IT@Intel White Paper

Intel IT
IT Best Practices
Cloud Computing and Employee Productivity
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Cloud Computing: How Client Devices Affect the User Experience

Mobile business PCs provide the optimum user experience and productivity when using cloud-hosted applications.

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Executive Overview

Intel IT, in partnership with Intel Architecture Group's End-User Platform Integration team, conducted testing and analysis to compare the user experience with different client devices when accessing a range of cloud-based applications.

Our results showed that the choice of client device significantly affects the user experience: For all the applications tested, mobile business PCs offered significantly higher performance than other devices.

In the tests, we compared the performance of mobile business PCs, an entry-level desktop, and a thin-client device across a representative range of applications hosted within public clouds and Intel's private cloud. These included rich Internet applications (RIAs), which use a runtime software framework executing on the client system, as well as traditional cloud-based applications that require only a Web browser for access. We found that:

- Mobile business PCs completed typical user operations up to 10x faster than the other devices tested.
- In general, the best user experience was provided by the combination of RIAs and mobile business PC, because RIAs take better advantage of the performance of the client hardware and do not need to move as much data over the network.

These test results reaffirm our decision to standardize on mobile business PCs as the primary client system for Intel employees. Mobile business PCs provide optimum user experience and productivity when using cloud-based applications. They also provide the flexibility to run all existing locally installed applications, whether connected or offline, with maximum responsiveness even when multitasking.

The growth of cloud computing, along with the consumerization of IT, is driving Intel IT to support a compute continuum in which users will increasingly be able to access applications and services using a spectrum of client devices in a variety of form factors. While mobile business PCs will remain our employees' primary client devices, we are enabling use of other devices such as smartphones and tablets. Providing employees with the freedom to use these devices, in addition to mobile business PCs, further enhances mobility and increases employee productivity. Employees may use these devices where it makes sense to accept the tradeoffs, such as performance.

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The IT@Intel program connects IT professionals around the world with their peers inside our organization – sharing lessons learned, methods and strategies. Our goal is simple: Share Intel IT best practices that create business value and make IT a competitive advantage. Visit us today at www.intel.com/IT or contact your local Intel representative if you'd like to learn more.

BACKGROUND

Intel IT manages a large IT environment that supports more than 80,000 employees across 150 sites worldwide. Intel employees are highly mobile, and we have standardized on mobile business PCs because they enable employees' diverse work requirements while delivering additional benefits, such as the ability to work offline. Mobile business PCs are currently used by about 80 percent of employees.

The consumerization of IT, along with the growth of cloud computing, is driving Intel IT to support a compute continuum that—in addition to mobile business PCs—will include a broad spectrum of client devices in a variety of form factors.

We anticipate that employees will increasingly be able to access applications and services using devices such as entry-level desktops, tablets, and smartphones. For example, more than 14,000 Intel employees currently use smartphones to access corporate e-mail and data that is not graphics- or compute-intensive.

At the same time, we are undertaking a multi-year transition to cloud computing to increase agility and efficiency. While our primary focus is on the development of a private cloud, we are also selectively using some public cloud services, such as customer-relationship management (CRM) applications to enhance the productivity of our sales force.

This transition to cloud computing will help to enable the compute continuum by providing Web-based services and IT applications that can be accessed across the spectrum of client devices.

Client-aware Cloud Computing

Over time, we expect that IT applications and services within the cloud will need to become client-aware, providing a user experience that is tailored to the capabilities and limitations of each client device. To do this, they will balance and optimize their use of cloud resources and client capabilities. (See Figure 1.)

Traditional cloud applications are accessed through a browser; most of the application code executes within the cloud. As a result, it has often been assumed that a Web browser is the only requirement for accessing cloud services—and that any client device capable of running a browser can provide a similar user experience. In other words, the cloud service is agnostic to the device that is accessing the service.

However, end-user devices differ widely in their attributes, such as screen size and keyboard, and in capabilities such as performance, security, and portability. These attributes and capabilities can greatly affect the user experience.

In addition, cloud application providers are increasingly offering rich Internet applications (RIAs), which distribute processing between the cloud and the client device as a way to improve application responsiveness. With RIAs, application code is downloaded to the client device and executes on the client using an RIA software framework. The RIA can therefore take advantage of the client hardware to provide better performance and new capabilities, some of which are equivalent to traditional client-installed applications.

