Low Cost NAS Solutions Using Open Source Technologies

by

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In Memory of Glenn Cappuccio.

He was a good project manager, and kept the team on track. We miss his determination to get the job done.

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Abstract

Typical off-the-shelf network attached storage (NAS) systems lack flexibility when it comes to expanding the size of the array as well as working with different sized hard drives. Many of the current implementations lack sufficient ability to reduce the wear and tear on consumer level hard drives; therefore, increasing the long term operating cost due to the replacement of faulty hard drives. The utilization of open source software will provide a more cost effective NAS solution. Additional software will provide an easy to use web-interface and RAID-like features to pool the disks together and provide data redundancy and recovery in the event of a failure. Our solution employs a NAS for three areas: home, small businesses and small/medium size businesses. We have constructed and demonstrated each of these three solutions.

1. Problem Statement

1.1 Introduction

In today's IT environment data loss, integrity and file sharing are of a paramount concern. The primary type of data in use by home based systems are media files, like music, movies and videos, and system backups. Small home offices store document files, database backups as well as media files listed above. Small businesses not only store all the data types listed above but typically require greater amounts of data storage and better network performance to accommodate the greater demand. There are several ways to prevent data loss and maintain data integrity. Some use cloud services to accomplish their goals while still others just use USB external hard drives to store their data, but the most reliable system is to use a Network Attached Storage (NAS).

1.2 Problem

Typical off-the-shelf NAS systems lack flexibility when it comes to expanding the size of the array as well as working with different sized hard drives. Also, many implementations lack sufficient ability to reduce the wear and tear on consumer level hard drives which will increase the need for replacement drives. There are commercial systems that provide similar features currently in existence, but at a significant premium.

1.3 Solution

Our project solves the need by providing a low cost, low power NAS with raid-like functionality that features multiple sized hard drives while keeping your data on-site, safe, secure and accessible from the cloud.

1.3.1 Description

In order to provide a low cost NAS solution only open source software was used. Each system has Debian Linux installed as the base operating system with Open Media Vault, which provides an easy to use web-interface. The RAID-like features are provided by using AUFS to group the disks together and SnapRAID to provide data redundancy and recovery in the event of a failure. Data access is based on an archival model.

Three different levels of a low cost, low power NAS are developed to meet the needs of three different use cases for potential clients:

The low-end NAS unit, w primary designed to be used in home networks, focus on pure efficiency. The board that was chosen to use in this project is the Banana Pi BPi-M1, which has the following specifications as seen in the following Table 1-1. The Banana Pi was selected for use as the low-end NAS because it features gigabit Ethernet, a SATA II port, and two USB 2.0 ports for connectivity. Other competing systems within a similar price range lacked the features listed above (RASPBERRY PI FOUNDATION n.d.). A kit that contained a power supply, heatsink and an acrylic case was purchased.

Table 1-1 Specification for the Low-end NAS

Banana Pi Hardware	Specifications
CPU	A20 Arm Cortex –A7 Dual Core
Memory	1GB DDR3
Onboard Storage	SD (Max 64GB)/ SATA II disk
Onboard Network	10/100/1000 Ethernet RJ45, Optional WIFI
USB 2.0 Ports	2

Source: BPI SINOVOP CO,. LIMITED&Banana PI team n.d.

The mid-range is a bit more powerful and provides greater connectivity for a more power-user or a very small business. Utilizing an ASRock C70M1 motherboard with the specifications listed below in the following table. The mid-range unit provides a few advantages over the low-end unit such as a more powerful CPU, more memory, more SATA ports, and the option to expand the systems connectivity through the PCI Express slot. Using the PCI Express slot the system can be expanded to include additional SATA ports or network interfaces as an example.

Table 1-2 Specifications for the Mid-range NAS

ASRock C70M1 Hardware	Specifications
CPU	AMD Dual-Core Ontario C-70 APU
Chipset	AMD A50M Chipset
Memory	2 x DDR3 DIMM Slots
	Supports DDR3 1333(OC)/1066/800 non-ECC, un-buffered memory
	Max. capacity of system memory: 16GB
Onboard Storage	SD (Max 64GB)/ SATA II disk
LAN	PCIE x1 Gigabit LAN 10/100/1000 Mb/s
	Realtek RTL8111E
Slots	1 x PCI Express 2.0 x16 Slot (PCIE1 @ x4 mode)
Storage	4 x SATA3 6.0 Gb/s Connectors, support NCQ, AHCI and Hot Plug

Source: © 2002 - 2015 ASRock Inc. n.d.

