IT@Intel White Paper

Intel IT
IT Best Practices
Storage and IT Investment Management/Budget
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Solving Intel IT's Data Storage Growth Challenges

We manage about 38.2 petabytes of raw primary storage capacity. By targeting greater than 60-percent utilization and aggressively deploying new Intel® Xeon® processor-based file servers as well as implementing a variety of techniques, we have achieved capital savings of USD 9.2 million while supporting significant capacity and performance improvements.

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Executive Overview

Intel IT is using a variety of techniques to accommodate growing demand for storage capabilities, without increasing costs. In 2011 Intel faced a 53-percent increase in storage capacity from 2010, and the continued build out of our private cloud could increase this demand even further.

We are managing the growth rate by the following:

- Reclaiming, right sizing, and right-tiering storage based on access, performance, and business continuity requirements
- Aggressively refreshing storage and preparing to enable efficiency technologies such as de-duplication and thin provisioning

We manage about 38.2 petabytes of raw primary storage capacity. By targeting greater than 60-percent utilization and aggressively deploying new Intel® Xeon® processor-based file servers as well as implementing a variety of techniques discussed in this paper, we have achieved capital savings of USD 9.2 million while supporting significant capacity and performance improvements.

Our multi-level approach to storage management, including service management, infrastructure management, domain management, and device management, is suited to Intel's complex, globally dispersed, high-volume shared storage environment.

We are using some of our storage techniques across the enterprise. Other storage techniques are currently in use more substantially for one or more business functions—Design, Office, Manufacturing, Enterprise, and Services (DOMES)—because they are tailored to a specific business function's current storage and business needs. Ultimately most of these technologies will be adopted for all the business functions.

These techniques—along with storage technologies that we adopt in the future to support new usage models—accommodate storage demand growth in a cost-effective manner while maintaining quality of service in our virtualized, multi-tenant computing environment.

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BACKGROUND

Like other organizations, Intel IT faces rapid growth in storage demand—as much as 35 percent year over year—which results in higher storage costs. We expect our increasing use of cloud computing to further escalate storage demand. We manage about 38.2 petabytes (PB) of raw primary storage capacity. By targeting greater than 60-percent utilization and aggressively deploying new Intel® Xeon® processor-based file servers as well as implementing a variety of techniques discussed in this paper, we have achieved capital savings of USD 9.2 million while supporting significant capacity and performance improvements.

Financially, it is impractical to increase our storage costs at the same rate as the rate of storage growth. We need new ways to cost-effectively manage storage growth while increasing business velocity and maintaining quality of service for our virtualized, multi-tenant computing environment.

Intel IT supports five critical business functions: Design, Office, Manufacturing, Enterprise, and Services (DOMES). Across these functions, we experience similar challenges with regard to managing storage and backup and recovery (BaR). Our globally dispersed, high-volume, shared storage environment is complex and consists of storage-area network (SAN) storage, network-attached storage (NAS), content-addressable storage (CAS), and tape libraries. The sheer number of managed storage objects and variations in usage makes storage management a challenge.

Modular Multi-level Storage Management Architecture

Comprehensive storage management strategies, architecture, tools, and processes are required to minimize the impact of our increasingly complex storage environment.

To help us meet our storage management challenges, we use a multi-level conceptual architecture for storage management, which includes service management, infrastructure management, domain management, and device management (see Figure 1).

Using this approach we can design the storage system from the top down to meet business requirements and build from the bottom up to support service needs. Each numerically higher level of