These capabilities include mobility: With some RIAs, users can replicate their cloud

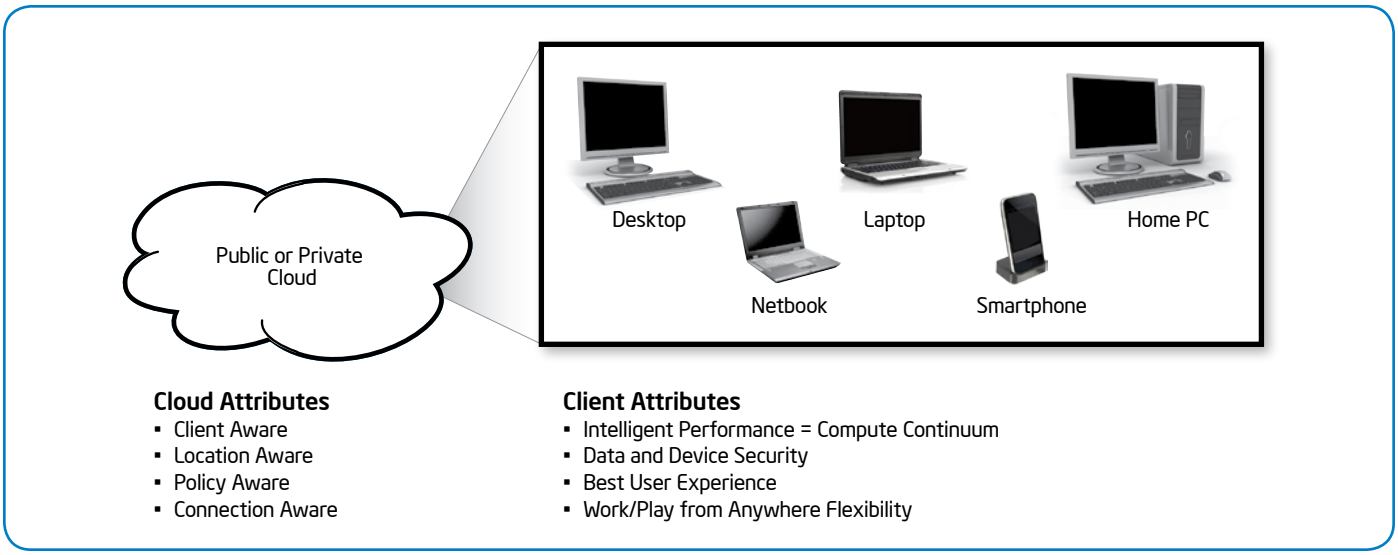

Figure 1. Client-aware cloud computing. In a client-aware environment, cloud applications are aware of key attributes associated with the client device, including type, location, policy, and available connectivity. Applications are run in the most efficient and effective manner by optimizing resources and capabilities both in the cloud and at the client. This balanced model is particularly important as more rich Internet applications, which take advantage of higher performance client devices, become available.

environment on the client, work offline, and synchronize with the cloud when they connect. Because they execute locally on the client, RIAs also reduce the load on the network and on the cloud infrastructure.

As part of the Intel IT planning process, we continually analyze new technology trends and their potential benefits to Intel. We use this analysis to help develop our strategy, including the Intel IT client roadmap.

In partnership with Intel Architecture Group's End-User Platform Integration team, we conducted testing and analysis to compare performance of various clients with rich and traditional cloud applications. We assessed the user experience and analyzed the implications for Intel IT client strategy.

APPLICATION TESTS

We tested clients with differing levels of capabilities and performance, ranging from mobile business PCs to a thin client. To gain a broad perspective of application performance, we tested each client with a representative selection of applications. These included RIAs and traditional applications, enterprise and consumer applications, and both internally and externally hosted services. In each test, we assessed the user experience by measuring the time taken to complete common user operations.