The high-end system is designed for use in a small to medium sized businesses. With the range provided by this level of high-end system, we are using server class components that provide greater reliability and expanded connectivity. It features an iKVM solution for remote management, quad gigabit network adapters, ECC memory, and supports up to 18 SATA drives. Expansion and additional connectivity is provided by the PCI-Express slot.

Table 1-3 Specifications for the High-end NAS

ASUS P9A-I/C2550/SAS/4L Hardware	Specifications
CPU	Intel ATOM C2550 Series FCBGA Processor(Avoton)
Memory	2 x DDR3 DIMM Slots
	Supports DDR3 1600/1333 UDIMM with ECC
	Max. capacity of system memory: 32GB
Onboard Storage	2 x SATA3 6GB/s ports
	4 x MiniSAS Connector
Onboard Network	4 x GbE LAN + 1 Mgmt LAN
USB 2.0 Ports	2
Expansion Slots	1x PCI-Express x8 (Gen2 X4 Link)
Management Solution	ASWM Enterprise ASMB7-iKVM

Source: © ASUSTeK Computer Inc. n.d.

1.4 User Profile

Each system is determined to have only two types of user. The first user will be the system administrator while the second will be actual users. Table 1-*4* and 1-*5* provides a profile for each of these two types of users.

Table 1-4 System Administrator User Profile

User Profile Form 1
Application: Open Media Vault web interface, Linux command-line
Potential Users: System Administrators
Software and Interface Experience: The user should have experience in using GUI and command-line interfaces. The user should be familiar with Linux operating systems.
Experience with Similar Applications: Need to have basic experience in the configuration of Linux based operating systems. Basic working knowledge with using OpenFiler and FreeNAS.
Task Experience: Using the Linux command-line to install the software. Additional configuration can take place through the web-interface once it is installed.
Frequency of Use: After the initial setup is complete only minimal interaction with the system would be required for routine operational/maintenance needs. Which can be as often as monthly or yearly depending on the organization's needs.
Key Interface Design Requirements that the Profile Suggests: Administrator will use web interface to make changes to the system and monitor its health. The network shares should be accessible to the end users.

Table 1-5 End User Profile

User Profile Form 2
Application: Any application that uses the smb/cifs or nfs protocols to use network shares.
Potential Users: End Users
Software and Interface Experience: User should have experience using network shares and manipulating computer files.
Experience with Similar Applications: Finder, Windows Explorer, Total Commander, Directory Opus, and Q-Dir.
Task Experience: Basic file manipulation using mouse and keyboard to create, modify, and delete as required.
Frequency of Use: Whenever the users' needs access to the NAS which could be constantly, daily, monthly, or yearly.
Key Interface Design Requirements that the Profile Suggests: The availability and uptime of the network share is critical. Easily accessible yet secure.

1.5 Use Case Diagram

Figure [1-1] shows all the different tasks that are required for the operations and maintenance of the NAS system along with the level of user that will need to perform these task.

