Network Architecture and Virtualized-Network Computing

Building an educational labratory network for teaching IT architecture and management

Garrett Gonzalez-Rivas, Richard Li, Bradley Emmons, Patrick Pfunk

Abstract

Learning IT architecture and management is challenging without hands-on experience, however most non-collegiate educational institutions lack the resources required to build a laboratory to provide such experiences. The opportunity to learn these valuable industry skills can be provided to a much larger demographic of students by creating such a network using second-hand and older enterprise equipment. Then students can learn, either through designing and implementing a network or by managing a pre-existing infrastructure, to harden, manage, and troubleshoot a complex industry-standard network. Through this plan, students can learn in a hands-on environment everything needed for a CCNA certification.

Introduction

The first step of designing and implementing such a network is to determine the roles the network needs to fulfill. For our network, we had to connect a set of 22 Raspberry Pi's to a powerful, massively-parallelable computing cluster through a network that could support the full throughput of each of the Pi's network interfaces in order to allow both high-speed internet and a latency-free connection to the virtual machines and containers to be hosted on the servers – the hosting of which is another role the network must fulfill.

Furthermore, the network needed to be built with a redundant Layer-3 network architecture to emulate the architecture of an enterprise network and to teach students the management of industry networks using industry equipment.

Our network uses several different systems common to the industry to teach students to use the management interfaces for them, including:

Mellanox, Cisco, Netgear, Brocade, Dell, Aruba, HP, Lenovo, MikroTik, Ubiquity, and PfSense.

Purpose

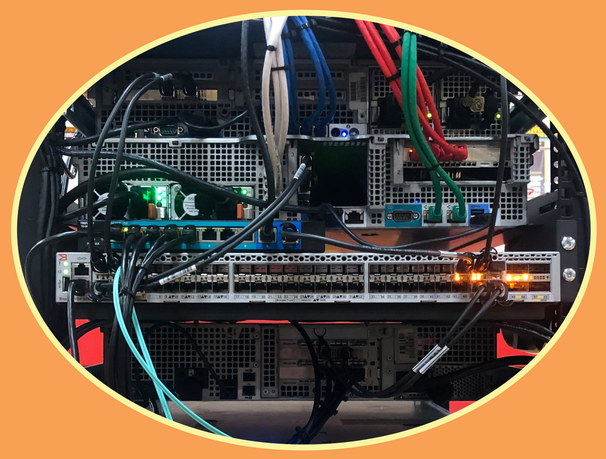
While the processing power that the servers possess is a resource in and of its self – in our instance, simultaneously hosting over 20 powerful virtual machines, each of which run several containers, or the servers being able to train complex neural networks on large data sets – the network itself is a resource for learning.

Designing, building, managing, and maintaining such a network can teach:

- how servers are built and the parts of a server
- how machines in a network connect to one another
- how to manage VLANs and layer-3 networks
- how to use PfSense, Windows Server, and other enterprise software

Equipment

The most important thing in choosing hardware for the network is fitting the equipment to the roles the network must fulfill and the budget it must stay within. If the network is being used as an educational aid to teach enterprise software and manage an enterprise network, many roles running on a dedicated machine in our cluster can be virtualized. Second-hand, used, and donated equipment will often work as well as using new equipment. In order to build a layer-3 network, the hardware that would be required is: two Layer-2 switches, two managed Layer-3 switches, old computers, and two servers.



Methodology

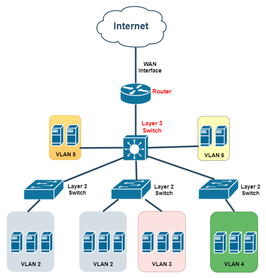
When building our cluster, our team started by learning about the hardware involved in building a network. Several members of the team had some experience with networking and building computers, however, it is possible to start this project with little or no prior knowledge due to the large amount of free educational resources online. Once we created a model of our network, we started acquiring second-hand hardware from data centers and companies on eBay and ServerMonkey, as well as reaching out for donations to local companies, large networking companies (HP, Cisco, and Mellanox), and the community through Nextdoor and Facebook.

Through several iterations of learning, building, and troubleshooting the network, we were able to build a powerful and effective enterprise-grade network and massively-parallelable server cluster.

Of the four servers, two of them are compute nodes, one is a controller and head node, and one is a storage server. The other three servers PXE boot from the storage server and all use ISCSI for their data connection from the server. Both compute nodes host virtual machines using Hyper-V and each virtual machine runs a series of containerized environments. The controller and head node server runs ADDS, DHCP, DNS, and all the other network administration roles that you would find in an enterprise or data center network in addition to managing the distribution of tasks when the two compute nodes are used in a single cluster. We also learned how to integrate a combined-cloud approach, where we used Microsoft Azure

Results

One of the results of the project was creating a laboratory network environment that students can use to learn how a Layer-3 network connects and how it should be managed. Below is a model of a Layer-3 network using VLANS in a similar configuration to the network that was implemented during this project. Understanding the network architecture can be tricky by looking at such a diagram, however, through building the network, the students who participated have an intuitive understanding of how it works and connects.



Using the network they built, the students learned, and will continue to learn, how to use industry standard software and manage multi-layer switching and routing, as well as all the other necessary skills to administer a network and acquire a CCNA certification. The students learned more information than they would have from an online course or book because they gained a deep understanding of how servers and networks operate through hands-on laboratory experiences.

The students learned best through troubleshooting issues that arose. One such issue was replacing a RAID controller with an HBA controller due to the memory bus limitations of the existing controller not being able to address the drives in server. In troubleshooting this issue, students not only learned about the levels of RAID, but also the anatomy of both RAID and HBA controllers, the difference between hardware and software RAID, and the PCIe standard and the protocols governing SATA and SAS communication.

There were many similar examples where students were able to gain a detailed understanding of the technologies involved in the project, beyond what they would have by taking a standard course. Another major benefit of this type of project was that it allowed students to delve more deeply into areas of the project/technology that they were interested in which helped them find their niche. In addition, this project promoted working as a group and built skills in communication and collaboration.

Conclusion

A laboratory network, such as the one discussed in this project, can be educational in three main ways:

- designing
- building
- managing

While designing the network, the students working on the project learned the standards and protocols used in enterprise networking, the common types of networks used in industry, the different technologies used in modern IT, and about the different hardware that a network is made from, such as the different types of switches and what makes them different.

In building the network, the students working on the project learned the components of a server, the process of refurbishing computer equipment, how to build computers, how to troubleshoot enterprise systems, and about general computing technology, such as the different levels of RAID and how to choose what is best suited for a particular application.

In managing the network, the students working on the project learned how to use management software to configure Aruba, Netgear, Brocade, Ubiquity, and Cisco networks, how to configure PfSense, how to manage Windows Server (as a cluster and as an individual server) including how to use it to manage a network using ADDS, DHCP, DNS, and more.

A project such as this is educational in many different ways and, becasue the harware does not degrade, can be rebuilt year after year in order to be used as a laboratory and teaching resource for as many students as possible.

Resources

- Boson NetSim for Cisco 200-301 CCNA
- Microsoft Azure Educational Resources
- Microsoft Windows Server Documentation
- IBM Documentation (Windows Server)
- PfSense Documentation

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