Creating a School Ethernet Network

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Introduction

Creating an effective and secure network for a school is likely to take a significant amount of resources, especially for one of the given size. The network must allow a high number of devices to connect, while retaining acceptable speeds. Controls must also be in place to prevent attackers from breaching the network. Several key kinds of devices and other equipment are necessary to meet these needs.

Switches

Switches would likely be highly advantageous for this kind of network. Switches are a kind of device that allow for numerous devices to be connected easily in a network, acting as a sort of intermediary, and permit traffic to be forwarded more efficiently. With the potential for such a high number of hosts, the use of switches can significantly increase the overall performance of the network by limiting communication to specific connections. Several switches will likely be needed, though having a single switch for each room would, of course, be superfluous and add unnecessary costs. A switch for each floor of the building, though, each of which is likely to share a purpose, seems appropriate. As such, four switches could be put in place, one located within the equipment room, and one in each of the three telecommunications closets. As each floor has between 17 and 21 rooms that must be connected, and thus between 34 and 42 connections, 48-port Layer 2 switches seem fitting for this purpose. With several switches in place, utilizing managed switches, which allow for these devices to be modified and overseen over the network itself via SNMP, would likely be beneficial, despite the added cost. Prices for these devices vary, but seem to cost several hundred dollars each. $400 appears to be a reasonable middle ground, with some reputable retailers selling switches for this price (*TP-LINK*

JetStream TL-SG3452 48-Port Gigabit Managed Switch, n.d.). With four switches that must be purchased, then, about $1600 should be allocated for them.

Routers

The use of a router is also critical for those using the network to be as productive as possible. Routers connect the network to the wider Internet, done by routing and forwarding packets between networks. Importantly, one must also consider the use of subnets. While one could reasonably make do without the use of subnets in this case, subnetting seems as though it would provide a greater level of security and performance here, making it worthwhile. An internal router fulfills this requirement, allowing messages to be properly forwarded between subnets. A single internal router should be sufficient to separate each floor of the building into its own subnet. A border router is also clearly needed to provide Internet access for the facility as a whole. With these routers needing only a handful of ports, they may actually be acquired for less money than the switches used in the network, in spite of the fact that routers typically cost more than switches. Wired routers that would be suitable for this purpose seem to be sold for approximately $200-$600, so $400 will be designated for each router, totaling $800 (*TP-Link - ER8411 - Enterprise Wired 10G VPN Router*, n.d.).

Modems

A modem or optical network terminal may also be needed to connect to the ISP's broader network, if they are using optical fiber or some other medium. A modem can convert the electrical signals used in Ethernet into the light waves used for fiber optic cables, and vice versa. If this modem is not provided by the ISP, it will have to be purchased. Thankfully, ISPs almost always provide the necessary modem or ONT to allow the customer to connect their network

("ONT: What It Is & How It Works," n.d.). So, while this is a critical technology, it likely does not need to have funds allocated for its purchase.

Firewalls and Intrusion Detection Systems

Devices that improve the network's security are another key piece of technology that should not be ignored. Firewalls, for example, are used to block any packets that can be deemed malicious with certainty. Stateful firewalls, as opposed to stateless firewalls, take this a step further by keeping track of connections and thoroughly checking the initial setup of these connections to see if they are malicious or benevolent. There are more advanced firewalls, but a firewall with stateful packet inspection seems to be an appropriate compromise. No matter what kind of firewall is chosen, however, not all malicious packets will be blocked, and so a method will be needed to more easily determine whether malicious activity is occurring on the network. An intrusion detection system can fulfill this need, identifying potentially malicious activity rather than blocking specific packets. An IDS provides warnings to network administrators, allowing for a better response to possible attacks. One stateful firewall, and one IDS, can be implemented between the internal and border routers to ensure that all traffic entering and exiting the network is checked. Effective hardware-based firewalls for this network, with built-in intrusion detection and intrusion prevention capabilities, seem to be sold for around $600 (*FortiGate FortiWiFi 40F Series*, n.d; *FortiNet FortiGate FG-40F Network Security/Firewall Appliance*, n.d.). Other technical methods of security, such as demilitarized zones or honeypots, may be beneficial, but are perhaps of little use for a network of this size. Many other security controls beyond these will certainly be necessary, but may fall under the configurations of the actual hosts used in the network, the protocols they use, and the people and processes within the organization, rather than actual devices themselves.

