UNIVERSITY OF BALAMAND

Faculty of Engineering

CPEN241: Information Networking

Assignment

Campus Network Design

Submitted by:

Rodolph Khlat

Michel Sfeir

Submitted to: Dr. Riad Saba

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<u>Design</u>:

The purpose of this project is to design network for a small campus using the information gathered throughout the networking course, along with the CCNA guide and several online websites as references. The Campus Area Network (CAN) design was put together with several key factors in mind, namely high quality, efficient cost, and capacity for potential future upgrades (specifically accommodation for a greater number of users and newer technology).

The campus includes 5 buildings, each with its own unique features and requirements. These buildings include a: Classroom Building, Dorm Building, Administration, Library Learning Center, and Student Union Building. The CAN is designed and tailored to perfectly fit the requirements of each building, with the aforementioned goals in mind, and deliver to the client the best result possible.

Per-Building Study:

Classroom Building:

We know that the classroom building has 20 rooms. As such, it is safe to assume that it would consist of two floors with 10 rooms each. Looking online we find the average size of a classroom to be 95 m^2 per classroom. This puts the total room area at around 950 m^2. Assuming a 20% right-of-way as above, we are left with a total area of 1187.5 m^2. To find the longest distance we need to assume the shape of the building. Most simply, let us say it is square:

$$Longest\ Distance = \sqrt{34.46^2 + 34.46^2}$$

$$Longest\ Distance \approx 48.7m$$

The average distance per user is half that value, with the addition of several extra factors such as the average cabinet to ceiling/cable, the average ceiling to wall extension/cable, and the patch cord length.

$$Average\ Distance/User = \frac{48.7}{2} = 24.36m$$

And to that 24.36m we add the following values:

- Average Cabinet to Ceiling/Cable: 2.4m
- Average Ceiling to Wall Extension/Cable: 2.4m
- Patch Cord Length: 5m

Thus,

$$Average\ Distance/User \approx 34.16\ m/user$$

In addition, one must take into consideration the additional length for work, connection and quality assurance = 10m.

Number of Outlets for the Classroom building:

We can assume that we need one outlet per classroom, for a total of 20 outlets for classrooms. In the cafeteria many people from many different classes need to be able to work at the same time, therefore 5 outlets may be more appropriate

$$Total\ Number\ of\ Outlets = 2 * 10 + 5 = 25\ Outlets$$

Administration Office:

For the administration office, it was stated that the administration building is 25m x 20, and three floors high. Thus, one can conclude (using Pythagorean) that:

$$Longest\ Distance = \sqrt{25^2 + 20^2}$$

$$Longest\ Distance \approx 32m$$

The average distance per user is half that value, with the addition of several extra factors such as the average cabinet to ceiling/cable, the average ceiling to wall extension/cable, and the patch cord length.

$$Average\ Distance/User = \frac{32}{2} = 16m$$

And to that 16m we add the following values:

- Average Cabinet to Ceiling/Cable: 2.4m
- Average Ceiling to Wall Extension/Cable: 2.4m
- Patch Cord Length: 5m

Thus,

$$Average\ Distance/User \approx 26\ m/user$$

Which is less than 90 meters (TP maximum interior length) and therefore acceptable.

In addition, one must take into consideration the additional length for work, connection and quality assurance = 10m.

Number of Users for the Administration Office:

$$Floor\ Dimension = 25 \times 20 = 500\ m^2$$

Also, the public right of way takes up 20% of the dimension percentage, leaving out public rooms, hallways and passages such as corridors, fire exits, bathrooms, etc.

$$Public\ Right\ of\ Way = 500 \times 0.2 = 100\ m^2$$

Thus,

$$Left\ Area\ for\ Pure\ Private\ Offices = 500 - 100 = 400\ m^2$$

$$Number\ of\ Offices\ That\ Can\ be\ Made = \frac{Left\ Area}{Average\ Private\ Office\ Size}$$

Thus,

$$Number\ of\ Offices\ That\ Can\ be\ Made = \frac{400\ m^2}{17m^2} \approx 23\ Offices$$

As for the number of outlets, it is stated that every office should have a minimum of 2 outlets, along with 3 outlets for public areas, 9 outlets for access points, and 9 more connections made to the ceiling as to accommodate future potential Li-Fi installation.

$$Number\ of\ Outlets = 23 \times 2 = 46$$

$$Total\ Number\ of\ Outlets = 46 + 4 + 9 + 9 = 68\ Outlets$$

Dorms Building:

For the dorms building, it is stated that it has 40 double rooms, 10 single rooms, along with a computer lab with 12 terminals and a student lounge.

