Computer Systems Infrastructure and Management 600099

Network Infrastructure Configuration Report

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Contents

Problem Breakdown

The task involves the development of a network infrastructure for the University as part of their new building expansion. The main point of interest for the expansion is to incorporate a relevant and efficient network infrastructure that aims to serve and connect the Engineering and Computer Science departments, by providing expansion upon their already existing building.

The university spans over 2 floors. There is need to develop a network solution that allows a connection across the different departments, where Computer Science and Engineering share spaces amongst the building. A network needs to be developed and plotted that aims to suit the requirements of the building as well as meeting the requirements of both departments. This will be achieved through a suitable, relevant, and efficient network design that allows the requirements to be met. The network chosen must meet the requirements of the internal structure.

For this, consideration needs to be taken for the density of the pooled space, capacity of offices and the potential for wireless connectivity, which will allow expansion across the entire space. The two departments require their networks to be separate but to also be able to connect and share resources with each other across the pooled space. This connection needs to be available not only for local computers, but where necessary this must also cover the needs of those who use their own devices in the workspaces available or across the campus local area network.

The network infrastructure solution must allow for the ability to support activities within the computer labs, even when these labs are at capacity. This means that a fast connection needs to be available and that maximum through-put needs to be considered, but the likelihood that the full potential of network bandwidth will be used is not high. Mitigation to allow for this should be in place, to allow for no issues in lab use where capacity is expected to be higher than normal, especially in times of deadlines for coursework submissions. Due to the location of the comms room, a high speed wired connection needs to be available throughout the building that can suitably provide power and connection across the entire space.

The comms room can be found towards the south side of the building and consists of a long spanning corridor with only one entry and exit point along an outer wall. The corridors span the length of the floors and allow for ample ability to get everywhere, with no visible issues that can be seen from the floor plans regarding navigation.

To meet the requirements, the proposal is for a three-tiered network design to allow for easy connection through the building, alongside allowing for future building expansions if these are deemed necessary later down the line. The corridors allow for Access Points to be situated in corners so that their connection can travel effectively through spaces without much interference or issues with walls effecting connection quality. The aim is to theoretically deploy the chosen network once the resources needed for this have been explored and discovered. This will help to gauge expected costs for this expansion which can be broken down later through a cost breakdown table. This includes the cabling, devices and additional network equipment that might be needed. Not all spaces within the building are expected to require a physical connection, but the building should have a wireless solution available throughout.

Solution

Network Design

The network will be split into three main segments which are the Core layer, Distribution layer and Access layer. The Core layer is the topmost part of the network that connects to an external firewall and is the backbone of the entire network. This layer allows for connection to the outside world and as such, the necessity for a firewall is key in keeping the overall network safe from potential threats from outside. The core layer needs to be designed with high availability and reliability in mind, and a fault tolerant design needs to be considered as well. Any failures need to be sure to have a minimal impact on the network and its connectivity (OmniSecu.com, 2020).

The second layer is the Distribution layer, which operates on the L3 band, and connects all the higher-level switches that will be deployed, to ensure that redundancy exists for the network. This layer defines the policy for the network and ensures that packets are delivered to the correct end devices and lays the foundations for connection to the lower Access layer. The required topologies for the network will be laid out in this layer before any connections can be made for the system. The Access layer, which operates on the L2 band, is where all end level connections will be made to the Distribution layer, for end-devices such as Computers, Printers and Mobile Devices.

Using VLANs for the Network

To set up the network so packets go to the correct place and allow departmental network separation, Virtual Local Area Networks (VLANs) can be used. This solution is used, as it is possible to have the departments on the same physical network or subnet, whilst separating them into multiple logical portions that act as individual networks. This is done by 'splitting' connected devices and only allowing them to connect and talk to other devices on the same VLAN.

For the network traffic, it is possible to use a switch which can utilise VLAN trunking to create a single virtual link that all VLAN data can travel across. There are two types of VLAN configurations, which are port-based (untagged) and tagged (Intelligent Technologies, 2017). Using a tagged VLAN allows for multiple VLANs to be configured using a single connected trunk port from one switch to another. This is done through a single connection to both physical switches using a single cable. Using VLAN tags across the trunk port on each switch allows for separation of VLAN A and VLAN B traffic without any physical separation. An example if we have three computers, where one is connected to VLAN A and the other two are connected to VLAN B. The two computers on VLAN B would be able to talk to each other but not to the computer on VLAN A which would be isolated from them. The amount of VLANs needed for this solution is three. There will be a VLAN set up for Computer Science, one for Engineering, and a VLAN for the shared resources for the pooled areas and wireless.

There will be a connection to each departmental VLAN and a shared VLAN which will primarily be in use in the pooled areas and on the wireless network. This will be done through Level 3 Multi-layer switches that can act as a switch and a router at the same time through inter-VLAN routing. The technique of Inter-VLAN routing is effective to route traffic to each VLAN on the network so that packets get to their intended destinations and are not visible to the other VLANs present on the network. The multi-layer switch allows for the ability to achieve switching and routing in a single box. This technique can be achieved in three different ways, but for this network, the use of inter-VLAN routing through a multi-layer switch is the chosen solution (Cisco, 2014).

To limit connection and packets through the VLANs, VLAN Access Lists (VACLs) can be used. This can be activated on a level 3 switch to block or permit inter-VLAN communication. Access can be permitted or blocked using IP addresses, Mac Addresses or through specified allowed ports. The default action blocks packets, but it is possible to configure this to allow the forwarding of packets amongst other things. Using VACLs allows for the communication to be shared through both departments but stops the departments from communicating with each other directly.

