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Networking Infrastructure Report

Task Breakdown

The task set was to design a network and wireless solution for the engineering and computing departments in two stories of a university building. Including justification and cost for components.

There were three main elements to this task: network design, physical design and equipment selection.

The network design portion consisted of devising the topology, which would determine how devices would be connected to the network. Including what switch, or stack they would be connected to, and how these stacks would cover various areas of the building.

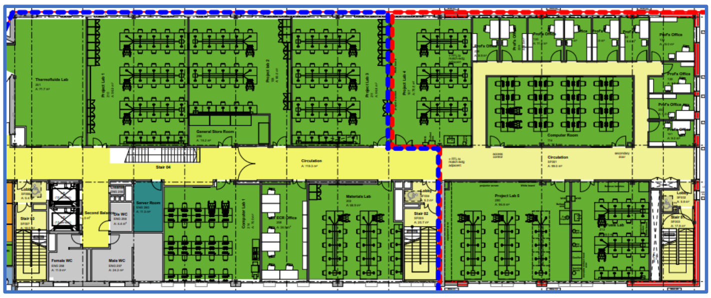
The physical design part of the task entailed developing the most efficient placement of switch cabinets and cabling throughout the building. With regards to cost, the locations of devices they would be connected to, and the communications room, which would function as the central hub for all connections. Also included was the placement of routers, with thought to their coverage, and necessary bandwidth, based on maximum likely load.

Equipment selection involves evaluating what equipment is necessary to create a solid, functioning network. As well as which upgrades are worth the cost, to achieve better functionality.

Floorplan analysis

When initially inspecting the floorplans, it was noted that all rooms were already grouped by department (see fig. 1). This made it easy to define areas, without having to worry about workstations on the same subnet requiring different software. Meaning that the main factors would be location, and number of workstations.

Fig. 1 – Areas 1-4



There were multiple risers available to run cables between floors. The locations of these risers were heavily considered when deciding the placement of switch cabinets, as a way to reduce the amount of cabling needed, and thus costs.

Assumptions

It was assumed that each room would require the same amount of connections as workstations, as such, any room without a workstation was excluded from area assignments and network diagrams. An expansion of this project would be to investigate the additional necessary and luxury connections available, including social/break areas, spare ethernet ports, lecturer computers, etc.

Another assumption was that the main router would reside in communications room on the second floor. As such, both the design and topology were centred around this room.

The final assumption was that the wireless network's maximum likely load would consist of full labs, offices and workspaces, as well as students roaming the corridors.

Area Specification

Initially, each room containing a workstation was grouped into an area, based on number of workstations, department, and physical location. By organising rooms in this way, the amount of switch cabinets used can be minimized.

The aim was to have each area contain a fairly large number of workstations, but not so many that a minor network error would affect a large proportion of the site. Providing a healthy balance between cost and reliability.

Areas 1 - 9 cover the second floor, and the last 3 areas cover the third floor: beginning in the top right corner, moving to the top left, and following the building around to the bottom right. This method results in groups of rooms in close proximity, allowing cabinets to be easily placed in such a way, that they can sustain multiple areas, with minimal cabling.

Fig. 2 - Initial Area Allocation

Area	Room/Sector
1	prof offices
	p lab 4
	c room
2	fuels lab
	p lab 5
3	mat lab
	c lab 1
	ecr
4	p lab 3
	p lab 2
	p lab 1
5	c lab b top
6	offices/tech support
	c lab b bottom
7	pooled lab
8	comp lab d
	comp lab c
	research
9	offices
	comms lab
	p lab 6
10	c lab 2
	hpl desks & office
	post grad
11	research workplace west
	west offices
	east offices
	research staff
	research workplace east

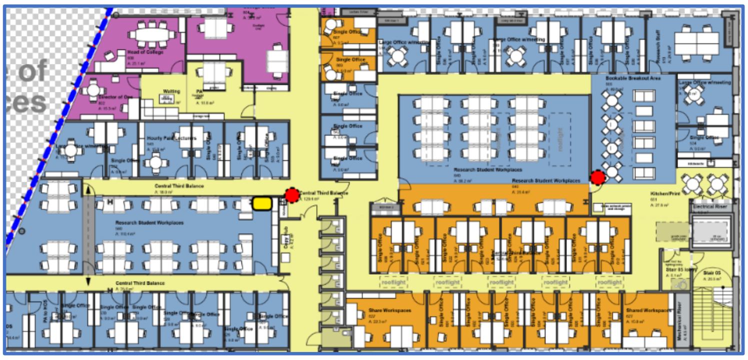
Floor 3 has fewer areas, due to a lack of workstations, compared to Floor 2, allowing each area to cover more physical space.

