State of Cloud Storage Providers Industry Benchmark Report:
A Comparison of Performance, Stability and Scalability

Executive Summary

Cloud storage is a young industry, but one that clearly has great promise for growth. Large organizations such as Netflix, Amazon, Google, NBC and Zynga already depend on cloud storage to manage and run their businesses, and cloud storage providers have only just begun to serve smaller enterprises. The unique architecture of the cloud not only offers unlimited storage capacity, but also lays the groundwork for eliminating the daily grind of data backup thanks to the cloud’s constant replication of data. As a result, this new market is populated by many competing cloud storage providers (CSPs) offering varying degrees of performance and reliability. Since no two CSPs are created equal, potential customers need to identify those that can deliver the appropriate price/performance levels to meet their specific business needs, but few possess the time, resources or in-house expertise to perform a thorough and proactive evaluation.

In April 2009, Nasuni began an ongoing and unprecedented evaluation process of CSPs based on a wide array of factors. Nasuni offers enterprise customers access to its Storage Services, which combine on-premise security and snapshot technologies with the vast raw storage resources of some of the leading CSPs. By being CSP agnostic, Nasuni can select from among the best providers for its customers. But to determine which providers were the best fit to meet specific needs Nasuni committed to completing rigorous CSP testing – a process that took more than two years and is still ongoing. It provides an unprecedented view of the real performance of the cloud. Indeed, these tests enabled Nasuni to correctly predict that two CSPs would likely soon leave the market due to poor performance.

This technical test looked at how CSPs perform in a specific use case, namely, how they perform for mid-sized organizations that want to take advantage of the cloud for primary storage, data protection and disaster recovery. Some providers, for example, have built their clouds to optimize their ability to deliver very large media files across the Web. Nasuni did not test for every possible use case.

As the first of its kind, this report reveals the findings of this ongoing testing and evaluation process, focusing on three key areas of importance for organizations that want to take advantage of cloud storage.
Performance

The cloud needs to respond quickly to queries and not slow when stressed. If performance is poor, organizations will spend too much time waiting on the cloud and productivity will suffer.

Stability/Availability

If organizations are to trust critical data to the cloud, it must be available at all times.

Scalability

One of the primary advantages of cloud storage is unlimited capacity. Without this property, the cloud is much less valuable to organizations.

Ultimately, only six of 16 providers passed Nasuni’s testing:

- Amazon S3
- AT&T Synaptic Storage as a Service (powered by EMC ATMOS)
- Microsoft Azure
- Nirvanix
- Peer1 Hosting (powered by EMC ATMOS)
- Rackspace Cloud

Two CSPs emerged as top performers in the Nasuni study: Amazon S3 and Microsoft Azure, with Amazon S3 being the standout across all evaluation areas.

Methodology

Since April 2009, Nasuni has conducted ongoing tests of the 16 largest CSPs. These tests are tiered so CSPs must pass the first test before proceeding to the next test. The five testing stages are as follows:

- **API Integration**, to ensure that it is possible to test the service at all. Nasuni wrote a custom connector in Python for each provider according to the documentation of the CSP's API and available best practices. The test itself was run through Python's own unit testing framework to provide pass/fail results for each of the basic APIs.

- **Unit Testing**, in which larger software components are broken down into their building blocks (units) and then tested for inputs, outputs and error cases. This enables Nasuni to determine whether each CSP can successfully handle basic functions such as writing and reading different file sizes, providing access from multiple locations simultaneously, and writing to the cloud with one connection and then reading the same file back from a different connection.
• **Performance Testing**, to measure response time (how quickly one can interact with the cloud), throughput (how fast data can move back and forth to the cloud), and the impact of a higher level of stress. To do this, Nasuni imposed a number of variables:

  - **Concurrency** (multiple simultaneous threads),
  - **Object size** (ranging from very small to very large), and
  - **Workload type** (read vs. write) and mixes.

In performance testing the cloud, location can bias or affect the provider being tested. Tests on Amazon S3 from Amazon EC2 yield better results than Amazon S3 tests from Rackspace Cloud Servers, for example. To minimize location bias, Nasuni ran benchmarks from three different geographic areas and hosting companies using the power of cloud computing. In addition, some cloud storage providers have optimized for large files and smaller object counts, while others have exclusively focused on smaller files. Nasuni’s object size tests enabled it to find the rare few that perform well at both ends of the spectrum.