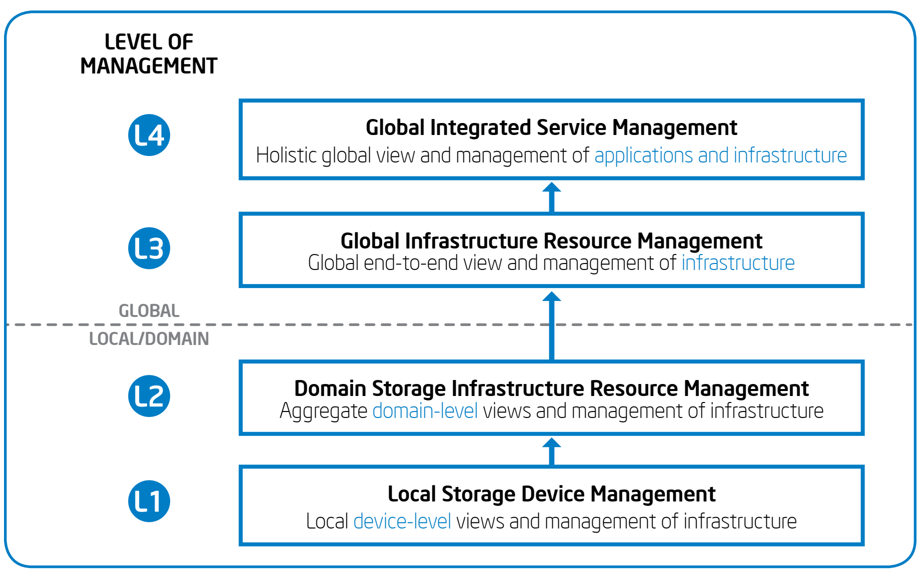

Figure 1. Our modular, multi-level approach to storage management helps us better manage our complex, high-volume environment.

management—beginning with L1—provides increasing business value through data aggregation, correlation, processing, and management information reporting. All levels of management can provide business intelligence (BI) and automation. For efficiency purposes, the automation of management tasks is done at the lowest level possible or practical. Higher-level management capabilities do not impede or prevent the delivery of basic storage services.

Storage Investment Decisions

We recently refined our data center strategy, and as part of this effort we use a new investment model to prioritize which storage investments will have the highest return on investment. We optimize these investments along three concurrent key performance indicators: cost, service-level agreements (SLAs), and effective utilization of storage resources.[1]

[1] For more information on Intel's data center strategy, see "Intel IT's Data Center Strategy for Business Transformation." Intel Corp., November 2011.

STORAGE SOLUTIONS TO MANAGE GROWTH

Because a single storage solution cannot adequately meet all line-of-business requirements, our storage solutions differ depending on specific business applications and use cases. Some solutions apply to several business functions, while others address a specific, unique requirement of a particular business function.

Over time, we expect that all business functions will use each of our key storage management solutions, which include:

- Increased storage refresh rate
- Unified network fabric
- Automated storage tiering
- Appropriate BaR techniques
- Application of analytics and process automation
- Efficiency technologies, such as thin provisioning and de-duplication

Using these solutions, we have increased storage utilization to more than 60 percent across our design grid and private cloud environments, while adding only 16 percent more storage capacity in 2011. In addition, we have avoided approximately USD 9.2 million in capital expenditures.

Storage Landscape Overview

Each business function uses applications that are suited for file-based NAS and block-based SAN storage. The SAN environment is also used as the back-end storage for file-based NAS. All business functions use a tape library for off-site disaster recovery storage. Figure 2 illustrates the storage landscape across Intel.

Because each business function has a specific focus and specific requirements, the relative distribution of SAN, NAS, and parallel

