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IT@Intel
How Software-Defined Infrastructure Is Evolving at Intel

Our ongoing SDI evolution keeps Intel IT agile, cost-competitive, and service-oriented so that we remain relevant to all our customers while advancing the enterprise technology capabilities.

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Executive Overview

For years, Intel IT has been evolving toward software-defined infrastructure (SDI), beginning with software-defined compute (SDC), to move from a proprietary fixed-function RISC Unix* compute environment to an agile Intel® architecture and Linux* compute environment. To fulfill our vision, we are working on software-defined networking (SDN) and software-defined storage (SDS).

We envision this SDI transforming our data centers into consolidated, energy-efficient data center facilities containing open-standards-based, agile, and cost-effective systems that will help us achieve the following benefits:

- Reduce capital expenditures with open-standards-based hardware and software and increased utilization of our current infrastructure.
- Automate manual provisioning to improve management efficiency and quality of service.
- Increase flexibility and agility of Intel IT and the services we provide.
- Limit the need for specialized knowledge through open interfaces.

We are at different stages of maturity for SDC, SDN, and SDS. SDC has already delivered capital-expenditure and management-efficiency benefits of hundreds of millions of dollars in business value annually. Open-standards-based SDN solutions are becoming enterprise ready. And we are piloting SDS solutions as they make their way to market.

Our ongoing SDI evolution keeps Intel IT agile, cost-competitive, and service-oriented so that we remain relevant to all our customers while advancing the enterprise technology capabilities.

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Acronyms

DOMES	Design, Office, Manufacturing, Enterprise, and Services
KPI	key performance indicator
NAS	network-attached storage
SDC	software-defined compute
SDI	software-defined infrastructure
SDN	software-defined networking
SDS	software-defined storage
SLA	service-level agreement

Software-Defined Infrastructure

Software-defined infrastructure (SDI) is more than a single technology; it is a combination of compute, storage, and network architectures defined by hardware and software solutions and processes. There is a misconception that SDI aims to eliminate traditional hardware. In fact, SDI aims to minimize supplier lock-in in favor of commodity hardware and industry-defined open standards and protocols.

We view SDI as the next evolution of the data center, incorporating high-performance computing and cloud technologies to build and manage infrastructure resources and enabling IT organizations to become more efficient and service-oriented.

Background

As Intel IT evolves to software-defined infrastructure (SDI), we are transforming compute, network, and storage environments in our data centers according to two key elements. First, we want to decouple the hardware and software infrastructure resources to lower capital expenditures and increase management efficiency. Second, we want to automate manual processes and establish dynamic, on-demand infrastructure provisioning capabilities.

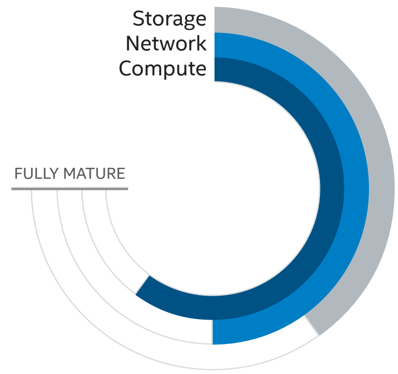
Expected Benefits of Software-Defined Infrastructure

We anticipate that open-standards-based SDI will offer the following benefits:

- **Reduce capital expenditures.** SDI can help us reduce capital expenditures two ways. First, we can work with industry-defined open standards and protocols to limit our dependency on proprietary hardware and software. Second, we can use cloud and virtualization technologies to increase utilization of our current IT assets instead of overprovisioning for worst-case demand situations.
- **Automate manual resource provisioning.** SDI offers operational efficiencies for compute, network, and storage resources. Automating resource management and provisioning will reduce the number of specialists needed, simplify monitoring and manageability, and expand self-service capabilities to improve quality of service and meet service-level agreements (SLAs).
- **Increase flexibility and agility.** SDI enables us to allocate infrastructure resources according to business needs, applications requirements, and infrastructure mapping, optimizing both IT value and user experience.
- **Limit the need for specialized knowledge.** Open interfaces increase the speed of integrating the infrastructure domain. As we evolve to SDI, we can reduce our spending and our dependence on proprietary hardware and software specialists and other support.

Some data center environments are further along in the SDI evolution than others. For example, because we have been using global resource pooling in our server environment since 1997, we have gained the experience necessary to take advantage of more cost and operational benefits. In comparison, we started exploring open-standards-based software-defined technology in the storage environment in 2014. Additionally, enterprise support for open-standards-based technology is more robust for the server environment than for the network and storage environments.