Test Systems

We tested three client systems, representing different device categories:

- **High end.** A mobile business PC representing a purpose-built laptop PC or desktop PC designed for business. We tested Intel® Core™2 processor with vPro™ technology-based systems; however, we are now deploying Intel® Core™ i7 vPro™ and Core™ i5 vPro™ processor-based systems as our business PC standard.
- **Mid-range.** A mid-range terminal PC or entry-level desktop with an Intel® Atom™ processor. Intel Atom processors enable a broad range of devices including netbooks, entry-level desktops, tablets, handhelds, smartphones, consumer electronics devices, and other companion devices
- **Low end.** A thin client or low-end Internet device that provides limited local compute capability for business applications.

Test system specifications are shown in Table 1.

Intel IT is rapidly migrating to Microsoft Windows 7*, but for this analysis we conducted testing using Microsoft Windows XP* for consistency with the thin client, which was supplied with Microsoft Windows XP Embedded Standard* to enable local execution of application code. Since we are drawing conclusions using a relative comparison of performance across a range of hardware devices and not based on the absolute performance figures, we do not expect our transition to Microsoft Windows 7 to alter our conclusions.

The systems used a wired 1 gigabit per second (Gb/s) LAN connection to provide consistent network bandwidth and help ensure that network speed did not constrain client performance in the tests.

Applications

We tested several cloud applications and services. For each, we tested the time taken to complete typical user activities, ranging from a single screen refresh to a scripted sequence of employee actions.

- Intel's enterprise resource planning (ERP) portal, a traditional enterprise cloud-based application running within a private cloud.
- Enterprise CRM software from a large supplier, provided through a public cloud service. We tested both a traditional cloud-based application and an RIA from the same supplier.
- A mapping application provided as an RIA from a public cloud.
- Two traditional web applications: an Intel internal employee portal running within our private cloud and an external supplier Web site.

INTEL'S ERP PORTAL

We tested the time taken to complete a scripted sequence representing typical user activity. The script included the following steps:

1. Log on, including authentication.
2. Generate a marketing report, based on an existing template, by selecting and filtering data.
3. Export data in a spreadsheet.

Results are shown in Figure 2. Completion times for the scripts varied widely among the tested clients, with the mobile business PC completing the script 77 percent faster than the thin client. Our analysis showed that more than half of the difference was in the authentication process, specifically in the exchange and validation of Secure Sockets Layer (SSL) certificates. The rest of the difference was the time required for the client to encrypt and decrypt the data exchanged with the server.

ENTERPRISE CRM APPLICATION

We executed typical operations with both a traditional cloud application and an RIA from the same supplier. Unfortunately, we were unable to test the thin client because we

Table 1. Test System Specifications

	High-end Client	Mid-range Client	Low-end Client
Processor	Intel® Core™2 Duo Processor T9400 (2.53 GHz)	Intel® Atom™ Processor 230 (1.6 GHz)	Single-core processor (1.5 GHz)
RAM	3 GB	2 GB	2 GB
OS	Microsoft Windows XP* (32-bit)	Microsoft Windows XP (32-bit)	Microsoft Windows XP Embedded Standard* (32-bit)

