

# Optimize End-User Computing With Comprehensive Modernization

From endpoint to data center, innovative Intel® technologies can help IT optimize security, agility, and the user experience across service delivery models.

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## Executive Summary

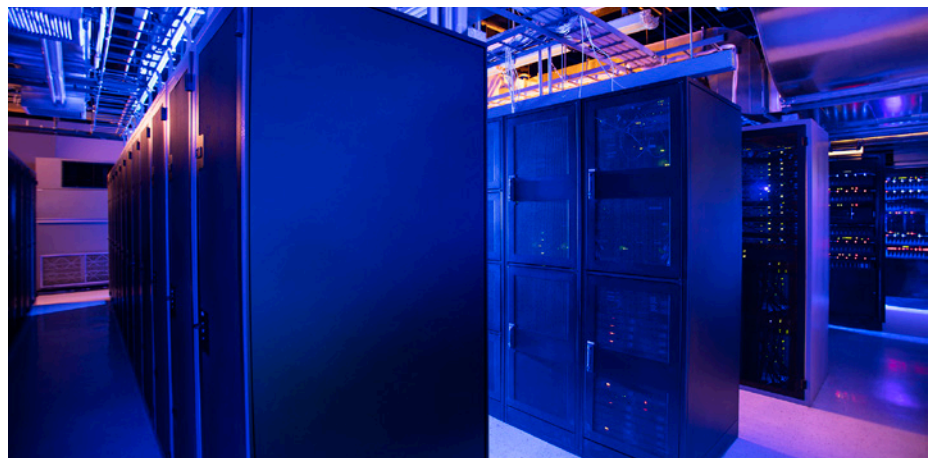
While client/server computing remains the standard for most enterprise use cases, advances in endpoint devices, service delivery methods, and virtualization solutions are leading many organizations to explore centralized, shared-resource delivery models. Interest in these advances is particularly strong in industries such as healthcare, financial services, education, and the public sector, which face challenges relating to data security, industry-specific regulations, distributed work environments, and other factors.

Successful end-user computing strategies deliver an exceptional user experience while providing manageability, security, and agility for the enterprise. IT planners can meet these needs by aligning user profiles, endpoints, and delivery models, and taking advantage of end-to-end Intel® technology innovations as they implement their client computing strategies. The latest Intel® Core™ vPro™ processors help enhance performance and security for both rich and thin clients. Infrastructure built on Intel® Xeon® Scalable processors, solid state drives based on Intel® Optane™ technologies and Intel® 3D NAND Technology, and next-generation networking solutions from Intel help optimize the user experience while contributing to cost-effective, future-proof clouds and data centers.

With end-to-end strategies and Intel technologies, enterprises can empower the digital workforce and strengthen the enterprise's ability to address strategic enterprise goals.

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## Business Challenge: Advance End-User Computing

Fast-moving business trends place new demands on the end-user computing (EUC) environment. Employees expect flexibility in where and how they work. Enterprise leaders demand tools to help them move fast, respond with agility, and collaborate effectively. Customers—whether consumers, patients, students, citizens, or businesses—expect a streamlined, agile, and consumer-like technology experience at every enterprise touch point. Security threats are constant—and costly. The average cost of a data breach was USD 3.62 million globally in 2017, representing a 5 percent increase in the United States.<sup>1</sup>

In addition to these universal issues, industries such as healthcare, financial services, education, and government experience additional pressures because of the sensitivity of the services they provide, the people they serve, or the data they collect. These industries are high-value targets for cybercriminals, who use stolen information for attacks that range from medical claims fraud to money laundering to national security threats. The cost of a data breach in healthcare is more than 2.5 times higher than the global

average across industries.<sup>2</sup> Organizations in the financial services and healthcare sectors are more likely than others to lose customers following a data breach.<sup>3</sup>

Government, healthcare, financial services, and education also operate under complex privacy and compliance regulations, risking steep penalties if data or devices are stolen or an institution cannot demonstrate compliance with governing policies. Policies can vary widely from one state, nation, or region to another, so enterprises must manage a complex web of security requirements and rapidly adjust their security strategies as new requirements are enacted or new threats arise.

Enterprises in these high-threat industries have rapidly evolved their EUC strategies to cope with the preceding issues and now lead many organizations in their EUC innovation. But enterprises across the board encounter similar issues and can benefit from the same approaches. Table 1 summarizes some business challenges that shape the EUC environment in healthcare, financial services, education, and government. This paper discusses approaches and technologies that can enable virtually any large organization to optimize its EUC environments.

**Table 1. Driving the need for end-user computing innovation.**

	Healthcare	Financial Services	Government and Education
<b>Industry-Specific Trends</b>	<ul style="list-style-type: none"> <li>Digital transformation</li> <li>Innovative care models</li> <li>Value-based compensation</li> <li>Triple Aim objectives</li> <li>Industry consolidation</li> <li>Personnel shortages</li> </ul>	<ul style="list-style-type: none"> <li>Heightened need for enterprise agility</li> <li>Frequent mergers and acquisitions</li> <li>Increased need for customer intelligence</li> <li>Rising cyber threats</li> <li>Increased regulatory complexity</li> </ul>	<ul style="list-style-type: none"> <li>Need to deploy new, mission-focused services or support new learning models</li> <li>Need to increase productivity and efficiency</li> <li>Rising security threats and privacy concerns</li> <li>Growing use of geographic information systems (GIS)</li> </ul>
<b>New End-User Capabilities Required</b>	<ul style="list-style-type: none"> <li>Real-time, secure collaboration</li> <li>Convenient, role-based access</li> <li>End-to-end data security and privacy protection</li> <li>Range of graphics, video, mobility, and user input capabilities</li> </ul>	<ul style="list-style-type: none"> <li>Secure collaboration</li> <li>End-to-end data security and privacy protection, including transnational geotracking</li> <li>Audit trail tracking</li> <li>Range of graphics, video, mobility, and user input capabilities</li> </ul>	<ul style="list-style-type: none"> <li>Cost-effective performance at varying levels</li> <li>End-to-end data security and privacy protection</li> <li>3D graphics for analysts, GIS users, and other data-rich applications</li> <li>Mobility for field employees, students, teachers</li> </ul>
<b>IT Issues in Meeting the Requirements</b>	<ul style="list-style-type: none"> <li>Wide range of user needs and experiences</li> <li>Need to ensure end-to-end security, including data encryption, identity verification, and role-based access</li> <li>Legacy network and data center infrastructure</li> <li>Budget constraints</li> </ul>	<ul style="list-style-type: none"> <li>Agility to respond to competitive and regulatory changes</li> <li>Need to manage branch offices, field sales, and so on with little or no local IT</li> <li>Need to ensure end-to-end security, including audit tracing and authentication</li> </ul>	<ul style="list-style-type: none"> <li>Budget constraints</li> <li>Complex procurement cycles</li> <li>Diverse user requirements</li> <li>Agging, complex infrastructure</li> <li>Need to manage field offices and schools with limited or no IT</li> <li>Need to protect confidential data</li> </ul>

## Meeting EUC Challenges with End-to-End Modernization

Optimizing the EUC environment often starts with reexamining and refreshing the client fleet. With outstanding performance and value-added enhancements, up-to-date devices based on the latest Intel® technologies can enhance enterprise agility and IT efficiency by making it easier to adopt transformative innovations, stay abreast of regulatory changes, and deploy the latest operating systems (see Figure 1). Organizations also gain built-in capabilities designed to help protect sensitive data and rapidly remediate damage if a breach occurs. Removing aging devices can also simplify client management and reduce total cost of ownership (TCO).<sup>4</sup>

EUC modernization may also include new service delivery models to address specific user and enterprise needs. Matched to the right use cases and enterprise requirements, virtualized service delivery can be attractive when IT teams need to manage remote offices, accelerate data access after mergers or acquisitions, or meet specialized requirements. But there are no one-size-fits-all answers for client computing, and no single endpoint device or service delivery method is ideal for every computing scenario. Delivery models that shift processing to the cloud or data center can add complexity to the back end and require significant infrastructure investments to ensure a satisfactory user experience.

