:

- Employees could buy the client platform of their choice, instead of being restricted to a few IT-qualified platforms.
- Intel IT would no longer have to build, distribute, or support client PCs.
- We would manage only IT assets, not personal data and applications; employees could run their personal applications outside the VUE.
- Users could achieve device-independent mobility, accessing IT services through a wide variety of consumer and mobile devices.

We created an initial design that is based on technology available today or within the next 18 months. We have built a working prototype based on this design. We also developed a vision of how the VUE may evolve over the next two years.

We are working with internal Intel business groups, suppliers, and other IT organizations to further analyze and investigate the benefits of our approach.

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Business Challenge

The traditional client PC computing model has effectively supported Intel's increasingly mobile users. About 80 percent of our employees use laptops as their primary client PC hardware. This provides them with access to a full set of IT applications both in the office and while traveling or at home.

However, the traditional client PC model also has disadvantages and limitations, both for IT and for employees:

- To build a client PC, Intel IT purchases a laptop from a vendor, deletes all vendor-supplied software, replaces it with our own qualified IT build, and distributes the machine to the user. We have greatly streamlined this process over the years, but it is still time consuming for IT and slows the delivery of new systems to users.
- To reduce total cost of ownership (TCO) and increase efficiency, we have standardized on a few client hardware platforms and a number of software applications. This limits user choice and can constrain user productivity.
- Employees increasingly have their own personal computing devices, including mobile computing devices such as smart phones, but have limited ability to access corporate data and applications using these devices.
- Corporate and personal data may be interspersed throughout a client's hard drive. This makes it difficult to apply IT policies only to corporate data while letting users manage their personal data.

Within Intel IT, our emerging technology engineering team is challenged with thinking about new client computing models. In early 2007, we began to discuss and develop a new approach with the potential to radically change how we do client computing, solve existing problems, and deliver a series of other business benefits.

At the time, we were investigating many emerging technologies including application streaming, virtualization, open-source software, and hosted computing. We saw that integrating these technologies to create a new computing environment could deliver even greater benefits than applying each technology individually.

Solution

Our approach is based on a virtualized IT environment that can run on any client hardware. We use streaming to deliver IT applications and corporate data to this virtualized environment, and we manage the environment remotely. Because the IT environment runs within a VM, it is protected, so employees can simultaneously use the rest of the client for personal applications and data. They can also use a variety of client devices and access their IT environment from each device. We believe that if implemented, this approach would enable new business models that deliver a range of benefits for IT and for users. We call our concept the Virtual User Environment (VUE).

Emerging Technologies and Shifting Computing Models

The VUE concept takes advantage of technologies and models that have emerged over the past few years, as shown in Figure 1.

Proliferation of Devices

In the past, the computer that Intel IT provided was often the only computer that an employee used. Now, many users have their own personal computers at home and may also carry small form factor computing devices such as smart phones and mobile Internet devices (MIDs). Today, employees have limited access to IT applications from these devices. With the VUE, we could potentially deliver full IT services on these employee-owned devices.

Open-Source Software

Traditionally, enterprise software was supplied only by large ISVs. Today, there is an increasing amount of open-source or free software. We could create an alternative VUE using Linux*, an open-source browser, and open-source office productivity software, and reduce cost by streaming it to groups of users.

Ubiquitous Network Access

Broadband Internet access is now available in most areas. With the proliferation of Wi-Fi* and the emergence of WiMAX, we are moving toward an "always connected" state.