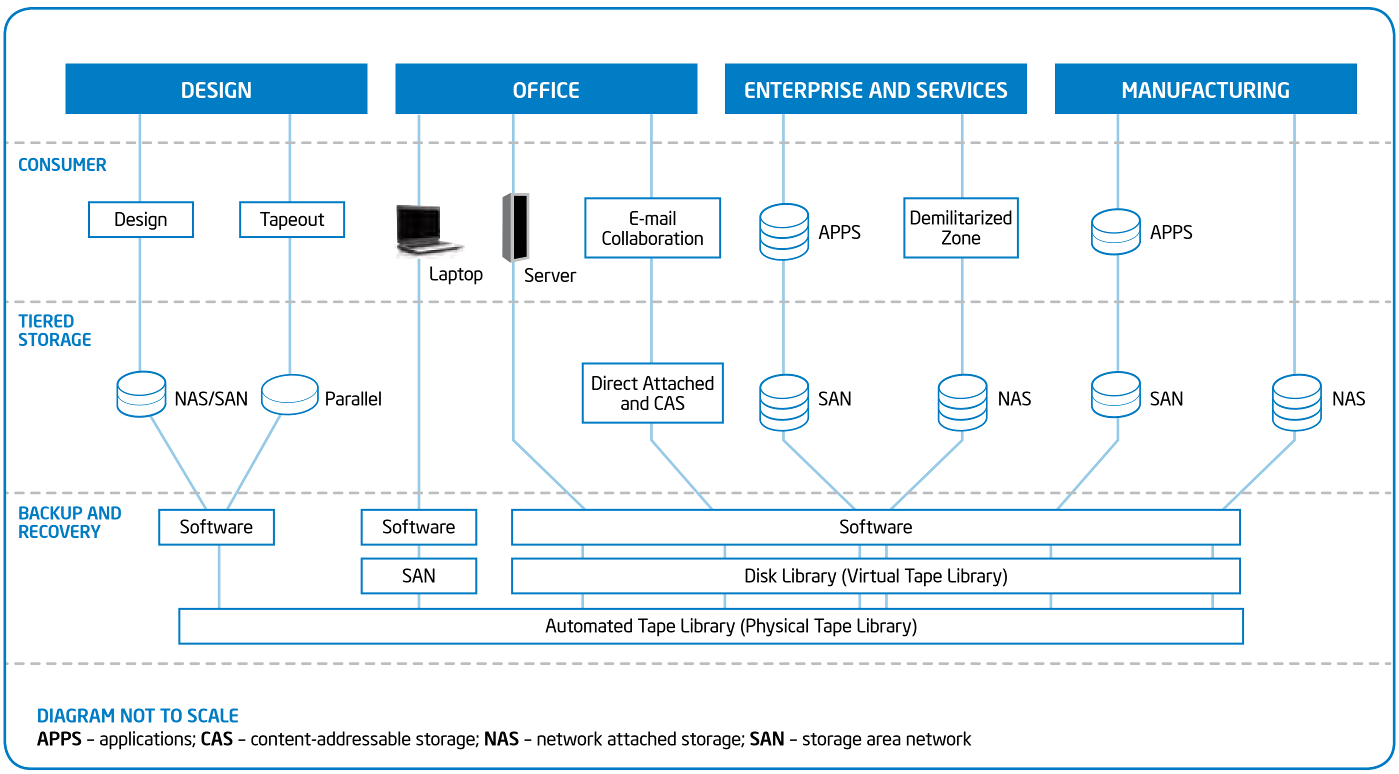

Figure 2. Across Intel's business functions, we use a variety of storage and backup-and-recovery techniques.

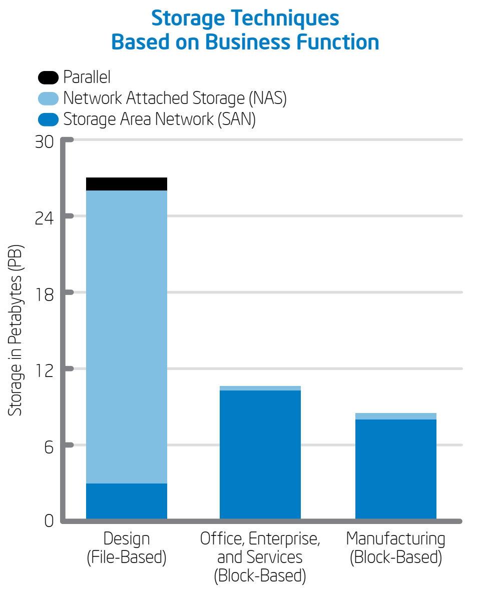

Figure 3. We choose storage solutions, such as network-attached storage, storage area network, and parallel, based on a business function's storage requirements. IT Automation has become part of IT and will be rolled into totals next year.

storage differs, as shown in Figure 3. For example, NAS—our largest storage growth segment—represents the bulk of the storage in Design, due to the nature of the silicon design process, which accesses a significant amount of data daily. Design also uses parallel storage for its high-performance grid, taking advantage of the processing power of new generations of Intel® processors.

In contrast to Design, the Office, Enterprise, Services, and Manufacturing environments primarily use SAN storage because their main storage requirements are block-based.

Enterprise-wide Storage Solutions

Several of the storage solutions that we implement offer benefit across all of Intel. For example, by refreshing older storage infrastructure, all business functions can take advantage of new technology and improved performance. Incorporating BI and automation into our storage management system also benefits our customers in all operational areas.