Rather than seeking a universal strategy, EUC planners need to take a user-centered approach that matches delivery models and device choices to user and enterprise needs. Then, by analyzing end-to-end impacts, deploying a modern architecture, and taking advantage of innovations from Intel, enterprises can optimize the power, agility, and security of their EUC environments and deliver cost-effective performance from the device to the data center.

## Developing a Strategy and Roadmap

Like other major IT projects, EUC modernization requires clear project objectives. These may include:

- Improve operational efficiency
- Simplify remote access
- Enable role-based application access
- Simplify application updates
- Extend the life of existing endpoints
- Improve desktop management
- Offer flexibility in bring-your-own-device, choose-your-own-device, or corporate-owned, personally-enabled policies

Planning and strategy development should also address:

- Capital costs for endpoints and infrastructure buildout, as well as costs relating to telecommunications services, data center power and cooling, software licensing, security technologies, management, and other IT elements
- Risks and constraints such as funding limitations and skills shortages
- Success metrics such as user satisfaction ratings, application response times, bandwidth consumption for peak user login periods, and planned versus actual costs for infrastructure build-out
- Requirements such as the need to improve usability without reducing security

## Client Virtualization with End-to-End Intel® Technology

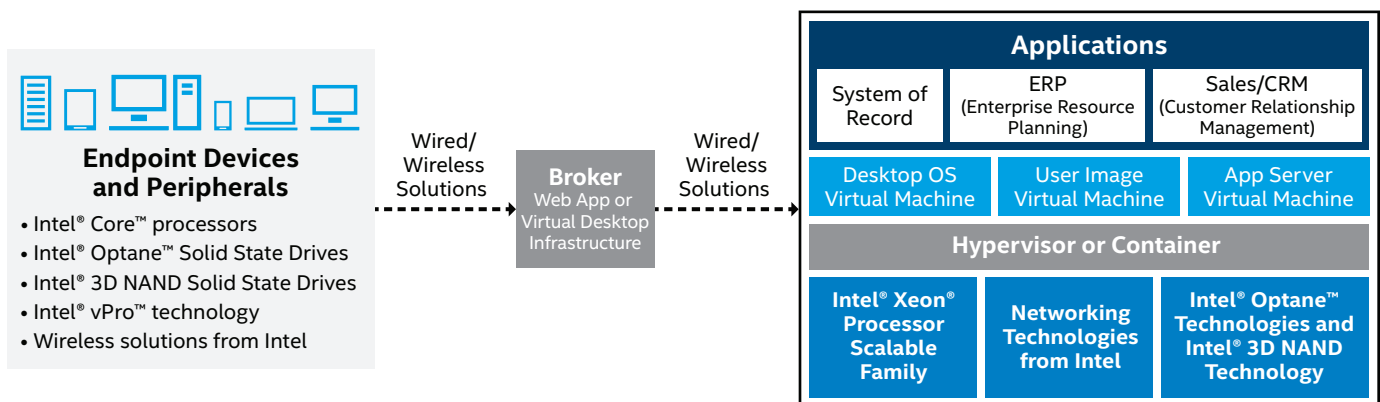


Figure 1. End-to-end innovations from Intel help enhance agility, security, and productivity for a range of service delivery options.

### Data Foundation for a Successful Strategy

The user’s experience is the number one success factor in implementing client virtualization,<sup>5</sup> so analyzing the user base is critical in moving from goals and objectives to a practical EUC roadmap. User analysis can help EUC strategists understand employee requirements, develop practical user profiles, and identify use cases that may be suitable for virtualized service delivery. The user analysis should target:

- Applications and software, including operating systems, performance-sensitive and graphics-intensive applications, and specialized applications that may not be available for virtualized deployment
- Data sensitivity and privacy, such as requirements that data be encrypted at all times or remain within geographic boundaries, or that user identities can be confirmed through strong authentication
- Mobility, form factors, and connectivity
- Specialized user interface capabilities, such as barcode scanning, full keyboard, touch, augmented or virtual reality, sensor, gesture, speech-to-text, or text-to-speech

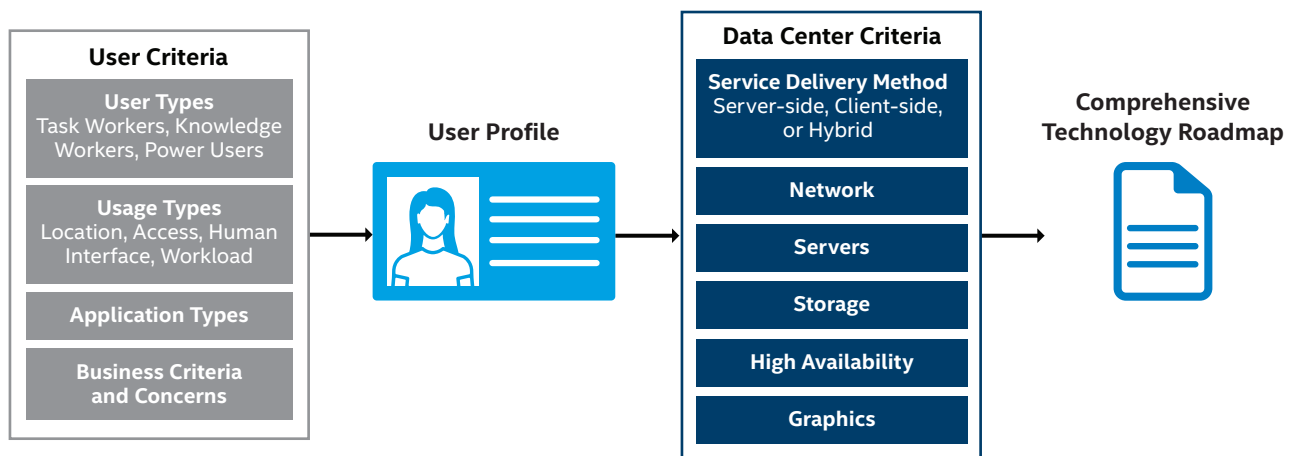
- Use case characteristics such as real-time collaboration, multiple monitors, nonvirtualized applications
- Work environments, including hospital, clinic, or research environment; remote office or headquarters; language lab or 24/7 learning environment; trading desk or call center

Many virtualization methods shift costs, complexity, and computing to the enterprise cloud or data center. To prepare for these infrastructure impacts, user analysis should also collect peak and average figures for workload traits such as:

- CPU and memory usage
- Storage requirements for user virtual desktops, centrally stored user data, and user profiles
- Disk I/O operations per second (IOPS)
- Disk read and write percentages
- Network bandwidth consumption

The resulting technology roadmap provides the basis for a successful EUC strategy (see Figure 2). Tools and guides are available from a range of vendors to assist in planning capacity requirements and monitoring the user experience once solutions are implemented.