• **Stability Testing**, to assess the long-term reliability of each CSP. Nasuni performs this test through the following process, which is repeated every five minutes on an ongoing basis:

  1. Write a file to the cloud;
  2. Infrequently read back a file from the cloud from a previous write (not the most recent one) and compare it against expected data; and
  3. Delete an old file from the cloud.

The results of this test reveal response-time consistency and the frequency and duration of CSP downtime. Nasuni measures long-term reliability from several locations so that results are not colored by local connectivity issues.

To pass, the provider had to perform with no data loss and have no significant unplanned outages, although planned outages by CSPs are an industry concern. Enterprises should expect CSPs to be available 100% of the time with no planned outages.

• **Scalability Testing**, to understand how well each CSP handles high object counts. Different clouds have different definitions of “high object counts.” In an ideal world, Nasuni would conduct an endless test that writes as many files of different sizes as it could to the cloud in perpetuity and would measure writing response time to determine whether it degrades as the system fills up. The ideal, of course, is not feasible, since most CSPs charge per operation, and testing costs would quickly become unsustainable.
For its testing, Nasuni defines “scalability” based on the following:

1. How many objects one can place in the cloud;
2. Whether performance remains constant as one fills the cloud or if it degrades over time; and
3. The reliability of the cloud over a long period of sustained high operation rates.

For this test Nasuni wrote small files (1KB) with many threads of concurrency for several weeks or at least until it hit 100 million objects. As Nasuni did so, it measured and tracked error rates and performance.

To pass, the CSP had to cross the 100 million object threshold successfully without degradation.

**Results**

**Basic Functionality: API and Unit**

Nasuni’s testing began with 16 CSPs. The initial qualifying tests set out to determine:

1. **Whether it is possible to build a connector for the service** (API testing); and
2. **Whether the service can perform basic functions**, such as writing different file sizes, simultaneous access, and writing to the cloud with one connection and then reading the same file back from a different connection.

The first two stages of basic testing – API and Unit – weeded out more than one-third of providers. Only one failed at the API stage, though several others required multiple passes and extensive discussions over several months with technical support to produce a working API.

At the unit level testing stage, five of the 15 remaining CSPs failed. Nasuni encountered missing, incorrect or inappropriate documentation, and often a simple write-read-delete operation would fail, especially if quickly executed. Most failures were related to the distribution and access of content within the CSP. If the CSP’s architecture was designed for slow access with less transactional operations such as archiving files or saving photos, Nasuni’s tests would severely stress the system, sometimes to the breaking point.

**Performance**

At the performance level, Nasuni examined how fast CSPs can write and read files in a variety of sizes. Of the 10 providers that qualified for this stage of testing, two failed due to performance levels that were too low to be acceptable to the vast majority of end-user organizations. Unlike the API and unit tests, however, the performance test does not generate a clear-cut pass/fail result. Depending on how a customer might make use of the cloud, a lower performance level may be acceptable. Caching, for instance, can shield an end user from slower performance times when reading files.
The results represented in the following charts show the performance of the top six providers with large files (1 MB), medium-sized files (128 KB) and small files (1 KB).

**Chart 1a: Average Write Speed for Large Files (1 MB)**

Charts 1a and 1b show results from performance tests on large files, with speeds shown in megabytes per second. In terms of writing large files to the cloud, Microsoft Azure had the highest average speed at 2.38 MB/sec, with Nirvanix close behind at 2.32 MB/sec. The rest of the top six providers posted comparable speeds with the exception of Peer1, whose average large write speed was 1.49 MB/sec.

**Chart 1b: Average Read Speed for Large Files (1 MB)**

For reading large files, Nirvanix was fastest at 13.3 MB/sec, followed by Microsoft Azure at 13.2 MB/sec. Amazon’s average speed took third with 11.28 MB/sec and Peer1 once again fell far behind the rest with 3.1 MB/sec, less than a quarter the speed of the top two.

*Please note that on charts 1a and 1b, larger bars represent faster speeds.*
Charts 2a and 2b compare how quickly each of the top six performers could read and write medium-sized files (128 KB). For writing medium-sized files, Microsoft Azure was fastest with an average speed of 2.1 MB/sec, followed closely by Amazon S3 at 2.0 MB/sec. The other providers fell significantly behind the top two, with most performing 28 to 41 percent slower than Microsoft Azure, and with Peer1 performing 70 percent slower than the leader.

