Imaging the MacBook Air

Leveraging Thunderbolt

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The ability to rapidly image large numbers of Mac computers for deployment is an important requirement for education system administrators. With the introduction of the MacBook Air, new hardware features such as all-flash storage and Thunderbolt—Apple's next-generation high-speed I/O technology—challenge the traditional performance and cost advantages associated with network-based restore.

Why Thunderbolt?

Network constraints

Network-based deployment tools traditionally provide the most efficient and cost-effective method for cloning a model image configuration to many systems concurrently. Apple's System Image Utility (SIU) tool creates unicast and multicast network-based restore workflows using NetInstall and NetRestore, while third parties offer similar network restore software.

The MacBook Air features 802.11n Wi-Fi connectivity for joining wireless networks. Wi-Fi restore with the MacBook Air is possible over wireless networks, however, performance of wireless infrastructure and bandwidth contention allow for only one image restore at a time using NetBoot or factory restore using Lion Internet Recovery. Using Wi-Fi technology to boot clients via NetBoot is not supported.

For wired networking, the MacBook Air uses an optional Apple USB Ethernet Adapter. This adapter operates as a 10/100-Mbps Ethernet network interface connected via USB 2.0, offering convenient connectivity for users who need wired Ethernet. The adapter's 10/100-Mbps limitation constrains network performance on the modern 10/100/1000 Gigabit Ethernet networks that are optimal for concurrent network restore.

Next-generation hardware

The slim form factor of MacBook Air is driving other changes to disk storage and I/O connectivity.

The current MacBook Air includes all-flash storage to increase performance, reliability, portability, and convenience. Read and write speeds are significantly faster on flash disks than spinning hard disk drives. They are also more resistant to shock and mechanical failure. Flash storage in the MacBook Air offers write speeds up to 250 MB/s, up to twice as fast as conventional 2.5-inch 5400-rpm notebook hard drives.

Thunderbolt connectivity revolutionizes I/O performance of MacBook Air, providing up to 10 Gb/s per channel and two bidirectional channels per port—making it up to 20 times faster than USB 2.0 and 12 times faster than FireWire 800. The Thunderbolt port on the MacBook Air allows for extreme expansion to peripherals, including Thunderbolt disks and RAID systems, and is also adaptable to other protocols (such as FireWire or USB 2.0) and breakout boxes.

By leveraging the next-generation high-speed Thunderbolt port with the benefits of all-flash storage, a system administrator can overcome many of the common bottlenecks associated with traditional network and direct-connected imaging, including boot time, image transfer, and disk write speed.

How fast is it?

Thunderbolt is capable of disk speeds measured in gigabytes per second. However, the realistic maximum is throttled by the speed capabilities of the disk hardware in use. Here are some examples of Thunderbolt configurations and their tested transfer rates.

Target disk mode
Using a Thunderbolt cable and booting the MacBook Air into target disk mode attached to a second MacBook Air, you can achieve a transfer rate of about 110 MB/s.

Note: Always use the latest available EFI updates to achieve optimal performance in Thunderbolt target disk mode.

External hard disk
With a Thunderbolt cable and an external Thunderbolt disk as the boot drive, you can achieve a transfer rate between 180 MB/s and 240 MB/s using current hardware. The top-end range of this throughput should saturate the write speed of a MacBook Air.

External RAID or SSD RAID
Using a Thunderbolt cable and RAID storage as the boot drive, you can achieve a transfer rate of over 450 MB/s. This throughput can easily saturate the write speed of a MacBook Air and leave significant space for future hardware performance improvements.

These numbers indicate that you can use Disk Utility or the command line asr tool to restore and verify a base install image of OS X Lion (approximately 4.6GB) directly from one MacBook Air to another in target disk mode in under two minutes. Using an external SSD RAID or Pegasus RAID, you can perform the same restore and verify in just under a minute.

Keep in mind that these speeds are constrained by the write speed of the MacBook Air, not by Thunderbolt throughput or by the external disk read speed.

MacBook Air Imaging Scenarios

A mass imaging project should have one goal when considering the amount of time, money, and resources: to clone a standard configuration to as many Mac computers as efficiently and accurately as possible.

There are also other determining factors in a deployment to consider. Many deployments require additional tasks such as tagging, gathering inventory data, or integrating with other IT infrastructure. The size and skill level of an institution’s workforce also play a significant role in choosing a deployment strategy.