## Building a Roadmap for Client Virtualization



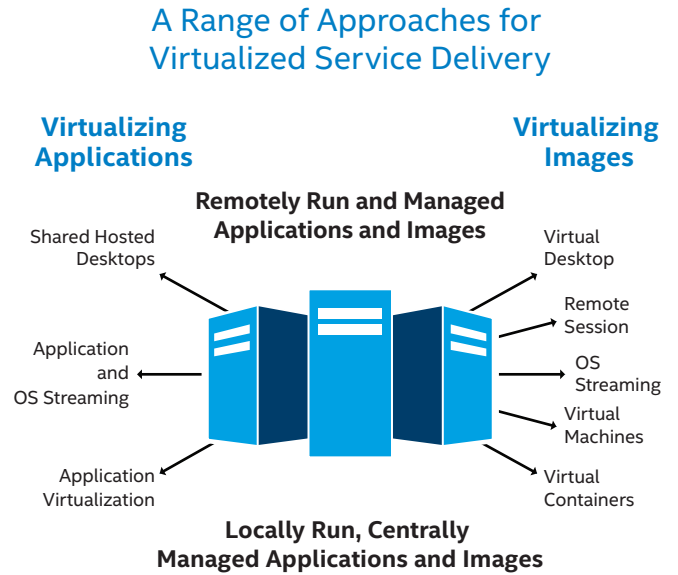
**Figure 2.** The client virtualization roadmap aligns user profiles and data center capabilities, to optimize user productivity while achieving enterprise and IT objectives.

### User Profiles

Although a large enterprise may have dozens of user segments, user profiling should work to minimize complexity by consolidating these segments into the smallest number that can address the majority of user and enterprise requirements—generally three to five profiles. Table 2 summarizes three basic user profiles: task workers, knowledge workers, and power users.

### Service Delivery Basics

EUC strategists who want to adopt virtualized service delivery can choose from a variety of approaches, from virtualizing user identities to running containerized applications to delivering entire virtual desktops. Delivery models differ based on factors such as which layers of the software stack are virtualized, how the layers interact, and whether virtualized elements run on the server or locally on the client (see Figure 3).



**Figure 3.** When user and enterprise needs call for virtualized service delivery, IT can deploy a variety of approaches.

**Table 2. Basic user profiles.**

User Category	Healthcare	Financial Services
<b>Task Workers</b>	<ul style="list-style-type: none"> <li>Typically use a single, virtualized application</li> <li>Simple connectivity needs</li> <li>Minimal need for performance or mobility</li> <li>Basic 2D graphics</li> <li>Variable security requirements</li> </ul>	<ul style="list-style-type: none"> <li>Most call center staff</li> <li>Data entry clerks</li> <li>Hospital admissions clerks, front office staff</li> <li>Remote-office clerks using a single application to handle defined customer service activities (for example, license applications or banking transactions)</li> <li>Language lab users</li> <li>Healthcare workers using form fill-out to document basic care</li> </ul>
<b>Knowledge Workers</b>	<ul style="list-style-type: none"> <li>Create and consume content</li> <li>Heavy web browsing</li> <li>Moderately complex applications, extensive multitasking, and real-time collaboration</li> <li>Variable mobility requirements</li> <li>Variable security requirements</li> <li>Moderate video and graphics</li> </ul>	<ul style="list-style-type: none"> <li>Teachers</li> <li>Nurses and physicians documenting complex care and rounding notes</li> <li>Medical transcriptionists</li> <li>Office workers using multiple applications</li> <li>Financial advisors using multiple applications to provide financial advice</li> <li>Most students</li> <li>Most administrators</li> <li>Care management planners, visiting nurses</li> </ul>
<b>Power Users</b>	<ul style="list-style-type: none"> <li>Create and consume complex content</li> <li>Heavy graphics, performance, or both</li> <li>Frequent mobility</li> <li>Variable security requirements</li> <li>Intensive 3D graphics and video</li> <li>Extensible multitasking, real-time collaboration</li> <li>Possible dual monitors</li> </ul>	<ul style="list-style-type: none"> <li>Administrators doing heavy data analysis and creating complex reports</li> <li>Government analysts using geographic information systems technology to develop disaster preparedness plans, improve resource management, or improve public safety</li> <li>Economic forecasters</li> <li>Physicians examining 3D medical images, researching medical literature, or developing care plans</li> <li>Data analysts studying and visualizing complex data</li> <li>Education content development specialists</li> <li>Teachers of engineering and visual arts subjects</li> <li>Engineering students</li> </ul>

Server-side delivery models handle processing in the enterprise data center or cloud. These models are best suited to task workers who access only a small set of applications, require little or no personalization or mobility, and have simple requirements for connectivity and graphics. These models require careful infrastructure planning and cost management.

Knowledge workers and power users—particularly those with high requirements for mobility and graphics, complex workloads, and latency-sensitive applications—benefit from models that support client-side computing and local caching. This can include applications that run locally on the client because robust virtualized implementations are not available, the use cases require mobility, or the applications are too latency-sensitive to maintain a consistent, responsive user experience. Paired with full-featured endpoints and local storage, client-side delivery can provide responsive user experiences and full mobility while minimizing back-end impacts.

Hybrid delivery models combine a client-side OS with a mix of client-side and server-side applications. Hybrid models run both virtual and nonvirtual workloads, offering broad flexibility in satisfying diverse requirements. For example, basic business applications might run remotely through virtual desktop infrastructure (VDI), with client-side delivery for mobile use cases as well as for latency-sensitive or performance-heavy applications.

Table 3 summarizes the major delivery models. Organizations that deploy virtualized service delivery will typically adopt multiple delivery methods and maintain a large base of rich clients to satisfy diverse requirements.

### Endpoint Advances for Rich and Thin Clients

Endpoints strongly influence user satisfaction, TCO, and infrastructure requirements, making endpoint selection critical to any EUC strategy. As Tables 3 and 4 show, client virtualization does not equate to thin clients. Instead, planners should consider user segment profiles and service delivery models together as they select devices. For example, endpoints for client-side and hybrid delivery models must support any workloads that use client resources.

**Table 3. Delivery models and endpoints at a glance.**

Delivery Model	Summary	Example Solutions	Suitable Endpoints
<b>Virtual Container</b>	Installs and executes virtual desktops in isolated containers on the client with centralized management	Citrix XenClient* VMware Horizon Mirage*	Rich client
<b>Application Streaming</b>	Packages applications within a virtual application tool that executes on the client and uses local resources  Can cache streamed applications on a laptop, enabling mobile users to work offline.	VMware ThinApp* Citrix XenApp* Microsoft Application Virtualization* (App-V*) Amazon AppStream*	Rich client
<b>OS Streaming</b>	Streams an OS and application image for execution in client memory or on local client storage  Stores application data in the data center	Citrix Provisioning Services*	Rich client
<b>Application Layering</b>	Runs virtual applications on the client, interacting with the OS and other apps as if installed natively	VMware App Volumes* Citrix AppDisks* Liquidware Labs FlexApp* Unidesk*	Rich client
<b>Shared Hosted Desktops</b>	Executes code in a shared session on a server OS with no local storage, no data persistence on the client, and little or no personalization	Citrix XenApp Microsoft Remote Desktop Services* (RDS*)	Rich or thin client, depending on application and mobility requirements and the need to access nonvirtual applications
<b>Virtual Desktop</b>	Centralizes computation and storage, but provides users with a complete virtual machine and customized desktop, including OS, applications, and settings	VMware View* Citrix XenDesktop* Microsoft Hyper-V*	Rich or thin client, depending on application and mobility requirements
<b>Desktop as a Service (DaaS)</b>	Delivers virtual or nonvirtual applications as a service, while offloading much of the back-end client virtualization infrastructure	Amazon WorkSpaces* Cisco DaaS Microsoft RDS VMware Horizon* DaaS	Rich or thin client, depending on application requirements

Intel actively innovates to ensure enterprises can deploy robust, compatible endpoints whatever their client computing strategy or preferred device type. With a consistent architecture and extensive product families to choose from, EUC planners can deploy thin and rich devices that help optimize the user experience while contributing to a secure, manageable, and cost-effective IT environment.

