ECE590 Enterprise Storage Architecture
Lab #0: Your Server

A major focus of this course is hands-on experience with real hardware. As such, you have been provided with a server recently retired from service here at Duke. You will explore and rejuvenate this server, giving it a new life under your command.

Directions:

- This assignment will be completed in your groups. However, every member of the group must be fully aware of every part of the assignment. Further, while you can discuss concepts with other groups, actual steps and answers should not be shared between groups.
- Format:
  - Physical work: Much of this assignment will be setting up and deploying your server; this will be graded by looking at the server when you're done.
  - Data recording: Some of the assignment will ask you to collect data and update a Google Sheet. This will include fields in green, yellow, or blue.
  - Written deliverables: Some of the assignment will ask for short answers or screenshots; this material should be collected in a file called ece590-group<NUM>-lab0.pdf, where <NUM> is your group number, and submitted via Sakai. Word documents will not be accepted. Anything you need to include in this document is highlighted in cyan.

1 Meet your server

Each group has been issued a Dell storage server (various models). In production IT environments, all equipment is managed in some form of asset tracking database. Your first step is to figure out what you have and update such a database with the basic physical info. Our asset tracking database will be this simple Google Sheet. If you do not have access to modify this sheet, request it.

Note: Some of the servers were used last year and have already been assigned names. As some network configs are already set up for these servers, we want to assign the same name as last year. To this end, servers are pre-populated in the sheet up to the serial number (also known as service tag). Check to see if your server’s serial number matches the ones pre-populated, and if so, use that row of the spreadsheet – you’ll populate the rest of the cells per normal. If your server is new, add a row for it and record all fields.

The name of your server is “esa<NUM>” where <NUM> is your group number.

By examining the server, identify the columns highlighted in green. Manufacturer and Model should be easy (see front bezel). For height, you have to understand how servers are measured in Rack Units.
(simply written as ‘U’), see this article for details. For the serial number, note that on Dell servers this is also known as the service tag, and is a seven-character alphanumeric string\(^1\).

## 2 Poke around inside

Let’s see the guts. Open the chassis and examine the interior. Take one or more photographs for PDF submission. Annotate the photograph(s) to indicate the location of the CPU heatsink (under which sits the CPU), the RAM, the storage controller card (if separate from the mainboard), the power supply(s). You may need to temporarily remove plastic cowlings or covers to see everything. The chassis may contain a map to help identify parts, and the instructor can help guide you.

Let’s check how much RAM we have. Ground yourself by touching the chassis, and then eject a single stick of RAM (push on the side-levers around it). Examine the label on it to determine the following for your write-up:

(a) The type of RAM (DDR1, DDR2, DDR3, etc.; this may be indicated by the prefix “PC1-“, “PC2-“, etc.; see here for details),
(b) The speed of the RAM (e.g. “PC2-3200”, “PC3-6400”, etc.; the latter gives the peak transfer rate in MB/s).
(c) The size of the RAM stick (e.g. 1GB, 2GB, etc.)
(d) The number of RAM sticks installed

Compute the total RAM installed by multiplying the size of the stick by the number of sticks, and document this in your write-up. (It is possible that you may have a mix of sizes installed, but this is fairly uncommon.) Reinstall the stick in the same slot it came from, ensuring the orientation is correct (to install, just slot it in and push down until it clicks).

Replace any cowlings or covers you removed and close the chassis.

## 3 Boot your server

In this phase, we’ll be recording some hardware details: the yellow columns in our asset database spreadsheet.

Hook up a monitor, keyboard, and power cable to the server (you only need one power cable even if you have two power supplies). In Hudson 01A, you may borrow a monitor/keyboard from a workstation, but you must restore the keyboard/monitor to the workstation before you leave!