INCREASE THE STORAGE REFRESH RATE

Upgrading older storage systems—both primary and backup storage—to Intel Xeon processor-based storage solutions provides many benefits. The new systems not only have more compute power to deliver intelligent data management and storage efficiencies, but also offer performance-to-cost efficiencies. That is, they feature new technologies that increase storage quality, business velocity, efficiency, and capacity at a lower cost.

The new systems, combined with our 10 gigabit Ethernet (10GbE) local area network have a lower latency than older systems, thereby supporting faster application response and greater productivity. We anticipate that the new systems will reduce our data center storage footprint by more than 50 percent in 2011 and 2012, and reduce our backup infrastructure cost due to greater sharing of resources.

UNIFY THE NETWORK FABRIC

When we originally deployed SANs, a single storage fabric was not a viable option so we created multiple SANs. However, advances in storage network technology now make it feasible to create a unified SAN fabric that uses virtual SANs to isolate components. A unified fabric improves economies of scales, simplifies management, and enables higher utilization of SAN fabric ports.

USE A TIERED APPROACH TO STORAGE

We have implemented a multi-tiered methodology for storage to better balance business requirements across performance, reliability, capacity, and cost. The high-end tier provides the greatest performance and reliability, but the cost is about 4x higher per usable gigabyte (GB) compared to lower-tiered storage. Our mission-critical Manufacturing and Enterprise Resource Planning applications use the high-end tier; we store less critical business application data in lower tiers. Several of our business functions, such as Office, Enterprise, and Design, use tiered storage, but the details of the exact tiering architecture differ depending on business needs.

USE AUTOMATED DATA MIGRATION

We are currently implementing automated data migration (ADM), which continuously monitors and identifies the activity level of data, and automatically moves active data and inactive data to the most appropriate storage tier based on policy. Active data moves to the highest performance tier, while inactive data moves to the tier with the lowest cost and highest capacity. Policy settings enable IT administrators to control and manage the automated activity.

The use of ADM enables a storage system to be both faster and less costly because it uses high-performance tiers only when needed and uses the low-cost and high-capacity tiers whenever possible. Policies provide control for how performance and cost are optimized, and automation means the storage system has no added management burden compared to slower, more costly systems.

In our tests, ADM reduces the cost per frame by 30 to 40 percent, by allowing the use of 7,200 revolutions-per-minute drives, and decreases the time required for storage administrators to troubleshoot performance issues and rebalance storage. We are deploying ADM into the production environment in the last quarter of 2011.

CHOOSE THE APPROPRIATE BACKUP-AND-RECOVERY TECHNIQUE

Backups can impose extra processing and bandwidth load on the network. As a result of our upgrade to 10GbE we can process backups much faster as we consolidate virtual hosts. To further optimize the BaR process, we deploy multiple BaR techniques across business functions: disk to tape (D2T), disk to disk (D2D), and disk to disk to tape (D2D2T). Each of these techniques provides a different balance of cost and convenience, as shown in Figure 4.

For example, the Office and Enterprise environment requires a 12-hour data recovery window. Therefore, for BaR for these environments we use D2D because disks offer faster data access, eliminating the need for a large number of them. Once a month, select Office and Enterprise data is written to tape, using D2D2T, for off-site storage.

In contrast, the Design environment has significantly more data to store but can tolerate slower data recovery, so D2T is the most cost-effective BaR technique to use.

IMPLEMENT BUSINESS INTELLIGENCE AND AUTOMATION

Intel IT is re-designing current storage management systems to provide a more scalable and efficient long-term solution, with BI and automation the key critical components. We carefully monitor how much capacity is being used, how quickly usage is growing, how much more capacity we can safely allocate, and when we need to rebalance or add capacity. We use capacity management and risk management metrics—Usable Capacity, Allocated Capacity, and Used Capacity—to support this analysis.[2] The metrics measure allocation and utilization with each storage pool, and can be aggregated to provide summary views at the frame and data center levels. Our BI solution also includes performance and efficiency management metrics.

Current Storage Techniques: Design Environment

Intel's Design engineers run 20 to 30 million compute-intensive batch design jobs every week, 52 weeks per year. These include critical high-performance computing tapeout parallel jobs, where more than 23,000 jobs can simultaneously use a single data set. The Design storage environment is optimized to enable jobs to reach this scale and keep the time spent on data access below 10 percent.

Intel IT backs up about 4.5 PB of Design data each week. Although this is a large amount of data, the number of platforms is minimal compared to that of the Office and Enterprise environment.