Table 4 lists relevant endpoint technologies for the most common user profiles, and the following discussion shows how innovations from Intel combine to deliver comprehensive solutions for the full range of virtualization use cases.

**Rich PCs for Knowledge Workers and Power Users**

Power users and knowledge workers require client-side or hybrid service delivery models, along with powerful endpoints and local storage, to run their complex workloads.

Endpoints based on Intel® Core™ vPro™ processors, Intel® Optane™ Solid State Drives, and Intel® Optane™ memory provide outstanding support for mobile use cases, performance-sensitive applications, real-time collaboration, and locally executing workloads. Intel Core vPro processors

enhance the user experience with high-performance support for demanding applications and multitasking workloads. These processors also provide capabilities aimed at improving enterprise security and management (see [Endpoint Security and Compliance](#)). The revolutionary improvements of Intel® Optane™ SSDs and memory technology help speed program execution and load times for the most demanding virtualized and traditional client workloads, with innovative Intel® 3D NAND SSDs providing cost-effective local storage for knowledge workers.

Rapidly advancing wireless communications, including wireless solutions for 5G from Intel, Gigabit Wi-Fi\*, and 802.11A-C technologies, also contribute to smoother user experiences and better virtualization performance for knowledge workers and power users. Gigabit Wi-Fi solutions achieve speeds up to 1733 Mbps, nearly twice as fast as 802.11ac 2x2.<sup>6</sup> Power users and knowledge workers can efficiently create, view, play, analyze, and share multimedia files, potentially reducing eye strain and errors for users who spend long hours working with 3D medical images, data-rich elevation maps, and other detailed images.

**Table 4. Mapping user profiles to endpoint innovations.**

User Profiles	Typical Endpoints	Financial Services
<b>Power User</b>	<ul style="list-style-type: none"> <li>Rich clients</li> </ul>	<ul style="list-style-type: none"> <li>Intel® Core™ i7 vPro™ processors</li> <li>Intel® Optane™ memory</li> <li>Intel® Optane™ Solid State Drives</li> <li>Wireless 5G and Gigabit technologies from Intel</li> <li>Intel® HD Graphics</li> <li>Intel® Authenticate Technology</li> <li>Fast IDentity Online (FIDO) compliant biometric authentication (Intel® Online Connect )</li> <li>Intel® Software Guard Extensions (Intel® SGX)</li> <li>Intel® Advanced Encryption Standard New Instructions (Intel® AES-NI)</li> </ul>
<b>Knowledge Worker</b>	<ul style="list-style-type: none"> <li>Rich or high-end thin clients</li> </ul>	<ul style="list-style-type: none"> <li>Intel® Core™ i5 vPro™ processors</li> <li>Intel® 3D NAND SSDs</li> <li>Intel® Wireless-AC</li> <li>Intel HD Graphics</li> <li>Intel Authenticate Technology</li> <li>FIDO-compliant biometric authentication (Intel Online Connect )</li> <li>Intel SGX</li> <li>Intel AES-NI</li> </ul>
<b>Task Worker</b>	<ul style="list-style-type: none"> <li>Thin clients for full server-based computing workloads</li> <li>Rich clients and high-end thin clients for hybrid delivery</li> </ul>	<ul style="list-style-type: none"> <li>Intel Atom®, Celeron®, or Pentium® processors</li> <li>Intel® Core™ i3 processors with Iris™ Pro graphics</li> <li>Intel Core i5 and Core i5 vPro processors for hybrid delivery, fleet management, and enhanced security</li> <li>Intel 3D NAND SSDs</li> <li>Intel® NUC</li> <li>Intel® Compute Stick</li> <li>Intel® Compute Card</li> <li>Wireless solutions from Intel</li> <li>Intel Authenticate Technology</li> <li>FIDO-compliant biometric authentication (Intel Online Connect)</li> <li>Intel SGX</li> <li>Intel AES-NI</li> </ul>

### Thin Clients for Task Workers with Server-Centric Delivery

Intel® technology-based thin clients provide powerful capabilities for a range of task workers. For value-focused environments where users' workloads require only server-centric delivery, thin clients based on Intel Atom®, Celeron®, Pentium®, and Intel® Core™ i3 processors offer extensive choices—and Intel has continued to advance these processor families. The newest Pentium® Silver processors deliver 58 percent faster productivity performance compared to a similar four-year-old system.<sup>7</sup> The newest Pentium Silver and Celeron processors now offer Gigabit Wi-Fi capability, to speed transmission of virtualized data and applications and enhance the user experience. Users who need graphics performance on a thin client can take advantage of built-in Iris® Pro graphics on an Intel Core i3 processor.

Thin clients based on Intel Core i5 and Intel® Core™ i5 vPro™ processors deliver high performance for more demanding workloads and mixed service delivery. These processors can help improve access to virtualized and nonvirtualized applications, increase overall productivity, and enable significantly faster collaboration for locally installed applications compared to thin clients with less powerful Intel® processors.<sup>8</sup> Options for reliable, value-sensitive local storage include Intel 3D NAND SSDs as well as SATA-based SSDs from Intel.

Intel has also innovated to create Intel technology-based thin clients in a variety of form factors. These endpoint technologies offer small footprints, value price points, and a range of features to meet user and enterprise needs. The new building blocks include:

- **Intel® NUC.** A 4x4-inch customizable mini PC based on Intel Core i3 and Intel Core i5 processors.
- **Intel® Compute Stick.** A device the size of a pack of gum that turns an HDMI\* display into a PC powered by Intel Atom or Intel® Core™ M3 processors.
- **Intel® Compute Card.** A credit card-sized computer that increases portability and is available with Celeron, Pentium, and Intel Core processors.

### Endpoint Security and Compliance

Security and compliance concerns cut across user segments, and Intel has built numerous capabilities into the latest Intel Core vPro processors and storage solutions from Intel to deepen security. Silicon-strengthened innovations from Intel can benefit both virtualized and locally executing nonvirtualized client workloads, and are particularly valuable for organizations that are mandated to implement data encryption, multifactor or biometric authentication, geofencing (to track movement of sensitive data across national or regional boundaries), data-access logging, and similar practices.

- **Hardware-aided encryption.** In addition to dramatic improvements in latency and read/write performance, Intel Optane SSDs work with high-end Intel Core vPro processors to offer full-disk encryption through Intel® Advanced Encryption Standard New Instructions (Intel® AES-NI) and other technologies. These solutions also allow IT to securely erase the storage media of a lost or stolen client—capabilities that are especially impactful in reducing security risks for mobile users.
- **Identity protection.** Intel® Authenticate Technology helps guard identities by strengthening protection of credential keys and IT policies. New sensors and infrared cameras on the latest Intel Core vPro processor-based endpoints can add biometric factors such as fingerprints and facial recognition to identity verification.
- **Fast IDentity Online (FIDO)-compliant biometric authentication.** Intel® Online Connect and the latest Intel Core vPro processors provide hardware-enhanced support for the FIDO biometric authentication standard. The FIDO standard is designed to strengthen authentication and allow a higher degree of trust for online and software-as-a-service transactions. Intel serves on the FIDO board of directors.
- **Safeguarding critical code.** Intel® Software Guard Extensions (Intel® SGX) helps protect critical application code and data from being disclosed or modified. This Intel technology can improve the confidentiality, security, scalability, and speed of private key operations and other highly sensitive applications.