SDI Maturity in Data Center Environments



Achieving Efficiency and Agility in Data Centers

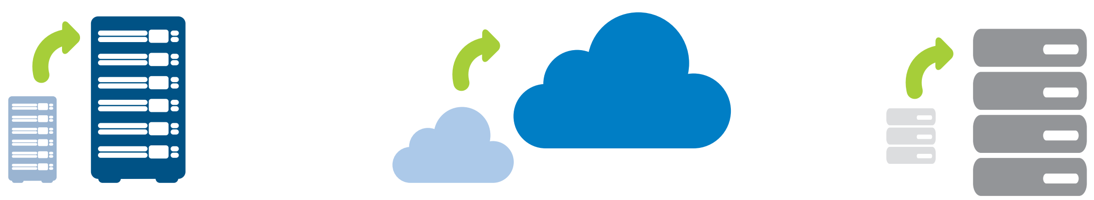
Intel IT operates 61 data center facilities worldwide. These facilities—combined with their compute, network, and storage resources—constitute our all-encompassing infrastructure. As efficiently and with as much agility as possible, these facilities need to support the business needs of Intel's critical business functions: Design, Office, Manufacturing, Enterprise, and Services (DOMES).

Our greatest challenge related to achieving efficiency and agility is the constantly increasing demand for data center resources (see Figure 1).[1]

Every environment has its unique controls and challenges; all of them are looking for efficiency and agility. Therefore, we are evolving to SDI to help us achieve efficiency and agility in our data centers.

[1] For more on our data center strategy, see the white paper "Intel IT's Data Center Strategy for Business Transformation."

Increasing Demand for Data Center Resources



COMPUTE
>30% annual growth in server capacity requirements; >85% average utilization for compute servers in the Design environment and <50% for the Office and Enterprise environments despite virtualization

NETWORK
Growth in compute demand results in wait times of 2–3 weeks to provision new services

STORAGE
Almost 40% demand increase for data storage; 90% is unstructured data

Figure 1. Our greatest challenge related to achieving efficiency and agility is meeting the increasing demand for data center resources.

3 Key Performance Indicators

- **Cost.** A 10% year-over-year improvement in cost per service delivery.
- **Utilization.** An 80% utilization of infrastructure.
- **SLAs.** Greater than 99% of Tier 1 and 95% of Tier 2 and Tier 3.

Intel IT's Software-Defined Infrastructure Journey

We began our SDI journey in 1997 (see Figure 2). During the first few years we focused on replacing proprietary RISC/Unix*-based servers with industry-standard Intel® architecture-based Linux* servers. By 2007 we had used cloud-like technologies to provide global resource pooling before cloud became widely adopted.

In 2009 we started using commodity networking hardware, and by 2014 we were exploring open-source software to find more cost savings and operational efficiencies in networking. Meanwhile, in 2013, we began exploring software-defined storage solutions.

We continue to evolve our infrastructure based on applicable SDI technologies using the following guidelines:

- Any change must not destabilize the existing production environment.
- Whenever possible, we leverage existing infrastructure investments.
- New technologies must provide measurable benefits, such as cost savings, higher efficiency, or more self-service.

To help determine data center investment priorities during our evolution to SDI, we have set key performance indicators related to cost, utilization, and SLAs. For cost, we want to see a 10-percent year-over-year improvement in cost per service delivery. For utilization, we want to achieve 80-percent utilization of our all-encompassing infrastructure. Finally, we are targeting SLAs of greater than 99 percent of Tier 1 and greater than 95 percent of Tier 2 and Tier 3.[2]

Our SDI vision will be achieved by evolving our infrastructure to software-defined compute (SDC), software-defined network (SDN), and software-defined storage (SDS).

[2] For more on SLAs, see "Quality of Service" on page 4 of the white paper "Intel IT's Data Center Strategy for Business Transformation."