With these considerations in mind, we have deployed several storage techniques tailored for Design's unique storage needs.

USE FIVE-TIERED STORAGE

In Design, we are in the process of implementing a five-tier storage approach to increase effective utilization of storage resources, improve our performance to SLAs, and reduce the total cost of ownership for Design storage. Figure 5 illustrates our current and future models for storage tiering in Design.

[2] For more information, see "Implementing Cloud Storage Metrics to Improve IT Efficiency and Capacity Management." Intel Corp., July 2011.

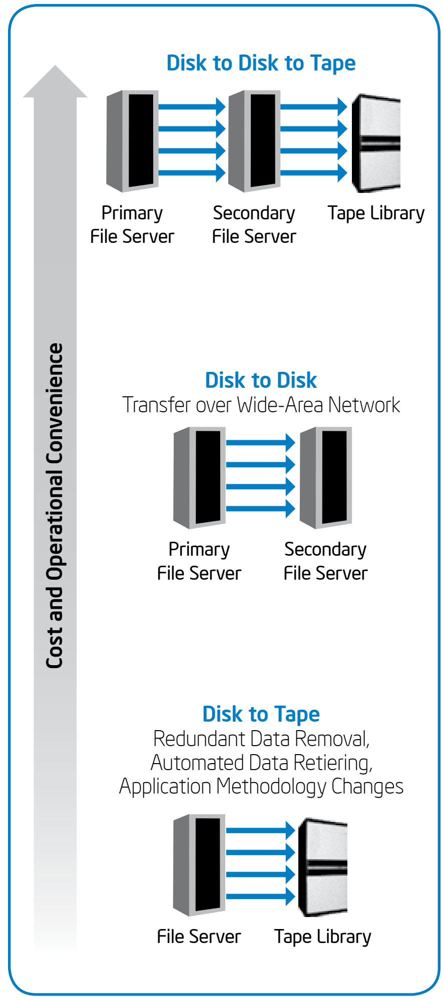

Figure 4. The backup-and-recovery technique we choose depends on a business function's need for convenience and cost efficiency.

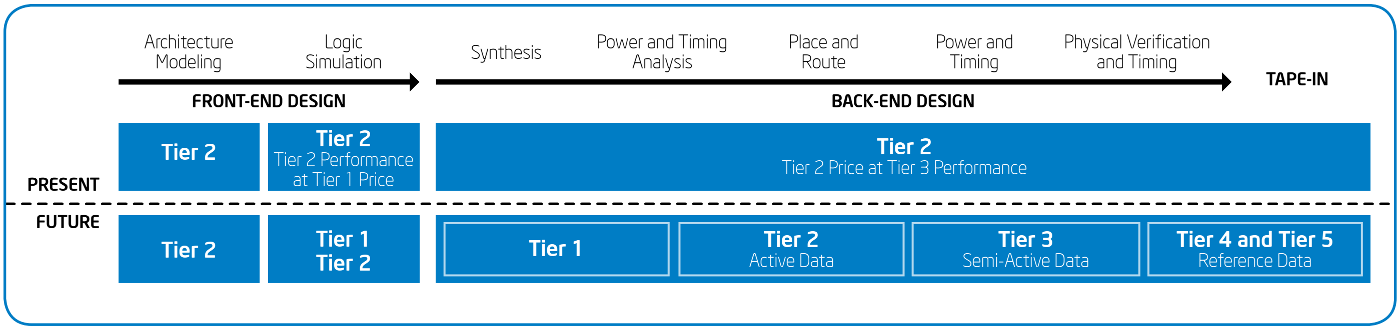

Figure 5. To improve the key performance indicators of effective utilization, performance to service-level agreements, and cost, we are moving to a five-tier storage model in the Design environment.