The most important thing to consider regarding VACLs is that each VLAN can only have one list and they are a list of permit / deny statements. Any issues with configuration due to their top-down nature can cause access problems or weaknesses. Using this method is expandable to the other departments in the building if there is ever a need to add the other departments to the VLAN configuration, but this method helps to isolate the VLAN network and achieve our requirement of network separation whilst still having a shared access area available (The Hook Up, 2019).

Building Considerations

The floor plan has a lot of issues that are not possible to correct but are worth mentioning. First is the location of the comms room. Being located where it is leads to much higher cabling requirements due to its distance from the far-right side of the building. It would be better if this room were more central to allow for a much easier cabling strategy to be taken up. Next is the comms rooms' location facing an exterior wall, which is bad because there can be issues later regarding damp or flooding which could easily cause network disruptions and damage to equipment. The mitigation to this issue is to use tall racks and a suitable online UPS that allow for the ability to get equipment shut down in the comms room in any such event.

Lastly, the comms room is close to electrical interference, in the form of the electrical riser close by, and the lifts situated opposite to the server room. If this room were to be used later for expansion purposes with siemens, there would be potential issues due to the EMI problems that will be caused by these lifts being so close in proximity. The risers located in the pooled computer lab are useful to allow cabling to reach the 3rd floor. Cables are needed to connect the switches from the comms room to the switches for each lab space and to an access point for wireless connectivity. There are also lifts situated within walking distance of the comms room to get this equipment upstairs for deployment. There are also places to store equipment for later use, including the electrical cupboard on the third floor and the general storage rooms on the second floor.

Designing the Network Topologies

There are three main areas of the building where there needs to be consideration towards which topology will work best and where. A single type of network topology is not ideal here due to the size of the building. Starting off, the best way to set up the lab spaces and main computer rooms will be through switches for each lab, with two switches connected through tagging where needed. Due to the nature of this connection, a star topology will be the best network topology for these labs (Computer Network Topology, 2019). It makes sense to have such a connection here because of the nature of the layout of the labs themselves. Half or all the computers in a lab will be connected to a switch which will be the central connection point for all these computers on the network.

This topology has many advantages for the lab spaces, the biggest one being the cabling situation. As each individual computer uses a single cable to connect to the switch and the network, it means that if there are any issues with a computer, it is easy to trace this back to the cable or the port on the switch, whilst having no effect on other computers on the network. This topology also allows for ease of device control and makes management a lot easier, alongside being great for high speed transfer of data to each individual connection. There is also ease of network extension through this method, adding new computers to the lab would simply be a case of adding a new cable to an empty switch port.

The biggest issue with the topology is that if the switch goes down then essentially the entire lab goes down too. This can be mitigated through a backup switch, which would allow a swap if the switch dies, and all that is needed is the reconnection of all port cabling into the switch. Another downside is this topology choice requires a lot of wires for connectivity.

For the smaller areas and office spaces, the best choice for these areas is the tree topology. This is the best choice here as the number of devices is expected to be low, but a wired solution of some kind needs to be available for the offices, rather than expecting these areas to be covered by a fully wireless approach. These switches will reside within one of the rooms in a cabinet with cabling going to each individual room to offer a wired port for connection. This topology allows for further connections in the small space and is quite easy to manage should there be any problems with any connections here (Computer Network Topology, 2019).

This topology is also a good choice to implement here as it offers easy maintenance and fault identification. It is a combination of star and bus topologies, but the feeling is that star topology alone is not suitable for this, due to the amount of devices expected to be in use, unlike the labs where it is expected many computers will be connected at one time and are of a fixed quantity. One of the problems of this solution however is that is more difficult to configure than the star topology is, and it also has the same issue as the star topology where a switch failure will cause a disconnection of the network. For the larger offices there is consideration for star topology, the same as what is implemented in the labs, but this depends on if there is need for it and should be decided when it is required.

The overall connection of the building is done through a connected mesh topology (Computer Hope, 2018). This is done at the top level to make the network more secure to a drop out or equipment failure. This is achieved through link aggregation, which allows for an inexpensive way to apply redundancy to the network. There are multiple connections to the switches located within each room, but these are not connected to each other which indicates the potential for a partial mesh solution here. Care needs to be taken to ensure that there are multiple connections from the comms rooms, to make sure the network is secure in case anything fails.

The big advantage there is regarding using mesh is that a failure of a device in the building will not cause an entire network failure and data will continue to be transmitted regardless of this. This style of topology is more costly, but it allows for a lot more redundancy within the network. It has the issue of being a more difficult network to set up and will require more time to get up and running in the initial stages.

Wireless Functionality

Wireless is necessary for the building, as it is needed to allow students and staff to be able to connect and access resources when travelling around the building or when using their own devices. This wireless network needs to reside on the shared VLAN, as the people connecting to this network could be from any department, therefore being on the shared VLAN allows them to access resources appropriate for themselves. A WLAN controller can be situated within the comms room so that the multiple access points within the building can be managed should there be any issues that need to be resolved quickly. Every access point will be connected to the same Service Set Identifier (SSID) to allow for ease of connectivity between all access points in the network.

Being on the same SSID means that once a user has a connection, wherever they go in the building, this connection will remain no matter where they go as long as they are on the campus, which means there is no interruption to service. Due to the hallways and their width, there must be consideration towards having omni-directional wireless antennae.