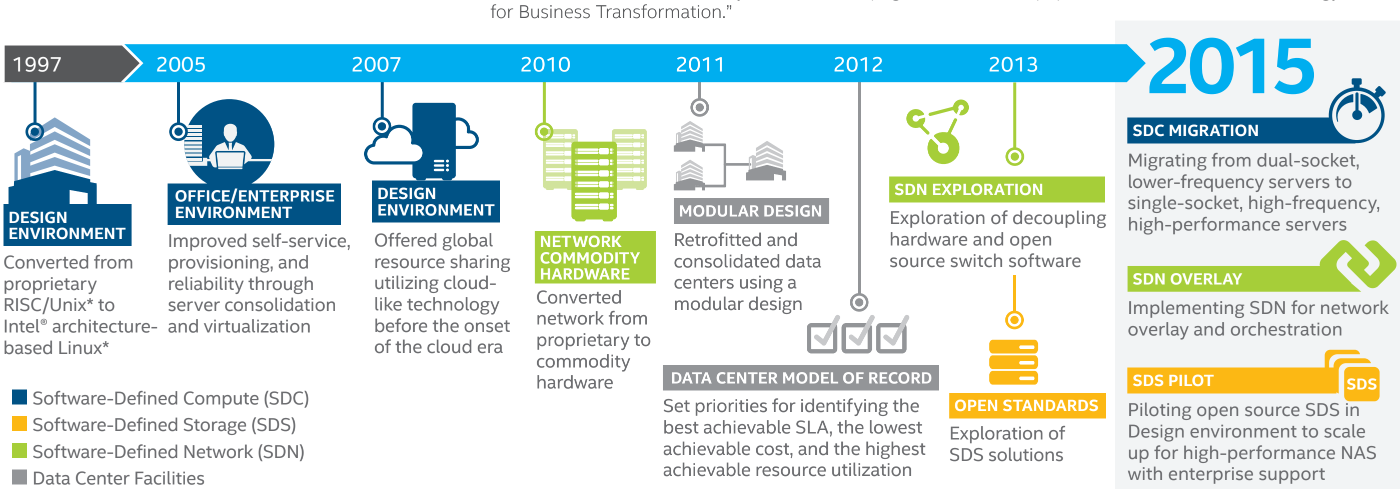


Figure 2. The timeline illustrates the compute, network, storage, and facilities milestones that make up our software-defined-infrastructure journey.

BEGINNING THE SDC JOURNEY

We converted from proprietary RISC/Unix* to Intel® architecture-based Linux* in our Design environment, resulting in accumulated capital expenditure savings of USD 1.4 B from 1997–2005.

Software-Defined Compute

In the late 1990s, our vertically integrated server solution grew too expensive and difficult to manage. This led to our initial foray into SDC in 1997: converting from proprietary RISC Unix to Intel architecture-based Linux. By 2005, our accumulated capital expenditure savings attributable to this conversion had reached USD 1.4 billion. By 2014, we were segmenting servers into four segments—basic, performance, throughput, and massive memory—to provide each critical business function with the most agile, efficient, and cost-effective service possible.

Segmenting servers allows us to achieve greater utilization of current infrastructure resources and make smarter decisions for server refresh so we do not have to overprovision for worst-case demand situations. For example, we can evaluate whether to replace dual-socket servers and four-socket servers with better performing single-socket servers that provide faster response times for applications.

Single-socket servers based on the Intel® Xeon® processor E3 and Intel® Xeon® processor E5 families have higher frequencies and lower core count. These servers provide more than 80 percent of the computing needs in Design. As we evolve to SDI, we improve efficiency by automating the distribution of batch jobs to appropriate resources (see Table 1).

After establishing the server segments, we examined each of the DOMES critical business functions to determine how to automate workloads. For example, we determined that Design is best served by automating workloads mostly on the performance and throughput segments. For performance server workloads, this means a reduction in application license costs; throughput server workloads offer inexpensive capacity. This enables both fast turnaround and throughput applications in Design to meet cost and time-to-market goals.

Table 1. Four server segments for software-defined compute

Server Segment	Server Description	Workload	Capacity
Basic	• Single-socket micro- or low-frequency	For cost-sensitive workloads, such as infrastructure and web servers, that require low core count and low performance, and operate on a smaller data size.	<1%
Performance	• 80%: Higher frequency, single socket, 32 GB for workloads within 8 GB per core • 20%: Higher frequency, 32 to 512 GB	For most workloads that require faster application responses, better data availability and proximity, and low-latency data access. This workload arrangement reduces licensing costs and lowers energy consumption.	>78%
Throughput	• Dual socket with 10 or more cores per socket	For workloads that need to maximize the number of jobs to be completed within a fixed time frame.	20%
Massive memory	• Four socket, up to 6 TB RAM per server	For high-memory workloads, including Design mask and tapeout applications that handle complex design data, Office and Enterprise applications that handle complex data warehousing, and financial data that requires quicker processing.	<1%

Software-Defined Network

Our SDN enables on-demand provisioning of networks and network services. By virtualizing the network through a programmable interface, we can better support internal customers—Intel application developers—working in a fast-paced Agile development environment. We want customers to get the network services and resources they need without having to negotiate a bottleneck in network provisioning.

An SDN helps increase the business value of the virtual machines in our data centers by reducing network-provisioning time and simplifying network creation in a self-service environment. With improved network management efficiency, we can use network applications for rapid service innovation and provide for newer multitenant models and distributed access control.