Assuming that the dorms building is made up of 4 floors, each accommodating 10 double rooms and 2 single rooms per floor (on average, because 10/4 = 2.5). Thus, the following assignments per floor were made:

Assuming that a dorm room has an average space of approximately 12 m^2/person, the total room area per floor is equal to:

$$Total\ Rooms\ Area = Number\ of\ People \times Average\ Space$$

Where

$$Number\ of\ People = Number\ of\ Double\ Rooms \times 2 + Number\ of\ Single\ Rooms$$

$$Number\ of\ People = 10 \times 2 + 2 = 22\ people/floor$$

Thus,

$$Total\ Rooms\ Area = 22 \times 12 = 264\ m^2$$

The total floor area is (right of ways = 20%)

$$Total\ Floor\ Area = 316.8\ m^2$$

Assuming the building is a square building:

$$Longest\ Distance \approx 25\ m$$

The average distance per user is half that value, with the addition of several extra factors such as the average cabinet to ceiling/cable, the average ceiling to wall extension/cable, and the patch cord length.

$$Average \frac{Distance}{User} = \frac{25}{2} = 12.5\ m$$

And to that 12.5m we add the following values:

- Average Cabinet to Ceiling/Cable: 2.4m
- Average Ceiling to Wall Extension/Cable: 2.4m
- Patch Cord Length: 5m

Thus,

$$Average\ Distance/User \approx 22\ m/user$$

Which is less than 90 meters (TP maximum interior length) and therefore acceptable.

In addition, one must take into consideration the additional length for work, connection and quality assurance = 10m.

As for the number of outlets for **double rooms**, every double room should have 4 outlets (2 for personal computers, 2 for printers, smart TV, etc.

$$Number\ of\ Outlets = 10 \times 4 = 40$$

In addition, it should have 4 outlets for access points, and 10 more connections made to the ceiling as to accommodate future potential Li-Fi installation.

$$Total\ Number\ of\ Outlets = 40 + 4 + 10 = 54\ Outlets$$

As for the number of outlets for **single rooms**, every single room should have 2 outlets (1 for personal computers, 1 for printers, smart TV, etc.

$$Number\ of\ Outlets = 2 \times 2 = 4$$

In addition, it should 3 more connections made to the ceiling as to accommodate future potential Li-Fi installation.

$$Total\ Number\ of\ Outlets = 4 + 3 = 7\ Outlets$$

The computer lab should be designed for 90 people with a 1:6 ratio and 12 terminals.

As for the student lounge, it should have maximum wireless coverage with minimal cables, and thus should have 4 access points and 6 outlets.

Library Building:

The Library building contains 5 offices. At about 17 m^2 per office (average size, found online), the total area of offices will be 85 m^2. We also have 2 computer labs. A 30 meters squared computer lab can usually support about 5 students. A good sized computer lab may be 120 metes squared, then, for a total are of 240 meters squared for computer labs. This leaves the following are for bookshelves and study desks:

$$Area = 2 * 20 * 40 - 85 - 240 = 1275\ m^2$$

Using Pythagoras the longest distance is:

$$Longest\ Distance = \sqrt{40^2 + 20^2}$$

$$Longest\ Distance \approx 44.7m$$

Which gives us:

$$Average \frac{Distance}{User} \approx \frac{44.7}{2} + 2.4 + 2.4 + 5 = 32.16\ m/user$$

We want to fit in as many study desks as possible in the remaining area while also leaving space for bookshelves. Let us say that we will have one desk for every two shelves. Let us also say that every such arrangement takes up about 25 meters squared of space. Therefore the number of desks we can fit in is: 1275/25 = 51

Number of Outlets for the Classroom building:

It is very important to have high speed internet available at every study desk so that students may sit there and work on their projects or do research. The offices meanwhile need to seat more than one person so they need multiple outlets each. And finally we need 12 additional outlets for the student terminals used for browsing the book catalogue

$Total\ Number\ of\ Outlets = 51\ (study\ desks) + 5 * 3\ (5\ offices\ with\ 3\ outlets\ each)$ + 12 (terminals) + 40 (2 computer labs of 20 computers each) + 4 (printers) + 16 (access points) = 138 Outlets

Student Union Building:

Per floor:

Dimensions = 15 * 25 = 375 m^2

Effective space (without right of way) = 375 * 80 / 100 = 300 m^2

Number of offices = 300 / 17 = 17 offices

Longest distance = 29.15

Average distance per user = 29.15/2 + 2.4 + 2.4 + 5 = 24.377

Add to that 10m length for work, quality assurance…

Number of Outlets for the Student Union building:

