Final Project:
Home Local Area Network (LAN)

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1. Introduction

1.1 Background

Computer networks are essential to our modern way of life. We depend on them to watch our favorite movies and TV shows, make online purchases, play video games, communicate with friends and family, and much more. As the number of devices and amount of data that is exchanged between them grow, it is inevitable that our home or office network will need to be upgraded to accommodate all the devices efficiently and securely.

As an information technology (IT) company that provides network solutions, we have been tasked with upgrading a home network, for a family of four, that has a number of modern devices including but not limited to desktop and laptop computers, tablets, and streaming devices such as ROKU. They are currently running on a legacy network using a 56 Kbs modem to connect to the internet and having difficulty running their devices. They would like to connect all their devices to the internet at broadband speeds. They are primarily concerned with a future-proof network that offers performance and security.

1.2 Purpose

The purpose of this report is to assess the networking needs of the family and provide networking solutions that incorporate reliability, scalability, security, and performance into the design. This will be achieved by mapping the physical layout of the home to select the right topology and hardware that will connect all the devices, by conducting an inventory of each end point device and identify their bandwidth needs to match the right transmission medium to ensure we are maximize their capabilities, and by selecting the right protocol for each layer of the Open Systems Interconnection (OSI) model.

1.3 Scope

The family lives in a single family, two-story home, located in Highland, New York, which is 100 miles north of New York City. The nearest neighbor is about 100 feet away. There are no power plants or large amount of electromagnetic interference (EMI) nearby.

As per the requirement of the customer, only broadband service will be utilized. Of the 13 available internet service providers (ISPs) available in the area, only 6 offer residential service, and only two offer broadband service (Optimum Online and Charter Spectrum).

Many of the devices will require wireless connectivity as well as a wired connection for the home desktop, which acts as the home server for sharing files, and the Xbox game system in the son’s room. The overall cost of the project is not of a concern.

2 Home Assessment

2.1 End Point Devices

- 3 Apple IPad 9.7 Inch 5th Gen (Wi-Fi Only)
- 2 IPhone 6s
- 2 IPhone X
- 1 MacBook Pro (13-inch, Mid 2012)
- 1 MacBook Pro "Core i7" Touch (15-inch, 2017)
- 1 Roku Ultra
- 1 Custom Built Desktop PC (i7, 4 GB RAM) running Windows 7 using a Marvel Yukon 88E8056 PCI-E Gigabit Ethernet Controller.
- 1 Xbox One s
- 1 Epson - WorkForce WF-2760 Wireless All-In-One Printer
- Honeywell WiFi 7-Day Programmable Thermostat

2.2 Bandwidth Analysis

To figure the amount of bandwidth the family needs, an analysis was conducted. The analysis uses simple arithmetic in determining the overall bandwidth usage and is just a rough guide to determining the family needs. The family also does not use cable and most of their family entertainment is streaming from their home movie collection that is stored on the desktop PC or streaming services like Netflix.

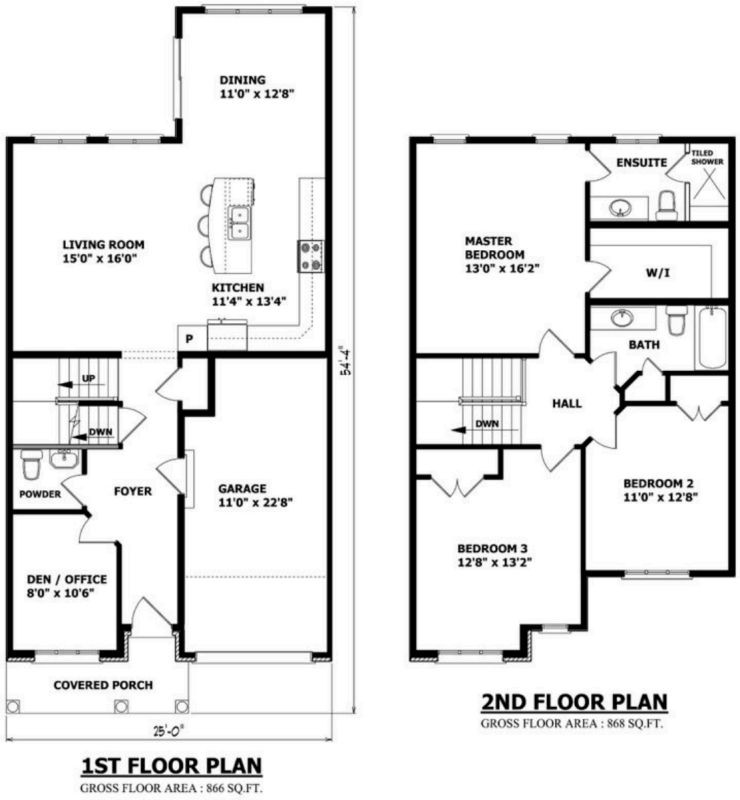
Each family member surfs the web about 4 hours a day and typically will visit a page for about 5 minutes. Three of them watch about 4 hours of video a day from either Netflix, home movies stored on their desktop PC, or YouTube videos. They also have a teenage son that like to play video games and can spend about 6 hours a day playing.