These broadcast their signal a full 360-degree radiation pattern, so that they have a large range and are not blocked much by walls or other thick objects that could impede connection quality. This ensures that connection is strong and that all access points are connected if they are nearby another access point, allowing for constant connectivity. There is also need for dual-band support. While 5Ghz is the new standard and has the best speeds, it also has a much lower working range than that of 2.4Ghz. There is also the problem that not all devices themselves support the 5Ghz channel, so if the choice were to only support the higher channel, it might lead to connectivity issues for older devices.

The wireless implementation will make use of the mesh topology to connect all access points together to be able to handle high levels of traffic. High levels of traffic are expected within the wireless network, especially when people are propagating the hallways, so this mesh network can help alleviate the traffic and allow the network to find the best route to the comms room based on the location of the user and which access point they are accessing from. The mesh topology can survive and continue working even if a device breaks, which is great for a wireless solution, meaning that the other access points closest can take over the workload until the device can be fixed or replaced, leading to no expected network disruption. The solution of a mesh topology also means less wired connections are needed for the solution, meaning money can be saved on cabling costs, but more access points will be required so that availability and connectivity is not adversely affected by this (HowStuffWorks, n.d.).

For access point placements, it’s important to take note of the range of the access points that have been chosen. The selected access point has a range of up to 122 meters, giving each access point a straight-line metres squared value of 10-12m estimated. With this, there needs to be strong consideration for access point placement and their distance from each other to help to make sure there are no dead spots due to coverage problems from one access point to another. Wireless coverage also needs to be considered, which can be calculated by taking the number of serviceable users and dividing this by the percentage of Wi-Fi adoption. Not all users will use the Wi-Fi and the adoption rate will be different due to a number of factors, but the more people adopting the Wi-Fi over the wired connections will add additional strain to the wireless solution, and this needs to be considered as well. A table covering wireless utilisation can be found in the appendix.

Selecting Suitable Equipment

To choose the most suitable equipment, there are many things that need to be considered beforehand. A router is needed at the topmost level to connect to the WAN and distribute an internet connection to all devices on the network. It is assumed that all campus-based computers can output 1Gbit, but it is not realistic to consider this as the optimal output. This is more of a maximum throughput, and therefore an estimated utilisation needs to be calculated here. If every computer is running at max utilisation of 1Gbps for each device, the max throughput is approximately 715 Gbps, not including a wireless network. But this is assuming max load and that all computers on the network are being utilised at the exact same time, which is not likely. A realistic expected max throughput for the network at 100Mbps is closer to 71Gbps rounded. This is only the physical wired devices on the network, so it also possible to assume there is wireless traffic added into the mix.

Some exploration was done for a router with capability to support 400-500 Gbps, although as stated, the likelihood this will ever be fully utilised is low. The next step is discovering the number of switches that will be needed throughout the building, the best locations for these and the realistic amount of connections there will be to each of these switches in a spatial area within the building. Consideration needs to be taken for capacity within labs, as this is an important thing to take into consideration when it comes to deciding what switches are needed and the quantity required. Some of the switches will also need to be able to do Power over Ethernet (POE) to be able to provide power to the access points for the floors.

Taking into account 2nd floor Computer Science labs A and B located on the left hand size of the floor plan, this room houses an estimated total of 133 computers, so to be able to connect this room, it would be necessary to use 3 switches. A suitable switch for this is the Ubiquiti 500W 48-port L2 switch. This is a good choice and suitable for the solution as it can output 1Gbit to each PC and can house 48 computers through its 48 ethernet ports. Using 3 of these within this lab would be suitable here and would allow all the computers to connect to the higher up L3 switch. This capacity is important as it is then possible to consider how many labs would require 2 or 3 of these switches, and provide other locations such as offices and research spaces a single switch, due to its high port count, which means less switches are needed overall.

For wireless functionality, an access point was found with 1750mbps dual band output. This speed is used to calculate the number of simultaneous users that can be serviced depending on usage counts. Considering aggregate throughput for the access point here taking into considering the max output of 1750mbps, if the speed of network transfer is currently at 5mbps, then the throughput would be approximately 350. This is calculated by dividing the max speed by the current speed. This can also be done for the utilisation speed of 100mbps, which would result in a much lower number of 17.

If the throughput is 350, then this number can be used to work out the number of serviceable users this access point can handle. If we consider that the throughput is 350 and all connected users are utilising only 25% of the Wi-Fi speed, then the amount of serviceable users here is 1400, with 68 being serviceable if all users were utilising 25% of the network where the throughput is 17. A table covering all the results of these calculations can be found in the appendix.

There is also the consideration towards Redundancy, which is important to make sure that if something happens to network equipment in the higher layers that it doesn't simply cripple the network. This is done here by selecting a suitable L3 switch and L2 switch and then buying a duplicate. For this solution, an L3 switch is purchased and connected to a 2nd L3 switch through trunking, both of which then connect to the L2 switch below it in the hierarchy. This element of mesh connectivity allows for network redundancy and for connectivity between all devices to route traffic correctly.

There are rooms where multiple switches will be placed and others where there will only be one. Regardless of this it is necessary to have cabinets wall-mounted in these rooms so that switches can either be in a corner out of the way or hidden out of sight in places such as the upper office spaces. The switches are at a height of 1U, which means that it is possible to effectively buy wall mounted cabinets to a max of 3U, but for upgradability purposes and to allow for expansion later for departments in the building that are not currently included in the brief, it was chosen to go with 5U cabinets which provide plenty of space for future upgradability along with still being big enough for rooms where 3U would have to be the absolute minimum such as Computer Science labs A and B.

