TOSHIBA

Lab Report

Asustor AS5404T 4-Bay NAS System

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Introduction

NAS systems are popular among private individuals, small businesses, and companies. They use them to store data on the network while simultaneously preventing accidental data loss due to storage media failures. Depending on the RAID (Redundant Array of Independent Disks or, historically, Redundant Array of Inexpensive Disks) configuration, NAS systems can offer improved cost-effectiveness, enhanced performance over a single Hard Disk Drive (HDD), and smart management functions.

RAID technology combines several smaller drives into one larger storage space, with redundancy features like parity or data mirroring. This means that if a drive fails, the data can be restored from the remaining drives after replacing the failed drive.

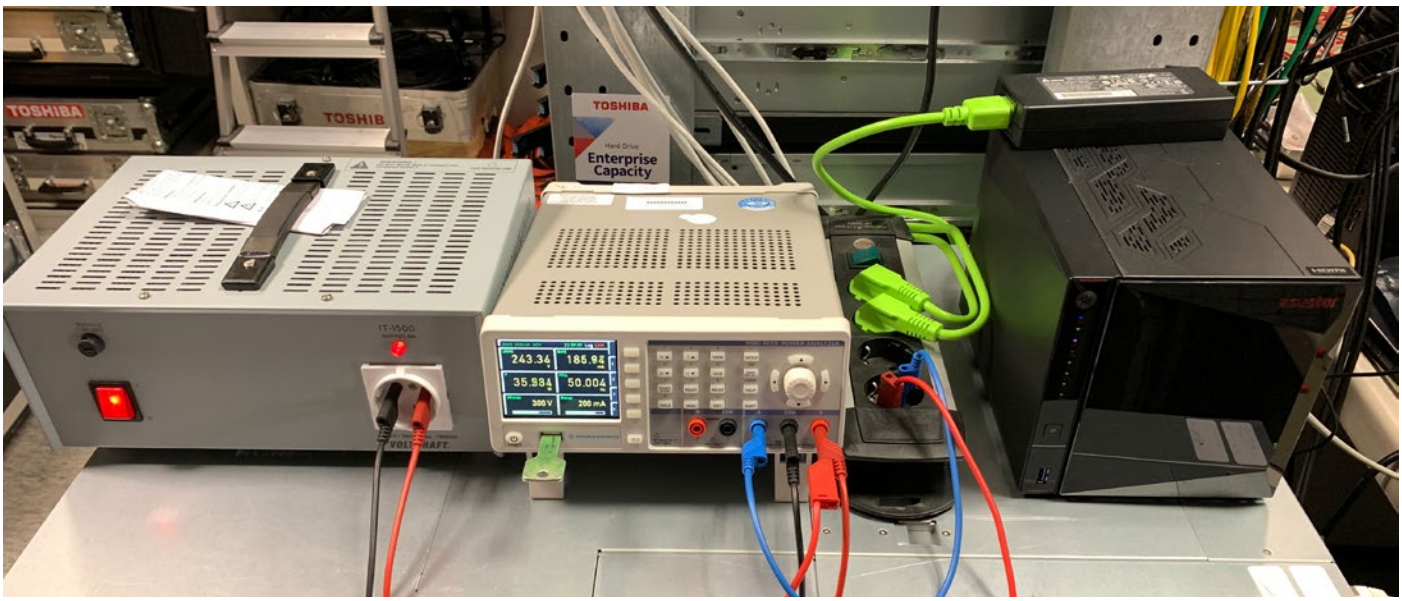
For NAS systems with one or two HDD drive bays, the configuration is straightforward: A single drive for one bay (without drive fail tolerance), and data mirroring (RAID1) for two drives. However, for the popular 4-bay NAS systems, several RAID configuration options are available.

But what is the best RAID configuration for a 4-bay NAS system? Which specifications are helpful and how much are they influenced by the individual use case?

Based on evaluation data from the Toshiba HDD Laboratory, this lab report offers guidance for such systems.

Asustor AS5404T

For the evaluation in the Toshiba HDD lab, our partner Asustor kindly provided a sample of their AS5404T NAS system – a 4-bay model with 2.5GbE network connectivity, promoted as an “Enthusiast Grade NAS with entry level pricing”. The AS5404T supports up to 4x M.2 SSDs for caching. However, since we aim to benchmark the base performance of the HDD array in continuous data flow applications, we ignored the cache option. It should be noted that SSD caching improves random performance during short bursts of incoming data or repeated reads from the same location. Ultimately, sustained performance depends on HDD speed and the chosen RAID configuration.



Picture 1: AS5404T measurement setup in the Toshiba HDD Lab

We installed 2x 256GB M.2 NVMe SSDs and created Pool1 with RAID1. This Pool1 was used for the operating system, while the later-installed HDD Pool2 was reserved for user data. This setup ensures that operating system disk interactions do not interfere with the storage workload.