According to the Federal Communications Commission (FCC), the minimum download speed need are as follows: to surf the web and read emails is about 1 Mbps (Megabits per second Mbps); to watch a high definition movie at 1080p resolution is between 5 and 8 Mbps; to play online video games from a console is about 4 Mbps (Federal Communications Commission, 2017).

Assuming each family member is using the internet with the most bandwidth usage (approx. 5 Mbps) at the same time, a family of four will require about 20 Mbps. However, the family wants to be ready for the future for features like 4K video and games. Additionally, they want uninterrupted service if they have guest or if the family grows. To meet these requirements the family will require about 80 Mbps. This is assuming that a 4K video will require about 8 Mbps and that about 10 people might be using it at the same time.

2.3 Physical Layout

The family has a two-story home with three bedrooms with each room having a coaxial jack. Most of the endpoint devices are portable and not bound to anyone room. The office is where the home desktop computer and all-in-one printer is located and acts as the family server room; the Roku box is located in the living room attached to their TV; the Xbox One S is located in bedroom 3 or the son's room. In the foyer is where the wireless programmable thermostat is located.



2.4 Security

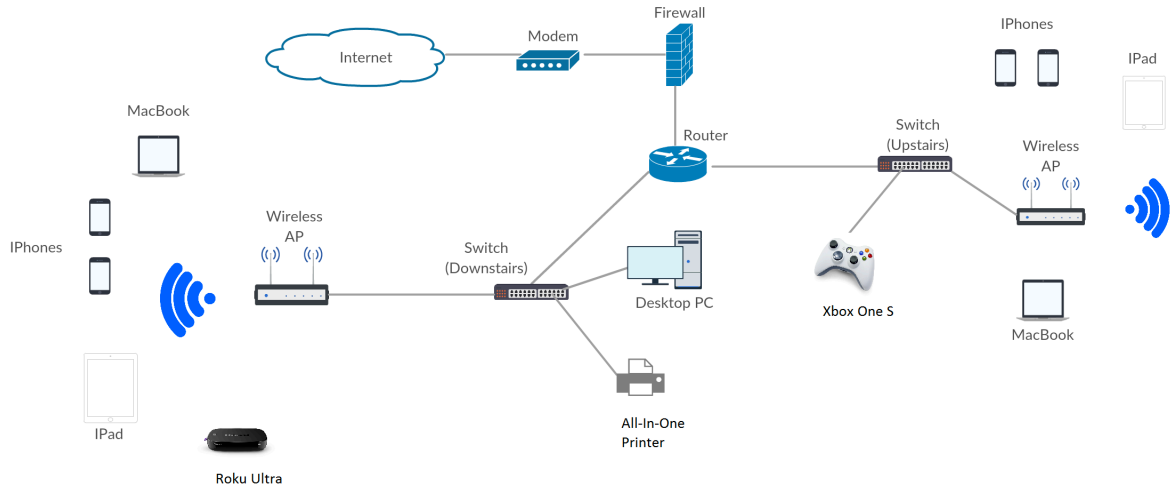
The family values their security as they pay all their bills online and have two children that they want to protect. They would like to filter web content for their children and limit the number of hours that their son goes online multiplayer games. They currently only have web filters enabled on each of the children's devices and have a shared network that is open to the public so no password is required to view their shared media.

3 Network Design

To ensure all of the devices efficiently communicate with one another, much thought and consideration must be made in the network design. A good network design is critical and if done poorly could be costly to the end user. Almost all well-designed networks take into account key features such as security, scalability, reliability, and performance.

3.1 Topology

A hybrid topology will be used using the star-bus topology. A number of devices in the home primarily are used through wireless transmission. These will be connected to an access point using a star topology. There will be two access points per floor and one on the front porch. All access points will be connected to a switch, by Ethernet wire, on each floor as well as all wired endpoint devices such as the Xbox One S and the desktop server.