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\(^1\) One thing that Dell does well is track the hardware configuration of things they sell. If you like, you can put that service tag into support.dell.com and it will tell you exactly how the system was shipped when Duke originally purchased it. Of course, it may have been upgraded or modified since then, but this resource can provide helpful clues regarding a system’s history.
Once connected, even though the system has no hard drives so far, we can still boot into the firmware and check it out. Unlike a laptop or desktop machine, a server has many different modules, each with firmware that initializes during boot, including:

- The **BIOS (Basic Input Output System)**, the basic firmware of the system
- The **storage controller card(s)**, which typically provides RAID functionality (Redundant Array of Independent Disks), which we’ll learn a lot about in class.
- The **network card(s)**, which are equipped with PXE (Preboot Execution Environment), the ability to boot an operating system over the network as opposed to from a local storage device.
- A **remote access card** (also known as a RAC, a management card, a Baseboard Management Controller (BMC), or some vendor-specific name, such as the Dell Remote Access Card (DRAC)), which is a separate processor that allows network-based control of the server in a manner almost equivalent to physical access; this is to allow for “lights-out” datacenters where all non-physical server maintenance is done over the network, even when a server is severely misconfigured or malfunctioning. (HINT: you’ll want to become familiar with your server’s remote access capability to avoid in-person trips to the datacenter once you rack your server).

Each piece of hardware will appear in turn during boot, most flashing up their own prompt to allow for user setup (e.g. “Press F2 for menu”). At any point, you can restart the computer by pressing Ctrl+Alt+Delete. Try to visit each boot-time configuration menu, but don’t make any changes. While doing so, the storage controller may complain that all its drives are gone; press whatever keys needed to ignore this for now.

You’ll need to specifically visit the main BIOS menu and the remote access card setup menu to make note of the MAC address (the physical Ethernet identifier) for each Ethernet port. Specifically, your server probably has four general onboard Gigabit Ethernet ports and a management Ethernet port (marked with a wrench icon) which is managed by the remote access card. We’ll just be using the first two normal ports plus the management port; you can ignore the latter two normal ports as well as any additional add-on Ethernet cards your server may have. We need the MAC addresses of the ports to register them on the Duke network (for use in the lab), and later we’ll turn them over to Duke IT so our servers can be registered in the Datacenter network.

While you’re in the BIOS (pictured below), you can also confirm the amount of installed RAM and the type and speed of CPU. Note the MAC addresses and hardware stats in the yellow tabs of the asset database.
4 Set up remote access

Recall that the remote access card will allow us to manage the server over the network, once it’s configured. The first step is the network configuration.

Connect an Ethernet cable between an internet-connected switch and the management port (marked with a wrench). If in Hudson 01A, you may borrow the Ethernet cable from a workstation but you must put it back when you’re done.

Reboot (Ctrl+Alt+Del) and get into the remote access card setup menu when prompted. In this interface, do the following:

- Enable DHCP so the card automatically gets an IP address from the Duke network (e.g. set the IP Address Source to DHCP, though this procedure may differ depending on the exact hardware/firmware you have).
- Set the DHCP hostname to esa<NUM>-m (e.g. “esa00-m”); we’ll adopt a naming standard where the hostname of the out-of-band management interface is the same as the host, but with ‘-m’ appended (it stands for ‘management’).
- Lastly, configure with username “root” and the password provided by the instructor.

What does this mean? DHCP is a protocol that allows a machine to get an IP address from the network itself when it boots. The DHCP server that gives out such addresses typically tracks clients via their MAC address, which is associated with the physical interface (i.e. burned into the chip). These requests may also contain a requested hostname, which, if available, is associated with whatever IP address the server is assigned by DNS servers, which translate names (e.g. “esa00-m.egr.duke.edu”) to IP addresses (e.g. …
10.22.34.55). Note: it may take up to an hour DNS to sync up, so plan to use the bare IP address in the near term.

At Duke, the network environment is set up so that hosts must be registered on the Duke network, which we’ll do next. Visit https://dukereg.duke.edu and login with your Duke NetID. Paste in the MAC address for the remote access card, set description to “esa<NUM>-m”, set type to “other devices”, and click Register.

While we’re here, go ahead and paste in the MAC address for the first Ethernet port, set description to “esa<NUM>”, set type to “Fedora/Ubuntu/Debian”, and click Register.