Wireless Access Points

For a building this size, Wi-Fi capability may be needed for mobile devices, laptops, and other systems for which a wired connection is impossible or unideal. Wireless access points would permit these devices to connect to the rest of the LAN. As Wi-Fi connections are secondary to Ethernet connections in this network, however, it is not critical for every point in the school to have a perfect connection. It would also be incredibly difficult to predict where WAPs would need to be installed for these connections, without knowing how the walls and rooms of the building, which may cause dead zones or a reduction in signal quality, are structured. As such, it will be assumed that one WAP can be installed in the equipment room and in each telecommunications closet. In reality, more WAPs would likely need to be installed for their connections to be fast and reliable. Modern high-speed wireless access points, which would be suitable for a building of this size, are sold for roughly $200 each (*Ubiquiti UniFi U7 Pro Access Point*, n.d.). Four of these, then, would cost about $800.

Cabling

10 Gigabits per second seems to be an appropriate speed for cabling, as even if many systems are communicating across the network at the same time, they will each retain a decent amount of bandwidth. As such, Category 5e and lower cables would not be acceptable for this purpose. In addition, while higher category cabling, like Cat 7 or Cat 8, could technically be chosen, the costs associated with these cables make them a poor choice in this context. Both Cat 6 and Cat 6A cables are able to provide 10Gbps speeds using the 10GBASE-T standard, making them attractive choices. However, out of these options, only Cat 6A is able to provide this level of speed up to 100 meters, which is roughly the length of the building in which these cables will be used. The furthest given connection is 98.17 meters, and so Cat 6A cabling will be necessary

to at least some degree within the building. Rooms that do not require the extra length that Cat 6A cabling can provide, however, can use Cat 6 cables to take advantage of their reduced cost. For simplicity, as exact floor plans do not exist, it will be assumed that half of the rooms will be within reach of Cat 6 cabling, with the other half requiring Cat 6A cables to obtain a speed of 10Gbps. Again, for simplicity, the budget will include 1 meter of cabling for each of the 148 host connections across the school's rooms. Cable runs from the telecommunications closets or the equipment room to each outlet will require an average of 54.75m of cabling per connection, with two connections for each of the 74 rooms. These cable runs, then, will need about 54.75m x 2 x 74, or 8,103 meters of cabling. Half of this will be designated as Cat 6A UTP cables, while the rest will be Cat 6 UTP. The connections between the modem and the border router, the border router and the firewall, and the firewall and the internal router should each need about 1 meter of cabling, as they could all be placed close together in the equipment room. The connection between the internal router and the switch for the first floor could also be accomplished within a cable length of 1 meter. To connect the internal router to switches on other floors, however, longer cables will be needed. The given height between floors is 3 meters, so this length of cabling, plus an additional 2 meters to connect the internal router and switches to their patch panels, will be needed for the connections between the internal router and the switches on the second floor and the basement floor. As the switch on the third floor will be connected to the router without an intermediary device, six meters of cabling, plus another two meters to connect the internal router to the first floor patch panel and the third floor switch to the third floor patch panel, will be necessary instead. Finally, the switches will need around 1 meter of cable for each of the 148 connections to the rooms around the school. The exact lengths of individual cables that must be purchased will depend on the actual distances between the classrooms and office

and the equipment room or telecommunication closets, which seemingly cannot be determined accurately with the provided information. However, using the total length of cabling, which has been determined, the approximate cost can be ascertained. With three 3 meters of cable to connect the modem, routers, and firewall, 19 meters of cabling to connect the internal router to each switch, 148 meters of cabling for each of the connections between the switches and the relevant patch panels, 8,103 meters of cabling to connect each RJ-45 jack to a patch panel, and 148 meters of cabling to connect each host to a jack, about 8,421 meters of cable will be required. 4,052 meters of this must be Cat 6A UTP cabling, while Cat 6 UTP cabling will be suitable for the other 4,369 meters. The cost for one meter of Cat 6 cabling is about $0.82, with Cat 6A costing roughly 25% more, for a cost of approximately $1.03 per meter (*CAT6 Cable Installation Costs: What You Really Pay For*, n.d; *Cat 6 Vs 6A: Which Ethernet Cable Is Better for Your Network Setup?*, 2025). So, about $4,174 should be budgeted for Cat 6A cables, and $3,583 should be budgeted for Cat 6 cabling.