3.2 Scalability

It is expected that number of connected devices will grow from 15.4 billion in 2015 to 75.4 billion by 2025. This is a 389 percent increase (Claveria, 2017). With this increase, it is very likely that family will want a network that is ready for the future and allow more devices to connect to their network.

To satisfy this requirement, there are two switches one for each floor. Although is sufficient, it limits the number of Ethernet cables running from first floor to second floor to just one. In addition, it offers more ports to connect more endpoint devices. With the number of wireless connected devices in the home. Wireless access points will need to feature multiple-input, multiple-output (MIMO) technology. This allows the wireless access points to service multiple devices by simultaneously transmitting and receiving a signal.

3.3 Security

Security is the most important element with performance second. Security and performance are indirectly related. As we add more layer of security, the performance of the network will be impacted negatively.

3.3.1 VLAN

To find the right balance, we would use virtual local area networks (VLANs) to isolate traffic to a specific purpose such having one the server on a separate LAN from the rest of the house. Having a VLAN for the Roku Ultra and gaming system prevent traffic jams. In addition, if the family wants to add internet protocol (IP) security cameras, it will limit traffic from the cameras to the home server for recording. Although VLANs are not popular in-home network, will the number of smart devices and IP security cameras they are gaining popularity. They also offer protection if you want to add guest to the network.

3.3.2 Separate Wired and Wireless Networks

Wireless technology is not a very secure transmission medium. Someone with packet sniffing software will be read the metadata and extract the three-way handshake which is the password to login into to network. Another software could be used to crake the encryption from various methods such as brute force. So, it would be necessary to separate the home desktop from all wireless devices since this is where all the family stores most of their private information. This is also why we choose to use a wired router/firewall vs a wireless router.

3.3.3 Firewall

A firewall will be integrated into the router. As the first line of defense, a firewall be setup to filter web content in and out of the house. This will be used to block the children from access certain sites and limit the amount of time that they could be on the internet. In addition,

3.3.4 Change Default settings

One security flaw that many do not take into account is securing their passwords. Routers and Access points typically have default passwords and many do not change it. In this design, we will change all default passwords and ensure they are strong passwords with varying characters and at least 10 characters long. Additionally, we will change the default IP of the router by ensuring it is not the same as the one provided by the ISP and not a one of the default one such as 192.168.1.x.

3.3.5 Encryption

As mentioned previously, wireless technology is not very secure; and with so many wireless devices connected throughout the home, there needs to be some level of protection. Encryption is the solution. All wireless access points will be configured to a WPA2 encryption algorithm.

3.4 Reliability

Devices will inevitable fail. To ensure that if one device fails, other devices can still operate without interruption. To achieve this there will be some redundancy in the network. By having implementing a star-bus topology we can ensure that not all devices are affected. Another way of getting network reliability is to have multiple wireless access points and switches on each floor. This will increase the strength of the signal and its reliability. Additionally, wireless access points will be in the center of the house to provide the most coverage equally across the home. Having a part of the network be wired also improves reliability because it doesn't have to worry about obstacles or other types of interference. This is why the endpoint devices that require the most reliability are on wired LANs.

3.5 Performance

The primary reason for the family upgrading their network was to improve performance across their devices so they could use streaming devices like their Roku Ultra. Having multiple switches and wireless access points will also improve performance. By having the game console wired to a switch via a Cat 6 Ethernet cable, it will improve gaming performance. By isolating the network using a VLAN, there will be less congestion and as a result will improve performance.

However, the most important element of improving performance is hardware that will connect the devices at their maximum throughput. By purchasing the family their own modem, they will not only save money but can ensure that it offers the best performance. All mobile devices are capable of handling 802.11ac transmission speeds so wireless access points will be 802.11ac compliant as well as having MIMO features. Additionally, by utilizing Cat 6 Ethernet cables to connect all wired devices will be sufficient to handle the Gigabit Ethernet ports on the endpoint devices. This will not only improve performance but future proof the home for upcoming technologies such as 4K videos.