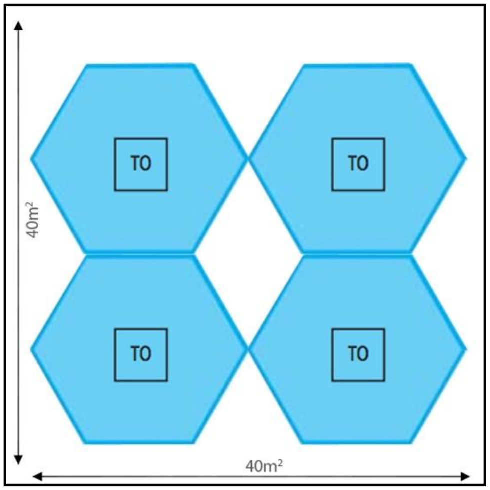
Every office should have 3 outlets

$$Total\ Number\ of\ Outlets = 17 * 3 + 6\ (Access\ points) = 57\ Outlets$$

Wireless Connectivity

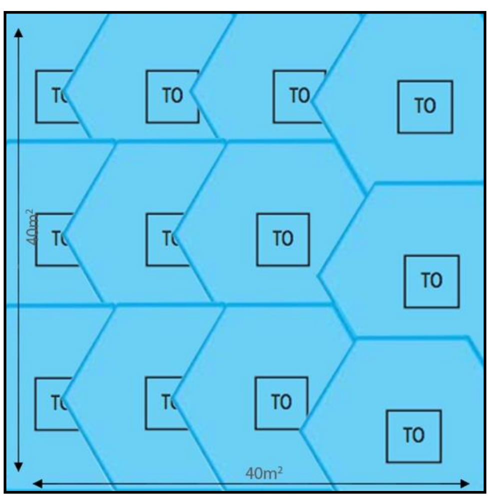
Although the floors are covered with cable outlets, with the new trends upcoming, mobility is no longer an option. New laptops are not including the Ethernet port anymore, while relying fully on the wireless connection. Phones as well, have no ability to connect over a cable connection. Therefore, access points are a must. The main problem we faced when designing the locations for access points is the compromises we had to do. The average range for an access point is $12m^2$ * radius. We divide the $400m^2$ into hexagons, where the distance from the center of the hexagon to the extremities is 12m. The arrangement of the hexagons will give us a relationship between coverage and cost. Fulfilling the coverage needs will lead to greater costs, and reducing the costs will compromise the coverage. We experimented with different locations, vary the number of access points as well as the locations, and we had the few figures, depending on the type of the application:

Minimum number of access points:



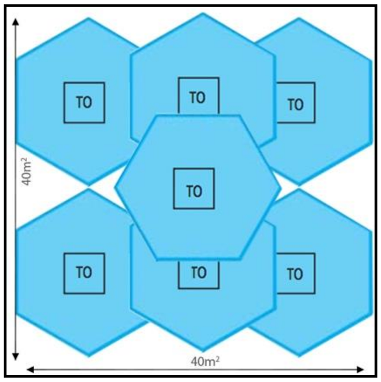
This model shows the minimum number of access points (i.e. 4) to cover the floor with wireless connectivity. Bare in mind that the hexagons shape is the recommended estimation of the connection, and the actual shape of the range depends on physical interference, but is more likely to be a circle. This provides the necessary and adequate connectivity for the users on floor (assuming the users are distributed homogenously) while they might need to look for an access point instead of taking it for granted. Ideal for budget constrains, not ideal for mobility between offices and in real time connections (such as calls, visual conferences) that require movement.

Maximum number of access points:

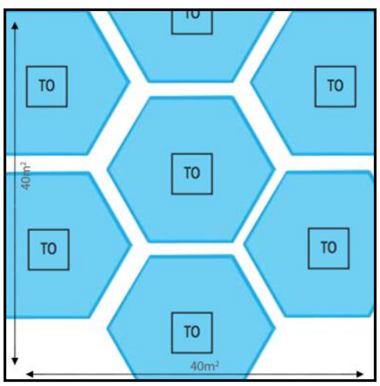


This model shows the required number of fully cover the floor with wireless connectivity. This is ideal when wireless connectivity is the main source to the internet and the cable connections are not used primarily. This type of connection is ideal where a lower ratio of users/access point, giving better data rates and generally access to more users. However, the security is not conserved inside the floor and a great amount of the transmission power is broadcasted through the walls.

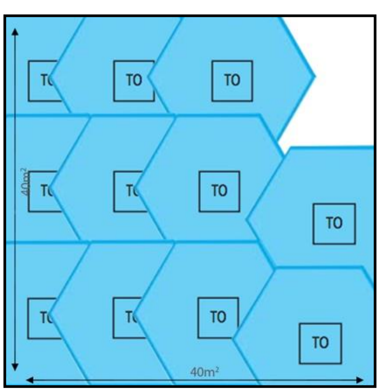
Few Other Designs



This manipulation of the orientation of the access points could provide a better range while maintaining the same number of devices and same security benefits, depending on the actual layout of the floor. It takes advantage of the shape of the hexagon to deliver the best range.