RJ-45 Outlets

RJ-45 outlets, or jacks, will be necessary to connect each host to the Ethernet network. These serve as a way to quickly plug in systems via a wired connection, using the RJ-45 connectors used in Ethernet cabling itself, which is discussed in the previous budget entry. Besides the equipment room and telecommunications closets, all 74 of the connected rooms will need two outlets. This means that 148 RJ-45 jacks are required. As referenced in the budget entry for Ethernet cabling, at a minimum, half of the jacks should support Cat 6A Ethernet cables, while the other half may only allow for speeds consistent with Cat 6 cables. If jacks are purchased in large supplies from a seller like Monoprice, however, the cost is about $2.25, regardless of the kind of jack being purchased (*Monoprice Cat6A RJ45*, n.d; *Monoprice CAT6*

RJ45, n.d.). As such, the budget should include funds for 148 of these outlets, totaling about $333.

Wall Plates

Each RJ-45 jack should, of course, also come along with a wall plate. These are typically plastic covers that conceal the internal workings of the outlet for safety and security, while also providing a cleaner appearance. As such, 148 wall plates should be used across all of the school's rooms, assuming outlets do not share a single wall plate. If both outlets used in each room can share a single wall plate, however, then only 74 wall plates would be necessary. These wall plates tend to be fairly inexpensive, with prices as low as $0.75 (*Monoprice 1-Gang Wall Plate for Keystone*, n.d.). At this price, 148 wall plates would cost about $111.

Patch Panels

Patch panels will also be necessary to simplify cable management. These contain a number of jacks packed closely together, which will be crucial for the dozens of Ethernet connections that will be implemented on each floor of the building. A patch panel in each of the telecommunications closets and in the equipment room will allow administrators to easily manage the connections to all outlets on that floor, and the connections to other floors. Given the number of connections that are needed, one 48-port patch panel should be sufficient for each floor. These can be purchased for about $100, so $400 should be allocated for patch panels, overall (*Intellinet CAT6 48-Port 1U Patch Panel*, n.d.).

Total Costs and Other Considerations

Each of the items laid out in this budget is, in some form, needed to create an effective network. With four switches costing $1,600, two routers costing $800, A combined stateful firewall and IPS costing $600, four wireless access points costing $800, over 8,000 meters of

cabling costing a total of $7,757, 148 RJ-45 jacks costing $333, 148 wall plates costing $111, and four patch panels costing $400, a minimum of $12,401 should be allocated for the materials needed to complete this project. However, there are several costs and items not covered by this budget. For one, it is reasonable to expect unforeseen challenges, and so a slightly higher amount of funds should be allocated for the project. This ensures that fluctuations in price are minimally impactful to the project, and reduces the risk that any last-minute changes bring the project over its intended budget. A budget of $14,000-$15,000 should cover any of these unplanned expenses. Further, additional funds could be allocated to use CAT 6A cabling throughout the entire building if desired, as well, for increased reliability and future-proofing. The purchase of certain hosts, such as laptops, desktop computers, and servers used to store and share information between users, will also be necessary, in all likelihood, but are outside of the scope of this project, as are the salaries of IT staff and the costs of maintaining this infrastructure in the long term. Further, there will likely be high costs associated with the installation of each of these technologies, which will vary heavily depending on the abilities of those in the organization and the precise details of the building's structure. While the installation of RJ-45 outlets, wall plates, and other technology, for example, should incur a relatively low cost, this may not be true of cable installation. If the cables are being run in a preexisting structure, there are likely to be many challenges, as several holes will likely need to be made in various walls to properly place the cables. This would be made worse if the walls, ceilings, and floors are made of a tough material, like bricks or concrete. While it is impossible to accurately determine how much this would cost without a better idea of the building's construction, installation could very well increase the cost of the network significantly. Still, a budget of $15,000 should be satisfactory to cover all expenses associated with the purchase of equipment and network technology.

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