Concerning read speeds for medium files, Amazon was the clear leader, far ahead of everyone else at 9.2 MB/sec. In second place, Microsoft Azure was 28 percent slower at 6.6 MB/sec. AT&T, Nirvanix and Rackspace posted comparable speeds in the 5.1 to 5.8 MB/sec range, with Peer1 again coming in last at 2.2 MB/sec, less than one-quarter the speed of Amazon.

Please note that on charts 2a and 2b, larger bars represent faster speeds.
Charts 3a and 3b compare how quickly each of the top 3 performers could read and write small files (1 KB) in terms of the number of objects per second.

In reading small files, Amazon S3 far outpaced its rivals, with 387 files/sec, 41 percent faster than its closest rival, AT&T. Peer1 was once again the laggard at 46 files/sec, 88 percent slower than Amazon S3.

In terms of performance for writing objects, Microsoft Azure took the top spot with 154 files/sec, closely followed by Amazon S3 at 135 files/sec. AT&T came in third at 98 files/sec, while the other three – Nirvanix, Rackspace and Peer1 – fell far behind with speeds of 46 files/sec, 31 files/sec and 22 files/sec respectively.

Please note that on charts 3a and 3b, larger bars represent faster speeds.

Overall, Amazon and Microsoft Azure come out as the strongest providers when it comes to performance, with fast read and write speeds across the board. For those end users who are mostly concerned with storing large files, however, Nirvanix’s network performed extremely well.
Stability

To determine a CSP’s stability, Nasuni created jobs that wrote a file to the cloud, infrequently read the file back to compare it against expected data, and then deleted an old file from the cloud. The goal was to determine:

1. How often the cloud goes down;
2. How long downtime lasts;
3. How long it takes to execute this test;
4. How the time it takes to execute the test changes; and
5. Whether data written can always be read back successfully.

The purpose of this test is to determine whether CSPs can deliver the caliber of reliability required by the mid-sized enterprise. This test is important because, as hard as it may be to believe, there are CSPs who intentionally take down their cloud service, sometimes for hours at a time, to perform maintenance and install upgrades.

Of the eight providers that made it to this stage of testing, however, none failed. Amazon S3 and Microsoft Azure were the top two performers in terms of average ping, but differences among the top six CSPs were small, with the exception of Nirvanix, whose average ping was more than three times that of the fastest CSP, Microsoft Azure.

Average Response Time

Please note that on this chart, shorter bars represent faster speeds.
Provider Availability

In terms of outages, Amazon had the fewest with just 1.43 outages per month. However, the duration of these outages was not significant as Amazon had an uptime that essentially equaled 100 percent. Availability for Microsoft Azure, Peer1 and Rackspace were comparable, with Nirvanix and AT&T coming in last place. Nirvanix, in particular, experienced a high number of outages relative to this peer group, though its availability was 99.8 percent. AT&T did not have a large number of outages, but their duration impacted its availability, which was the lowest of the top six providers at 99.5 percent.

<table>
<thead>
<tr>
<th>Provider</th>
<th>Average Outages Per Month</th>
<th>Percentage Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon</td>
<td>1.4</td>
<td>100%</td>
</tr>
<tr>
<td>AT&amp;T</td>
<td>10.4</td>
<td>99.5%</td>
</tr>
<tr>
<td>Azure</td>
<td>11.1</td>
<td>99.9%</td>
</tr>
<tr>
<td>Nirvanix</td>
<td>332</td>
<td>99.8%</td>
</tr>
<tr>
<td>Peer1</td>
<td>6.8</td>
<td>99.9%</td>
</tr>
<tr>
<td>Rackspace</td>
<td>10.3</td>
<td>99.9%</td>
</tr>
</tbody>
</table>

Scalability

For this test Nasuni continuously writes small files (1KB) with many threads (concurrency) for several weeks or at least until it has written 100 million objects. Ideally, the test would involve billions of files over a longer period of time, but the costs of performing such a test are prohibitive. As it writes these files, Nasuni measures and tracks the error rates and performance. Two of the eight providers that went through this stage of testing failed.

Without proper testing, it is impossible to differentiate between an industrial-strength CSP and a lesser operation. In fact, some providers

It is not difficult to create something that looks like cloud storage. It is very difficult, however, to create a cloud that is truly scalable, reliable and always available.
have asked Nasuni to cease testing at this stage because they said it was negatively impacting their customers, which is a truly frightening statement. True cloud storage should be able to accommodate billions of files without any visible strain. Those CSPs that faced performance issues under Nasuni’s test are simply not equipped to deliver an appropriate level of service to customers.