The only alteration to this initial allocation, was during the physical planning phase, due to area 11 being unnecessarily large. To combat this, the east and west portions of area 11 were separated into two areas. This separation would reduce load, and increase reliability. However, the main reason for the decision was to save on costs, by significantly reducing the amount of cabling between the cabinet, which was to be located on the east side, and the workstations in the west.

Fig. 3 – Updated Allocation

11	research workplace west
	west offices
12	east offices
	research staff
	research workplace east

Fig. 4 – Areas 11 and 12



Network Diagram Iterations

After creating groups, the next step was to represent these groups in a network diagram. For this project, Cisco Packet Tracer was used, due to previous experience with the product.

Initially, the centre of the network was represented by one router and one core switch, which would connect to each area's stack. In these stacks, each room was allocated one switch, for simplicity. This would be later be changed, to represent the number of switches that would be required in a real-world scenario.

Appendix 1 and 2 show the first two iterations of the diagram. first with Floor 2, then with the addition of Floor 3.

When Floor 3 had been fully mapped, the initial connections to the core were implemented, (as seen in Appendix 2) these connections did not correctly represent the necessary order of the stacks. However, before deciding the order of the stacks, (it was necessary) to deduce the lowest number of switches required, for the amount of ports needed.

This entailed grouping smaller rooms in an area onto one switch, allocating larger rooms multiple switches, and/or larger switches, as well as considering combining or separating areas. Fig. 4 shows the final switch allocation, which resulted in 22 switches, down from 29. 17 of these would be 48 port switches, and the 5 others would be 24 port switches.

Fig. 4 – Switch Allocations

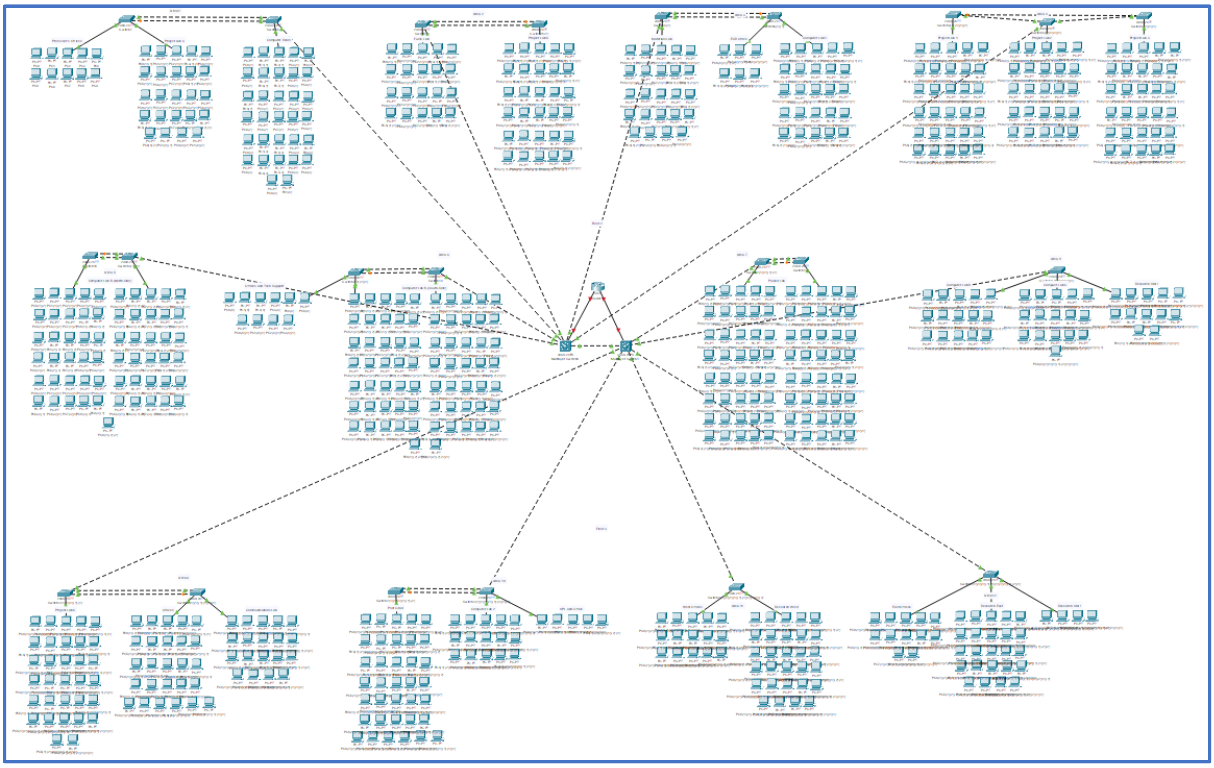
Area	Room/Sector	Workstations	Switch Ports	Ports Left
1	prof offices	10	\/	N/A
	p lab 4	24	48	14
	c room	32	48	16
2	fuels lab	20	24	4
	p lab 5	30	48	18
3	mat lab	24	24	0
	c lab 1	25	48	17
	ecr	6	^	N/A
4	p lab 3	35	48	12
	p lab 2	25	24 + ^	0
	p lab 1	35	48	13
5	c lab b top	61	48 + 24	9
6	offices/tech support	9	\/	N/A
	c lab b bottom	72	48 + 48	1
7	pooled lab	80	48 + 48	16
8	comp lab d	15	48	5
	comp lab c	16	^	N/A
	research	12	^	N/A
9	offices	26	48	3
	comms lab	19	^	N/A
	p lab 6	32	48	16
10	c lab 2	15	24	4
	hpl desks & office	5	^	N/A
	post grad	36	48	12
11	research workplace west	29	48	4
	west offices	15	^	N/A
	east offices	12	\/	N/A
	research staff	4	\/	N/A
	research workplace east	24	48	8