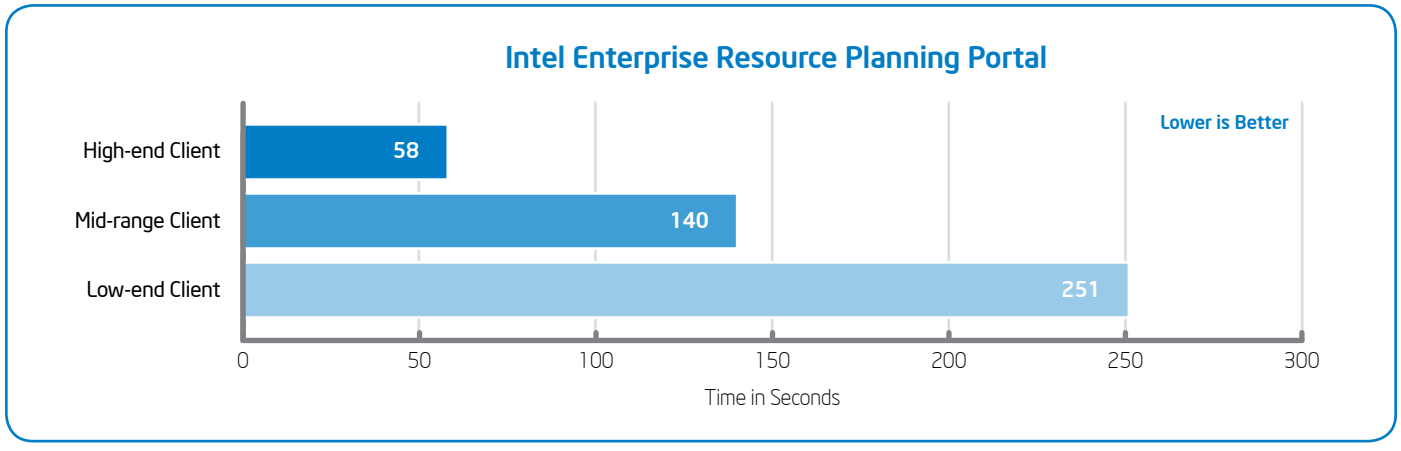

Figure 2. Time to complete a scripted sequence of user actions using Intel's enterprise resource planning portal. Intel internal measurements, January 2010.

could not install the RIA framework on its local OS; this was because it did not provide the Microsoft Windows* registry rights necessary to install the RIA runtime.

We therefore conducted two tests: In each, we compared performance of the mobile business PC and entry-level desktop with the traditional cloud application and the RIA.

The first test measured screen refresh time. The second test executed a script containing a typical user operation sequence: launch application, synchronize with cloud, and check sales status.

As shown in Figures 3 and 4, the mobile business PC executed the script faster in both tests than the entry-level desktop. The RIA provided the highest performance and best user experience.

Screen Refresh

Screen refresh was faster on the mobile business PC than on the entry-level desktop, with both the RIA and the traditional cloud application. With the RIA, the mobile business PC completed screen refresh about 5x faster than the entry-level desktop, as shown in Figure 3.

On both PCs, screen refresh was faster with the RIA than with the traditional web application. The effect was most pronounced on the mobile business PC, with a performance improvement of about 10x.

The performance improvements observed with the RIA were due to the RIA's ability to execute and cache data locally on the client. As a result, it was able to take better advantage of the Intel Core 2 Duo processor in the mobile business PC and did not need to move data over the network to refresh the screen.

Scripted User Sequence

We observed the same performance trends as in the screen refresh test. As shown in Figure 4, the mobile business PC performed the best overall, and the sequence completed faster with the RIA than with the traditional application on both PCs. Again, this was due to local execution on the PC.

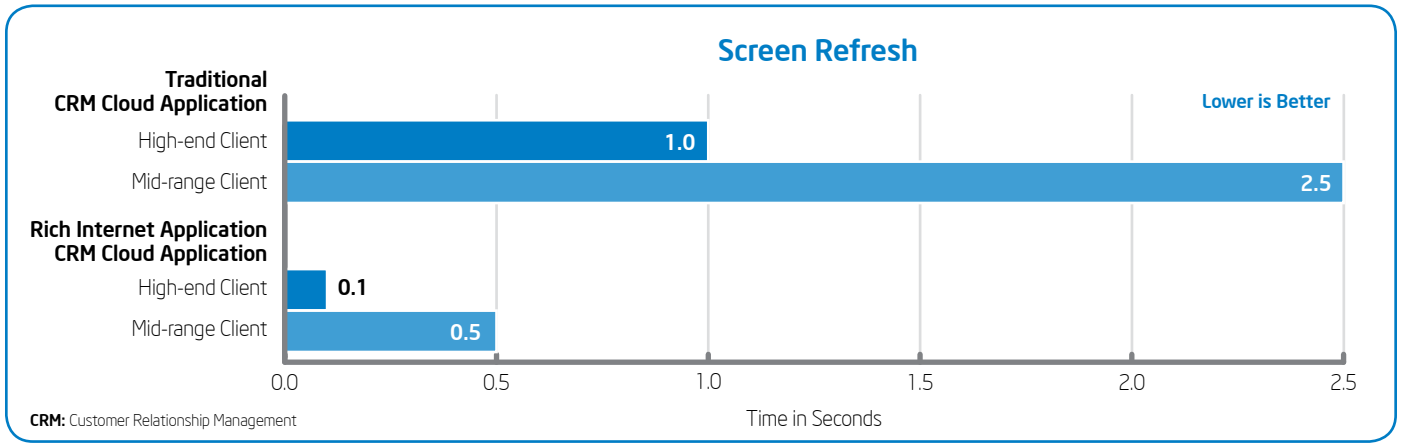

Figure 3. Time required for screen refresh with a rich Internet application (RIA) and a traditional customer relationship management (CRM) cloud application. Intel internal measurements, January 2010.