### Managing the EUC Environment

Endpoint innovations from Intel equip IT teams with powerful tools for managing their EUC environments, including branch offices and mobile users. In addition to hardware-enhanced security, endpoints with Intel Core vPro processors and Intel® Active Management Technology (Intel® AMT) can simplify and strengthen remote management. IT teams and managed service providers can apply virus patches more simply and improve recovery in the event of a breach, helping to stay ahead of threats. Using out-of-band management capabilities, technicians can power-on a mobile client or an entire fleet of Intel Core vPro processor-enabled clients, helping reduce energy consumption and support costs while discovering, managing, and repairing endpoints.

**HIGHER-END PROCESSOR =  
BETTER VIRTUAL PERFORMANCE**

Thin clients with powerful Intel® processors ran complex virtualized workloads up to 155% faster.<sup>9</sup>

**155%  
FASTER**



Along with full-disk encryption, Intel® SSD Professional Family drives and endpoints with Intel AMT are designed for easy configuration, management, and recovery with support for the Trusted Computing Group's OPAL\* 2.0 policy control standard. IT can use Intel® Remote Secure Erase to remotely sanitize old data across the base of enabled devices as well as wipe the disk of a compromised client.

### Architecting and Building Out the Back End

EUC strategies that include hybrid or server-side delivery models can draw heavily on the resources of servers, storage, and networks, particularly when deployed with thin clients. These approaches require a modern architecture from devices to data centers to ensure consistent, cost-effective virtual performance (see Figure 4).

Paired with careful capacity planning and technology selection, a modern architecture helps avoid bottlenecks that can impair productivity and satisfaction, affect other data center workloads, and drive unanticipated back-end costs. Organizations can build out their data center or cloud using the same software-defined strategies and approaches that support their other next-generation workloads. By deploying data center technologies from Intel, organizations can meet capacity needs while providing added-value innovations that increase scalability and performance for client virtualization and other demanding workloads.

### Capacity Planning

Server-centric virtualized workloads are unpredictable and incur spikes when large numbers of users log in and open major applications or when IT teams deploy software updates. EUC strategists can plan for these spikes by using the workload characteristics gathered during the roadmap planning phase of the EUC modernization initiative (see the earlier [Developing a Strategy and Roadmap](#) section).

By considering peak and average requirements for each major user profile, together with endpoints and delivery models, EUC strategists can forecast infrastructure requirements and expand their infrastructure accordingly. Microsoft, Liquidware Labs, Lakeside, uberAgent, and other solution providers offer tools and guides to assist in planning capacity requirements and monitoring the user experience.

Organizations migrating to Windows\* 10 should note that this OS affects the virtualization footprint for server-based delivery. ProjectVRC.team—a community-based organization that provides a “virtual reality check” by publishing independent research on desktop virtualization, data center, and cloud technologies—reports that fully tuned versions of Windows 10 and Windows\* 7 have similar overall IOPS usage profiles, but Windows 10 has a larger impact on storage and I/O throughput than Windows 7. Windows 10 allows a larger write block size, which can increase the need for networking capacity as throughput increases. ProjectVRC.team recommends that organizations with limited server and storage capacity for client virtualization consider upgrading or modernizing their back-end infrastructure before using Windows 10 for large-scale VDI-based service delivery.<sup>10</sup>

## End-to-End Architecture for Client Virtualization

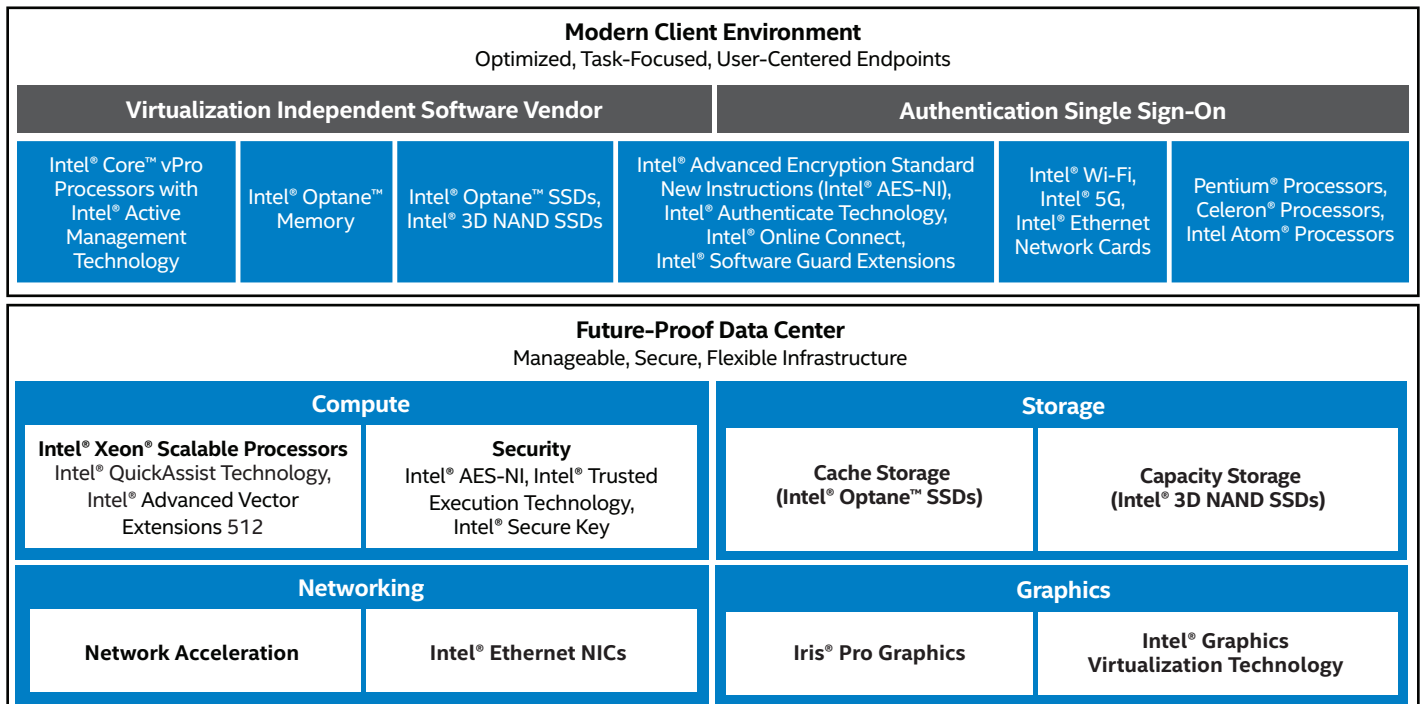


Figure 4. Innovative technologies enhance end-user computing for practical endpoints and practical infrastructure buildout.

## Hyperconverged Infrastructure and More

Hyperconverged infrastructure (HCI) combines compute, storage, networking, and virtualization software resources in comprehensive turnkey appliances. Intel® architecture-based HCI appliances leverage advances in Intel® technology to simplify and speed time-to-value for client virtualization, enhancing performance, security, and cost effectiveness.