4 Hardware

4.1 Internet Service Provider

Optimum Online was selected as the Internet Service Provider (ISP) as this was the only broadband service with the required speeds. To save money and get the most out of our internet service provider the family will have their own modem. The only available modems that are compatible with Optimum Online are listed below:

- Arris TM822 - 2 port 3.0 modem
- Arris TM804 - 4 Port 3.0 modem
- Arris TM1602 - 2 port 3.0 modem
- Arris TM1672 - 2 port 3.0 modem
- Motorola SBV6220 3.0 modem
- Cisco DPQ3212 3.0 modem

We went with the Arris TM822 – 2 port 3.0 modem as this offers the highest possible service speeds of 343 Mbps with the Data Over Cable Service Interface (DOCSIS) protocol and has a 1 Gigabit Ethernet port. This was more than adequate for the family needs. It also has multiple channels for uploading and downloading for improved performance as well as IPv4 and IPv6 support for future addressing.

4.2 Router

As routers are the gateway into the home, a router should be very secure. When choosing routers this was a primary factor. In addition, to limit the number of layers of security we opted for a multipurpose router that incorporates many services such as VPN, VLAN, and firewall capability.

Ubiquiti Network's EdgeRouter X was the best solution of security and performance. It is a wired router that has a built-in firewall. It has 5 Gigabit ports and will leave three remaining for scalability. Its Operating system comes with some of the latest protocols such as IPv4 and IPv6 addressing, VPN and VLAN capability, DHCP and DNS forwarding services, and web filtering.

4.3 Switches

The key factors in choosing a switch was the number of ports and the speed that each port offers. Since we want to setup a different VLANs and some of the devices may be upstairs and others downstairs we will need a Layer 3 switch. Although layer 3 are like routers it will not replace the functions of the router.

The ZyXEL GS1900-8HP was the best solution as it offers 8 ports that can handle all wired connections and will have some to spare for future additions. Each of the ports are 8 Gigabits which is adequate to handle the maxim throughput of each device. It offers improved performance with a switching capacity of 16 Gigabits per second (Gbps) which gives the greatest throughput of the switch. It is a managed switch which offers VLAN capability to segment certain traffic patterns. An added plus is inexpensive. We will add one to the first floor and one to the second floor. This will limit the number of wires that have to be ran.

4.4 Wireless Access Points

When choosing a wireless access point, some of the key features we were looking for was having Multi-User Multiple Input Multiple Output (MU-MIMO), supports 802.11ac, dual ban frequencies, and multiple antennas. We chose to go with the TP-Link AC1200 Wireless Access Point. It had all the features required for an affordable price. It features 2x2 MIMO access points with four internal antennas at 4 dB each. It has only one Gigabit Ethernet port but all wired connections will be connected to the switch. It has dual band for faster speeds.

There will be two of these one on the first floor and one on the second floor. The advantages of having one upstairs and one downstairs is for better signal strength and less interference from appliances such as the microwave.

5 Transmission Media

5.1 Wired

For best performance and security, having a wired connection is optimal. This is why the first connection from the ISP will be over some type of physical medium such as fiber optic or coaxial cable. Optimum Online uses a quad shield RG6 coaxial cable from the neighborhood node to the home. RG6 has a thicker copper core and additional shielding that protect from interference and attenuation. The ISP access point (modem) will be within 10 feet of the coaxial wall jack. The same RG6 coaxial cable will be ran from the wall jack to the modem.

From the modem, as well as all connected devices by wire, will use a Cat 6 cable which is a twisted pair Ethernet cable. It offers the best performance with up to 10 Gbps at 55 meters. This is well within this length limit for each of the connecting devices. This also ensure the home is ready for the future.

Having the game console connected by Cat 6 is to provide the fasted connection which is need for an uninterrupted gaming experience. Connected the desktop PC by wire ensure security and fast file transfers when sharing across the devices.

5.2 Wireless

The primary transmission medium that the family will use will be through wireless technologies. To ensure that the family is ready for the future, using an 802.11ac wireless access points provides backward compatibility with speeds up to 1300 Mbps. By having multiple antennas and with MU-MIMO provides the greatest throughput. Additionally, data will be transmitted using the WAP2 encryption algorithm.

There will be two wireless access points - one located on the first floor and one on the second floor. Each of these wireless access points can connect up 400 simultaneous connections, 100 on each of the 4 antennas. Additionally, the home is also scalable to allow for additional wireless access points such as on the front porch or back yard.

6 Protocol Description

6.1 Physical Layer Protocols

At the lowest layer of the Open Systems Interconnection (OSI) model, is the physical layer that connects the devices. Optimum Online provides high speed broadband access using the latest DOCSIS 3.1 standard on their modem. The benefits of DOCSIS is that it has theoretical speeds of up to 10 Gbps downstream and 1 Gbps upstream. It is fully duplexed, meaning it can download and upload at the same time. The signal is sent using a RG6 coaxial cable that uses F-type connectors to connect the devices. To connect all other wired devices, we will use a shielded twisted pair (STP) copper wire using the IEEE 802.3an or 10BASE-T and Cat 6A standard. This provides speeds up to 10 Gbps at 500 meters.