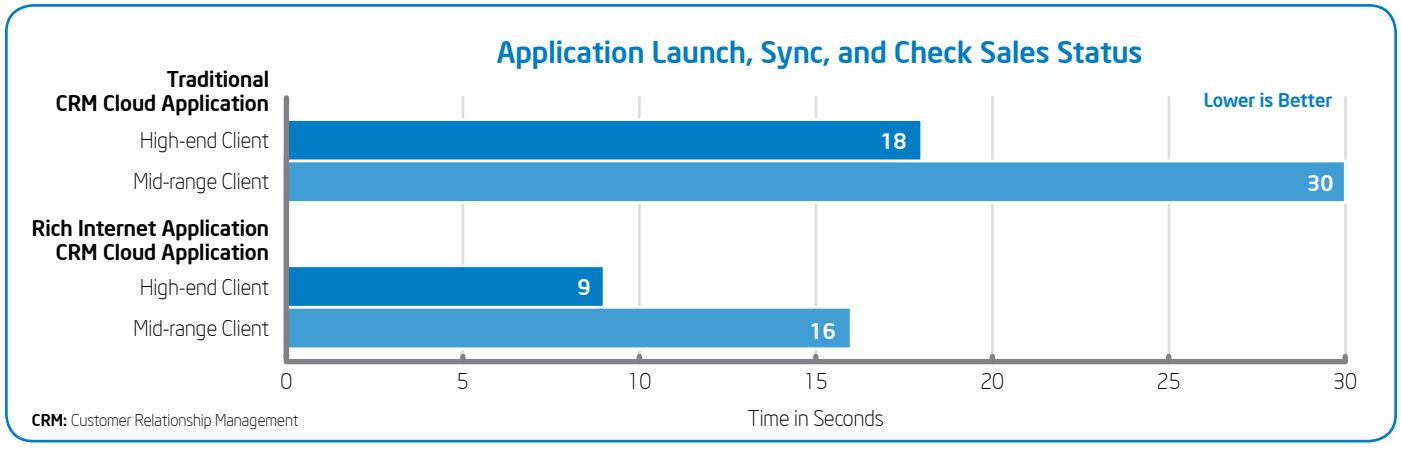

Figure 4. Time required to complete a scripted sequence of common user operations with customer relationship management (CRM) software: launch, sync, and check sales status. Intel internal measurements, January 2010.

MAPPING RIA

With the mapping RIA, we compared the time taken to refresh the screen when zooming the map view. This is a CPU-intensive feature found in about 80 percent of applications using the same RIA framework.

The mobile business PC completed the operation in about 0.1 seconds—an order of magnitude faster than the other clients, which each required several seconds, as shown in Figure 5. The thin client was slowest: It required about 6 seconds to fully display the zoomed view, a delay that would be unacceptable to most users and clearly demonstrated how a client device can limit web application performance. We observed that the RIA fully utilized the processing power of each client device; on the thin client, CPU utilization reached 100 percent, effectively stalling the interaction.

TRADITIONAL WEB APPLICATIONS: INTERNAL AND EXTERNAL

Web browsers typically include tools that measure the time required to load web pages; these tools provide a readily available way to quantify the end-user experience with traditional cloud applications. We used one of these tools to compare performance when executing two different applications. We did not test the thin client because the tool could not be installed on the device.

Intel Employee Portal

We tested the time taken to load the Intel employee portal, a Web site hosted internally within our private cloud and accessed over our corporate network.

We measured two components of the total response time: the time taken for the data to reach the client over the network, and the time for the client to process and display the data. As shown in Figure 6, the network time was similar for both devices; however, once the data reached the client, the mobile business PC displayed it more than 10x as quickly as the entry-level desktop, resulting in a much faster user experience overall.