Although a UPS is a device that is normally used to protect your server from data loss in the event of a power cut, a UPS is still included in the equipment table for this solution. This is because a UPS can help keep the network on long enough for those who are still connected via wireless devices to be able to save their work. Unfortunately, the UPS doesn't cover wired computers. There could be consideration to do this later, but the main objective is to save the integrity of the network for a short time should there be any problems. The UPS included in the equipment table is suitable due to its high voltage output and has a 60-minute time of life on battery, and handles the job very well, and should be used only as a failsafe where needed. The main benefit of including this UPS is if local servers are implemented later, so this UPS adds to upgradability for possible expansion later down the line.

Cabling Considerations

There are a few factors in play in consideration of cabling. Cabling is a necessary part of the network as it allows computers to be connected at the access layer. For the router, there was initial consideration to use Cat 6A Ethernet for this to connect the router to the L3 switches. This is decided against because of the ability for someone to be able to tap into the cables, which meant all uplink cables from switches and the connection between router and switches was best to be done through Fibre cabling. The Fibre cabling that felt most appropriate was OM3 multimode laser optimised fibre. The reason why multimode is chosen over singlemode is that multimode is better for shorter distance transmission and has low attenuation and low dispersion up to 100m for a 40Gbit base in these environments, which is perfect for this solution. Link Aggregation is used for the connections to make sure that the network survives in case of any faults.

The next consideration is what cables are the best choice for the connection of the L3 switches to the L2 switches. For this Cat 6A was chosen for use, with an element of shielding added to the cables. The same cabling is also used for the L2 switches to each switch in the building. The longest estimated cable from an L2 switch in the comms room to an L2 switch in the upper offices of the 3rd floor is 90m. The drop in quality for a Cat 6A cable is 100m, so this means that there is no area within floors using risers that exceeds 90m, so the Cat 6A cables are great. These switches are also connected with link aggregation to allow additional redundancy if there are any cable issues.

To traverse the floors, it is possible to make use of the risers within the pooled lab and the riser situated in the top right bottom corner next to the Stair 1 stairway. The risers are useful to traverse the floors and provide cabling to the professors offices and labs on the 3rd floor, whilst the risers within the pooled lab are used to provide wired connections for the lower left 3rd floor and central right side 3rd floor research spaces, without the need to traverse one cable the entire way from comms room to riser to top right corner from the pooled labs. Making adequate use of the correct riser closest to the location allows for cables to never exceed the 100m limit, where a repeater would be needed. Using shielded cables helps when using any cabling that passes the lift, because this is a potential source of EMI so shielded cables help prevent this.

For connection to the L2 1Gbit switches situated close to or inside the rooms where connections will be, it is best to use Cat 5e cabling for this. This cabling is not shielded like the Cat 6A chosen for the traversal across the building for all the spread around switches, but these cables only need to go in an enclosed space or within rooms and the likelihood that these connections will have problems with EMI is not as much of a concern. There is also the fact that Cat 5e cabling has a max throughput of 1Gbit through its cables, whereas Cat 6A can do 10Gbit, but anything more than 1Gbit would be unnecessary. For the uplink for the switches, fibre OM3 will be used for uplink of switches to send data back and through the network.

Cost Breakdown

The creation of the infrastructure requires planning and a cost breakdown is essential towards understanding that this cost breakdown is efficient and correct. A breakdown table can be found in the appendix. In terms of equipment costs, the most expensive thing on the list to purchase is the router. This router has capabilities of up to 400 Gbps running across 24x 10 GbE ports, 4x 40 GbE ports and 4x 100 GbE ports and comes in at a price of approx. £19,678.08 after some conversion is done. This is quite expensive but comes with a 5-year warranty from the manufacturer, which leads to peace of mind. It can be considered to purchase a second router for redundancy considerations but at this time this is not included in the breakdown. Realistic throughput weighs in around 71 Gbps for wired connections, and the assumption is that a connected wireless network will not go towards exceeding the maximum capacity of the listed router. There are more expensive routers with higher throughput capacity numbers, but they feel overkill, whilst this router feels like it fits the solution well, also taking up only 1U of rack space within the comms room.

For the L3 and L2 switches for the network, it is chosen to go with Ubiquiti switches. This is to keep the switches within the same manufacturer ecosystem. The L3 switches chosen are great here as they have enough ports to support the features needed for the network, have 10 GbE support and SFP is included for uplink, as SFP is important to be able to use fibre cabling for uplink purposes. They come in at a price of £3,829.20 from FS.com with a 5-year warranty included. The L2 switches are suitable here as they provide 1 GbE support and include 48 ports, which is enough to support the wired devices estimated from the floor plan diagram, in some cases however multiple of these switches will be needed to provide enough connections. The 24 port L2 switches are included too, as some areas such as upper offices only need wired connections for less than 24 devices so for places where there isn't as many wired connections expected, savings can be made on cost by purchasing lower maximum port switches. The 48-port switches come in at £773.58 each and the 24-port switches come in at £550 each, both with 1-year warranties included.

To cover the wireless for the network, for the two floors 52 access point devices will be needed. These have been selected from the same brand as the switches to allow ecosystem integration. These access points are chosen because they supply a connection up to 1750 Mbps across simultaneous dual band, which is a technology that allows for the bands to be combined to deliver a higher overall connection speed. They are omni-directional, which means their placements in rooms and corridors allow for the ability to maintain a strong connection, and connection will be seamless with the use of the wireless mesh network topology. They are also controlled by software, so this can save money on not needing to purchase a separate WLAN controller to get things set up. Each Access Point comes in at approx. £120.10 after conversion.