Deploying a proprietary SDN controller for our overlay network will reduce network-provisioning time. We plan to continue to work with OEMs and the open source community to develop open source SDN controllers. This will help us achieve cost benefits as well as management efficiencies and better customer support.

We started evolving to SDN in 2010 when we transitioned from proprietary hardware to commodity hardware. In 2014, we began exploring open source switch software to end our reliance on proprietary, nonprogrammable software.

As part of our overall SDI vision, we continue to explore ways that the commoditization of hardware and software can help us lower our cost per port by more than 50 percent for 10 Gigabit Ethernet. While we have begun to test open source SDN software in a pilot environment, we plan to continue to multisource OEMs until commodity hardware and software with acceptable enterprise-class support is available.

As we continue to acquire hardware based on lowest cost, we will examine the viability of automating on four segments in a strategy similar to the way we have segmented SDC according to basic, performance, throughput, and massive memory workloads.

COMMODITY HARDWARE

We transitioned our network from proprietary to commodity hardware, resulting in a cost reduction of more than 50%.

Software-Defined Storage

The final data center environment to evolve toward SDI is storage. SDS will help us achieve the following goals:

- Automate routine tasks, such as self-provisioning, modification of existing allocated storage, and deletion.
- Move from a proprietary hardware-software integrated appliance model to a standards-based decoupled hardware-software model.

NETWORK-ATTACHED STORAGE

We piloted a scale-up shared file storage solution for high-performance network-attached storage.

Automation for routine storage tasks has been in production for several years, and we continue to enhance automation for new types of storage. We started exploring SDS in 2013 and have conducted pilot implementations for the Design and Enterprise business functions. SDS allows us to use standard hardware with open-standards-based enterprise-class storage software at a lower cost.

Initial pilots of SDS solutions for block storage and shared-file storage produced mixed results.

- **Block storage.** While assessing block storage for medium performance needs, we encountered performance, scalability, and technology maturity challenges. Further, current implementations are not cost effective.
- **Shared file storage.** In this pilot we supported more than 5,000 compute nodes using high-performance open-standards-based hardware and software. We achieved a 50-percent reduction in equipment costs, compared to using proprietary equipment, without any decrease in performance. Based on these results, we expect to realize a significant cost advantage in the future.

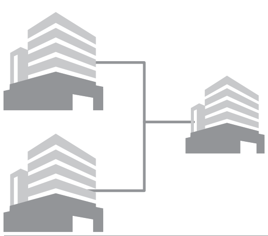
Our SDS evolution is still in the early stages. Obstacles exist in scalability and stability. While solutions are maturing, currently no single SDS solution is optimal for all storage workloads.

Data Center Facilities

As SDC, SDN, and SDS mature into SDI, we are increasing effective utilization of our data center facilities.

We have identified opportunities to reduce the number of Intel data centers by as much as 35 percent, using techniques such as the following:

- Close, retrofit, or reclassify data centers and improve efficiency.
- Co-locate local infrastructure with Design and Manufacturing data centers or provide services from a server closet.
- Manage local infrastructure sites remotely.
- Improve facility space and power efficiency through strategic investments such as open-air cooling, densification of data centers, and the raising of data center inlet temperatures while remaining within the servers' environment operating specifications.



DATA CENTER FACILITIES

We have implemented a modular design for our data centers that increases efficiency while using fewer facilities. We have also set KPIs for identifying the best achievable SLA, lowest achievable cost, and highest achievable resource utilization, allowing us to move toward a data center Model-of-Record.

Conclusion

As Intel IT evolves toward SDI, we continue to test and deploy open-standards-based solutions that help us decouple hardware and software infrastructure resources and automate manual provisioning processes for our compute, network, and storage environments. As SDI matures, we will continue to increase effective utilization of data center and infrastructure resources.

Our SDI evolution relies on open-standards-based technology advancements for hardware and software in SDC, SDN, and SDS. In SDC, we are already automating workloads on four server segments (basic, performance, throughput, and massive memory) that support Intel DOMES business functions. SDN open-standards-based hardware is already in use. And we are monitoring and helping to develop enterprise-class open-standards-based SDN controllers. Open-source switch software will soon be a priority for advancing SDN cost savings and management efficiency. SDS pilots have shown progress in open-standards-based storage solutions, and we are committed to increasing storage workload automation to carry out our SDI vision.

Evolving to SDI is helping us transform our data centers into consolidated facilities containing open-standards-based, agile, and cost-effective systems.

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We connect IT professionals with their IT peers inside Intel. Our IT department solves some of today's most demanding and complex technology issues, and we want to share these lessons directly with our fellow IT professionals in an open peer-to-peer forum.

Our goal is simple: improve efficiency throughout the organization and enhance the business value of IT investments.

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