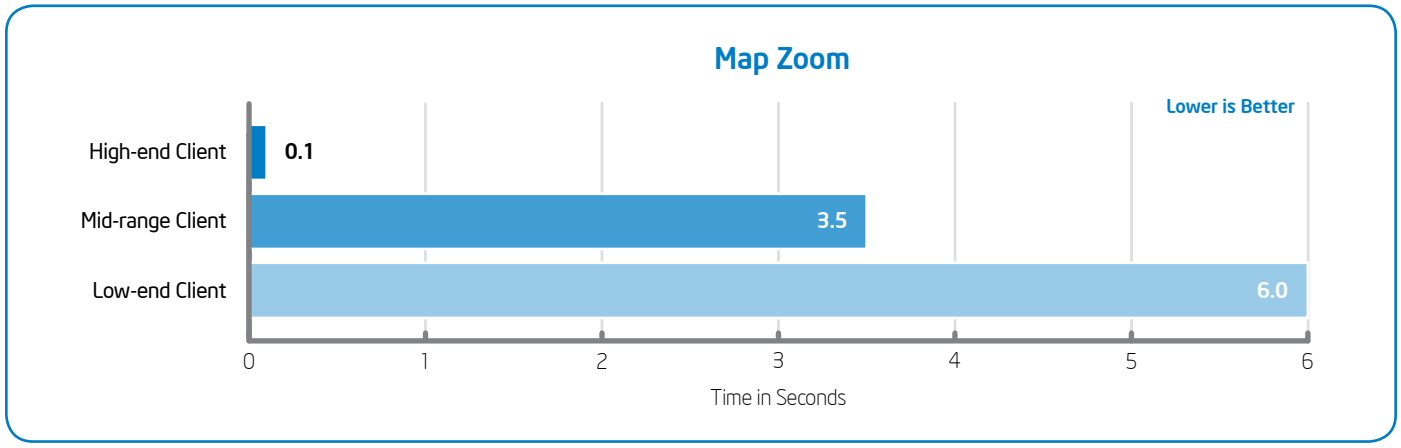

Figure 5. Time to zoom using a mapping rich Internet application. Intel internal measurements, January 2010.

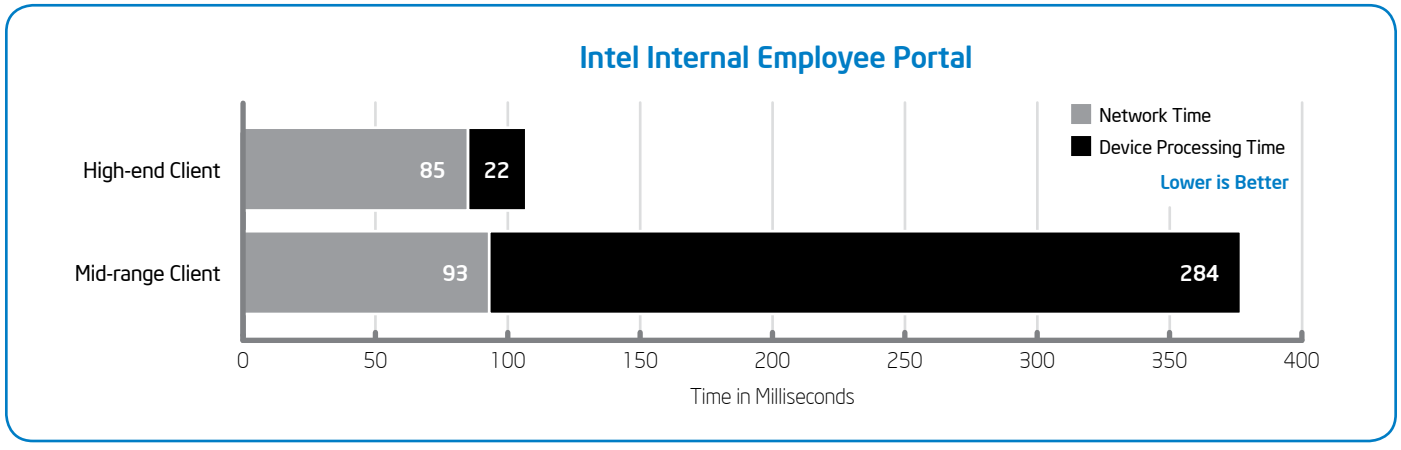

Figure 6. Time to load the Intel internal employee portal. Intel internal measurements, May 2010.