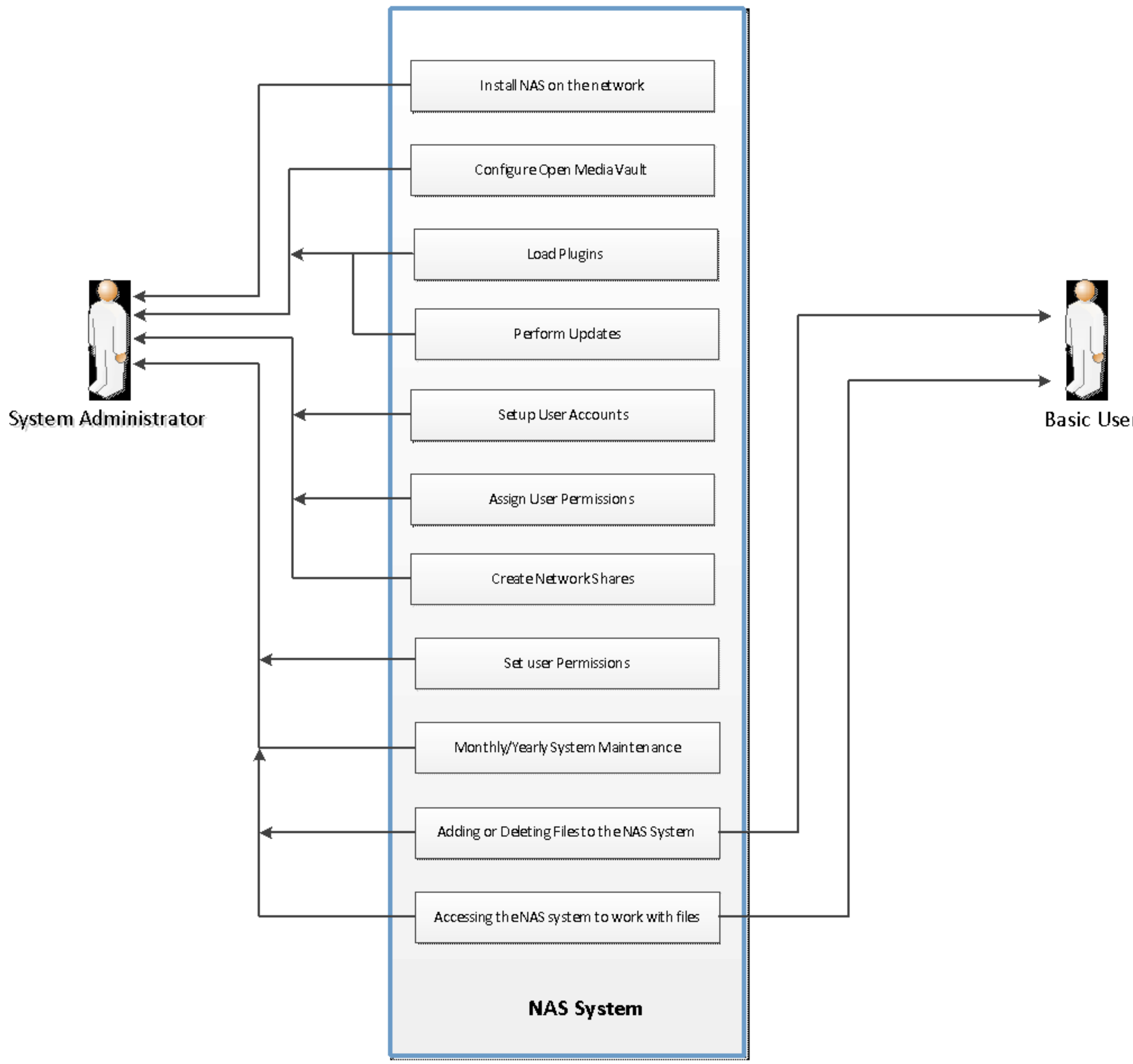


Figure 1-1 Use Case Diagram

1.6 Network Diagram

The following Figure 1-2 depicts a typical network setup for both the low and mid-range units. In this configuration the NAS system is accessed by other devices through a switch.

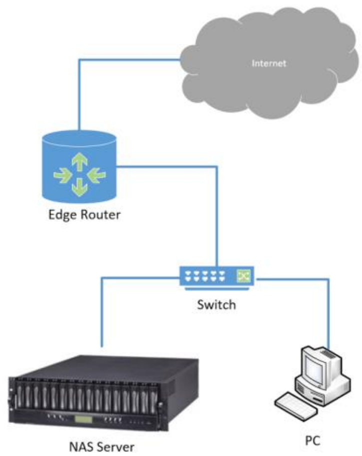


Figure 1-2 Low and Mid-range Network Diagrams.

Figure 1-3 depicts one of the several different network setups that are possible with the high-end NAS system. This NAS system utilizes bonded interfaces which increase network throughput to the virtualization server and to the other clients connected through the switch. This system also features an Intelligent Platform Management Interface (IPMI) for remote management purposes.