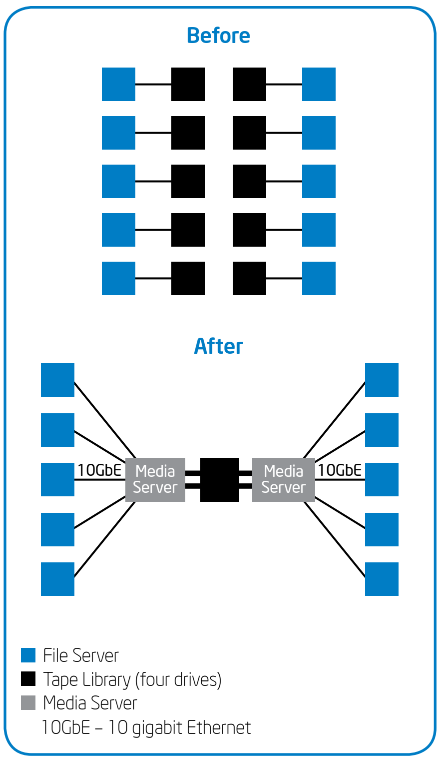

Figure 6. Using media servers for backup in the Design environment has improved backup performance and utilization, and has also reduced storage costs.

The five tiers of Design storage are based on performance, with Tier 1 offering the fastest access to data. Lower tiers offer slower data access, but are less expensive. We use those tiers for data that is less frequently accessed or not critical to a particular Design step.

USE SCALE-OUT STORAGE

We are making a strategic shift from a fragmented scale-up storage model to pooled scale-out storage, to support performance and capacity on demand. Scale-out storage enables just-in-time storage acquisition and deployment while supporting increased utilization of space and more aggressive re-use of space that efficiency technologies free up.

IMPLEMENT DATA DE-DUPLICATION

Data de-duplication has the potential to substantially improve storage efficiency—critical to controlling storage costs in Design because of the immense amount of data this environment generates every week. Our initial data de-duplication tests indicate that the rate of data reduction depends heavily on the type of data. Pilot results for Design showed a 6 percent to 48 percent reduction in data, depending on file characteristics, with an average of 25.5 percent.

Because data de-duplication is compute intensive, it is most effective when used with the latest generation of Intel Xeon processors. We are working closely with a third-party application supplier to take advantage of data de-duplication. As the technology becomes more widely available, we anticipate also using data de-duplication in the Office and Enterprise environment. Pilot testing in the Office and Enterprise environment showed de-duplication provided a 40-percent data reduction for D2D backups of laptops.

USE MEDIA SERVERS TO REDUCE THE NUMBER OF TAPE LIBRARIES

In Design, our standard approach to backup has been to attach file servers directly to backup tape drives, as shown at the top of Figure 6. This approach resulted in islands of back-end storage devices, with less than 14-percent utilization, along with inefficient use of data center space.

Shared media servers—which have been in use in the Office and Enterprise environment for some time—connect multiple file servers to a single tape library, as shown at the bottom of Figure 6. In the Design environment, we have deployed shared media servers based on the latest-generation Intel Xeon processor. By doing so, we have reduced the number of required tape libraries significantly, improved utilization to 90 percent, and cut data center space requirements by two-thirds. We also achieved a 1.4x improvement in backup throughput. Through the use of media servers, we have saved USD 215,000 in one data center and expect to save close to USD 1 million, as we upgrade our other data centers with 10GbE capability.

After a successful production pilot, this BaR technique is the new BaR plan of record for data centers with 10GbE connectivity.

USE SOLID-STATE DRIVES

The increasing complexity in the design of silicon chips creates large design workloads that have considerable memory and compute requirements. We typically run the workloads on servers that must be configured to meet these requirements in the most cost-effective way.

We are strategically using Intel® Solid-State Drives (Intel® SSDs) to cache directory information and are also targeting them to cache very active data to meet bursts in input/output operations per second (IOPS) demand while scaling storage servers. Test data showed that we can speed up key directory operations up to 10x and address peak IOPS bottlenecks for design jobs. This targeted usage enables high performance while lowering the total cost of storage by supporting more lower-cost hard-disk storage capacity on each server.

In Intel IT tests, Intel SSDs provided a 1.74x performance-normalized cost advantage for specific Design workloads.[3] Intel SSDs use a different, less-costly memory storage approach than that used for RAMs. We use Intel SSDs in our parallel storage, which supports the last stage—called tapeout—of the design process. The Intel SSDs account for less than 4 percent of the approximately 1 PB of Design parallel storage capacity but provide significant I/O acceleration for key directory operations. The Intel® architecture-based parallel storage platform, including the Intel SSDs, provided a 2.2x to 3x boost for extremely I/O intensive tapeout workloads.