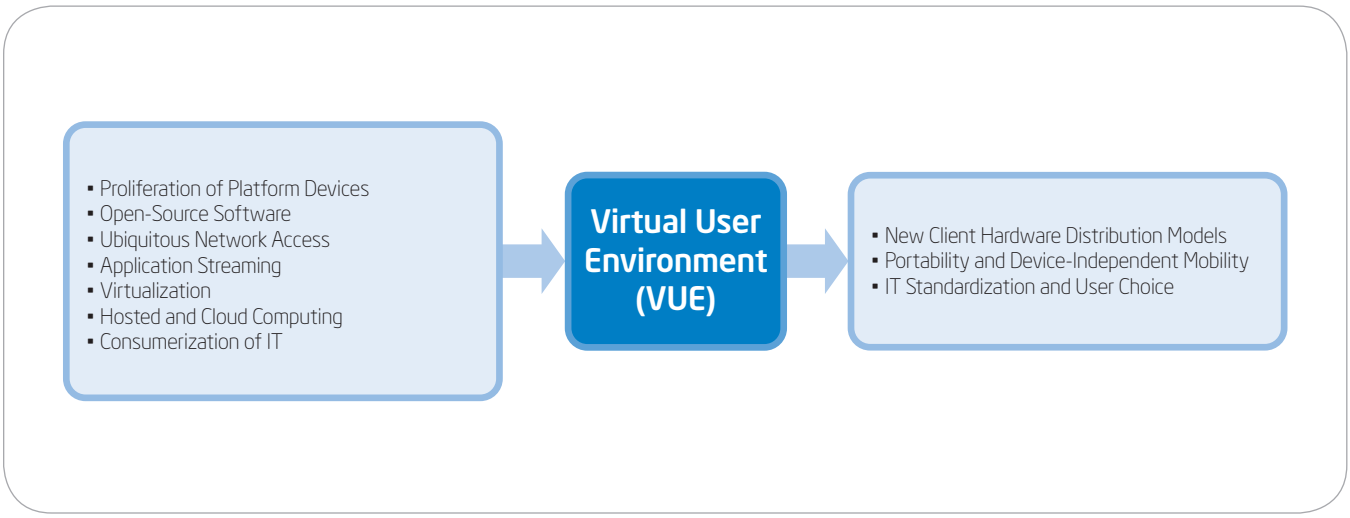

Figure 1. Technologies and shifting computing models.

Streaming Technologies

Streaming uses agents to deliver OSs and applications to clients, without the need to install the software locally on the client. This provides the benefits of centralized manageability and security, together with full client application capabilities.

Virtualization

Three types of virtualization are emerging: hardware, OS, and application. Hardware virtualization, such as Intel® Virtualization Technology (Intel® VT), virtualizes parts of the platform and exposes them to the OS at different levels. This allows direct access to hardware features from multiple OS environments, as well as improved performance. Virtualizing the OS lets us run it on other OSs and allows us to isolate it from other OSs on the same platform. With application virtualization, the application is virtualized into a container that is then delivered to a host system. This helps ensure that the application runs within the same environment in which it was packaged and that it is isolated from other applications running on the same OS.

Hosted and Cloud Computing

Suppliers are increasingly offering software as a hosted service over the Internet. IT organizations can use this to deliver new services more quickly, without costly investment in infrastructure, and provide users with more choice.

Consumerization of IT

Traditionally, technology became available to enterprises first, then later spread to consumers. That trend continues with the spread of networks and shared storage into the home. However, a reverse trend is also emerging rapidly. Now, a variety of technologies that were first adopted by consumers are now spreading into the enterprise. These include instant messaging, social media, small form factor platforms, wireless networking, and MIDs. This creates more choice for enterprise users and increases the possibility of using the same devices for both IT and personal use.

Key Value Areas

As we developed our ideas, we began to see potential value in three key areas.

Client Hardware Distribution

Today, we supply only a few qualified hardware platforms and support a limited number of IT applications. We do not allow employees to install some personal applications because of potential security threats.

With the VUE, this situation could change completely. Potentially, Intel IT would not have to buy and distribute client hardware at all; employees could buy the platform they want.

Employees could use this platform to run their favorite consumer applications, such as photo and movie editing, Voice over IP (VoIP), and personal business software. IT applications would run in a protected "bubble"—a virtualized environment—on the same platform.

We would not be concerned with the personal applications employees use, because those applications would run outside the VUE and would not interfere with it. Potentially, users would have the flexibility to run the VUE and their personal applications on different OSs.

Portability and Device-Independent Mobility

We quickly realized that by virtualizing the IT environment, we could make it portable across many platforms. Potentially, any device capable of hosting a VM could host a VUE. Ultimately, this might include platforms other than traditional full-featured PC clients, such as smaller netbooks and handheld-size MIDs based on Intel® Atom™ processors. When users travel, they could access the VUE from any capable device.