The HDDs

For the lab evaluation, we used the Toshiba NAS HDD model N300 with a popular capacity of 8TB (model number HDWG780 with firmware level 0501). These 3.5-inch N300 NAS Hard Drives offer unprecedented reliability for NAS and other high-performance storage systems. They are optimised to meet the reliability, endurance, performance, and scalability requirements of 24/7 high-capacity storage for personal, home office, and small business use. The N300 is available in capacities of up to 22TB.

Configurations

Four drives may be configured as:

RAID5

Incoming data is distributed and stored in stripes across three disks, with a fourth stripe carrying the parity information. In the event of a drive failure, data can be reconstructed using the parity. This RAID5 configuration offers 75% storage efficiency, as the four 8TB drives provide 24TB of usable data space. Data can be read from 3 or 4 disks in parallel, resulting in fast read speeds. Writing is also performed in parallel, but the parity must be calculated and written, which can reduce write speed. During a rebuild, all parity must be recalculated, which is a resource-intensive process.

RAID10

This configuration is considered a strong alternative to RAID5. Instead of using parity for redundancy, RAID10 mirrors data across two disks while striping it. This avoids the resource-consuming parity calculations required by RAID5 during writes and rebuilds. Data can still be read from all four drives, but is written to only two drives at a time. The trade-off is reduced storage efficiency - only 50% - due to mirroring.

RAID6

RAID6 uses a parity concept similar to RAID5, but stores two parity stripes, allowing it to tolerate two drive failures. This is advantageous in worst-case scenarios where a second drive fails during the rebuild of a previously failed drive. RAID10 also tolerates two drive failures, but only if they are not from the same mirrored pair. RAID6 allows any two drives to fail. However, because two drives are used for parity, RAID6 is typically used in systems with more than four drives. With only four drives, storage efficiency is 50%, the same as RAID10. The added tolerance for random drive failures may justify choosing RAID6 over RAID10, so we evaluated this configuration as well.

Picture 2: Toshiba N300 NAS HDD in Asustor tray

These are the "fio" (flexible IO tester) command lines:

```
fio --filename=test --size=2T --direct=1 --rw=write --bs=1m --iodepth=64 --time_based
--runtime=20m --group_reporting --name=job1 --ioengine=windowsaio --thread --numjobs=1
--group_reporting --output=write.txt --norandommap --randrepeat=0

fio --filename=test --size=2T --direct=1 --rw=read --bs=1m --iodepth=64 --time_based
--runtime=20m --group_reporting --name=job1 --ioengine=windowsaio --thread --numjobs=1
--group_reporting –output=read.txt --norandommap --randrepeat=0

fio --filename=test --size=2T --direct=1 --rw=randrw --bssplit=4k/20:64k/50:256k/20:2M/10
--iodepth=8 --time_based --runtime=20m --group_reporting --name=job1 --ioengine=windowsaio
--thread --numjobs=32 --group_reporting --output=mixed.txt --norandommap --randrepeat=0
```

Table 1: Fio measurement scripts

Methodology

For each RAID configuration, we setup one HDD storage pool in the NAS, waited for full initialis ation and created a thick-provisioned iSCSI block storage target using 80% of the usable pool size. We connected one iSCSI target via the 2.5GbE network interface to an application server, created a Windows logical drive, filled it with 2TB of test data and benchmarked its performance. In a second round, we created two iSCSI targets on the HDD pool and connected each to the application server via separate 2.5GbE connections, utilising the full network bandwidth of the AS5404T, which has two 2.5GbE ports.

We benchmarked the following workloads:

- sequential writing of 1MB blocks
- sequential reading of 1MB blocks
- random read/write workload with mixed block sizes

Note: Most NAS systems are used for shared file storage (i.e. via SMB protocol). However, benchmarking shared file storage is difficult to reproduce consistently. Therefore, we used the more deterministic iSCSI block storage approach, assuming the results would roughly translate to shared file storage performance as well.

To discuss and understand the results for a multi-drive configuration, the performance of a single drive was evaluated with the reference scripts as well:

Disk Model	PartNr	Firmware	Capacity	Single Disk Performance		
				SeqWrite	SeqRead	Mixed
				MB/s	MB/s	MB/s
N300 8TB	HDWG780	0501	8TB	281	283	68

Table 2: fio performance results for a single HDD

Results for one HDD pool (RAID5, RAID6 and RAID10) with single 2.5GbE connection

Manufacturer	Model	Disk Model	Disk Capacity	Number	Config	Capacity	Performance		
							SeqWrite	SeqRead	Mixed
							MB/s	MB/s	MB/s
Asustor	AS5404T	N300 8TB (HDWG780)	8TB	4	RAID5	24TB	287	288	54
					RAID6	16TB	236	281	35
					RAID10	16TB	289	288	68

