A critical part of any IT infrastructure is storage. Microsoft’s Storage Spaces solution offers storage administrators a software-based and cost-effective platform for building private clouds. Storage Spaces is flexible, resilient and highly available, while also being less complex and easier to manage than traditional storage.
An Evolving Industry
Traditionally, storage devices have been purpose-built. Not only are they costly, but they require specific operational and management skills since each device comes from a different vendor and each has its own set of capabilities. As a result, storage has been expensive to buy and run, and hard to use.

The cost of storage continues to be prohibitive for many today, especially given the continual demand for more of it. By some estimates, storage is scaling out a rate of two to three times that of compute. If the individual storage devices are expensive, then adding more of them further adds to an already costly piece of the network. Clearly, an alternate solution is needed.

For Microsoft, the answer lay in transferring many of the design and technology principles from its public cloud to building Software-Defined Storage (SDS) in Windows. As an example, the public cloud is run by hundreds of thousands of computers. Using purpose built hardware for this task would simply be too cost prohibitive. Instead, public clouds rely on a model whereby commodity hardware is employed and the “smarts” or intelligence is pushed from the hardware into software. With this model, scaling up becomes much more economically feasible.

Defining Storage Spaces
Storage Spaces, Microsoft’s SDS platform for the private cloud, provides storage solutions for virtual or physical deployments (Figure 1). With the virtualization
capabilities in Storage Spaces, administrators can use commodity hardware for single computer and scalable multi-node deployments. The platform can be used by a range of users—including enterprise and cloud hosting companies—who use Windows Server. Windows is not only used to manage the storage, but serves as a consistent management interface for the compute and network infrastructure as well.

With Storage Spaces, Windows provides a more flexible administration model: disks are organized into one or more storage pools, from which, in turn, storage spaces are created. Storage pools serve as the fundamental building blocks for Storage Spaces and are created by administrators based on their deployment needs. Given a set of physical disks, for example, an administrator can create one pool by using all available physical disks, or multiple pools by dividing the physical disks as required. In turn, Storage Spaces are virtual disks created from free space in a storage pool with the following attributes: resiliency level, storage tiers, provisioning type, and precise administrative control.

The administration of storage pools is controlled through access control lists (ACLs) and delegated on a per-pool basis. This approach supports hosting scenarios that require tenant isolation. Because Storage Spaces follows the familiar Windows security model, it can be fully integrated with Active Directory Domain Services. Storage Spaces is integrated with failover clustering for high availability and with Cluster Shared Volumes (CSV) for scale-out file server deployments. It can be managed using any of the following Microsoft offerings: System Center Virtual Machine Manager, Failover Cluster Manager, Server Manager, Windows PowerShell, or Windows Management Instrumentation (WMI).

Storage Spaces is supported by a range of OEMs (http://blogs.technet.com/b/windowsserver/archive/2015/05/05/next-generation-storage-for-the-software-defined-datacenter.aspx), which means that administrators are free to purchase different commodity hardware at different price points to meet their needs. It can be used as a standalone solution or, for those customers who need to run at scale, as part of a highly integrated, software-defined stack available from Microsoft (Figure 2).
The software-defined stack is within Windows, available to any Windows customer, and brings together Storage Space and Hyper-V at scale. For those building a highly scalable environment, Windows Systems Center is available as well and integrates with the technology within Windows to enhance the management experience. At the Hyper-V layer, the software provides management for customers who have to manage hundreds or thousands of Virtual Machines (VMs). It aggregates the management of the VMs, rather than having the customers try to manage each of the physical computers on which the individual VMs are running. At the Storage Spaces layer, Systems Center Operations Manager provides management, as well as health and alerting information.

Essentially then, Windows becomes the infrastructure for a complete, end-to-end compute, storage, networking, and management stack. Having this software-defined stack available from a single provider can be highly advantageous for data center customers as they no longer need to purchase individual components from multiple vendors and try to stitch them together. It also simplifies both management and support.

This software-defined stack is a prime example of how the principles of running a public cloud are applicable to all Microsoft customers, regardless of scale. Whether a large or small customer, each needs a solution that is resilient to disk failure, for example. Windows provides that capability. If, on the other hand, the customer is a large enterprise in need of a greater set of functionality, the software-defined stack can deliver that as well, with Systems Center providing the cohesive integration so that management is simplified and the solution is easy to use.