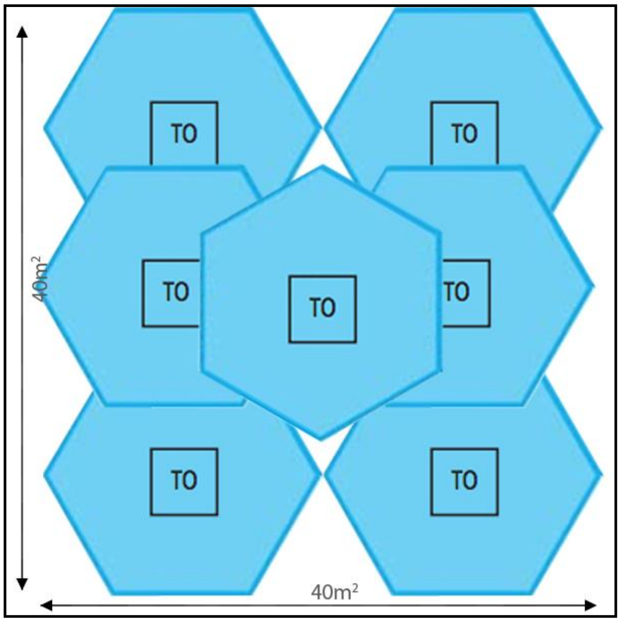


This design is a evenly distributed with a satisfying amount of access points to support users. The spacing between the access points could easily be manipulated based on the floor to mark them with the walls, giving best coverage with acceptable number of access points. The only drawback that deterred us from using this design is the security. While security measures could be taken on higher levels, a great matter of security is the determined by the range of the wireless network, in this case a good connection can be established outside of the premises.



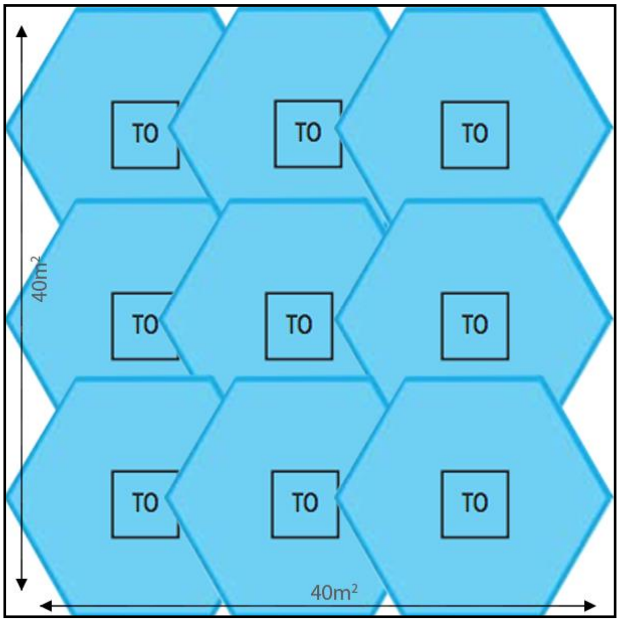
This is the same design as for the maximum coverage, but with the elimination of one hexagon, enough space for the distribution room which does not require wireless connection (very minimal activity is conducted in the distribution room.)

<u>The most practical design</u>



Not minimum, but it covers most of the floor with little weak spots. It provides good security buffer, and the increase in number of access points does not dramatically decrease the efficiency, as it both provide better support to higher number of users, and better wireless coverage, with the increase in the number of access points used.

The decided plan



Although the most practical plan shows a big deal of performance and cost efficiency, we are choosing a different plan. We are going to increase the costs a little in here, as we are going to provide every single private office with access point connections. This will maximize the data rates, user capacity, coverage, and, of course, the cost. The corridors are going to have good connectivity from the adjacent offices so no need to provide them with particular access points. The way we are going to equalize the equation in here is by supporting future technology: Li-Fi. Li-Fi needs a unit per private office, since it depends on visible light which does not propagate through the wall. This design provides the same security established earlier, by having the location of the access point is going to be in the center of the office, giving minimum propagation through the wall. However, once the switch to Li-Fi happens, the security will be at its best, given that almost no light is propagating outside the given parameter. This design needs 23 access points. However, the actual number of access point units installed will vary (every other office could have an access point unit which will provide sufficient coverage with acceptable cost and the same support desired for the future), based on the layout of the offices. But the connections from the panel to the office is fixed. The summary provided in the Bill of Quantities draw the actual number of access points used per building.

Technology

Utilizing the best technology is a part of the network design of which we yield the utmost of the costs. We need to be careful in foreseeing the future of the trends, and whether the extra cost will pay off or not. All external cables used are fiber optics multi-mode 62.5 nm that spans the distances between the buildings. All internal cables used, except uplinks and downlinks, are cat6, which is not the best of the current technology but the compromise had to be made based on two main factors: the cost and the availability. At the moment, the cat7 is not currently available locally, as well as the import of this type of cables, in addition to the initial cost, is not worth the difference in performance (between cat6 and cat7.)