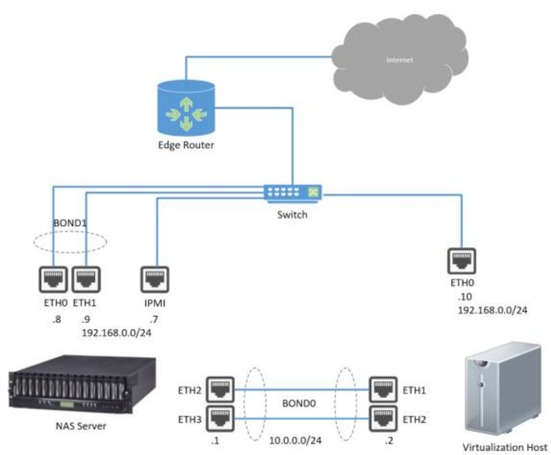


Figure 1-3 High-end Network Diagram

1.7 Gantt Chart

The Gantt chart below in Table 1-6 shows all the milestones that were required for this project to be completed.

Table 1-6 Gantt chart

	Task Mode	Task Name	Duration	Start	Finish	Predece	Resource Names
1		**Milestone 1**	**24 days**	**Tue 9/1/15**	**Fri 10/2/15**		
2		1: Preliminary Project Research	4 wks	Tue 9/1/15	Mon 9/28/15		Internet Accesss
3		2: Create Units' Parts Lists BOMs	3 wks	Tue 9/1/15	Mon 9/21/15		Email /Internet Access
4		3: Order Parts For the Units	2 wks	Mon 9/21/15	Fri 10/2/15		
5		**Milestone 2**	**20 days**	**Fri 10/2/15**	**Thu 10/29/15**		
6		**4: Build the Units**	**4 wks**	**Fri 10/2/15**	**Thu 10/29/15**	**2,3,4**	
7		4.1 Stress Test hardware (ram, hard drives,cpu,etc.)	1 wk	Fri 10/2/15	Thu 10/8/15		
8		**4.2 Setup and Configure Software**	**1 wk**	**Fri 10/2/15**	**Thu 10/8/15**	**7**	
9		4.2A Install Debian OS	5 days	Fri 10/2/15	Thu 10/8/15		
10		4.2B Install and Configure Open Media Vault	5 days	Fri 10/2/15	Thu 10/8/15		
11		4.2C Format and Mount Hard drives	5 days	Fri 10/2/15	Thu 10/8/15		
12		4.2D Setup SnapRAID	5 days	Fri 10/2/15	Thu 10/8/15		
13		4.2E Setup AUFS	5 days	Fri 10/2/15	Thu 10/8/15		
14		4.2E -i Create Kernal Modules	5 days	Fri 10/2/15	Thu 10/8/15		
15		4.2E - ii Compile Tools	5 days	Fri 10/2/15	Thu 10/8/15		
16		4.2F Setup Pydio for Web Access	5 days	Fri 10/2/15	Thu 10/8/15		
17		4.2G Audit System for Vulnerablities and Functionality	1 day?	Fri 10/2/15	Fri 10/2/15		
18		**4.3 Develop Testing Requirements for All 3 units**	**2 wks**	**Fri 10/2/15**	**Thu 10/15/15**	**7,8**	
19		4.3A Sequential Write Performance	10 days	Fri 10/2/15	Thu 10/15/15		
20		4.3B Sequential Read Performance	10 days	Fri 10/2/15	Thu 10/15/15		
21		4.3C Random Write Performance	10 days	Fri 10/2/15	Thu 10/15/15		
22		4.3D Random Read Performance	10 days	Fri 10/2/15	Thu 10/15/15		
23		**4.3E Power Usage**	**1 day**	**Fri 10/2/15**	**Fri 10/2/15**		
24		4.3E-i Write Power Usage	1 day	Fri 10/2/15	Fri 10/2/15		
25		4.3E-ii Read Power Usage	1 day	Fri 10/2/15	Fri 10/2/15		
26		4.4 Test the Units	1 wk	Fri 10/16/15	Thu 10/22/15	7,8,18	
27		4.5 Collect desired Data	1 wk	Fri 10/16/15	Thu 10/22/15		
28		**Milestone 3**	**5 days**	**Fri 10/23/15**	**Thu 10/29/15**		
29		5 Research Comparable NAS units that match all 3 unit areas	1 wk	Fri 10/23/15	Thu 10/29/15		
30		6 Risk Management Analysis	1 wk	Fri 10/23/15	Thu 10/29/15		
31		7 Cost Analysis	1 wk	Fri 10/23/15	Thu 10/29/15		
32		**Milestone 4**	**32 days**	**Thu 3/3/16**	**Fri 4/15/16**		
33		**10 Prepare for Technical Demonstration**	**32 days**	**Thu 3/3/16**	**Fri 4/15/16**		
34		10.1 Combine all available informations from various resources	31 days	Thu 3/3/16	Thu 4/14/16		
35		10.2 Produce all materials needed for presentaion	24 days	Tue 3/15/16	Fri 4/15/16		
36		10.3 Live Demonstration	1 day	Fri 4/15/16	Fri 4/15/16		