There are different vendors for the cabling, but in these cases, it is chosen to go with broadbandbuyer.com for the Cat 6A 500m cable spools and Amazon for the Cat 5e boxes of raw Ethernet cable. Since the cables are also raw cable they will need to be cut and assembled so packs of RJ-45 connectors are needed to wire to either end of the cables after they are cut to the appropriate length. The prices are also reasonable for cabling needed, based off estimate measurements from the floor plan diagram. Transceiver modules are needed to convert SFP to Ethernet for uplink, cabinets are needed for the equipment within the comms room and individual rooms and a UPS is preferred to avoid total system shutdown during a power cut or electrical fault. All the prices and quantities required for these are within the equipment costing table in the appendix, although these are to be taken as rough estimates as to what might be required.

Deployment

Physical Infrastructure Deployment

The comms room will house the router, the L3 switches and L2 switches required for the deployment of the distribution layer and will also house the 2nd floor switch for the Wireless Mesh network with a large 42U cabinet, which allows for upgradability or a server within in the future if necessary. Due to the use of the Mesh network for the Wireless, there is only need to connect one of the access points to the switch, after which the software can be used to connect all the access points to the same SSID as mentioned in the section regarding the wireless solution choice. Where possible, most rooms will have a wireless access point included towards the centre of the room, whilst every hallway has a wireless access point separated 10-15m from the next access point on the hallway. The access point can be powered through the switch using Power over Ethernet, making sure the voltage is correct.

Cabling is concise in its use and should be thought about from the early stages. The longest cabling section is to the L2 switch located on the 2nd floor, towards the top right corner for the professors office. The length of this cable is approximately 60m, which falls 40m below the maximum length for an Ethernet cable before it begins to degrade. Cabling to the individual rooms should traverse the false ceilings and be truncated together using cable trunking to keep the space needed for wires small so that it won't take up a lot of space in its routing. There are cabling pathways that make use of the risers situated in the pooled labs and the riser to the top right of the floor plan. This top right-side riser creates the longest estimated cabling for the entire building to the technicians office on the 3rd floor but is estimated to still fall below the 100m limit.

To connect the access points to the network on the 3rd floor, an additional switch will be housed in the technicians office and be configured to create Wireless across the floors. It is unavoidable that cabling will need to use some routing which goes past the second floor lifts, but on the 3rd floor care is taken to make it so that as little as possible of the cable routing passes the lift. Through the use of Cat 6A shielded cabling, the hope is that potential EMI is prevented and thus no issues come up from this, but consideration has still been taken to avoid using cabling routing that passes these lifts where possible. The offices for the other departments are not covered by the physical cabling but they are supported by the wireless solution. It is important to note the cabling measurements are purely estimates and measurements for the building are recommended before any cabling is purchased.

Due to the range of the access points, they will be placed near each other relative to around 10-12 squared metres to maintain coverage from one access point to another. For switch locations, the floor plan shows where the switches could be located and where the wiring to them would be. Most switches have been placed in their own rooms, which would then be situated within a wall mounted cabinet that allows space for any upgrades in the future. This is done to provide an easy way to see how the structure of the physical plan looks on the diagram, but there is argument in some cases to have some switches bundled with other close by switches to lower the cost and need for these cabinets.

Logical Infrastructure Deployment

With everything selected it is possible to consider a logical deployment for the network. The diagram for this focuses on enabling redundancy and spanning tree protocol to avoid a broadcast storm happening when data is transferred too rapidly between the switches, where the avenue for multiple switches leads to pathways being shut off the alleviate this issue. At the entry layer the Internet enters the network and passes through an external firewall. This firewall is needed to protect the network, but there is also need for another internal firewall that protects access after the router in case of a breach through the network. This firewall is added to strengthen the network from a breach from inside the network. Moving into the distribution layer, the use of 4 switches using a mesh style is recommended to allow protection against redundancy, whilst the higher level L3 switches are necessary to allow for inter-VLAN routing and VACLs to be used.

The main 4 switches are configured for the spanning tree protocol but can also be configured with VACLs to stop inter-VLAN communication. The logical diagram aims to give a rough estimate on the amount of switches needed for network deployment, but it is not possible to show all devices that may be connected as well, which is why the physical network diagram to show where this equipment will be housed and how much cabling is expected to be required is also important.

The difference between the physical deployment and logical deployment is regarding the number of computers connected to each individual switch, to which VLAN these switches are connected to and where all network connections start and end. The logical diagram in the appendix aims to show the overall layout of the network, showing the number of expected switches for the network, whilst also showing which VLAN each switch is found on. The access points connect to a single switch that is located on each individual floor located itself on the shared VLAN. This diagram helps to show how the network will be set up and which switches are on which VLAN.

Evaluation

The organisation and initial planning of the infrastructure for the university building was difficult initially due to some misunderstanding and through a lack of knowledge. The infrastructure for the network follows a well-known and well recommended hierarchical structure. The three-layer network design is successful in considering all aspects of the networks creation, considering costs, floor plan limitations and overall estimations for maximum throughput for a network of this size.

Considerations for cost are just, where there has been effort to make sure that the network is suitable to the task and covers issues of redundancy to avoid issues with network loss through equipment or logical failures that are unavoidable. Cost breakdown using the equipment table aim to show briefly how much things cost and considers approximations for measurements.