The next job undertaken was deciding the order of the stacks, however it seemed that the order was mostly irrelevant. Although, a Cisco forum post revealed there may be a slight performance advantage to using a 24 port switch over a 48 port switch as a stack master, due to it having less ports to manage. (Doherty, 2014) Although this claim is dubious, there seemed to be no disadvantage in following it, so the stack order was mostly decided based on using smaller switches as masters.

A realisation was soon made, that one core switch can only support eight stacks, so another was added. After this addition, and the split of Area 11 (covered later), the resulting diagram was Fig. 5.

An important element to note is that each switch has been linked to its stack with multiple cables. This is a redundancy measure, allowing the network to still function, at a reduced speed, if one cable becomes faulty.

Fig. 5 – Final Stack Ordering and Connections



Topology Analysis

This final topology could be compared to star and tree topologies, it aims to minimise disruption with its segmentation, whilst still retaining a large degree of connectivity.

The relation to the star topology is the central core switches, which, if compromised, could result in large portions of the network being taken down. However, this effect is reduced by spreading the load across two core switches, rather than one.

The relation to the bus topology is the high speed SFP+ cables that connect the stacks to the core switches. These cables, called buses, carry the data for the connections of all the workstations in the stack at the same time, instead of just the data for one connection. The advantage of this topology is speed; however, the bus could be a bottleneck if it must serve too many connections.

A combination of these topologies is called a tree network, this is where multiple star networks, known as leaves, are connected by high speed buses, known as branches. This topology makes the most of the advantages of both the star topology and bus topology, whilst increasing the network's reliability, and reducing the bandwidth on the buses, by having multiple. The tree topology is extremely close to the topology which has been produced for this project.

Cabling, Cabinet and WAP Placement

The most important element of cabinet placement was cost. This would equate to a balance between the amount of Areas covered, and the amount of cabling needed. It was decided that the cheapest, most efficient cabinet layout would involve five cabinets.