**Key Features**
Storage Spaces in Windows Server 2012 RS includes a number of critical features including:

**Tiering.** Traditionally, flash-based solid state drives (SSDs) provide a lot of performance, but are expensive, while hard disk drives (HDDs) provide a lot of capacity, but limit performance, and are inexpensive. Storage Spaces in Windows Server 2012 R2 combines the best attributes of SSDs and HDDs in a capability known as tiering (Figure 3). It lets users create virtual disks with two tiers of
storage—an SSD tier for frequently accessed data and a HDD tier for less-frequently accessed data. Storage Spaces transparently moves data at a sub-file level between the two tiers based on how frequently data is accessed. As a result, storage tiers can dramatically increase performance for the most used (“hot”) data by moving it to SSD storage, without sacrificing the ability to store large quantities of data on inexpensive HDDs.

Resilient Storage. Storage Spaces provides three storage layouts or resiliency types:

- **Mirror.** Writes data in a stripe across multiple disks, while also writing one or two extra copies of the data. The mirrored virtual disk is resistant to either single or dual disk failure, depending on how the storage administrator chooses to configure it. Because it helps protect data from disk failures and provides great performance—especially when SSDs are added to the storage pool and storage tiers are used—it is ideal for most workloads.

- **Parity.** Writes data in a stripe across physical disks, while also writing one or two copies of parity information. It can be used for archival and streaming media workloads, or other workloads where the administrator wants to maximize capacity and is okay with lower write performance. One configuration option available in parity is dual parity, whereby the storage is resilient to dual drive failure. The algorithm underlining dual parity was developed by Microsoft Research for use in Windows Azure and is called LRC Erasure Coding.
- **Simple (no resiliency).** Writes data in a stripe across physical disks without any extra copies or parity information. Because the simple layout doesn’t provide any protection from disk failures, it is used only when the storage administrator requires the highest performance and capacity, and is okay with losing or have to recreate data if a disk fails. A simple layout can also be used when the administrator’s application provides its own data protection.

![Reduced Mean Time To Recovery](image)

**Figure 4.** Drive failures in a pool can degrade resiliency in contained storage spaces. When a drive fails and one or more spaces becoming degraded, Storage Spaces automatically starts repair of the affected spaces, provided there is sufficient spare storage capacity in the pool. If the pool has a hot spare drive, Storage Spaces automatically uses it to provide capacity for repairing degraded storage spaces.

**Parallel Rebuild.** Historically within a storage system, the administrator would typically designate some physical disks as hot spares. These drives were held in reserve and unused until a failure occurred. This approach has a number of disadvantages; namely, the drives sit idle until a failure occurs. When one does occur, the hot spare comes online and the system has to move all of the data from the failed drive to the hot spare. The speed of that process is limited to the speed of that single drive, so the rebuild often takes a long time.

As opposed to this traditional approach, Storage Spaces employs a parallel rebuild model, whereby the mirror and parity spaces in which a disk fails are repaired using spare capacity on other disks in the pool (Figure 4). Storage Spaces also includes background scrubbing and intelligent error correction to allow continuous service availability despite storage component failures.
**Continuous Availability.** Storage Spaces is integrated with failover clustering, which allows it to deliver continuously available service deployments. One or more pools can be clustered across multiple nodes within a single cluster. Storage spaces are accessed by one node. The storage will seamlessly fail over to a different node when necessary in response to failure conditions or load balancing. Integration with CSVs permits scale-out access to data.

**Write-Back Cache.** Storage Spaces in Windows Server 2012 R2 supports the creation of a write-back cache that uses a small amount of space on existing SSDs in the pool to buffer small random writes (Figure 5). Random writes, which often dominate common enterprise workloads, are directed to SSDs and later written to HDDs.

**Storage Spaces Value Proposition**
There are a number of key benefits to be garnered from using Storage Spaces. Besides offering a cost-effective storage platform to build private clouds, Storage Spaces provides simple, consistent management through familiar Windows interfaces (Figure 6). Storage Spaces also boasts flexibility, allowing administrators to build storage
solutions with varying degrees of performance, capacity and resiliency. Another key benefit of Storage Spaces is its ability to reduce mean time to recovery. The resiliency types and parallel rebuild model it supports ensure any storage component failures can be addressed quickly and with minimal effort, while also allowing for continuous service availability.

**Conclusion**

Traditional storage solutions can be complex, expensive and difficult to manage. They also don’t typically scale cost-effectively. The Storage Spaces solution from Microsoft addresses these concerns by providing SDS for virtualized workloads.

Future improvements to Storage Spaces will offer users even more benefits. For example, in Storage Spaces in Windows Server 2012 R2, SAS connections are required from the server to the JBOD. This can create a great deal of complexity when it comes to cabling, since every server has to be able to see the disks. Scaling out the storage just adds cabling and as a result, increases complexity. With the next version of Storage Spaces Direct, which leverages Storage Spaces technology, that SAS fabric model will be essentially replaced by one in which servers are connected over Ethernet. The next version of Windows will also offer further enhanced software-defined capabilities to allow a broader range of device types to be used.