Now reboot your server, and enter the remote access card menu again. You should now see a valid IP address for remote access, e.g. 10.22.34.45. You can also check this IP address via the DukeReg interface; just refresh your registered devices and you should find the same IP address listed for “esa<NUM>-m”.

At this point, you should be able to navigate your web browser to the IP address and/or hostname of the remote access card and see the remote access interface. When this is working, do the following:

- Use the power control to power the server off and on.
- Access the remote console. Take a screenshot and include this in your write-up.

Once remote access is working, note this in the blue “Remote access setup?” column in the asset management spreadsheet.

5 Install drives

5.1 Physical installation

All storage devices in the servers have been removed by Duke IT for privacy reasons. You will replace these drives with spares acquired for this course. Each student server will end up with:

- Four traditional spinning-platter hard disk drives (HDDs): SAS protocol, either 73 or 146 GB, either 10k or 15k RPM. Note: These hard drives are pretty old, so drive failures are anticipated. This is a good thing, as tolerating drive failure is a big part of the course!
- One solid state drive (SSD): Kingston SATA 120GB, new.

See the instructor to obtain your drives. For HDDs, be sure to end up with a matched set, where each drive has the same capacity and speed.

Install all drives into Dell drive trays.

Power off your server, and install the drives into the front of your server, with the SSD going first (top left), then the HDDs. Remove any blanking panels as needed.
Note the quantity (4), size, and rotational speed of your hard drives in the yellow HDDs column of the asset tracking sheet.

5.2 Storage card setup

ABOUT RAID AND STORAGE ADAPTERS: Your server is equipped with a high performance storage adapter card, which is what connects the front-mounted drives to the system. This card typically handles drive redundancy via RAID (Redundant Array of Independent Drives, which will be covered in detail in class) in hardware. This is a good thing, but for this course, we want to do the RAID stuff ourselves, so we can experiment with it. Therefore, we will be handling the drives in software instead, bypassing the RAID features of the storage adapter card.

To make this possible, we need to tell the card to do nothing but expose the drives directly to the operating system. Reboot and enter the storage card’s configuration menu by pressing the appropriate key (e.g. Ctrl+R) when prompted (it may vary depending on your exact hardware). Note: for Dell servers, the storage card is often called a PERC (PowerEdge Expandable RAID Card). The PERC 6 interface is shown below.

Once in the configuration tool, create a single virtual device (VD) for each physical drive (PD). For example, the shot below shows the creation of a virtual device with just the attached SSD (as indicated by the size of ~120GB):

The PERC 6 interface when creating a single-drive VD
Proceed to make 5 total VDs: one for the SSD, and one for each of the four HDDs.

NOTE: Some disks may appear as “Foreign”, meaning they were part of a RAID array on a Dell server before we got to them. In this case, go to the “Foreign View” tab, and in Controller 0, use F2 to see operations, and select Foreign Config -> Clear. Then you can make VDs out of them as described above.

When done, take a remote screenshot or local photograph of the PERC configuration interface showing your VDs and include it in your write-up.

6 Operating System Installation

We're going to install Linux as our operating system, specifically Ubuntu Linux Server. There are many trade-offs between operating systems in general and Linux distributions specifically, but Ubuntu Linux Server should work well for us as it combines decent ease of use with a rich software library.

Note that the install process for a server OS includes more steps than a traditional desktop OS (including even Ubuntu Desktop), as server admins (like you!) need more fine-grain control of the installation.

Before proceeding, ensure that the first regular Ethernet port is connected (if you have only one Ethernet uplink cable, move it from the management port).

6.1 Basic installation steps

Obtain an Ubuntu Server 16.04.3 (or later) DVD or USB stick, and boot from it. Proceed to install Ubuntu Server when prompted. Navigate through the installation prompts per usual (defaults are fine for most of it; please keep the language settings set to English so the instructor can assist with the server if needed).