1.8 Test Results

Initial testing conducted on the units consisted of stress testing the hardware components. The testing on the hardware components was done to verify the stability of the hardware and detect any errors that might cause potential problems in the future. The results of each test can be found in Appendix A.

The following commands were run to stress different components:

- Stress - Used to test available CPU and RAM resources on each unit for a continuous 24 hours.

- Badblocks - Command used on each hard drive to reveal any faulty blocks.

1.8.1 Power Usage

Power usage was collected using a Kill-A-Watt meter to measure the total system's power consumption during a particular task.

Readings were taken while the systems were in different states:

- Idle with hard drives spun down
- Idle with hard drives spun up
- Writing a file over SMB
- Reading a file over SMB
- Syncing parity data

1.8.2 Network Functionality

Network functionality was tested using the SMB protocol to access the network shares on each of the units.

The following test were performed to verify the network functionality of the NAS systems.

- Writing a file
- Reading a file
- Writing a directory
- Reading a directory
- Writing a large collection of small files (photo album)
- Reading a large collection of small files (photo album)
- Writing a large file (HD video)
- Reading a large file (playing a HD video)

- Writing two large files simultaneously (two HD videos)
- Reading two large files simultaneously (playing two HD videos)
- Writing for large files simultaneously (four HD videos
- Reading for large files simultaneously (playing four HD videos)

1.9 Budget

Listed in the following Tables 1-7 to 1-9 are the total parts cost for each version of NAS systems. Table 1-10 shows the price for three 3TB NAS hard drives. The hard drives are contained in a separate listing because the type, speed, and capacity of the hard drives will vary depending on the requirements for a particular environment. By using AUFS and SnapRAID each unit will be able to use different sized drives to mimic a raid like environment, which will vary the actual cost of the hard drives. Since all the software used in the building of each NAS systems is free and open sourced it is not included in any of the budgets.

Table 1-7 Price List for Low-end Banana Pi Unit

Item Type	Item	Qty.	Unit Price	Line Item Total
CPU + Motherboard + Memory	Banana Pi BPi-M1	1	$34.99	$34.99
Case	Acrylic Case for Banana Pi	1	$5.45	$5.45
USB Power Supply	NorthPada Micro USB Power Supply Wall Charger	1	$7.99	$7.99
Hard Drive Enclosure	Mediasonic ProBox K32-SU3 3.5" SATA Enclosure	2	$19.99	$39.98
External AC Power Adapter	3.5 Inch Hard Drive External AC Power Adapter	1	$10.94	$10.94
SD card	SanDisk Ultra 32GB UHS-l/Class 10 Micro SDHC	1	$16.25	$16.25
Heat Sink	Aluminum Heat Sink for Banana Pi CPU	1	$3.49	$3.49
				Subtotal
				$119.09

Table 1-8 Price List for Mid-range Unit

Item Type	Item	Qty.	Unit Price	Line Item Total
CPU + Motherboard	ASRock C70M1	1	$32.98	$32.98
Memory	Muskin Enhanched Essentials 4GB DDR3 1333	1	$18.99	$18.99
Case	NZXT Source 210	1	$47.98	$47.98
Power Supply	SeaSonic SSP-300ST	1	$41.98	$41.98
SATA data cable	Nippon Labs Premium 18" SATA Cable	1	$4.99	$4.99
				Subtotal
				$146.92

Table 1-9 Price List for High-end Unit

Item Type	Item	Qty.	Unit Price	Line Item Total
CPU + Motherboard	ASUS P9A-I	1	$380.99	$380.99
Memory	Kingston 8GB DDR3 1600 ECC	1	$57.99	$57.99
Case	Rosewill RSV-L4500	1	$99.99	$99.99
Power Supply	SeaSonic S12G-650	1	$80.98	$80.98
SAS to SATA cable	HighPoint Int-MS-1M4S SFF-8087 to 4 SATA Fan Out Cable	4	$16.28	$65.12
SATA power splitter	BYTECC SATA4-POWER Molex Connector to 4X Serial SATA Power Splitter	2	$8.98	$17.96
				Subtotal
				$703.03