Fig. 6 – Cabinet Location Spreadsheet

Switch Cabinet Location	Areas Covered	Units needed	Cabinet Size (u)	Spare Units	Risers Used
project lab 5	a1, a2, a9, a10	8	10	2	plec riser
computer lab 1	a3, a4	5	8	3	
computer lab b	a5, a6, a7	6	8	2	
computer lab d	a8, a12	2	4	2	mech riser
research west	a11	1	4	3	combined riser

The first cabinet would be placed in Project Lab 5 on the north east side of Floor 2, a central location, to cover Areas 1 and 2. As well as delivering connections through the Plec Riser to Areas 9 and 10 on the floor above.

Fig. 7 – Cabinets 1 and 2

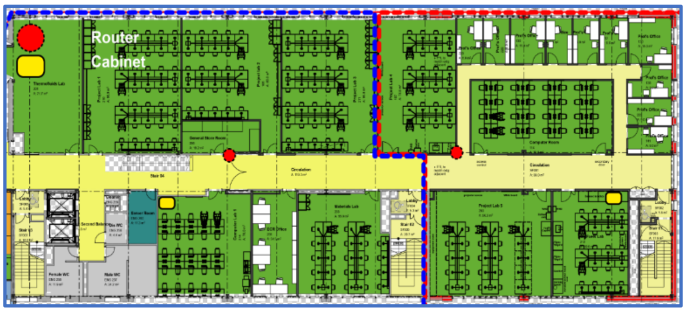
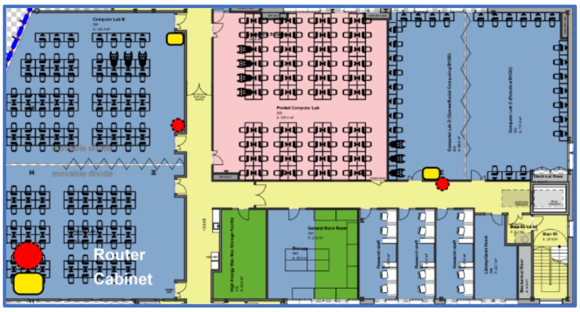


Fig. 8 – Cabinets 3 and 4



Cabinet 2 would reside in Computer Lab 1, on the north west side of the second floor. It would provide connections for Areas 3 and 4.

Cabinet 3 was placed in Computer Lab B, on the south west side of Floor 2. It would cover Areas 5, 6 and 7, a large chunk of Floor 2.

The fourth cabinet was placed on the south east side of the second floor, in Computer Lab D. It would cover Area 8, and utilize the nearby Electrical Riser to provide connections to Area 12.

The fifth cabinet would be placed in the west Research Student Workspace, this cabinet would cover Area 3. Using the Combined Riser in the south to access the communications room.

Wiring would primarily be routed through the hollow ceiling, and down the walls, directly to workstations, etc. Fibre (SFP+) cables would be used to link the core switches and central router, similarly to a bus topology. Whilst regular SFP cables would link the switches in each stack together. Then Cat5e cables would be used to connect the switches directly to workstations and WAPs.

Using singular SFP+ cables in a bus fashion results in higher speeds, and less weight than multiple Cat5e cables, whilst also requiring less ports. This could result in a bottleneck if a large amount of bandwidth were required at once, although this is unlikely, due to the small stacks in this topology.

The SFP cables will be used in the slower, 1 Gigabit SFP ports, to communicate between the switches and the core switches. This is necessary because, SFP+ cables cannot communicate at speeds lower than 1 Gigabit.

Cat5e cables were selected to connect to devices, because the devices do not require the high speeds that SFP provides, allowing a large saving on cost.

The splitting of Area 11 did not switch allocation, only the location of the cabinet holding Area 12's switches. The reason behind the split was the large amount of space that the area covered, any switch placement would result in excessive cable runs. So, the decision was made to reduce on cabling. This decision would not require an extra cabinet, and would further justify the need for the cabinet in Area 8.

With the knowledge that one router's coverage was required roughly every 150sq meters (Williamson, n.d.), the decision was made to measure the floorspace's area. Then calculate the number of routers required, based on this area.

To do this, the floorspace was split into top, middle and bottom, and measured using the scale provided, from bottom to top. See Fig. 9 for results.