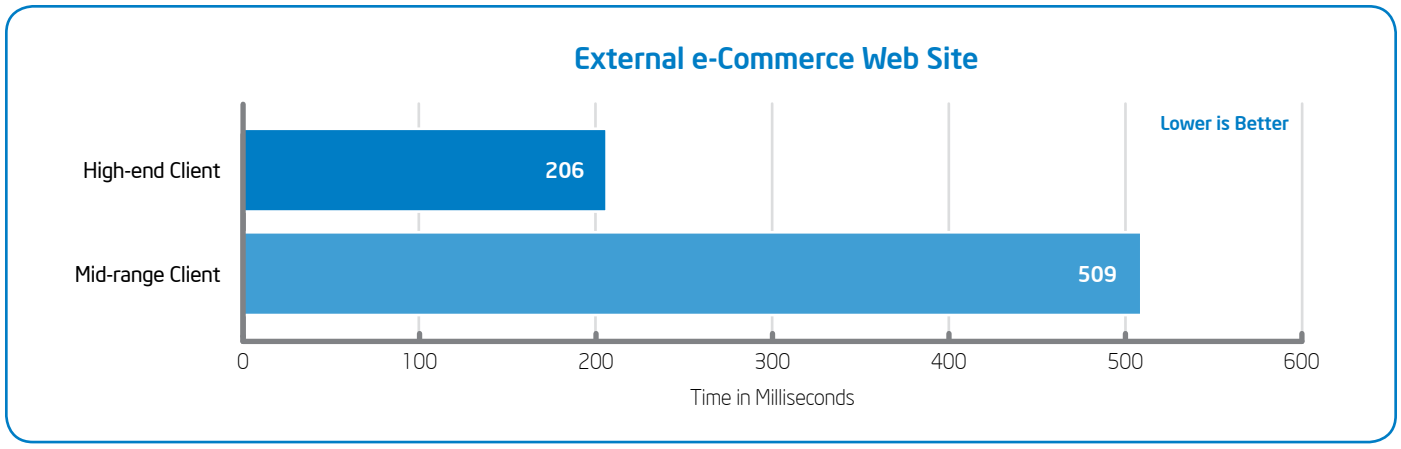

Figure 7. Time to load an external e-Commerce Web site. Intel internal measurements, May 2010.

External e-Commerce Site

We tested the time to render all components of a web page on an external supplier's e-Commerce Web site. The mobile business PC completed the operation about 2.5x faster than the entry-level desktop, as shown in Figure 7.

ANALYSIS AND CONCLUSION

Client performance significantly affects the user experience with cloud-based applications.

In our tests, mobile business PCs provided the fastest response times and the best user experience with all RIAs and traditional cloud applications. We also observed that CPU utilization was lower on the mobile business PC than on the other systems; this provides the processing headroom necessary to simultaneously run existing locally installed applications as well as cloud-hosted applications with optimum performance.

Because users may access cloud-based applications many times during a typical work day, the time savings that we observed in the tests can translate into significant productivity gains as well as increased user satisfaction.

The best application responsiveness was delivered by the combination of a mobile business PC and RIAs, because the RIAs executed locally on the client and were able to take advantage of the higher performance provided by the Intel Core 2 Duo processor. In addition, some RIAs enable offline usage, with significant productivity benefits for our mobile workforce. RIAs also reduce network traffic because more data is stored locally on the client.

The test results reaffirm our decision to standardize on mobile business PCs as the primary client system for Intel employees. Mobile business PCs provide the best user experience and productivity when using

cloud-based applications; in addition, they can run all existing locally installed applications and offer other advantages, such as the ability to work offline.

The growth of cloud computing, along with the consumerization of IT, is driving Intel IT to support a compute continuum in which users will increasingly be able to access applications and services using a spectrum of client devices in a variety of form factors.

While mobile business PCs will remain our employees' primary client devices, we are enabling access from smartphones and tablets, and we are evaluating an even wider range of devices for potential future use. Providing employees with the freedom to use these other devices, in addition to mobile business PCs, further enhances mobility and employee productivity. Our results demonstrate the tradeoffs—such as performance—of using these different devices to access cloud services.

ACRONYMS

CRM	customer relationship management
ERP	enterprise resource planning
Gb/s	gigabits per second
RIA	rich Internet application
SSL	Secure Sockets Layer

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