Primarily all the family mobile devices will be connected wirelessly. The primary wireless protocol being used will be the 802.11ac standard since many of the devices will be connected using the GHz radio frequency range. For guest of outdated devices, or if they want longer range they will be using the 802.11n standard at the 2.4 GHz radio frequency. This standard can reach speeds up 450 Mbps for the 2.4 GHz and 1300 Mbps for the 5 GHz.

6.2 Data Link Layer Protocol

Using a TCP/IP model sometimes the protocols overlap. In this case Ethernet is part of the data link layer and this protocol breaks data into frames that offer sequencing and error detection. There are various forms of Ethernet Standards. Wireless transmission still use the Ethernet stand but use the 802.11 (Wi-Fi) specifications. The switches will use VLAN as the protocol to separate the network in to different segments and uses the Media Access Control (MAC) to locate the devices on the network using MAC lookup tables stored onto the switch.

6.3 Network Layer Protocols

To route traffic across the network, we will use the Internet Protocol (IP) version 4. To future proof the home, each network interface card is capable of also handing the newer IPv6 which offers addresses. The IP protocol is a connectionless protocol that uses packet-switching. It encapsulated data into packets and in its header, you will find information about the destination and source.

6.4 Transport Layer Protocols

Primarily the family will be using the Transmission Control Protocol (TCP) as this is a connection oriented protocol. This provide reliability by providing a three-way hand shake between the two devices. For the gaming console and the Roku, they will primarily use the User Datagram Protocol (UDP) because this is a connectionless protocol and speed over reliability is needed. To provide more performance and security each process will be dedicated to a port. For the gaming console, we would setup up port forwarding on the router to ensure a direct link of communication is provided

6.5 Sessions Layer Protocols

As we move to higher layers, the number of protocols used increases. Some of the protocols that will be used will be the Network File System (NFS) and Server Message Block (SMB) that manages how files are accessed. For more secured connections, the family will be using the Secure Shell (SSH)

6.6 Presentation Layer Protocol

For secure communication over the web the family will be using the Secure Socket Layer (SSL). This provides an encrypted layer to the message be sent. This would be used when making online purchases or doing online banking. Although the WAP2 wireless encryption algorithm is

defined in the 802.11ac is could also be considered a part of the presentation layer because of the encryption it provides.

6.7 Application Layer

When the family surfs the web, they would be using the Hypertext Transfer Protocol (HTTP) and for more secured sites would be using the HTTPS protocol. When looking up another client machine they would be using the Domain Name System (DNS) protocol. To be assigned IP address automatically they would be using the Dynamic Host Configuration Protocol (DHCP). For sending and receiving email they will be using the Internet Access Protocol (IMAP). To remote into their desktop PC that is running Windows 7, they would be using the Remote Desktop Protocol (RDP). With the amount of applications that can be ran there is an unlimited number of protocols that may be used at this layer. These were just some of the most common the family would be using.

7 Lessons Learned

Designing a network takes careful consideration and must focus of factors such as budget to work with, available resources, customer needs, physical obstacles, interference, and finding a balance between performance and security.

In designing this home network, it was discovered that the perfect network with the latest and best technologies can be very expensive and might not work with everyone's budget; and it doesn't guarantee it will be ready for the future. In some cases, even if cost is not a factor, some resources just might not be available. Such as having the ISP providing data over fiber optic cables. For this home, only cable was the fastest available option. There may be a situation where obstacles prevent from laying wires so a wireless solution is used. In addition, if there are a number of physical barrier between a wireless access point, the signal may be degraded, or if the home is located near electric power plant or some large electric magnetic field such, or devices running like a microwave will also degrade the signal.

The biggest and most profound lessoned learned is that there must be a balance between performance and security. We always want the fastest speeds but to do so we will need to compromise security. So much thought and planning of the network should be used to accomplish this such as segregating highly sensitive information to a separate VLAN.

However, it was also discovered that technology is always changing and so too can our network designs. For example, some networking protocols come and go as fast as they were available, such the case with Facebook and twitter, the Internet Relay Chat (IRC) is not as popular as it once was with chat rooms of the early and late 90s. So network design is a continuous cycle that we will continuously have to evaluate.

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