Current Storage Techniques: Office, Enterprise, and Services Environments

Intel's Office, Enterprise, and Services environments feature a large number of platforms but generate less data than the Design and Manufacturing environments.

Our enterprise private cloud is focused on Office, Enterprise, and Services; therefore, any storage solutions we choose for these business functions need to support a highly virtualized, multi-tenant computing infrastructure. In addition, BaR requirements for these environments include less than 12 hours of recovery time.

RIGHT-SIZE STORAGE WITH THREE TIERS

To satisfy the needs of the Office, Enterprise, and Services environments while being as cost-efficient as possible, we use a three-tiered storage architecture.

- **H1.** Highly reliable, scalable high-end frames using high-performance Fibre Channel (FC) drives.
- **M1.** Mid-range frame with high-performance FC drives.
- **M2.** Mid-range frame with lower cost high-capacity Serial Advanced Technology Attachment (SATA) drives.

IMPLEMENT THIN PROVISIONING

Because many customers use only a small portion of their storage allocation, we use thin-provisioning technology to over-allocate capacity and thereby increase utilization of storage resources (see Figure 7). However, over-allocation also requires improved capacity and risk management so that we have adequate capacity to meet customer requirements.

We mitigate that risk by using BI to predict storage usage behaviors and by carefully monitoring storage headroom. If a certain threshold is reached, we take action to rebalance allocations in different storage pools. Although currently rebalancing is a manual process, we hope to eventually automate it.[4]

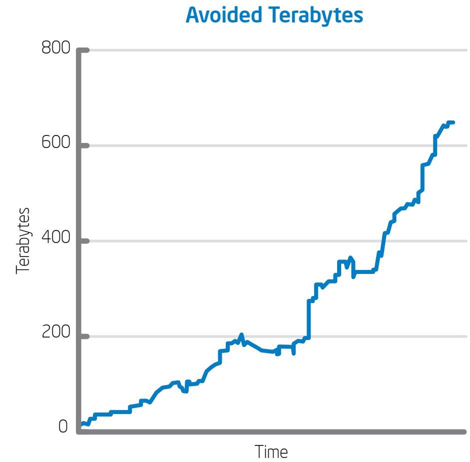

Figure 7. Transitioning to thin provisioning has enabled us to avoid growing storage capacity at the same rate as demand is growing.

[3] For more information, see "High-Performance Computing for Silicon Design," Intel Corp., November 2009.

[4] For more information, see "Implementing Cloud Storage Metrics to Improve IT Efficiency and Capacity Management," Intel Corp., July 2011.

Current Storage Techniques: Manufacturing Environment

In our Manufacturing environment, we save one year of data associated with every step of the manufacturing process for every single wafer produced. Production data comprises about 200 raw terabytes (TB) of storage, and the business continuity copy requires another 250 TB. Overall, Manufacturing has about 10 PB of raw storage. With every technological advance, such as changes in wafer size, process changes, increased core count, or new features of the chipset or CPU die, Manufacturing data increases linearly.

Intel's Manufacturing data resides in as many as 40 large databases and is stored on 40 to 45 SAN-attached servers. Data loss cannot be tolerated, so synchronous storage is required. Overall, our goals for Manufacturing storage are maximizing data safety while minimizing disk storage, and supporting a recovery time of 24 hours.

USE A DUPLEX STRATEGY INSTEAD OF STORAGE FRAMES

We are deploying a new flash recovery area for backing up our large Manufacturing databases, using a duplex strategy rather than storage frame solutions. With this approach, the database application does the work in place of the storage frame, except for control files. In addition to faster backup, this solution also provides recovery from data corruption, something that was not available with our previous backup solution.

STORE PRODUCTION DATA AND BAR DATA IN TWO SEPARATE BUILDINGS

Our business continuity plan for Manufacturing differs from the one we use for other business environments. We maintain two factories that are exact copies of each other so that if one factory goes down, production can continue at the other. However, we also keep our backup data in a separate building from the main data center, so that if a disaster such as a broken water pipe or an earthquake occurs, the backup data can be restored according to Manufacturing BaR SLAs.