Select the first network interface when prompted, and because you registered this interface’s MAC address in DukeReg back in section 4, it should get an IP address successfully.

Set the machine’s hostname to “esa<NUM>“, where <NUM> is your group number.

For user setup, pick the username and password of your choice. Later in installation, we’ll set a root password so for instructor access as well. Do not encrypt your home directory when prompted.

6.2 Partitioning

ABOUT PARTITIONING: Hard drives are commonly divided by into very large chunks called partitions to logically divide the storage. For example, desktop Linux systems commonly have a partition for the root directory (e.g. byte locations 0 through 110GB) and a separate smaller partition for swap space (e.g. byte locations 110GB through 120GB). At this point in the installation, we’ll be partitioning drives as we see fit, and selecting which partitions will hold the operating system.
When prompted to pick a partitioning method, choose **Manual**, as shown below:

![Partitioner Interface](image)

On a production server, you would always have the OS on redundant storage (e.g. a pair of hard drives configured for **mirroring**), either in hardware (using the storage adapter’s hardware RAID functionality) or in software (by setting up OS-managed RAID at install time).

*However, our goal is to learn about storage systems, so we want raw block-level access to our hard drives, so we’re going to deviate from the standard practice, and install the OS to a partition on the single SSD (while reserving some of the SSD space for experimentation as well).*

Therefore, when presented with the partitioner interface, just select the ~120GB SSD shown first:

![Partitioner Interface](image)

Create a new empty partition table when prompted\(^2\). Then select the free space to make a partition for the OS root directory:

\(^2\) If you somehow ended up with data on your SSD (e.g. you are reinstalling from scratch for some reason), instead delete the existing partitions at this point.
Make the new partition **40 GB**:

Make the partition Primary when prompted\(^3\), located at the beginning of the drive. In the partition detail view that comes up, ensure the filesystem\(^4\) is set to **ext4**, the mount point is “/” (this is the root directory of the OS), the label is set to “**ROOT**” (this helps identify the partition more easily), and that the bootable flag is set to **on**. Example:

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\(^3\) This is a very old distinction. The partition table standard originally only allowed for four partitions. Then a backwards-compatible amendment was made so one of those partitions was allowed to contain other “extended” partitions. We don’t need more than four partitions, so we can ignore this ancient issue.

\(^4\) Filesystems are what translate raw block locations into the concept of files and directories we’re familiar with. Ext4 is a particular filesystem commonly used in Linux. Filesystems will be covered in great detail later in the course.
Now we’ll set up some swap space, as even though these servers have tons of RAM, the Linux kernel still prefers to have some. Since we don’t anticipate needing virtual memory swapping, it need not be large; just 2GB will suffice. Select the free space on the SSD and make a **2GB primary partition** whose use is set to “swap area” instead of ext4, with bootable flag off.

At this point, we’re done partitioning. Note that we did not touch any of the HDDs: we’ll worry about them much later, after the OS is installed. We could have created additional partitions to divide the operating system (such as making a separate area for /home, where user home directories live) or create partitions not in the normal UNIX naming scheme (such as /movies or /music). However, a simple single root is good enough for us. This setup leaves us 120-42 = 78GB of free raw SSD space for later experimentation. Ensure your partitioner view looks like the below, take a screenshot or photograph for your write-up, then and select “Finish partitioning and write changes to disk”, and confirm when prompted.
6.3 Operating system data is copied

Time passes.

6.4 Updates and software selection

After the initial copy, it will want to configure network updates. When prompted for a proxy, leave it blank. When it comes to updates, choose “install security updates automatically”.

For software selection, just add “OpenSSH server” (so we can SSH into our server).

6.5 Software is downloaded and installed

More time passes.

6.6 Finishing up

ABOUT BOOTLOADERS: The bootloader is the software that is started by the system firmware in order to begin loading the operating system. Classically, it is 512 bytes of code at the very first sector of the hard drive, but in all modern operating systems, this code is just enough to load more code from elsewhere on the drive, and this larger code is the rest of the bootloader. This code then presents any boot menus or graphics and loads the OS kernel, which then initializes and loads userspace programs such as the GUI or login prompt.