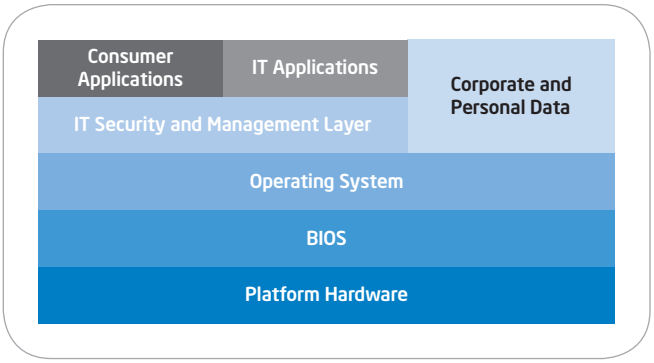

Figure 2. Today's IT platform. IT applications and data are ingrained into the platform. Personal and corporate data co-exist as user data.

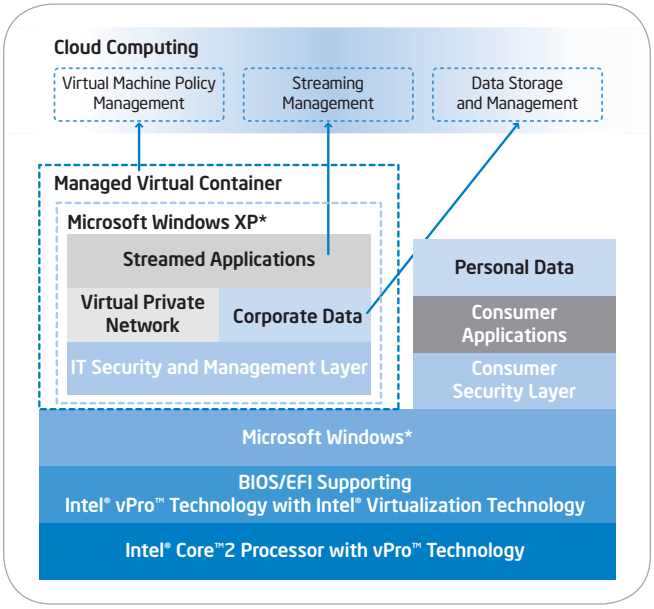

Figure 3. Virtual User Environment (VUE) initial architecture.

This realization made us think about mobility in a new way and ultimately led us to the idea of device-independent mobility. Traditionally, mobility has been defined as carrying your computer wherever you go. Our concept moves mobility up from the hardware platform itself to the application and data layer. We are redefining mobility as the ability to access IT applications and data from wherever you are, and from a variety of devices including full-featured desktop PCs at home or in Internet cafes, MIDs, and potentially televisions and computers built into cars.

IT Standardization and User Choice

Like other IT organizations, we reduce TCO through standardization. Today, this means standardizing on hardware platforms and OSs. With the VUE, we could change the way we think about client standardization. Rather than standardizing at the hardware and OS level, we would standardize within the VUE. Because of this, the end user would have a choice of hardware platform, OS, and consumer applications.

VUE Architecture

Figures 2 and 3 compare our traditional client architecture with the initial version of the VUE. Figure 3 represents what we believe can be achieved using technology that exists today or will become available during the next 12 to 18 months.

In our traditional client model, personal and corporate data are ingrained into the platform, where they coexist as user data and cannot be easily separated. In contrast, the VUE approach clearly separates personal and corporate data. This means that through the VUE, we can easily apply Intel data retention and management policies to corporate-specific data only.

The VUE environment is encrypted to protect IT data and applications. We also run our corporate security software within the VUE. We let users run their choice of security software to protect their personal environment.

We use VM policy management software to control the VUE. This lets us implement policies such as enabling access to the corporate network only from within the VUE. We can also determine when the bubble expires or whether users can load data into the VUE from USB devices. Intel® vPro™ technology integrated into the platform also facilitates remote management, with Intel VT accelerating the performance of the virtualized software.

Even though this initial version of the VUE represents what can be achieved with technology that is readily available in the short

term, it represents a radical departure from our traditional client architecture, shown in Figure 2.

On the user's client device, the VUE runs within a VM as a managed virtual container. We use a cloud computing approach, in which the OS, applications, and data may be stored remotely—whether on servers located at an Intel data center or hosted by a supplier—and streamed to the container as needed by the user, transported on a USB thumb drive or delivered by a combination of both methods.