NEXT STEPS

Although our current storage techniques are helping to keep Intel's storage costs down and meet our customers' storage needs, new usage models and increasing business velocity require us to continually search for new storage techniques. Currently, we are investigating the following storage technologies and approaches:

- Disk-based archiving. Currently we archive data on tape because this is the most cost-effective archiving method. However, as disk-based archiving costs drop, we may move some archiving to disk, as it is inherently more reliable than tape storage. We are exploring a more effective archiving solution, with a systematic framework, across Intel.
- Client-compute continuum models. As the types of devices being used at Intel grow, our storage solutions need to support customers accessing their data from any device and from both the intranet and Internet—without compromising data security. We are deploying a scale-out object-based storage solution to meet the demands of this new usage model.
- Expanded use of SSDs. To accommodate the increased I/O throughput demand on our current storage arrays, we anticipate increasing our use of SSDs, both in Design and eventually in Office and Enterprise, to improve storage throughput performance. We are currently evaluating optimal placement of SSDs, to determine if using them in arrays, the fabric, or on host servers provides the most cost-effective I/O performance. In addition, three data centers are now piloting NAS scale-out solutions that use Intel SSDs in them.
- Support for big data. Business groups increasingly require analysis of security logs and better BI for improved decision making. We are investigating storage techniques that affordably provide support for data mining and large-scale analytics.
- Differentiated services storage (DSS) policy-based caching. DSS is an intelligent policy-based caching method. This innovative technique has the potential to significantly increase storage performance wherever solid-state storage is used as a caching device. In addition to DSS, we are investigating the use of Intel® Rapid Storage Technology.
- Fibre Channel over Ethernet (FCoE). Unifying the network in densely virtualized server environments provides both technical and financial benefits. Therefore, we are investigating using FCoE in both the Office and Enterprise environment.

CONCLUSION

Storage growth contributes significantly to Intel's data center costs. We manage about 38.2 PB of raw primary storage capacity. By targeting greater than 60-percent utilization and aggressively deploying new Intel Xeon processor-based file servers as well as implementing a variety of techniques discussed in this paper, we have achieved capital savings of USD 9.2 million while supporting significant capacity and performance improvements.

The storage techniques we choose are tailored to each business function's storage needs and requirements. Some storage techniques we employ across the enterprise. Other storage techniques are currently more useful in certain business function environments than in others—although ultimately we expect to deploy various storage techniques in all business functions.

In all cases, our storage techniques offer cost benefits to IT and performance benefits to our customers. For example:

- Infrastructure refresh. New storage systems based on the latest generation of Intel Xeon processors will reduce our data center storage footprint by more than 50 percent in 2011 and 2012.
- Thin provisioning. During the first year of deployment, thin provisioning reduced our requirements for storage growth by almost one-quarter.
- SSDs. SSDs in an Intel processor-based parallel storage platform provide a 1.4x increase in backup throughput for specific design data sets and enable larger scale-out storage servers to reduce cost per usable TB.
- Data de-duplication. In pilot tests, data de-deduplication reduced the Office and Enterprise storage footprint from 3.2 PB to 1.9 PB for client disaster recovery services; pilot results for Design showed a 6 percent to 48 percent reduction in data, depending on file characteristics, with an average of 25.5 percent.
- ADM. In our tests, ADM showed a potential to reduce the cost per frame by 30 to 40 percent.
- Media Servers. These servers, based on the latest Intel Xeon processor, connect multiple file servers to a single tape library. In the Design environment, they have improved utilization to 90 percent, cut data center space requirements by two-thirds, and provide a 1.4x improvement in backup throughput.

We will continue to evolve our storage environment and employ a wide variety of storage techniques that allow us to meet an annual storage demand growth rate of at least 35 percent, without increasing our costs correspondingly.

CONTRIBUTORS

Douglas Ervin

ACRONYMS

10GbE	10 Gigabit over Ethernet
ADM	automated data migration
BaR	backup and recovery
BI	business intelligence
CAS	content-addressable storage
D2D	disk to disk
D2D2T	disk to disk to tape
D2T	disk to tape
DOMES	Design, Office, Manufacturing, Enterprise, and Services
DSS	differentiated services storage
FC	Fibre Channel
FCoE	Fibre Channel over Ethernet
GB	gigabyte
IOPS	input/output operations per second
NAS	network-attached storage
PB	petabyte
SAN	storage area network
SATA	Serial Advanced Technology Attachment
SLA	service-level agreement
SSD	solid-state drive
TB	terabyte

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