Although with time cat6 is going to obsolete and will not be able to carry the expected data rates, it is going to give us excellent performance for enough time, until Li-Fi is commercially available. At the time of this report, Li-Fi is still under development, but is promising spectacular data rates. Therefore, we are going to work as hard as possible to make connections for easy future Li-Fi compatibility. This will come with extra cost, but we are going to reduce the impact of this cost in the wireless connections, by using these Li-Fi connections for the access points, and making the switch to Li-Fi almost immediate. We are going to elaborate on this point in the wireless section.

Network Topology

Based on the prices of the switches, logical star, physical star is the best topology to implement. It might be slightly more expensive to implement than other topologies, but the security and the efficiency that it provides compensate this cost and makes the Ethernet switch the best current topology to implement.

Performance

In terms of performance, we are expecting up to 1 gbps of data rates, and a bandwidth of 250MHz using the Ethernet type 1000BASE-TX. As for the uplinks and downlinks, as well as the connection between the buildings and the redundancy cables, we are using single mode fiber optics cable of the Ethernet type 10GBase-LX. These links support up to 10 gbps and can easily maintain the network demand. Access points section is going to provide more information on the design of the access points, but basically it will easily support the devices by the needed data rates, and can be easily swapped with newer technologies along the road (although the best technologies are being implemented.)

Moreover, the switches being used are managed switches which gives us the ability to prioritize certain type of applications on the others, giving VoIP and video conferences a higher priority with less throughput and less delay, over the rest of less important services such as the mail or file transfer which could be more flexible.

Reliability

As the sketch of the network design may or may not show, the reliability is achieved through redundant connections between the buildings, from different entrance points, and on different paths. Although the maximum redundancy is achieved by connecting every building by every other building, practically it is not efficient. It would cost a lot to build and maintain, therefore the design should be achievable. A connection from the building to another and to the main distribution center is the minimum, and acceptable redundant connection, but we insured an extra connection for every building would offer more stable connection. The sketch of the network will better demonstrate this point, but basically every building is connected to the two nearest buildings to it, and to the administration building, which will host the distribution center. This will insure a robust connection even if a single, or double connections went down, providing sufficient time to fix the problem.

Our design has a good proof for the future, and it could go a long way without the need of upgrading. The sore spot of the network would be the use of cat6 which is not the best type in the global market (it is in the local market,) but this point is actually designed well. Cat6 should easily span us at least ten years before holding back the network, and by that time, Li-Fi is the technology to be implemented, which will eliminate the need for cabling (for the most part.)