Prototype

We have implemented a prototype that includes key aspects of this initial architecture. In our prototype, the client systems are standard corporate and consumer PCs based on Intel® Core™2 Duo processors running Microsoft Windows* or Linux; the VUE OS is Microsoft Windows XP*.

We use hypervisor and VM policy management software from an established VM software supplier. We use an off-the-shelf application streaming product, with a client component within the VUE communicating with a server component running on Intel's corporate servers.

In the current prototype, we provide cloud storage using a commercial Internet-based data storage service, and we have the option to cache data locally as well. Today, our prototype environment resides on removable memory, and we move it between machines by plugging the memory into the USB port on each machine. In this way, we have been able to transfer the prototype from a system at Intel to a consumer PC at home. All traditional client functionality is available within the VUE, and we have demonstrated that we can use the VUE to access IT applications over the corporate network from both home and office locations.

Our internal benchmarks indicate that hardware virtualization substantially accelerates performance of the virtual client. We tested a laptop equipped with Intel's forthcoming Intel® Centrino® 2 with vPro™ technology, which includes Intel VT. We found that a virtualized client environment on this platform can run approximately 60 percent faster than the native client environment on a current Intel IT-managed laptop model based on the 1.8 GHz Intel® Pentium® M processor 750.

A VUE of the Future

The technologies underpinning the VUE are evolving quickly. As a result, we anticipate that the VUE will also evolve, adding new capabilities as they are enabled by the available technologies. Figure 4 shows what we think could be implemented within about two years. Because these capabilities do not exist today, the following description of this possible future is speculative.

One important change is the addition of a client native hypervisor. This layer underlies the entire client environment, so that both the corporate and personal applications run within virtualized containers hosted by this hypervisor. This arrangement further protects the IT environment. The hypervisor provides each guest OS with direct access to the client hardware resources. This could eventually give us the ability to run multiple OSs on a client platform simultaneously, yet keep them completely separate from each other. With this arrangement, the performance and security of each guest OS are not dependent on a host OS. Security is enhanced because the guest OS cannot be manipulated through a host OS.

In this future scenario, compute-intensive tasks initiated in the personal environment, such as malware scans, do not affect the performance of IT applications. Similarly, if the personal OS crashes, the IT container is unaffected. A service and management layer provides security services to the VUE, independent of the VUE OS.

We also anticipate virtualized mini-OSs specialized for different purposes—a development that is already occurring in server-based software. These lightweight OSs enable the system to run without

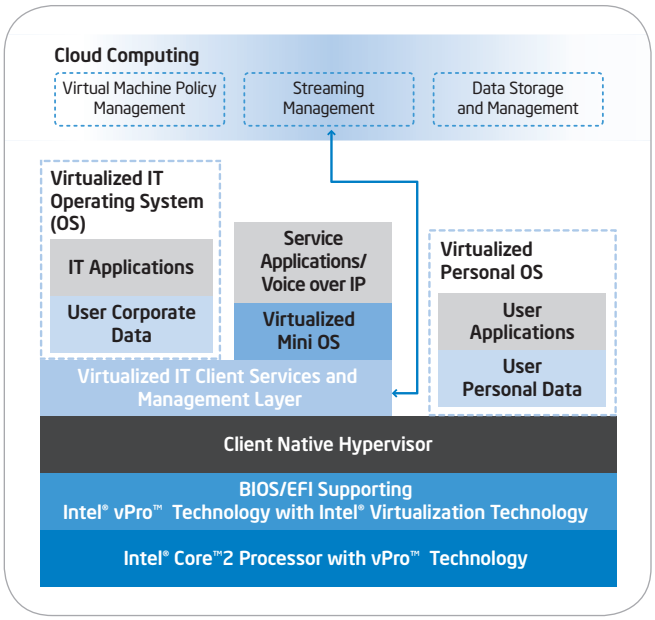

Figure 4. Possible future Virtual User Environment (VUE).