Fig. 9 – Area Measurement Results

Area	Floor Width (m)	Floor Height (m)	Floor Area (m)	Routers Needed	Coverage %		
Bottom	28	12	336	2.24	99.64	(not including slant)	
Middle	4	15	60	0.4	99.4	actually 100	
Top	30	11.8	354	2.36	99.46		
			Total:	10			

It was calculated that roughly five routers would be necessary to provide coverage to an entire floor. The next steps would be to place these routers into central positions, decide which switches they would be connected to, and whether or not they would be powered by PoE.

Appendix 3 and 4 show the final floorplans, featuring the placements of the WAPs. Which would each be connected to a switch in the closet available cabinet.

In the bottom section on Floor 2, the WAPs would connect to the 48 port switch in the Computer Lab D cabinet (A8), and an Area 7 48 port switch in the Computer Lab B cabinet, respectively.

In this section on Floor 3, they would be connected to the 48 port switch in the Computer Lab D (A8), and the 24 port switch in the Research West Cabinet (A11).

In the middle section on Floor 2, the WAP would connect to an Area 7 48 port switch. The WAP in the middle section on Floor 3 would connect to the 48 port switch in Research West (A11).

In the top section on Floor 2, the WAPs would connect to Area 2's 48 port switch, and Area 3's 48 port switch, respectively. In this section of Floor 3, they would both connect to Area 2's 48 port switch.

Equipment and Cost Breakdown

Router

Using an online bandwidth calculator (Anon., n.d.), the estimated bandwidth was 75mb/s, this figure was used as a criteria for router selection. Another necessity was 10Gbe, as this router would be the centre of the entire network, it would need high communication speeds to effectively handle all ~750 workstations as well as mobile devices etc. The router would need to have 2 of these 10Gbe ports, to connect to both of the core switches, otherwise they would need to be daisy chained. This would route all of the load through one of the core switches, making responsible for the entire network.

The model was decided on was the ASR1001-X, which would cost £4,335.78, with a 78% discount (Anon., 2020). It is a mid-high range router, with high bandwidth, memory and processing power. It features 2 SFP+ ports, which would connect to the core switches, as well as 6 regular SFP ports. This router may be overkill, but it was difficult to find routers with SFE+ ports.

Switches

There needed to be a selection of 48 and 24 port switches, to account for both the smaller and larger stacks. The ports would need to be at least 1GbE, and they would potentially need to support PoE, dependant on cost. Flexstack, a Cisco technology to improve stacking performance, was considered, but proved too costly, and it was unclear how much it could improve performance.

The 48 port model that was decided on was the WS-C2960S-48TS-L, which would cost £283.96, at a 93% discount (Anon., 2020). 17 of these were needed, which would equate to £4827.32.

It's a mid-range, end of life switch, which is very reputable and widely used. It features 48 1GbE ports, as well as 4 SFP ports, which would be used to connect to the core switches, and the switches within stacks. It may be end of life, but it is still very powerful, and will easily suit the needs of the university.

The 24 port model that was decided on was the WS-C2960S-24TS-S, which would cost £217.54 at an 87% discount (Anon., 2020). 6 were needed, which would cost 1305.24. It is very similar to the chosen 48 port switch, due to it being in the same line of products. It features 24 1GbE ports as well as 2 SFE ports, and is again a powerful switch, with the capability to suit the university's needs.

Neither of these switches support PoE, as the price difference was too large to justify, between PoE and non-PoE models. The 48 port PoE model cost ~£500 more (Anon., 2020), and the 24 port PoE model cost ~£250 more (Anon., 2020). The luxury would definitely not be the cost.

Core Switches

The multilayer, or core, switches would be responsible for connecting the router to the all of the stacks. They would each need at least 6 SFE ports to the stacks, and two SFE+ ports to connect to the router, and each other, for redundancy.

There was a limited selection of switches with two SFE+ ports, as well as an extra 6 SFE ports. So, the cheapest solution was to purchase 12 SFP port switches, in addition to 10 Gigabit SFE+ modules. The switch model selected was the WS-C3850-12S-S, available for £2068.26 (Anon., 2020), and the chosen network expansion module was the C3850-NM-2-10G, which cost £467.45. In total, two of each would cost £5071.42.

The 3850 is a powerful switch, designed for medium to large scale operations, with a large amount of memory and high bandwidth. The additional expansion module provides it with the 10Gb speeds to better take advantage of the router.