With HCI architectures, storage attaches directly to the compute elements, reducing layers and shrinking the potential for delay-inducing queuing and latency problems. Most HCI solutions incorporate software to reduce common causes of network overload—from boot storms when many users log on at once, to mass OS upgrades.

In addition to delivering robust technologies, Intel works with industry leaders and experts from companies including Citrix, Microsoft, and VMware/EMC to advance robust virtualization solutions that provide optimal performance on each new generation of Intel® processors.

### Infrastructure Considerations

Infrastructure planning focuses on the need to meet user expectations and enterprise requirements while minimizing costs. Server, storage, and network technologies must work together to provide the performance and capacity to deliver consistent, secure, and responsive user experiences, even during usage spikes.

Servers must provide the capacity and throughput to optimize the number of users per server. Planners build success by deploying server infrastructure that can handle anticipated increases in the number of and types of users as well as scale to meet the demands of emerging applications and use cases. To manage cloud and data center TCO, server build-out must also address non-performance factors such as floor space, power and cooling, reliability, availability, and serviceability.

Storage latency can cause delays in virtualized, shared storage environments, where I/O can come from many different desktops at the same time and IOPS demands can vary widely depending on a user's applications. With multiple virtual machines (VMs) scrambling their I/O requests into a random stream, the high rates of random access can create an "I/O blender" effect that strains the shared infrastructure unless capacity needs are met. Storage latency can also be slowed by multiple layers of queue depth in the storage controller. IOPS targets should focus on peak rather than average workloads, and the storage infrastructure should ensure adequate IOPS resources for consistent user satisfaction. With modern storage architecture, planners can use tiered approaches to balance cost, capacity, and throughput requirements. Modern storage architecture also flattens the layering of queue depths and supports flexible scale-out expansion.

Network and communications infrastructure is crucial to ensuring responsive experiences, including for real-time collaboration tools such as Skype\* for Business. However, the added network and communications capacity to deliver those responsive experiences can drive steep increases in costs. Build-out should focus on maintaining IOPS and latency goals even during network bursts and when data is traveling from enterprise data centers to regional or branch offices. Most server-side virtualization workloads will need network speeds of 10GbE or faster to handle peak loads. Organizations serving virtualized graphics workloads to large numbers of knowledge workers and power users will benefit from 40GbE. Capacity planners should also consider user segments with heavy write requirements.

### Infrastructure Innovation

Intel has been rapidly advancing its server, storage, and networking technologies to deliver integrated, industry-leading solutions for data center and cloud computing. Intel innovations enable enterprises to deploy reliable, cost-effective infrastructure with balanced, energy-efficient performance for virtualized service delivery workloads.

#### Powering Cloud and Data Center Servers: Intel® Xeon® Scalable Processors

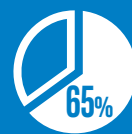
Intel Xeon Scalable processors, which are part of Intel's most significant data center and network processor advancements in a decade, provide dramatic benefits for virtualization capacity and TCO. These processors can support up to 4.2 times more VMs than a four-year-old system and improve TCO by as much as 65 percent over a four-year lifetime.<sup>11</sup> TCO benefits include faster service deployment, higher server utilization, lower energy costs, and space efficiency in the data center.<sup>12</sup> Intel Xeon Scalable processors also increase overall performance by an average of up to 1.65x over the previous generation across key industry-standard workloads.<sup>13</sup>

Intel Xeon Scalable processors integrate innovative features to increase performance and availability for data center build-out and virtualized service delivery. For example, innovations on processors, chipset accelerators, networks, SSDs, and software combine to strengthen the processors when they function as storage controllers. Tight integration with storage and network

**Intel® Xeon® Scalable Processors<sup>14</sup>**  
Compared to four-year-old systems



**UP TO 4.2x MORE VMs**



**65% LOWER TCO  
OVER 4 YEARS**

interfaces helps increase performance and throughput while simplifying management and TCO (see “Storage Innovation” below). Other enhancements include:

- **Intel® QuickAssist Technology.** Helps provide hardware acceleration of cryptography and data compression operations.
- **Intel® Advanced Vector Extensions 512.** Helps boost performance on computationally demanding tasks.
- **Intel® Omni-Path Architecture.** Helps facilitate cost-effective deployment of large, high-performance clusters by providing an integrated high-speed fabric.
- **Intel® Resource Director Technology.** Brings new levels of visibility and control over how VMs and containers access shared resources, helping improve workload density and deliver consistent performance for dynamic service delivery.
- **Intel® Trusted Execution Technology, Intel AES-NI, and Intel® Secure Key.** Support for these and other security enhancements from Intel helps protect data, harden systems against attack, and strength enterprise security initiatives.

#### Storage Innovation: Intel® Optane™ SSDs and Intel® 3D NAND SSDs

Transformative advances in storage and memory technology from Intel help deliver breakthroughs in predictably fast storage performance, with low latency and cost-effectiveness for server-based client virtualization and other data-intensive computing.

The Intel® Optane™ SSD Data Center (DC) P4800X Series brings disruptive increases in performance and flexibility to both traditional and software-defined storage architectures. Based on revolutionary 3D XPoint™ Memory Media, Intel® Optane™ SSDs help avoid data center storage bottlenecks, accelerating virtualized workloads and contributing to lower overall TCO for the data center. SSDs in the Intel® Optane™ SSD DC P4800X Series offer hardware encryption and can be remotely managed, helping increase data security and IT efficiency. Intel Xeon Scalable processors and Intel® Optane™ SSDs together handle up to five times more IOPS and reduce latency by up to 70 percent, compared to out-of-the-box drives based on the Non-Volatile Memory Express\* (NVMe\*) protocol.<sup>15</sup>

The Intel® SSD Data Center (DC) P4500 Series uses innovative Intel 3D NAND Technology to deliver outstanding quality, reliability, and advanced management capabilities. Organizations can deploy the two SSD families to create a two-tier, all-NVMe architecture that optimizes storage throughput and latency by using Intel® Optane™ SSDs as an ultra-fast cache tier serving primarily write traffic, and Intel 3D NAND SSDs as a capacity tier to handle read-intensive workloads. Intel 3D NAND SSDs, such as the Intel SSD DC P4500 Series, offer cost-effective replacements for traditional hard disk drives, increasing density and improving the performance of virtualized applications and services.

Adding further power and flexibility to the storage environment, Intel® Memory Drive Technology transparently integrates an Intel® Optane™ SSD into the memory subsystem of an Intel Xeon Scalable processor without requiring changes to the OS or applications. Using these technologies together, organizations can extend system memory and accelerate their virtualization and other latency-sensitive workloads with transparent, cost-effective, and high-performance access to both DRAM and SSD capacity.

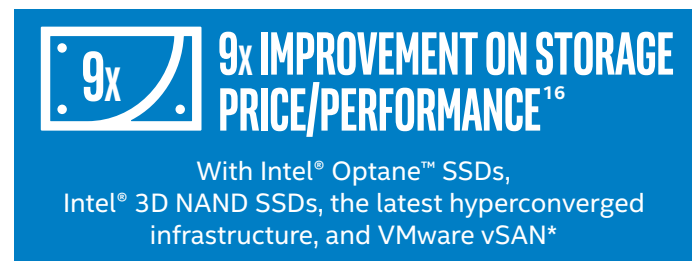
#### High-Throughput Network Technologies

Intel offers a broad family of network infrastructure technologies to facilitate efficient and affordable service delivery. The chipset used with new Intel Xeon Scalable processors provides integrated Intel® Ethernet connectivity at speeds of up to 4x10GbE, helping reduce power consumption and total system cost while boosting performance through high throughput and low-latency data transfer. Using iWARP (Internet Wide-Area Remote Data Memory Access Protocol), integrated Intel Ethernet also improves transfer latency of large storage blocks to further accelerate virtualized client workloads. Intel® Ethernet Converged Network Adapters help provide rapid, reliable movement of virtualized workloads and stored data, and are available at 1GbE, 10GbE, 25GbE, and 40GbE.