You’ll be prompted to install the GRUB bootloader. Because we want our server to boot, say yes, and choose our SSD (likely /dev/sda).

After this, you’ll be told the install is complete. Remove the install disc or USB key and reboot.
7 OS checkup

Ensure that you can login to your management interface (esa##-m) via a web browser, and that remote console works. **Take a screenshot for your write-up.**

Ensure that you can SSH to your primary interface (esa##) with the login and password you created.

Look at the “/proc/meminfo” and “/proc/cpuinfo” files and/or run the “top” command to verify your CPU/memory stats.

Run “sudo fdisk -l /dev/sd?” to look at the drive info and partition tables of all our drives. **Take a screenshot for your write-up.**

Once all this is done, note this in the **blue “OS install ok?” column in the asset management spreadsheet.**

If everything seems to be in order, then it’s time to send this server to its new home: the FitzWest Datacenter.

8 Rackmount installation

Servers such as these are meant to live in racks. As discussed in section 1, the width and height of the server is standardized so it can be packed with total density into racks with dozens of other systems from various vendors. Servers are mounted in with rails.

8.1 The FitzWest Datacenter

At some point, after a tour and some training, you will be granted access to the FitzWest Datacenter.

*DO NOT TOUCH ANYTHING THAT’S NOT YOUR SERVER IN THERE!* 

A rack has been set aside for use by this course; you’ll be installing your server in there. Rolling carts are available to help transport your server to there, and a day will be arranged where most if not all groups will be expected to do the move with instructor support.

8.2 Rails?

A selection of Dell-style rails has been procured, but unfortunately, there is no guarantee that the rails present are compatible with our servers. So our first step is to look up the physical mounting guide for these servers and compare it to the rails on hand.

Take the service tag you identified in section 1 and put it into [support.dell.com](http://support.dell.com). Under “Manuals and Documents”, find the “Rack Installation Instructions” for sliding rails. Grab the rails on hand and see if they match. Indicate the answer in the **blue “Rails ok?” column in the asset management spreadsheet.**
If you found good rails, you’ll use them (see section 8.3). If not, see section 8.4.

8.3 If you have matching rails

When you move your server to FitzWest, install the rails and your server per the manual. Servers should be installed at the bottom-most free spot in the rack!

8.4 If you do not have matching rails

If your server is small enough (1U or 2U), we can just have it sit on top of a server that does have rails. This is not ideal, and would not be accepted in a production datacenter, but it won’t affect us for this course.

If your server is big (4U+) or if there are not enough rail-having servers available, you can use universal rails. See the instructor if this is the case; additional universal rails may have to be ordered, so see if you need them ASAP.

8.5 Cabling

Run Ethernet cables from the network switch “esa-net-01” to your management Ethernet port and your first regular Ethernet port. (We’ll be applying network redundancy later in the course, but this will do for now.)

Run a power cable from the Power Distribution Unit (PDU) on the left of the rack to the left power supply of your server. Similarly, run a power cable from the right PDU to your server’s right power supply. Each PDU is fed from a different power company substation, and therefore this provides power redundancy in the event of a power failure.

Note that this is a different network from the one in Hudson 01A, so the IP addresses you had before will not work. Temporarily connect a keyboard and monitor to your server and collect the management IP address (shown at boot time) and the system IP address (available via the ifconfig command after logging in). Ensure you can access these addresses from another system (such as your laptop).

Remove the keyboard and monitor: this is a lights-off server, so you should be able to do everything over the network from now on. If you do everything right, you should never have to come back to the datacenter except for cabling-related issues or hardware failures.

Once system is racked and working, update the blue “Location” column in the asset management spreadsheet to indicate the FitzWest datacenter and U position (written on the rack itself) of the bottom of the server.
9  You did it!

Congratulations, you now have an enterprise-class server online, logged in our asset tracker, and ready for work!

Take a photograph of your group with your server and include it in your write-up! 😊