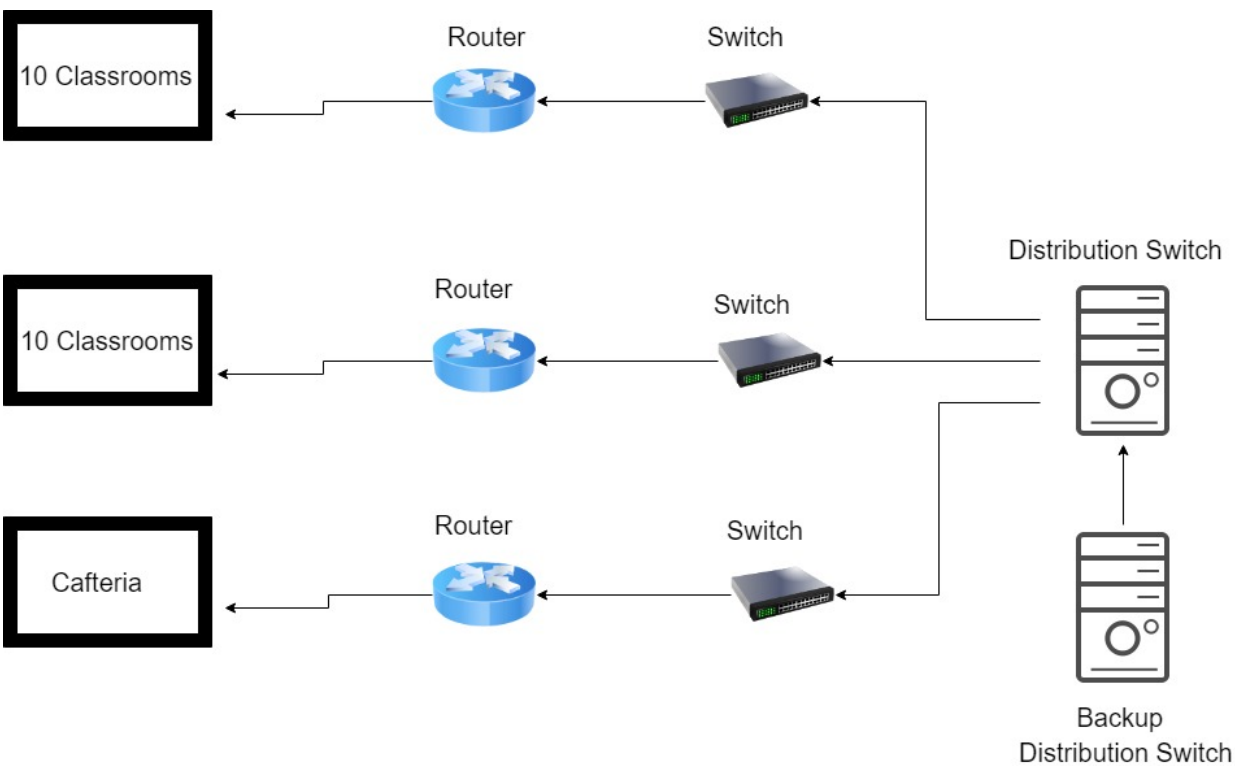
Data Center

The use of a data center is found to be inconvenient to our design due to several factors. First, cloud servers are becoming more and more cheaper, faster, and reliable than small scale servers. Second, the maintenance of the physical conditions of the server, as well as the security of the server, makes the cloud server more convenient. Adding to that the physical space that the server occupies at the time where space is becoming more and more scarce, we find the cloud servers a very practical solution. Moreover, upgrading the server would cost a fortune, and would need to move the data from the old server to the new; cloud servers eliminates the need of this process. In addition, using a cloud server would relief the campus network from unnecessary stress when accessing the data from outside the network. Finally, in time where different options exist at the same time, some options could sound great on paper but needs a lot of hardware to implement and could be risky investment. Cloud servers give us the ability to try new arrangements easily and without the commitment of the local servers. An example would be if teachers decided to record sessions and uploading them to the server. To implement this, we need to change the whole server structure, even if we had a solid one before, to adapt to this change. If the project was unsuccessful, the loss would be very huge. However, cloud servers give us the option to increase the capacity instantaneously and with very minimal commitment that we can move back with almost no loss. Another example of the benefit of this flexibility, is that some events on campus could use some bandwidth for information at the time but might not need them for a long time (e.g. Video Competition,) which gives us the ability to only increase the capacity when we need to. Determining the size and contents of the data center can use the last benefit we mentioned of the cloud servers, we do not need to give a lot of buffer between the actual capacity and future capacity as we can increase on demand. So we are going to upload the local library to the cloud server, and use the cache process for storing the data. Meaning that, we are going to rent four different types of storage devices on the cloud server, and the cache process will prioritize the data, and move them around these devices based on the request frequency as well as other factors. We are renting 1,600 GB as optimized storage for all library data. Anytime this capacity is not sufficient, we can expand the capacity as needed. We are dividing this total capacity into four main categories based on the type of the storage:

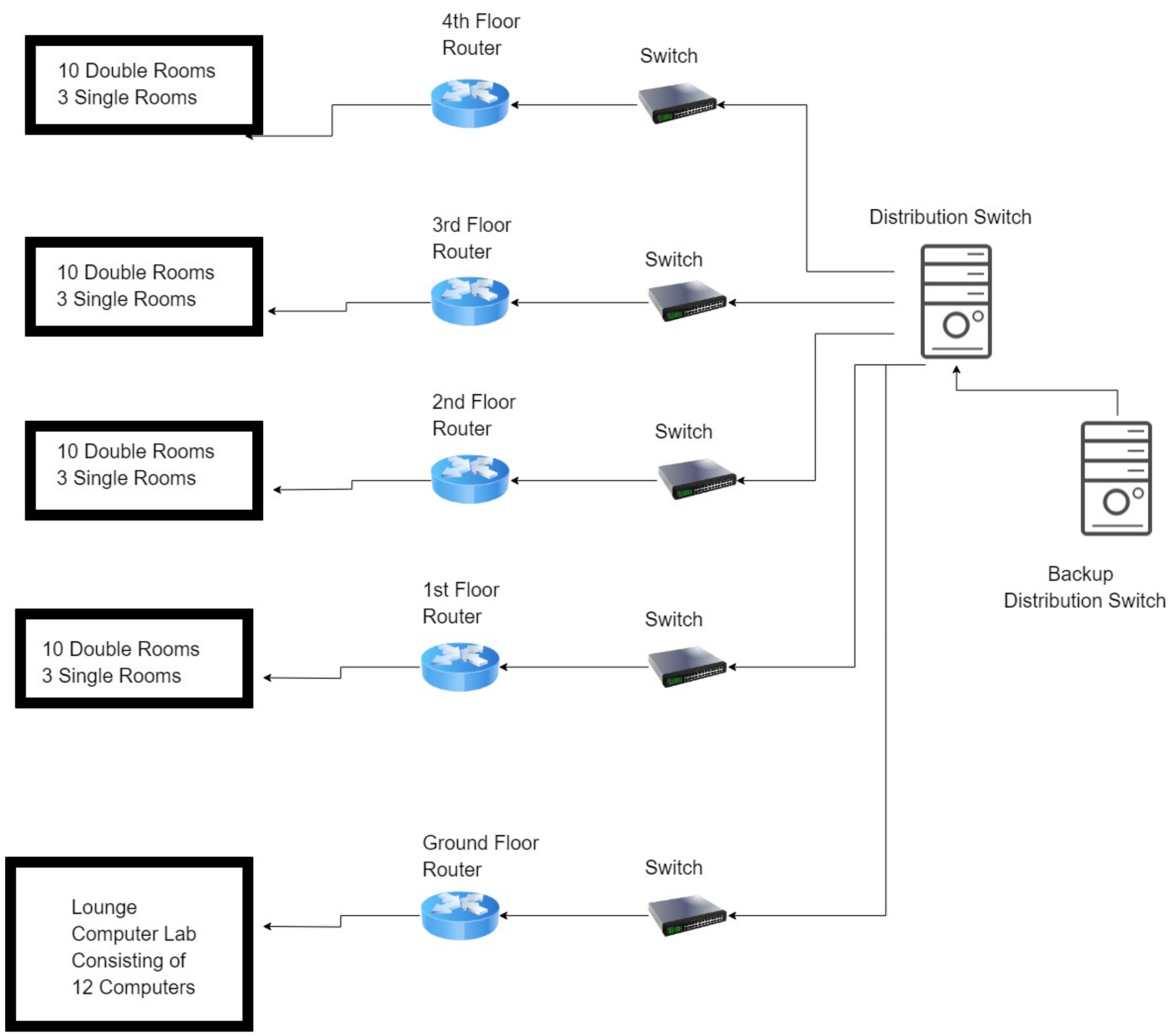
1) General Purpose SSD 100 GB
2) Throughput Optimized HDD 500 GB
3) Cold HDD 500 GB
4) Magnetic HDD 500 GB

The following image explains more about the classification and distribution of the storage. Enough storage is left to backup the data and create mirrors for data with high demand.