#### Virtualized Graphics

Advances in graphics virtualization technologies offer new ways to optimize the responsiveness of media-rich workloads in virtualized environments. Intel® Graphics Virtualization Technology (Intel® GVT) offers multiple ways to improve the user experience for virtualized graphics computing.

- The highest graphics performance comes from Intel® GVT-d, which provides a virtual dedicated graphics acceleration engine by assigning one VM to each physical Intel processor.
- Intel® GVT-g offers mediated pass-through to Intel processor graphics, maintaining a virtual GPU for each VM, with part of performance-critical resources directly assigned. The ability to run a native graphics driver inside a VM, without hypervisor intervention, in performance-critical paths achieves a good balance among performance, feature, and sharing capability.
- Intel® GVT-s enables shared virtual shared graphics acceleration, mapping multiple VMs to a single physical Intel processor.



**9x IMPROVEMENT ON STORAGE PRICE/PERFORMANCE<sup>16</sup>**

With Intel® Optane™ SSDs, Intel® 3D NAND SSDs, the latest hyperconverged infrastructure, and VMware vSAN\*

## Conclusion

No single device or delivery model is right for every user segment, industry, or enterprise. Effective strategies focus on the user experience, segmenting the user base, selecting devices and delivery models that meet user and organizational needs, and modernizing the infrastructure to absorb the demands of server-side and delivery models.

End-to-end technology innovations from Intel can help enterprise IT teams optimize their EUC environment, whether their strategy calls for traditional or virtualized service delivery and rich or thin clients. With end-to-end planning and Intel technologies, IT can prepare to increase user satisfaction, improve security and agility, and empower the enterprise to tackle changing requirements, capture exciting new opportunities, and take on the toughest challenges.

Find the solution that is right for your organization. Contact your Intel representative or visit [intel.com/ITcenter](https://intel.com/ITcenter).

### Learn More

- Intel in Financial Services: [intel.com/content/www/us/en/financial-services-it/financial-services-overview](https://intel.com/content/www/us/en/financial-services-it/financial-services-overview)
- Intel in Healthcare and Life Sciences: [intel.com/content/www/us/en/healthcare-it/healthcare-overview](https://intel.com/content/www/us/en/healthcare-it/healthcare-overview)
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- Intel in Education: [intel.com/content/www/us/en/education/intel-education](https://intel.com/content/www/us/en/education/intel-education)

### Intel Publications and Other Resources

- “Virtualized Graphics Processing Enhances Collaboration,” 2016. [intel.com.au/content/www/au/en/solution-providers/documents/intel-citrix-rich-virtualized-graphics-brief](https://intel.com.au/content/www/au/en/solution-providers/documents/intel-citrix-rich-virtualized-graphics-brief)
- “Banks Seek to Stop Fraud in Its Tracks with Simpler, Stronger Authentication,” 2017. [intel.com/content/www/us/en/financial-services-it/frictionless-end-point-authentication-brief](https://intel.com/content/www/us/en/financial-services-it/frictionless-end-point-authentication-brief)
- Calculate the Return on Investment for Data Center Modernization. [estimator.intel.com/serverroi](https://estimator.intel.com/serverroi)

### Intel® Technologies

#### Security

- Intel® Authenticate Technology: [intel.com/content/www/us/en/security/authenticate/authenticate-is-hardware-enhanced-security](https://intel.com/content/www/us/en/security/authenticate/authenticate-is-hardware-enhanced-security)
- Intel® Online Connect: [intel.com/content/www/us/en/security/online-connect](https://intel.com/content/www/us/en/security/online-connect)
- Intel® Software Guard Extensions: [newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/08/blockchain-infographic.pdf](https://newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/08/blockchain-infographic.pdf)

#### Clients

- Intel® Core™ vPro™ processors: [intel.com/content/www/us/en/products/processors/core](https://intel.com/content/www/us/en/products/processors/core)
- Intel® SSD Professional Family: [intel.com/content/www/us/en/products/memory-storage/solid-state-drives/professional-ssds/pro-6000p-series](https://intel.com/content/www/us/en/products/memory-storage/solid-state-drives/professional-ssds/pro-6000p-series)
- Intel® Wireless solutions: [intel.com/content/www/us/en/products/wireless](https://intel.com/content/www/us/en/products/wireless)

#### Data Center

- Intel® Xeon® Scalable processors: [intel.com/content/www/us/en/processors/xeon/scalable/xeon-scalable-platform](https://intel.com/content/www/us/en/processors/xeon/scalable/xeon-scalable-platform)
- Intel® Optane™ SSDs: [intel.com/content/www/us/en/products/memory-storage/solid-state-drives/data-center-ssds](https://intel.com/content/www/us/en/products/memory-storage/solid-state-drives/data-center-ssds)
- Intel® 3D NAND SSDs: [intel.com/content/www/us/en/products/memory-storage/solid-state-drives/data-center-ssds/dc-p4500-series](https://intel.com/content/www/us/en/products/memory-storage/solid-state-drives/data-center-ssds/dc-p4500-series)
- Network Infrastructure Solutions: [intel.com/content/www/us/en/communications/communications-overview](https://intel.com/content/www/us/en/communications/communications-overview)
- Intel® Graphics Virtualization Technology: [01.org/igvt-g](https://01.org/igvt-g)

### Third-Party Solutions

#### Hyper-Converged Infrastructure

- Dell EMC: [dell.com/en-us/converged-infrastructure/benefits](https://dell.com/en-us/converged-infrastructure/benefits)
- HPE: [hpe.com/us/en/integrated-systems/hyper-converged](https://hpe.com/us/en/integrated-systems/hyper-converged)
- Nutanix: [go.nutanix.com/rs/nutanix/images/Desktop-Virtualization-Solution-Brief.pdf](https://go.nutanix.com/rs/nutanix/images/Desktop-Virtualization-Solution-Brief.pdf)

#### Client Assessment and Capacity Planning

- Liquidware Stratusphere FIT: [liquidware.com/products/stratusphere-fit](https://liquidware.com/products/stratusphere-fit)
- Lakeside Systrack Assessments: [lakesidesoftware.com/assessments](https://lakesidesoftware.com/assessments)
- uberAgent: [uberagent.com](https://uberagent.com)
- Microsoft Assessment and Planning Toolkit: [microsoft.com/en-us/download/details.aspx?id=7826](https://microsoft.com/en-us/download/details.aspx?id=7826)
- Brian Suhr and Sean Massey, Architecting EUC Solutions, CreateSpace Independent Publishing Platform, 2016.