To conclude, aspects of the network are considered throughout where justification is used to make sure that any decisions are understood and make sense for a network infrastructure of this size. Floor plan diagrams and logical diagrams are presented to give a more visual approach and justify some of the decisions made when going through the initial layout for equipment and cabling. Cabling considerations were one of the most important aspects of the report, as choosing a solution that meant cables exceeded the 100m range of Ethernet would mean more would need to be spent on repeaters, which weaken network signal even across cabling.

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Appendix

Costing

Equipment	**Quantity**	**Price per Unit Inc. VAT**	**Reseller**
Juniper MX204-IR Router	1	Approx. £19,678.08	It-market.com
S5850-48S6Q 48-Port 10Gb SFP+ L3 Managed Ethernet Switch	2	£3,829.20	FS
LC-LC UPC Duplex OM3 Multimode Fibre Patch Lead 2.0mm PVC (OFNR) 5m	75	£6.36	FS
Ubiquiti US-48-500W UniFi 48-Port Layer 2 Managed Gigabit PoE+ Switch w/ 2 x 1GbE SFP Ports & 2 x 10GbE SFP+ Ports (500W) 1U high	20	£773.58	Broadband buyer.com
Ubiquiti US-24-500W UniFi 24-Port Layer 2 Managed Gigabit PoE+ Switch w/ 2 x SFP Ports (500W) 1U high	11	£550.00	Broadband buyer.com
Juniper Networks QSFPP-40GBASE-SR4 Compatible 40GBASE-SR4 QSFP+ 850nm 150m MTP/MPO DOM Transceiver Module	8	£42.00	FS
FS for Juniper Networks EX-SFP-10GE-T Compatible, 10GBASE-T SFP+ Copper RJ-45 30m Transceiver Module (JU)	34	£62.60	FS
UniFi UAP-AC-PRO up to 1750 Mbps	55	Approx. £120.10	Direct
EssCable CAT6A Solid S/FTP LSZH Ethernet Cable, Violet, 500m Reel (Low Smoke)	6	£240.00	Broadband buyer.com
CAT5e 305m Networking/Ethernet Cable	40	£23.99	Amazon
Belkin RJ45 Modular Connector 25 pack	100	£1.97	Amazon
15U FREE STANDING DATA CABINET 600 X 600	1	£210.00	Orion
RackyRax 550mm Deep Wall Mounted Data Cabinet	22	£58.80	Cable Monkey
Mini Trunking 3m 25 x 16mm	75	£2.50	Pro-Fix
CertaUPS C400 3kVA UPS 60 mins	1	£1489.50	Server Room Environments
	TOTAL:	£64,182.18	

Equipment Links

Equipment Name	Equipment Link
Juniper MX204-IR Router	https://www.it-market.com/en/juniper-mx204-ir1?var=6
S5850-48S6Q 48-Port 10Gb SFP+ L3 Managed Ethernet Switch	https://www.fs.com/uk/products/29123.html
LC-LC UPC Duplex OM3 Multimode Fibre Patch Lead 2.0mm PVC (OFNR) 5m	https://www.fs.com/uk/products/41727.html
Ubiquiti US-48-500W UniFi 48-Port Layer 2 Managed Gigabit PoE+ Switch w/ 2 x 1GbE SFP Ports & 2 x 10GbE SFP+ Ports (500W) 1U high	https://www.broadbandbuyer.com/products/19928-ubiquiti-us-48-500w/?gclid=CjwKCAjwkun1BRAIEiwA2mJRWUxrtiWwQ4h3d20_PESjdCQ9UsF4vYgm46db95xAK4smKT52QRnUrBoC9tQQAvD_BwE
Ubiquiti US-24-500W UniFi 24-Port Layer 2 Managed Gigabit PoE+ Switch w/ 2 x SFP Ports (500W) 1U high	https://www.broadbandbuyer.com/products/19926-ubiquiti-us-24-500w/
Juniper Networks QSFPP-40GBASE-SR4 Compatible 40GBASE-SR4 QSFP+ 850nm 150m MTP/MPO DOM Transceiver Module	https://www.fs.com/uk/products/36439.html?fbclid=IwAR0M4fO-LgOxLeC2Gat9WvKX1Prb8V4WPGsXYqgyXFNNwpfmvXiAqGfAYe4
FS for Juniper Networks EX-SFP-10GE-T Compatible, 10GBASE-T SFP+ Copper RJ-45 30m Transceiver Module (JU)	https://www.fs.com/uk/products/73107.html?gclid=CjwKCAjwte71BRBCEiwAU_V9h4x4X_i0HIU7x_VvSmaRICFCVpzpSaTLk8n2ztdSBB0nEw-SHzKpjBoCl6wQAvD_BwE
UniFi UAP-AC-PRO up to 1750 Mbps	https://store.ui.com/collections/unifi-network-access-points/products/unifi-ac-pro
EssCable CAT6A Solid S/FTP LSZH Ethernet Cable, Violet, 500m Reel (Low Smoke)	https://www.broadbandbuyer.com/products/21536-esscable-tri-c6a-s-ftp-500/
CAT5e 305m Networking/Ethernet Cable	https://www.amazon.co.uk/CAT5e-305m-Networking-Ethernet-Cable-grey/dp/B00L3BR7K6
Belkin RJ45 Modular Connector 25 pack	https://www.amazon.co.uk/Belkin-RJ45-Modular-Connector-Pack/dp/B00004Z5TO/ref=sr_1_2?dchild=1&keywords=Belkin+RJ45+Modular+Connector+25+pack&qid=1589308863&s=electronics&sr=1-2
15U FREE STANDING DATA CABINET 600 X 600	https://www.rackcabinets.co.uk/products/15u-free-standing-data-cabinet-600-x-600?variant=28422521946184&gclid=Cj0KCQjwzN71BRCOARIsAF8pjfgocYqfQjFnNXN_MNK1y6fI3r8oDcO5KsSxTteTnnImR1Q42GixYhoaAio9EALw_wcB
RackyRax 550mm Deep Wall Mounted Data Cabinet	https://www.cablemonkey.co.uk/data-cabinets/88920-550mm-deep-wall-mounted-data-cabinet.html?ipa=191613&gclid=Cj0KCQjwzN71BRCOARIsAF8pjfiXCv-3bVkPAWrgb6DaTZ15LXjzjSESg2U84TU3UgcqOPeSenC1eqMaAgI2EALw_wcB#/682-build-assembled/2791-locking_side_panels_rr_l2_-no/2933-height-6u/2969-width-550mm
Mini Trunking 3m 25 x 16mm	https://www.toolstation.com/mini-trunking-3m/p44772?store=H5&utm_source=googleshopping&utm_medium=feed&utm_campaign=googleshoppingfeed&gclid=Cj0KCQjwzN71BRCOARIsAF8pjfiJvtGWUYV0WtLUJPgUJFHnGy4MKAvzcKPeJSkS9tmsdDGRLdNehWQaAn00EALw_wcB
CertaUPS C400 3kVA UPS 60 mins	https://www.serverroomenvironments.co.uk/certaups-c400-3kva-ups