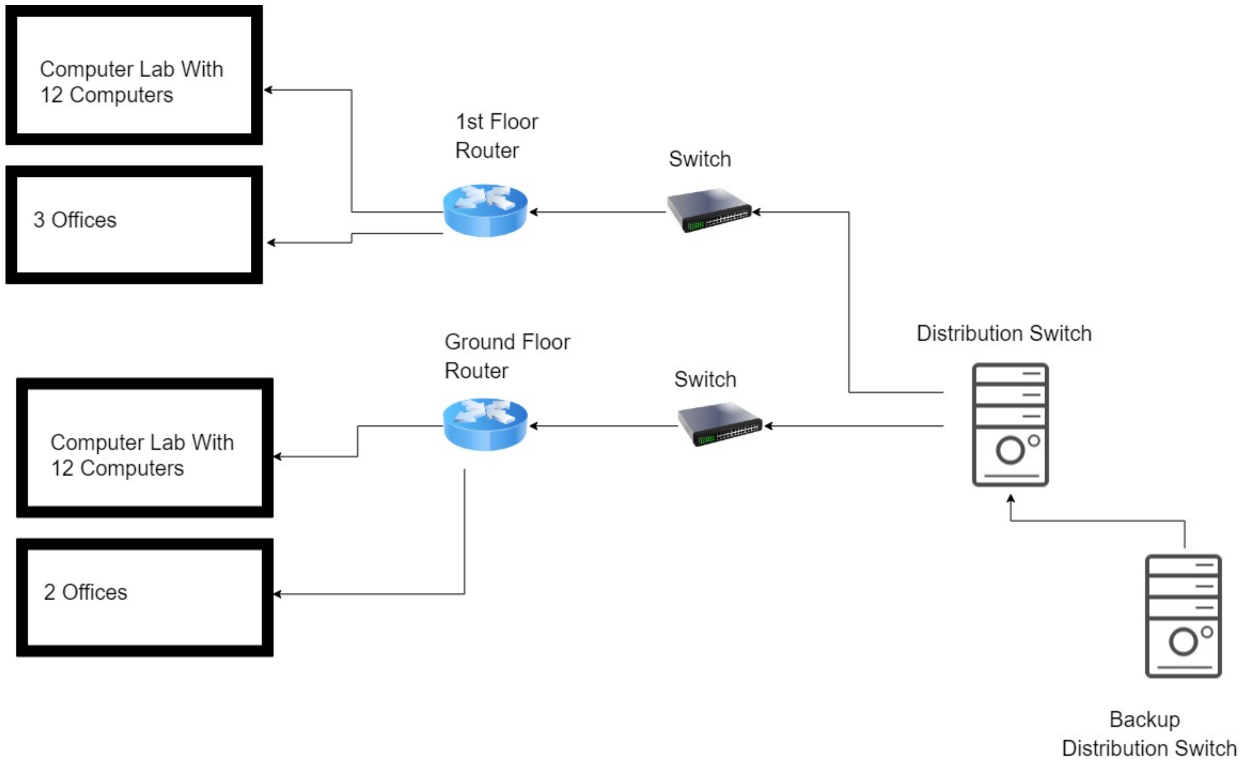
Drawings



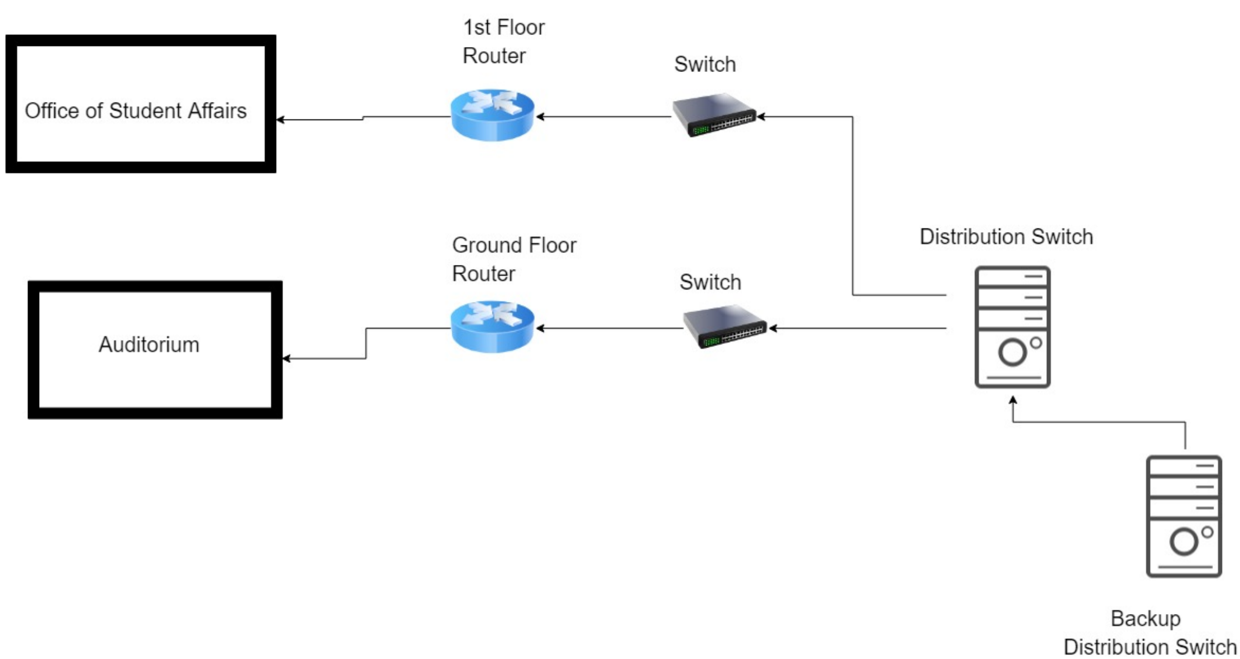
’The classroom building



The student dorms



The library



The student union building

Bill of Quantities:

Component	Description	Unit price	Quantity	Cost
Fiber optic	Fast cable	30$	200	6000$
D-Link Wireless N300	300Mbps router	20$	10	200$
WAVLINK AC1200	1200Mbps	40$	5	200$
TP-Link ethernet switch	8-port gigabit switch	20$	8	160$
NETGEAR	16-port gigabit switch	70$	6	420$
Cisco SG200-26	Distribution switch	100$	11	1100$
Dell PowerEdge R730	Rack server	2769$	1	2769$
WS-C2960G-24TC-L Cisco	Core switch	3295$	1	3295$
ASA5512-K9 cisco	Firewall	2307$	1	2307$
CAT6-UTP	Cable	4.05$	66	267.3$

The total price if this design is approximately **17,453 $.**

Conclusion

In the ever changing technologies we are witnessing, holding a handful of inventions and creating an interconnected system is a must. Our job is to minimize the cost and the potential risk of going obsolete instantly, by giving a solid structure for the network to be futureproof for a number of years. While we deal with a lot of variables and uncertain information, we make the best out of them by taking minimal chances and depending on the best of knowledge to serve the community. The engineering code dictates us to devote our energy and power to serve humanity and make life much easier. By that, I believe that the proposed design is the best fit to serve the campus and provide a reliable source of information, for the upcoming learning generations to rely on for their studies.

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