Table 1-10 Price List for Hard drives Used

Item Type	Item	Qty.	Unit Price	Line Item Total
Hard drive	WD Red WD30EFRX 3TB IntelliPower SATA 6.0Gb/s 3.5" Hard Drive	3	$109.99	$329.97

1.9.1 Comparison of existing commercial products.

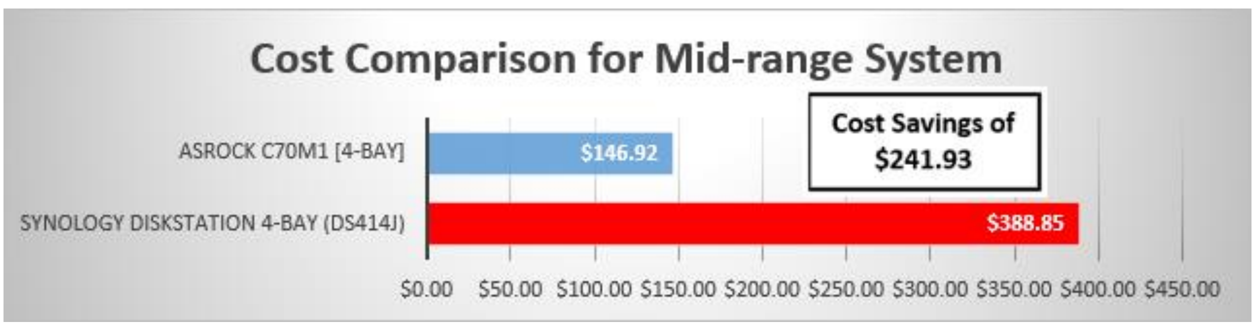
To prove how our solution is really a low cost solution we compared our actual cost with that of a commercial NAS system from Synology. Synology was chosen because their systems have close to the same specifications of our systems. The specifications which were required was that they had to have the same number of bays or be close to, and they had to have the same number of network interfaces. It is important to note that all comparisons exclude the purchase of the hard drives.

The first comparison shown in Table 1-11 was with the Low-end NAS. Our system was compared to that of the Synology DiskStation 1-bay. As shown there is a cost savings of $58.90.

Table 1-111 Cost Comparison for Low-end NAS

The next comparison shown in Table 1-12 was with the Mid-range NAS. Our system was compared to that of the Synology DiskStation 4-bay. As shown there is a high cost savings of $241.93.

Table 1-12 Cost Comparison for Mid-range NAS



The last comparison in Table 1-13 thru 1-14 was done on the high-end NAS. This unit had to be compared twice because there was no commercial solution that had 18 bays. First comparison was with the Synology 12-bay RackStation, which show a significant cost savings of $1,359.59.

Table 1-123 Cost Comparison for High-end NAS

The second comparison was conducted using the same unit with the inclusion of a 12-bay Expansion Unit, showing an even greater cost savings of $3,103.97.

Table 1-134 Cost Comparison for High-End NAS with Expansion

1.10 Conclusion

Three different models of NAS systems were built in order to meet the requirements of three different use cases. Preliminary stress testing was conducted on each NAS components including the hard drives, CPU, and memory. During the stress test of the mid-range unit it was found that the power supply was faulty, and needed to be replaced before continuing. During the testing of the low end a hard drive failed its stress test, it was found to have a bad SATA cable. Also found during initial testing of the low end unit was very poor network performance. This required changes to be made to the kernel parameters in order to meet an acceptable network performance rate. An additional purchase of a power adapter was required so that a SATA hard drive could be used with the low-end unit because the unit is unable to supply the appropriate voltages to run the drive on its own.