Utilisation - Wired

Building Throughput Needs	Aggregate Throughput (Number of wired devices / internet speed)
General Throughput (25mbps)	715 * 25 = 17.875gbps
High Throughput (100mbps)	715 * 100 = 71.5gbps

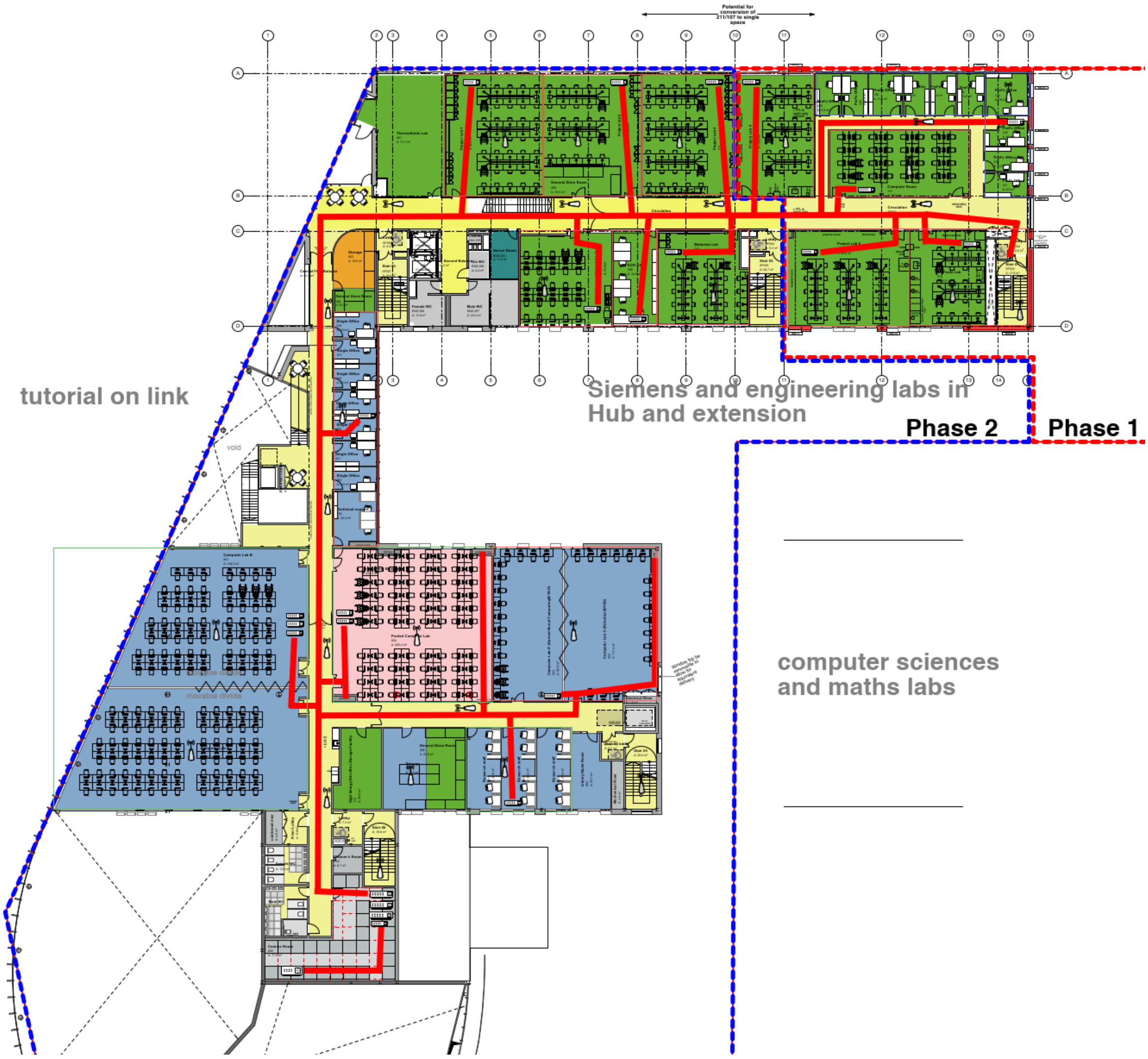
Utilisation – Access Points

User Throughput Needs	Max Users (AP Throughput / Throughput per User)	Serviceable Users per AP (Users per AP / Active Users) Low Activity (25%)	Serviceable Users per AP (Users per AP / Active Users) High Activity (50%)	Serviceable Area Serviceable Users per AP / WiFi-Adoption)
General Throughput (5mbps)	1750 / 5 = 350	350 / 0.25 = 1400	350 / 0.50 = 700	700 / 0.70 = 1000
High Throughput (100mbps)	1750 / 100 = 17	17 / 0.25 = 68	17 / 0.50 = 34	34 / 0.70 = 48