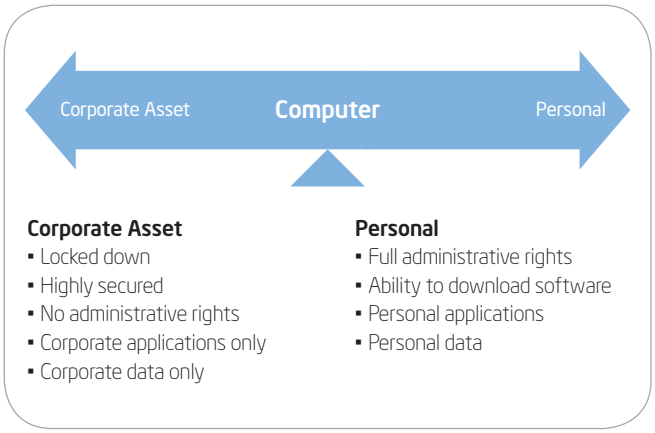

Figure 5. With the Virtual User Environment (VUE), IT organizations can simultaneously fulfill corporate responsibilities and allow user preferences.

consuming more resources than necessary to perform a specific function. For example, we envision that such an OS might run VoIP. Another mini-OS might enable a PC to act as a DVD player without needing to boot the primary personal or corporate OS, resulting in faster startup and longer battery life.

Current Limitations

Several limitations exist:

- To run a VUE, each device would have to be capable of running a virtualized environment. This trend may accelerate as mobile and consumer devices incorporate more-powerful processors, such as Intel Atom processors.
- Network bandwidth is still a limitation outside the corporate environment, though broadband availability and speed are improving rapidly.
- Security is a concern. VUE data is stored within the cloud, requiring a new security support model to help ensure that a user can securely access the data from different clients. Another potential concern is that today, the VUE client software runs on a host OS and thus could be vulnerable to attack from a non-managed host environment. In future, the use of client native hypervisor could protect against these attacks.
- Vendors would have to tailor applications appropriately for each type of client environment, such as ultra-mobile devices. This is beginning to take place, but much more is needed. Vendors also need to make sure all applications run in virtualized environments, without requiring direct hardware access, and they need to develop better software licensing models for virtualized environments.

Business Benefits

IT organizations continually have to balance user preferences and corporate responsibility. Today, most IT organizations have swung toward corporate responsibility and favor treating clients primarily as corporate assets. This tends to restrict user capabilities. With the VUE, IT organizations do not have to make a choice; they can simultaneously fulfill corporate responsibilities and allow user preferences, as shown in Figure 5.

The VUE concept could transform how we provide IT services and how employees use them. This could result in new IT business models that deliver significant benefits both for Intel IT and for employees.

IT Benefits

The new approach could allow us to create new models for distributing client hardware, manageability, support, and security.

Distribution and technology adoption

IT could get out of the business of buying and distributing hardware. This would accelerate technology adoption. Employees could select their own hardware based on the latest technology available from vendors, rather than choosing from a small, pre-qualified list of IT platforms. This approach would also reduce the time required to deploy new client systems; employees could begin using their new system immediately, because we could stream their IT environment directly to it.

Various scenarios are possible:

- An employee might receive a stipend towards purchasing hardware of their choice, which would then be employee-owned.
- We might specify that employees select from a small set of certified or preferred vendors, or it might be possible to let them buy from any vendor.
- We could offer multiple OS options for the VUE; because each of these would run within the virtual container, we would not need to qualify each OS for every hardware platform.

Manageability

The VUE approach facilitates changes in the way we could manage the IT environment, which in turn would deliver a series of business benefits.

We could focus on protecting and managing only IT assets. We would not be responsible for managing personal data. In our traditional client environment, personal and corporate data are interspersed throughout a user's disk storage, making it difficult to enforce appropriate policies for management and retention of corporate and personal data. The VUE will clearly separate corporate data from personal data so that we can effectively manage corporate data only.

We could improve system utilization and performance by taking advantage of multi-core processors. We could dedicate one or more cores to a VUE, guaranteeing performance for corporate applications.

We would be able to distribute new applications more quickly because we do not need to integrate them into each hardware platform and because we can immediately deliver them using streaming. We also believe that, because we are creating a virtualized container, it will be easier to combine this container with other components in a service-oriented architecture (SOA) approach, resulting in faster development of new applications.

Support

Today, supporting clients is one of our biggest IT costs. With the VUE approach, hardware would be employee-owned, and IT would no longer be responsible for managing it. This could substantially reduce our overall hardware support costs.