Following are three MacBook Air imaging scenarios that compare price (estimated),[1] performance, and efficiency data. These scenarios attempt to factor unboxing and setup time into the efficiency equation when comparing traditional network-based restore workflows to Thunderbolt-based restore workflows.

Multicast network imaging

Hardware required

- One Mac mini with Lion Server ($999)
- One 48-port Gigabit Ethernet switch ($500)
- 47 Apple USB Ethernet Adapters ($1363)
- 48 Cat 5e or Cat 6 Ethernet patch cables ($150)

Resources required

- Two employees for imaging and unboxing
- Physical space for approximately 50 MacBook Air notebooks, cabling, and power
- Example disk image (approximately 10GB)

Scenario

Using a Mac mini with Lion Server, you can use the Server Admin Tools to configure the NetBoot service and NetRestore startup disks. To use the NetBoot service, hold down the N key to start each MacBook Air, and boot over the network with the Apple USB Ethernet Adapter. On the server, configure a multicast ASR server stream to advertise your disk image. Because the Bonjour-advertised multicast stream can be seen by all the MacBook Air computers, you can restore and verify the disk image to all 47 network-booted clients concurrently (48 port switches minus one port for the server).

Note: You'll need to invest some additional time beforehand in an initial multicast tuning analysis to determine an ideal multicast data rate for your network and hardware.

Scenario measurements[2]

- Time to image 1000 MacBook Air notebooks: approximately 21 hours
- Hardware cost: $3012

Conclusion

Although network-based restore allows for excellent concurrency, the space and hardware costs associated with a two-person MacBook Air–compatible setup can be expensive, even if you need to add only Apple USB Ethernet Adapters to your workflow.

It's reasonable to expect a maximum real-world Fast Ethernet throughput of between 8 and 9 MB/s using the Apple USB Ethernet Adapter. Unboxing, staging, beginning the restore, and removing each device adds a few extra minutes to the restore workflow. Assuming a 10GB image, you need an average restore throughput of under 4 MB/s to saturate a two-person workflow. Also note that adding more employees to this scenario results in a significant decrease in worker efficiency because concurrent restores at this speed yield lengthy waiting times between batches. Doubling the image size to 20GB requires only about 6 MB/s—still within the performance realm of Fast Ethernet.

There are other factors to consider, such as the physical space needed to stage and image 47 MacBook Air notebooks concurrently, power requirements for providing AC for those computers, and potential network configuration and optimizations needed to successfully use multicast traffic.

In short, concurrent imaging using the Apple USB Ethernet adapter is a reasonable imaging solution if you have sufficient space, a very small workforce, and preexisting knowledge of both image restore and multicast network tuning.

Thunderbolt target disk mode imaging

Hardware required

- Four Apple Thunderbolt cables ($196)
- Four 13-inch MacBook Air computers with Thunderbolt (no cost, part of imaging pool)

Resources required

- Two employees for imaging and unboxing
- Physical space for eight MacBook Air computers (four imaging and four restoring), cabling, and power
- Example disk image (approximately 10GB)

Scenario

On each of the four MacBook Air computers acting as imaging systems, copy the disk image configuration to a desired location (such as the OS X desktop). Hold down the T key to boot each MacBook Air that requires restore; this will start up the MacBook Air in Thunderbolt target disk mode. Connect the Thunderbolt cable from each imaging station to a MacBook Air in target disk mode. The internal disk drive of a MacBook Air connected via Thunderbolt target disk mode will automatically mount on the imaging station. Restore and verify the disk image using Disk Utility or the command line asr tool. When restore is complete, use the Finder to unmount the restored disk of the Thunderbolt-connected MacBook Air. Hold down the power button to safely shut down the MacBook Air.

Scenario measurements[3]

- Time to image 1000 MacBook Air computers: approximately 21 hours
- Hardware cost: $196

Conclusion

Using only affordable Apple Thunderbolt cables and hardware already available in the imaging pool, you can achieve almost the exact performance as the multicast imaging setup but at a much lower cost.

Imaging using Thunderbolt target disk mode yields a throughput of over 100 MB/s. Yet a two-person restore team at four imaging stations need only achieve an average of 65 MB/s per MacBook Air to maximize their efficiency; the additional speed benefit isn’t realized because a team of two can’t prepare the machines for imaging fast enough to maximize this restore speed.