- <sup>1</sup> "2016 Cost of Data Breach Study: Global Overview," Ponemon Institute, June 2016. [public.dhe.ibm.com/common/ssi/ecm/se/en/sel03094wwen/SEL03094WWEN.PDF](http://public.dhe.ibm.com/common/ssi/ecm/se/en/sel03094wwen/SEL03094WWEN.PDF)
- <sup>2</sup> "2016 Cost of Data Breach Study: Global Overview," Ponemon Institute, June 2016. [public.dhe.ibm.com/common/ssi/ecm/se/en/sel03094wwen/SEL03094WWEN.PDF](http://public.dhe.ibm.com/common/ssi/ecm/se/en/sel03094wwen/SEL03094WWEN.PDF)
- <sup>3</sup> "2016 Cost of Data Breach Study: Global Overview," Ponemon Institute, June 2016. [public.dhe.ibm.com/common/ssi/ecm/se/en/sel03094wwen/SEL03094WWEN.PDF](http://public.dhe.ibm.com/common/ssi/ecm/se/en/sel03094wwen/SEL03094WWEN.PDF)
- <sup>4</sup> Planning Guide: "A Business Investment Strategy for Device Refresh, Intel's Guide to Managing Costs and Increasing Productivity," January 2014. [intel.com/content/dam/www/public/us/en/documents/white-papers/enterprise-mobility-pc-upgrade-strategy-guide.pdf](http://intel.com/content/dam/www/public/us/en/documents/white-papers/enterprise-mobility-pc-upgrade-strategy-guide.pdf)
- <sup>5</sup> Nathan Hill and Michael A. Silver, "Define and Prioritize the User Experience to Succeed with VDI and DaaS," Gartner, March 6, 2017, summarized in LoginVSI, "Don't Compromise on the User Experience: Apply Gartner's Recommendation for Successful VDI Deployments," July 2017, available for download at [loginvsi.com/resources/white-papers](http://loginvsi.com/resources/white-papers). The Gartner research note is available for purchase at [gartner.com/doc/3629617/define-prioritize-user-experience-succeed](http://gartner.com/doc/3629617/define-prioritize-user-experience-succeed)
- <sup>6</sup> "Wi-Fi That Smashes Through the Gigabit Barrier!" [intel.com/content/www/us/en/wireless-products/wireless-ac-gigabit-wifi-infographic](http://intel.com/content/www/us/en/wireless-products/wireless-ac-gigabit-wifi-infographic)
- <sup>7</sup> As measured by SYSmark\* 2014 SE on a Pentium® Silver processor N5000 versus a Pentium® processor rsN3540 (58 percent) and Pentium® Silver processor J5005 versus Pentium® processor J2900 (68 percent) - Pentium® Silver processor N5000, PL1=6W TDP, 4C/4T, up to 2.6 GHz, Memory: 2x2GB DDR4 2400, Storage: Intel® Solid State Drive, OS: Windows\* 10 RS2. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit [intel.com/benchmarks](http://intel.com/benchmarks).
- <sup>8</sup> Prowess Consulting, "Select the Right Thin Client to Improve User Experience," 2017. [prowesscorp.com/wp-content/uploads/2017/04/Intel-Health-Vertical-Thin-Client-Report.pdf](http://prowesscorp.com/wp-content/uploads/2017/04/Intel-Health-Vertical-Thin-Client-Report.pdf)
- <sup>9</sup> Prowess Consulting, "Select the Right Thin Client to Improve User Experience," 2017. [prowesscorp.com/wp-content/uploads/2017/04/Intel-Health-Vertical-Thin-Client-Report.pdf](http://prowesscorp.com/wp-content/uploads/2017/04/Intel-Health-Vertical-Thin-Client-Report.pdf)
- <sup>10</sup> ProjectVRC.team, Windows 10 in VDI: First Analysis and Performance Best Practices, October 2015. [projectvrc.com/white-papers/18-windows-10-in-vdi-first-analysis/file.pdf](http://projectvrc.com/white-papers/18-windows-10-in-vdi-first-analysis/file.pdf)
- <sup>11</sup> News Release, "Intel Unveils Powerful Intel Xeon Scalable Processors, Bringing Next-Generation Business and Consumer Experiences to Life," July 11, 2017. [newsroom.intel.com/news-releases/intel-unveils-powerful-intel-xeon-scalable-processors-bringing-next-generation-business-consumer-experiences-life](http://newsroom.intel.com/news-releases/intel-unveils-powerful-intel-xeon-scalable-processors-bringing-next-generation-business-consumer-experiences-life)
- <sup>12</sup> Up to 65 percent lower four-year TCO estimate example based on equivalent rack performance using VMware ESXi\* virtualized consolidation workload comparing 20 installed 2-socket servers with Intel® Xeon® processor E5-2690 (formerly code-named Sandy Bridge-EP) running VMware ESXi 6.0 GA using Guest OS Red Hat Enterprise Linux\* 6.4 compared at a total cost of USD 919,362 to five new Intel® Xeon® Platinum 8180 processor (formerly code-named Skylake) running VMware ESXi 6.0 U3 GA using Guest OS Red Hat Enterprise Linux 6 64 bit at a total cost of USD 320,879 including basic acquisition. Server pricing assumptions based on current OEM retail published pricing for two-socket server with Broadwell-based Intel® Xeon® processor systems—subject to change based on actual pricing of systems offered.
- <sup>13</sup> Intel® Xeon® Scalable Processors World Record Benchmarks. [intel.com/content/www/us/en/benchmarks/server/xeon-scalable/xeon-platinum-world-record](http://intel.com/content/www/us/en/benchmarks/server/xeon-scalable/xeon-platinum-world-record)
- <sup>14</sup> News Release, "Intel Unveils Powerful Intel Xeon Scalable Processors, Bringing Next-Generation Business and Consumer Experiences to Life," July 11, 2017. [newsroom.intel.com/news-releases/intel-unveils-powerful-intel-xeon-scalable-processors-bringing-next-generation-business-consumer-experiences-life](http://newsroom.intel.com/news-releases/intel-unveils-powerful-intel-xeon-scalable-processors-bringing-next-generation-business-consumer-experiences-life)
- <sup>15</sup> News Release, "Intel Unveils Powerful Intel Xeon Scalable Processors, Bringing Next-Generation Business and Consumer Experiences to Life," July 11, 2017. [newsroom.intel.com/news-releases/intel-unveils-powerful-intel-xeon-scalable-processors-bringing-next-generation-business-consumer-experiences-life](http://newsroom.intel.com/news-releases/intel-unveils-powerful-intel-xeon-scalable-processors-bringing-next-generation-business-consumer-experiences-life)
- <sup>16</sup> When comparing results from [evaluatorgroup.com/document/evaluating-server-based-storage-performance-enterprise-workloads](http://evaluatorgroup.com/document/evaluating-server-based-storage-performance-enterprise-workloads) to [intel.com/content/www/us/en/storage/evaluator-group-storage-paper.html](http://intel.com/content/www/us/en/storage/evaluator-group-storage-paper.html):
- **Previous configuration:** Storage media: 1 x P3700 + 4 x Seagate 1TB 10K HDD; Performance: 80 IOMark-VM-HC; Price/Performance: \$2048 / IOMark-VM-HC.
  - **Current configuration:** Storage media: 2 x P4800X SSD + 4 x P4500 4TB SSD; Performance: 800 IOMark-VM-HC; Price/Performance: \$237 / IOMark-VM-HC.

All information provided here is subject to change without notice. Contact your Intel representative to obtain the latest Intel product specifications and roadmaps.

Intel technologies' features and benefits depend on system configuration and may require enabled hardware, software, or service activation. Performance varies depending on system configuration. No computer system can be absolutely secure. Check with your system manufacturer or retailer, or learn more at [intel.com](http://intel.com).

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase.

Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system.

Cost reduction scenarios described are intended as examples of how a given Intel-based product, in the specified circumstances and configurations, may affect future costs and provide cost savings. Circumstances will vary. Intel does not guarantee any costs or cost reduction.

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