There are many other potential benefits. We would no longer have to recover client IT assets when employees leave Intel; the hardware would already belong to the employee, and we could simply terminate the employee's VUE. Today, we provide and manage hardware used by on-site contractors; instead, we could simply provide

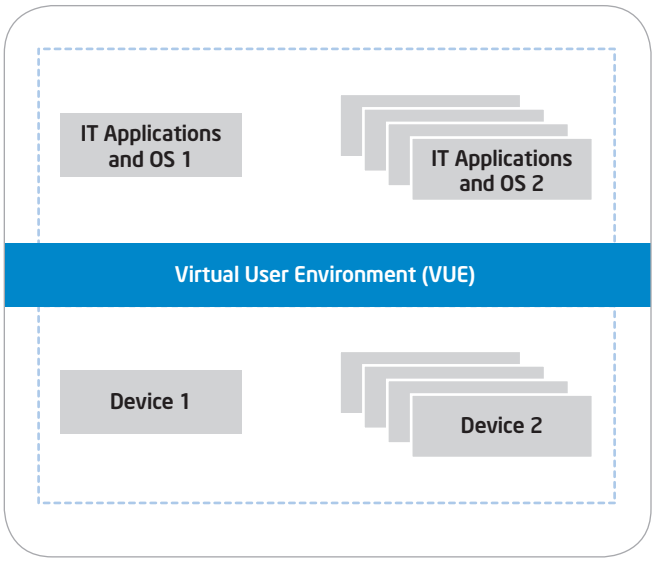

Figure 6. With the Virtual User Environment (VUE), IT groups could provide multiple OS and application combinations on multiple platforms.

them with a bubble they would run on their own systems that expires when their contracts end. We would no longer have to create custom reference builds for shared environments such as kiosks, because each environment could be delivered within the VUE to the employee's personal device.

Security

Today, our client hardware runs a single umbrella security solution that covers all corporate and personal data. With the VUE on a native client hypervisor, we would only need to protect the corporate environment. By running a separate virtualized client, we can potentially shrink the footprint IT has to manage and protect. This allows us to run applications and the OS as appropriate in their own virtualized spaces, letting us put better security models in place for each item rather than a one-size-fits-all solution for the whole platform.

Employee Benefits

The bubble concept could increase employee satisfaction and productivity by offering more choice, mobility, and reliability.

More choice

Today, we support a limited number of PC configurations and applications. With the bubble, employees would be able to buy the platform that they want and run their choice of consumer applications on it. They could select platforms based on the most recent technology, rather than having to choose from a list of IT-qualified platforms. Because the IT and personal environments are separate, they might even be able to select their own hardware support supplier, while continuing to get support from Intel IT. They could select which OS they want for their personal use and also which OS they want for their VUE. They could potentially use more than one bubble, enabling them to select best-of-breed applications that run only on a specific OS, as shown in Figure 6.

Increased mobility

With the VUE, device-independent mobility could become a reality. The IT environment will no longer be tethered to a specific piece of hardware; instead, the user will access IT services from any capable client hardware. Over time, employees might be able to use IT services from a growing range of mobile devices as well as home devices such as televisions. This could increase users' productivity and ability to respond quickly.

Increased reliability
If an employee loses a PC or if a hard drive fails, the potential impact to Intel will be greatly reduced. We will be able to immediately restore the employee's VUE to any new device, and terminate the VUE on the old device. We also expect greater system reliability; because IT and personal employee applications run in separate virtualized environments, there is no potential for application conflicts.

Conclusion

We have defined a new way to deliver computing and demonstrated its feasibility by implementing a prototype. We are currently working with Intel business groups and external suppliers to define our technology requirements and encourage the industry to meet those requirements. Within Intel, we are partnering with our finance specialists to analyze return on investment (ROI) and with our security team to assess and document risks. We are also working with other IT organizations to implement proof of concept client virtualization projects. We believe that the VUE could potentially transform the way that IT delivers services, enabling the development of new IT business models that deliver substantial benefits both to IT groups and to users.

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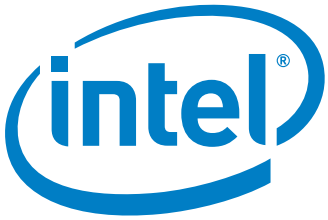
Acronyms

Intel® VT	Intel® Virtualization Technology
MID	mobile Internet device
ROI	return on investment
SOA	service-oriented architecture
TCO	total cost of ownership
VM	virtual machine
VoIP	Voice over IP
VUE	Virtual User Environment



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