Table 3: fio performance results for one pool and a single 2.5GbE connection

Results for one HDD pool (RAID5, RAID6 and RAID10) with dual 2.5GbE connections

Manufacturer	Model	Disk Model	Disk Capacity	Number	Config	Capacity	Performance		
							SeqWrite	SeqRead	Mixed
							MB/s	MB/s	MB/s
Asustor	AS5404T	N300 8TB (HDWG780)	8TB	4	RAID5	24TB	365	428	49
					RAID6	16TB	290	323	44
					RAID10	16TB	358	351	68

Table 4: fio performance results for one pool and dual 2.5GbE connection

In this setup, sequential performance (~290MB/s) is limited by the 2.5GbE network bandwidth. RAID6 shows slightly lower sequential write performance due to dual parity calculations. In mixed workloads, RAID10 (striping & mirroring) performs best, followed by RAID5 and RAID6.

Recommendations:

- For maximum data protection: use RAID6 (at the cost of speed and capacity)
- For maximum capacity: use RAID5 (with reasonable protection and speed)
- For maximum performance in mixed workloads: use RAID10 (with some compromise on protection and capacity)

Note: If the network runs at 1GbE (common in home-routers, switches and PCs), RAID level has minimal impact on performance due to the 1GbE bandwidth limit (~110MB/s).

These results follow the same trend as the single 2.5GbE setup, but are no longer limited by network bandwidth. Recommendations remain the same: RAID5 for capacity, RAID6 for protection, RAID10 for performance at mixed workloads.

Results for two HDD pools (RAID1) with dual 2.5GbE connections

HDDs perform best in sequential operations due to minimised seek operations. Creating two iSCSI blocks on one pool causes frequent seeking at concurrent access to the two blocks. Using two separate RAID1 pools avoids this. The AS5404T supports this configuration. We created one iSCSI block per pool and connected them via separate 2.5GbE interfaces.

This setup reached the bandwidth limit of dual 2.5GbE. If the network and application support multiple logical storage entities (block or shared folder), this configuration offers optimal performance, exceeding RAID10, while maintaining similar protection and capacity efficiency.

Manufacturer	Model	Disk Model	Disk Capacity	Number	Config	Capacity	Performance		
							SeqWrite	SeqRead	Mixed
							MB/s	MB/s	MB/s
Asustor	AS5404T	N300 8TB (HDWG780)	8TB	4	2xRAID1	16TB	522	572	108

Table 5: fio performance results for two pools and dual 2.5GbE connection

Power consumption and HDD temperature
We measured power consumption for different conditions:

Power Consupmtion		Disk	Number	Power					
				Off	Sleep	Idle	Operating 1x2.5GbE	Operating 2x2.5GbE	Startup Max
				W	W	W	W	W	W
Asustor	AS5404T	N300 8TB	4	1	20	50	55	58	78

Table 6: Power consumption

Temperature		Disk	Temperature			
			Ambient	Sleep	Idle	Loaded
			degC	degC	degC	degC
Asustor	AS5404T	N300 8TB	23	24-26	35-38	43-46

Table 7: HDD temperature

20W in sleep mode (no storage access, no NAS GUI access) is basically the power of the NAS processing unit. The HDD's power impact is minimal. (HDD power mode "standby", 0.57W for one HDD as per datasheet).

50-60W is the power consumption during full data operation. The operating power of four HDDs is added. (8.19W for one HDD as per datasheet).

Both values are excellent, supporting energy efficiency and sustainability.

The AS5404T's cooling system keeps HDD internal temperatures below 50°C, even under load. Long-term reliability may degrade above 45°C. Idle or sleep periods with lower temperatures help mitigate this. For continuous full-load operation, the ambient temperature should not exceed 23°C for extended periods.

Conclusion

The Asustor AS5404T is an excellent mid-range 4-bay NAS. With 4x Toshiba N300 HDDs, it delivers high capacity, strong performance, and good protection against disk media failures. With one 2.5GbE port, RAID5/6/10 configurations saturate the network (~250MB/s). With both ports, performance reaches 350–400MB/s. Using two RAID1 pools achieves over 500MB/s, the theoretical limit of dual 2.5GbE.

Power consumption of the unit is rather low (20W sleep, ~50W level active) and cooling is effective, maintaining HDD temperatures within recommended limits for long-term reliability.

Note of thanks to our partners

Critical to the success of this lab report has been the collaboration. "I would like to thank our partner for his support on this project. Asustor kindly provided the AS5404T NAS system, enabling us to evaluate RAID configurations and performance in a real-world 4-bay setup. With our Toshiba N300 NAS Hard Disk Drives, we were able to demonstrate throughput, energy efficiency, and reliability. The results offer valuable guidance for users seeking optimal configurations for mixed workloads, capacity, or data protection."

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Interested in performing a test in our lab yourself or planning a visit? We'd be happy to support you.

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