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3 Appendix A

3.1 Test Results for the stress test and hard drive check

Stress command stress test			
Date	**NAS Unit**	**Expected**	**Pass/Fail**
10-8-2015	Low-end	Run stress continuously for 24 hours on CPU and RAM, 0 errors reported	passed
10-8-2015	Midrange	Run stress continuously for 24 hours on CPU and RAM, 0 errors reported	passed
10-8-2015	High-end	Run stress continuously for 24 hours on CPU and RAM, 0 errors reported	passed

Hard Drive Badblock Disk Check			
Date	**Hard Drive**	**Expected**	**Pass/Fail**
Oct 02-2015	Low-end_sda	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	Low-end_sdb	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	Low-end_sdc	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	Midrange_sda	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	Midrange_sdb	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	Midrange_sdc	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sda	Run badblocksTest, pass complete, 0 bad blocks found	passed

Oct 02-2015	High-End_sdb	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdc	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdd	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sde	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdf	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdg	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdh	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdi	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdj	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdk	Run badblocksTest, pass complete, 0 bad blocks found	passed
Oct 02-2015	High-End_sdl	Run badblocksTest, pass complete, 0 bad blocks found	passed

3.2 Test Results for power consumption

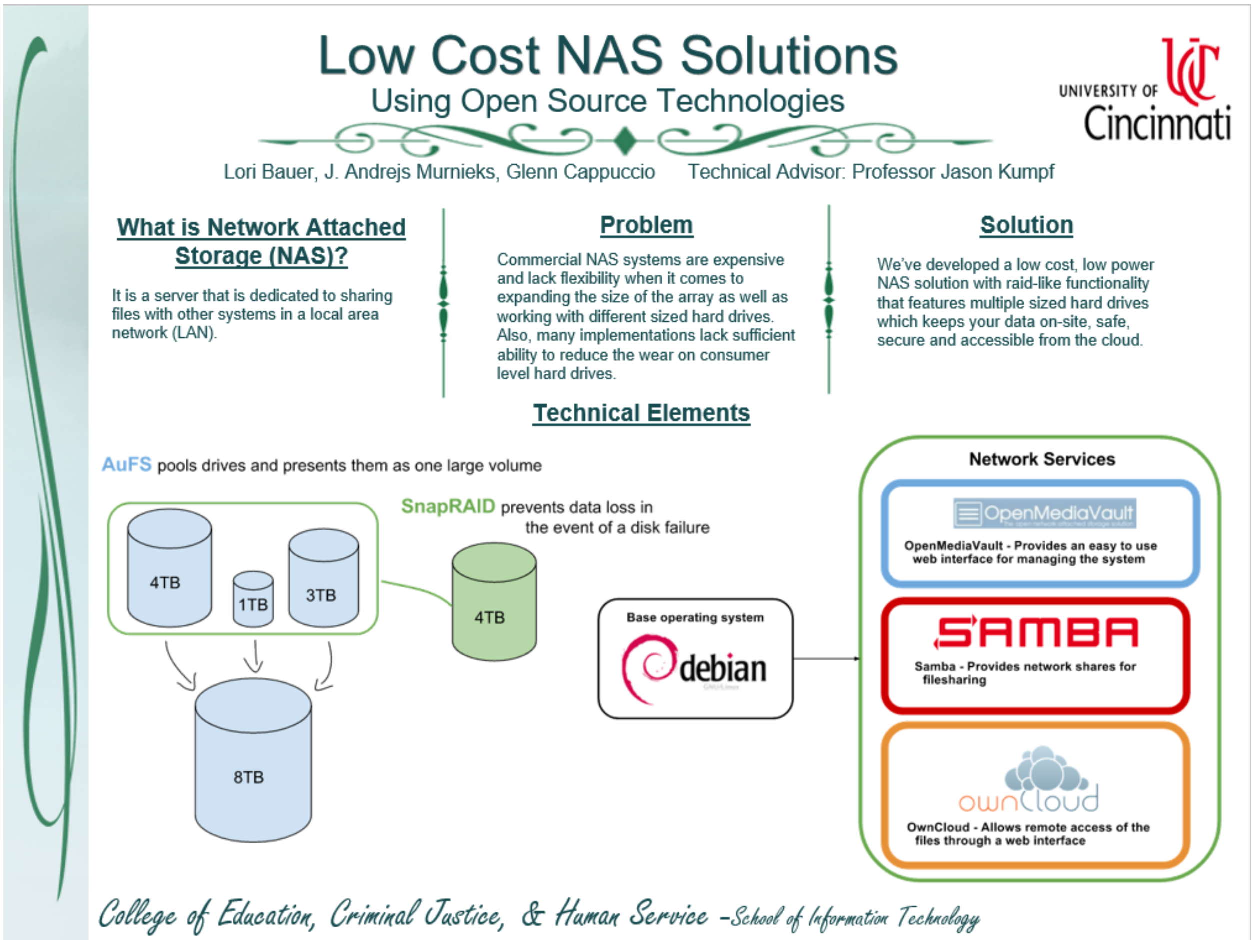
Baseline Power Consumption for each NAS Unit			
Date	**NAS Unit**	**Item #**	**Value**
Oct 02-05 2015	Low-End	2.a. Idle with drives spun down	7.5W
		2.b. Idle with drive spun up	19.0W
		2.c. Writing a file over SMB	12.4W
		2.d. Reading a file over SMB	12.8W
		2.e. Syncing Parity data	22.6W
Oct 02-05 2015	Midrange	2.a. Idle with drives spun down	32.2W
		2.b. Idle with drive spun up	47.1W
		2.c. Writing a file over SMB	46.4W
		2.d. Reading a file over SMB	46.1W
		2.e. Syncing Parity data	53.1W
Oct 02-05 2015	High-End	2.a. Idle with drives spun down	52.1W
		2.b. Idle with drive spun up	88.4W
		2.c. Writing a file over SMB	64.7W
		2.d. Reading a file over SMB	65.9W
		2.e. Syncing Parity data	106W