The top two performers were, yet again, Amazon S3 and Microsoft Azure. For writing objects, the error rate for both was effectively zero. There was a very small error rate with reading objects for Microsoft Azure at 0.07; Amazon’s error rate for reading was effectively zero.

**Best of Show: Amazon S3**

Ultimately, six CSPs passed the test:

- Amazon S3
- AT&T Synaptic Storage as a Service
- Microsoft Azure
- Nirvanix
- Peer1 Hosting
- Rackspace Cloud

However, Amazon S3 and Microsoft Azure were clearly the standouts, with Amazon S3 offering the best overall results. Though Nirvanix was faster than Amazon S3 for large files, and Microsoft Azure was slightly faster when it comes to writing files, no other vendor posted the kind of consistently fast service across all file types as did Amazon S3. Amazon S3 had the fewest outages and best uptime, and was the only CSP to post a 0.0% error rate in both writing and reading objects. And though Microsoft Azure had a slightly faster average ping time than Amazon S3 (likely because Amazon S3 is much more heavily used than Microsoft Azure), Amazon nevertheless had the lowest variability.

* Nasuni’s testing of CSPs continues, so these standings could change in future reports.

**Analysis**

Cloud storage has the potential to truly disrupt the storage market due to its ability to provide “inherent” data protection and unlimited scalability, while imposing minimal infrastructure and management requirements on customers.

Like most technologies, this nascent market can be broken into three segments: Large enterprise, midmarket and small-business/consumer. Many large enterprises do not want to depend on an outside vendor for storage of critical files and, as such, are working to build their own private clouds. Nevertheless, a number of large businesses that function primarily online, such as Facebook and Zynga, are taking advantage of CSPs for their storage infrastructure.
As a result, CSPs are largely oriented to serving these customers and their very large appetites for storage.

Midmarket enterprises, on the other hand, face a dilemma. Even if it were appropriate for the business to build a private cloud (and in most cases, it is not), they are not large enough to possess the economies of scale they need to build one, so they must rely on a CSP for cloud storage. However, as stated above, CSPs are largely focused on serving very large enterprises and, without help, mid-sized enterprises will find customer service at the larger cloud providers lacking. The IT director for a 500 employee company, for example, will find it difficult to raise someone on the phone at a large CSP to troubleshoot problems. In addition, mid-sized organizations may discover they lack the technical expertise to interface properly with the CSP's APIs and other aspects of their technology. Major CSPs cater to developers, not IT personnel at end-user organizations.

Finally, there are a number of CSPs catering to the small business and consumer markets, but they are riddled with security issues and do not provide robust data protection. Customers often cannot recover lost data and service-level agreements are typically non-existent. However, these shortcomings may be acceptable to some in this segment of the market, since the data being sent to the cloud may not be terribly sensitive.

Of the three markets, the midmarket faces the most vexing dilemma: companies in this space require the performance of the top CSPs, but they do not deliver the volume of business to be "interesting" to those CSPs. Mid-sized enterprises need the help of partners that can fill this service void by managing the relationship with the CSP, and providing value-added services such as enhanced data protection, responsive customer service and guaranteed levels of performance.

The largest CSPs are the equivalent of the hard drive vendors in traditional storage, offering low prices and a high quality raw storage service through sheer operational excellence and economies of scale. But raw cloud storage lacks performance, security, and any sort of comprehensive account management. Raw cloud storage is just as unusable to most businesses as a solitary hard drive. In much the same way that the hard drive industry evolved, the CSP market will continue to consolidate, leaving only a handful of players who have the massive economies of scale required to compete effectively in what will eventually become a commodity business. And just as companies such as EMC emerged to package commodity disk drives into intelligent systems, a new generation of storage vendors is now emerging who are focused on harnessing the power of raw cloud storage to deliver complete storage systems built to run businesses.

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.

Social Media Links

Twitter
www.twitter.com/nasuni

The Nasuni cloud storage blog
http://www.nasuni.com/blog

About Nasuni

Nasuni, a next-generation enterprise storage company, delivers Data Continuity Services that offer a new breed of data protection, accessibility and support to organizations that require their data be accessible 100 percent of the time with no risk of data loss. Nasuni’s storage services offer primary data storage, offsite disaster recovery, data backup and a 100 percent reliability guarantee that is supported by the storage industry’s most stringent service level agreement. With Nasuni, organizations can simplify IT, ensure business continuity, and reduce the total cost of storage. For more information, visit www.nasuni.com.