However, scaling Thunderbolt target disk mode is much faster and more affordable than a multicast restore. By adding four additional workers and using four more MacBook Air computers (for a total of six workers and eight computers), you reduce the overall time to image 1000 MacBook Air computers from approximately 21 hours to 9—over a full work day faster. Using additional staff concurrently does increase worker costs, but if you have a team of technicians readily available, the hardware cost increase ($196 for four more Thunderbolt cables) is negligible.

Thunderbolt target disk mode using the Apple Thunderbolt cable is an effective, simple way to help a small- or medium-size team deploy MacBook Air computers a few times a year, allowing easy scaling as needed, depending on the imaging project.

External Thunderbolt disk imaging

Hardware required

- Eight Apple Thunderbolt cables ($392)
- Eight external Thunderbolt disks, RAID or SSD ($4000)

Resources required

- Six employees for imaging and unboxing
- Physical space for about eight MacBook Air notebooks, eight Thunderbolt disks, cabling, and power
- Example disk image (approximately 10GB)

Scenario

Install OS X Lion on each of the external Thunderbolt drives. On each Thunderbolt drive, copy the disk image configuration to a desired location (such as the OS X desktop). Connect a Thunderbolt drive to each MacBook Air and hold down the Option key to start up. Select the connected Thunderbolt drive as the startup disk. Using the Thunderbolt drive as the startup disk for each MacBook Air to be imaged, restore the disk image using Disk Utility or the command line asr tool. When restore is complete, safely shut down the MacBook Air by pressing the power button and choosing Shut Down.

Scenario measurements[4]

- Time to image 1000 MacBook Air notebooks: approximately 7 hours
- Hardware Cost: $4392

Conclusion

Booting from an external volume directly to OS X provides better throughput than using Thunderbolt target disk mode. An external Thunderbolt drive can restore an image to a MacBook Air in excess of 200 MB/s—driving restore times down to approximately 50 seconds for a 10GB image restore. To achieve these speeds, you need eight Thunderbolt disk drives and six workers to keep each imaging station filled with unboxed and ready-to-image computers—anything less means time wasted while readied computers wait to be imaged.

Because using a Thunderbolt SSD or RAID disk nearly or completely saturates the write speed of the internal flash storage in MacBook Air, further imaging throughput scalability depends on how quickly the workforce can unbox computers and keep all concurrent Thunderbolt disk imaging pipelines filled. As the time to image a MacBook Air approaches only a few dozen seconds, almost all performance gains come from optimizing the unbox, stage, connect, and repackage phases of the imaging process. The actual disk image restore process takes only a fraction of the complete preparation time.

Taking into account the tripled workforce (six employees) and increased cost of using external Thunderbolt disks, a well-staffed imaging shop can restore up to three times as many MacBook Air notebooks in a considerably smaller space than it could using a multicast imaging setup. The saved space could, in turn, be reinvested in additional imaging pipeline scaling and workforce for even greater returns on space/performance efficiency.

Investing in Thunderbolt disks instead of using target disk mode yields performance gains of a couple of hours per 1000 computers for similar disk sizes. Deploying larger disk image configurations, in which the faster Thunderbolt disk speeds help to accelerate the image restore portion of the MacBook Air preparation, yields even greater performance gains.

External Thunderbolt disk imaging is ideal for large IT shops and imaging depots that are staffed appropriately for large imaging projects. These teams require the fastest possible throughput to maximize efficiency and meet tight deadlines.

From a performance standpoint, smaller organizations—even those who may find a multicast setup or target disk mode to be ideal for an initial deployment—can benefit from having one or two external Thunderbolt drives available for single image restores at a help desk. Restoring the software for a repaired MacBook Air in mere seconds can help IT support deliver a new level of customer service to their end users.

MacBook Air Imaging Conclusions

Taking into consideration both the revolutionary MacBook Air hardware and the additional steps needed to prepare a fleet of MacBook Air computers for imaging, it's clear that workforce, hardware costs, and space limitations are all factors in deciding which imaging process is best. To deliver the most efficient imaging restore process, it's critical to keep each imaging station filled while minimizing the amount of time a workforce has to wait for imaging stations to become available.

For many customers, using the traditional network-based imaging workflow with MacBook Air doesn't offer optimal performance or simplicity. Thunderbolt target disk mode is a low-cost solution that allows for easy workforce scaling regardless of staff size. This process leverages the lightning-fast Thunderbolt technology and requires minimal effort to get started right away.