3.3 Test Results for Network Connectivity

Network Connectivity for Each Unit			
Date	**NAS Unit**	**Item #**	**Pass/Fail**
Jan 18-22 2016	Low-end	Writing a file	passed
		Reading a file	passed
		Writing a directory	passed
		Reading a directory	passed
		Reading a large collection of small files (photo album)	passed
		Writing a large collection of small files (photo album)	passed
		Reading a large file (playing a HD video)	passed
		Writing a large file (HD video)	passed

		Reading two large files simultaneously (playing two HD videos)	passed
		Writing two large files simultaneously (two HD videos)	passed
		Reading four large files simultaneously (playing four HD videos)	passed
		Writing four large files simultaneously (four HD videos)	passed
Jan 18-22 2016	Midrange	Writing a file	passed
		Reading a file	passed
		Writing a directory	passed
		Reading a directory	passed
		Reading a large collection of small files (photo album)	passed
		Writing a large collection of small files (photo album)	passed
		Reading a large file (playing a HD video)	passed
		Writing a large file (HD video)	passed
		Reading two large files simultaneously (playing two HD videos)	passed
		Writing two large files simultaneously (two HD videos)	passed
		Reading four large files simultaneously (playing four HD videos)	passed
		Writing four large files simultaneously (four HD videos)	passed
Jan 18-22 2016	High-end	Writing a file	passed
		Reading a file	passed
		Writing a directory	passed

		Reading a directory	passed
		Reading a large collection of small files (photo album)	passed
		Writing a large collection of small files (photo album)	passed
		Reading a large file (playing a HD video)	passed
		Writing a large file (HD video)	passed
		Reading two large files simultaneously (playing two HD videos)	passed
		Writing two large files simultaneously (two HD videos)	passed
		Reading four large files simultaneously (playing four HD videos)	passed
		Writing four large files simultaneously (four HD videos)	passed


Low Cost NAS Solutions
Using Open Source Technologies
UNIVERSITY OF Cincinnati
Lori Bauer, J. Andrejs Murnieks, Glenn Cappuccio
Technical Advisor: Professor Jason Kumpf
What is Network Attached Storage (NAS)?
It is a server that is dedicated to sharing files with other systems in a local area network (LAN).
Problem
Commercial NAS systems are expensive and lack flexibility when it comes to expanding the size of the array as well as working with different sized hard drives. Also, many implementations lack sufficient ability to reduce the wear on consumer level hard drives.
Solution
We've developed a low cost, low power NAS solution with raid-like functionality that features multiple sized hard drives which keeps your data on-site, safe, secure and accessible from the cloud.
Technical Elements
AuFS pools drives and presents them as one large volume
4TB
1TB
3TB
8TB
SnapRAID prevents data loss in the event of a disk failure
4TB
Base operating system
debian
Network Services
OpenMediaVault
OpenMediaVault - Provides an easy to use web interface for managing the system
SAMBA
Samba - Provides network shares for filesharing
ownCloud
OwnCloud - Allows remote access of the files through a web interface
College of Education, Criminal Justice, & Human Service -School of Information Technology