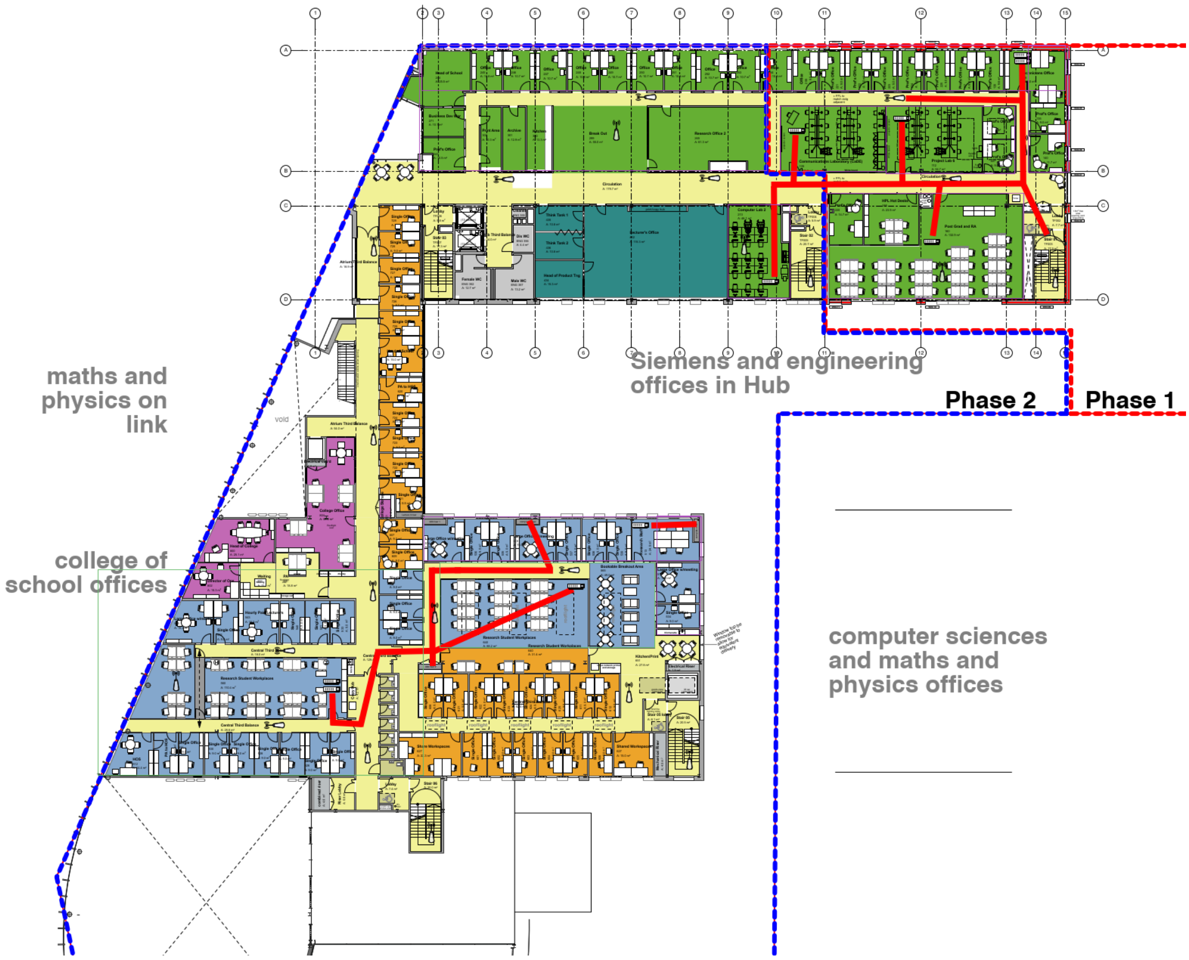
Wired Connections per Room Estimates

Second Floor Room Name	Quantity	Third Floor Room Name	Quantity
Computer Science Labs A + B	133	Lower Left Comp	15
Pooled Lab	80	Lower Left Research	29
Computer Science Labs C + D	31	Lower Right Comp	12
Project Lab 1	35	Lower Right Research	28
Project Lab 2	25	Upper Offices	29
Project Lab 3	35	CaDe	18
Project Lab 4	24	Project Lab 6	16
Project Lab 5	30	Post Grad and RA	36
Computer Room 1	32	Computer Lab 2	15
Bio Fuels Lab	20		
ECR Offices	6		
Materials Lab	25		
Lower Research	12		
Tech Support and Offices	9		
Upper Prof’s Offices	20		
Total:	**517**	**Total:**	**198**

Adjusted Floor Plan – 2nd Floor



Adjusted Floor Plan – 3rd Floor



Logical Topology Diagram