For customers with large MacBook Air deployments or integrators who image and deploy MacBook Air computers, external Thunderbolt disks allow for the maximum possible speed and efficiency—if staffing is not an issue. Not only are many external Thunderbolt drives on the market today capable of maximizing restore times for the MacBook Air, but they also have performance throughput headroom for future flash-storage performance increases. Like target disk mode, the process for restoring using external Thunderbolt disks requires minimal training and configuration.

It's also worth mentioning that many imaging workflows—both network and disk based—also include automated deployment activities such as workstation renaming, software package installation, user account creation, asset tagging, or other configuration tasks. Many of these operations are staged during the imaging process to take action the first time an imaged Mac starts up. Thunderbolt restore processes take these tasks into account, only they do so over the much faster Thunderbolt connection. Configuration of automated deployment tasks is outside the scope of this document.

Considerations for Disk Image Creation

There are many ways to create an image that's scanned and ready for restore. Disk Utility or the command line `hdiutil` allow for read-only disk images, compressed disk images, and, when using the command line, different types of compression for disk images.

For multicast network restore, using a compressed disk image is fastest. Having fewer bits to transfer over a network generally yields the fastest possible restore times, but it also requires the most network and asr server tuning for workstation and network-specific variables. And though it's not the fastest, a read-only image is sufficient and the most straightforward mechanism for multicast imaging.

For Thunderbolt imaging, you just need a read-only disk. There's no advantage to compressing the disk image so that fewer bits need to transfer across the Thunderbolt cable. Compression simply adds unnecessary client CPU performance overhead during the restore process. Always use a read-only disk image that's scanned for restore when imaging with Thunderbolt.

Additional Resources

Apple Pro Training Series

Find more information on disk images and the imaging process in the Apple Pro Training series books *OS X Lion Support Essentials* and *OS X Lion Server Essentials* by PeachPit Press.

Detailed information on automating common deployment tasks when imaging Mac clients is included in the Apple Pro Training series book *Mac OS X Deployment v10.6* by PeachPit Press. While this book was written for Snow Leopard, it applies to Lion deployments.

These titles are all available for purchase in the iBookstore.

Additional documentation

Netboot/Netinstall: MacBook Air can use USB Ethernet Adapter for Netboot or Netinstall: http://support.apple.com/kb/HT3735

Mac OS X Server: NetBoot clients cannot start up from the server (NetBoot trouble-shooting): http://support.apple.com/kb/TS3678

About Thunderbolt to Thunderbolt cable (2 m): http://support.apple.com/kb/HT4614

MacBook Air EFI Firmware Update 2.2: http://support.apple.com/kb/DL1448

MacBook Air EFI Firmware Update 2.4: http://support.apple.com/kb/DL1497

Lion Server: Advanced Administration: https://help.apple.com/advancedserveradmin/mac/10.7/#

Disk Utility Help for OS X Lion: https://help.apple.com/diskutility/mac/10.7/help/index.html

asr(8) Mac OS X Manual Page: https://developer.apple.com/library/mac/#documentation/Darwin/Reference/ManPages/man8/asr.8.html

[1]Prices quoted are from the U.S. Apple Online Store for Education as of June 8, 2012, do not include taxes or shipping, are subject to change, and are listed in U.S. dollars. [2]Testing was conducted by Apple in February 2012 using production 1.8GHz dual-core Intel Core i7–based 13-inch MacBook Air units. Throughput speeds for multicast imaging over USB to Ethernet Adapter are the average of three trials restoring a 3.68GB compressed disk image of a default OS X Lion v10.7.2 install in 650–700 seconds (yields ~6.5 MB/s) using Apple Software Restore (asr). Tests are conducted using specific MacBook Air units; actual results may vary. [3]Testing was conducted by Apple in February 2012 using production 1.8GHz dual-core Intel Core i7–based 13-inch MacBook Air units. Throughput speeds for target disk mode are the average of three trials restoring a 3.68GB compressed disk image of a default OS X Lion v10.7.2 install in 42 seconds (yields ~110 MB/s) using Apple Software Restore (asr). [4]Testing was conducted by Apple in February 2012 using production 1.8GHz dual-core Intel Core i7–based 13-inch MacBook Air units. Throughput speeds for external Thunderbolt disk imaging are the average of three trials restoring a 3.68GB compressed disk image of a default OS X Lion v10.7.2 install in 20 seconds (yields ~230 MB/s) using Apple Software Restore (asr). Tests are conducted using specific MacBook Air units; actual results may vary.

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