WAPs

The maximum number of wireless users possible would be roughly 800, assuming one at every workstation, and 50 in corridor spaces. However, taking into account that only 75% of these users would connect to the WAPs, and that only 25% of those people would be actively using it at one time (Williamson, n.d.), those 800 concurrent users would be reduced to 150 concurrent users, which would be the aimed amount of serviceable users.

The selected WAP model was the AIR-AP1815I-E-K9, which costs £179.99 (Anon., 2020), 10 were required, costing 1799.99. This WAP is a mid-range model designed for medium size businesses, which, in the proposed configuration should be able to handle the target of 150 concurrent users.

One of this WAP's defining features is called 'Mobility Express' which allows for a WLAN to be configured using only the access points, without the need for a wireless controller. Making it easier to configure, and saving on costs.

Cabinets

There would need to be a variety of cabinet sizes, due to the differing number of switches/stacks per cabinet. Future expansion was considered whilst deciding which cabinets to buy. There needed to be room for extra switches and airflow. However, due to the already high utilization of the space, a large number of spare units would not be necessary. It was assumed that the communications room was already equipped with the necessary racks and mounts.

Three models were decided on, in 4u, 9u and 12u sizes. All of the models are affordable and secure, with a large amount of extra space, for airflow, and cable management.

The 4u model costs £55.98 (Anon., 2020), the 9u model costs £87.08 (Anon., 2020), and the 12u model costs 101.85 (Anon., 2020). Two 4u cabinets, two 9u cabinets and one 12u cabinet come to a total of £387.97.

Cabling

As mentioned earlier, the network would use a combination of Cat5e (UTP), SFE and SFE+. SFE and SFE+ transceivers were already included with the router and switches, so only the cables needed to be purchased.

OM4 cables were selected, due to their high bandwidth, data transfer rate, and range. All of these cables were purchasable in custom lengths (Anon., 2020).

3 0.5m OM4 fibre cables would be required to connect the core switches and the router, as well as 19, to connect the switches within the stacks. These cost £2.76 each, so 21 cables would cost £57.96.

12 more fibre cables of differing lengths would be required to connect the core switches to the stacks. Fig. 10 shows the required lengths and costs.

Fig. 10 – Core to Stack Cable Prices

Switch Cabinet Location	Distance to Switch (m)	Cable Length	Cable Type	Cost (£)
project lab 5	57	60	OM4	32.05
computer lab 1	40	45	OM4	25.03
computer lab b	15	17	OM4	11.93
computer lab d	21	25	OM4	15.67
research west	7	10	OM4	8.76
			Total	93.44

The network would feature 748 workstations, and 10 WAPs, which would all require Cat5e cables, in varying lengths. To break down the total length required, the distance from the switch to the furthest workstation in a sector was measured. This distance was rounded up, to account for cable management, and designated as that sector's cable length. The resulting length was multiplied by the number of workstations in the sector, producing the required length.

Each sector's needed cable length was then added together, alongside the lengths needed for the WAPs. Resulting in a total of 1405 meters. See Appendix 5 and 6 for the spreadsheet of calculations.

The largest reels of Cat5e available were 305m, at £59.99 (Anon., 2020). Five reels would be required, costing £299.95. RJ45 plugs were also necessary, two for each cable, so or 758 cables, 1516 connectors were required. These connectors were sold in multiples of 100 or 500, 1600 units totalled £133.20 (Anon., 2020).

Cost Analysis

The total cost for the proposed solution is £19234.07 (see Appendix 7 for breakdown). Cost saving was a huge element of this solution, so a large number of the suggested products are end of life, or discounted. The router was very expensive in comparison to the other items, maybe unnecessarily so, however it seemed to be the only one to suit the topology.

Reflection

Overall, the proposed solution is affordable and powerful, with a suitable amount of future proofing, considering the current utilization of the building. It also features some redundancy measures within the stacks, and between the router and cores, which should enable the system to remain active during technical difficulties.

In retrospect, there may be more ideal components for the job, but the recommend items should do the job to a good standard. If I were to re-do this project, the main change I would make would be including SFE+ switches and connections within stacks and between them and the cores. As well as this, I would expand the wireless solution. In particular, increasing the number of wireless access points, because further research shows that a much larger amount is needed to actively support the estimated number of users.

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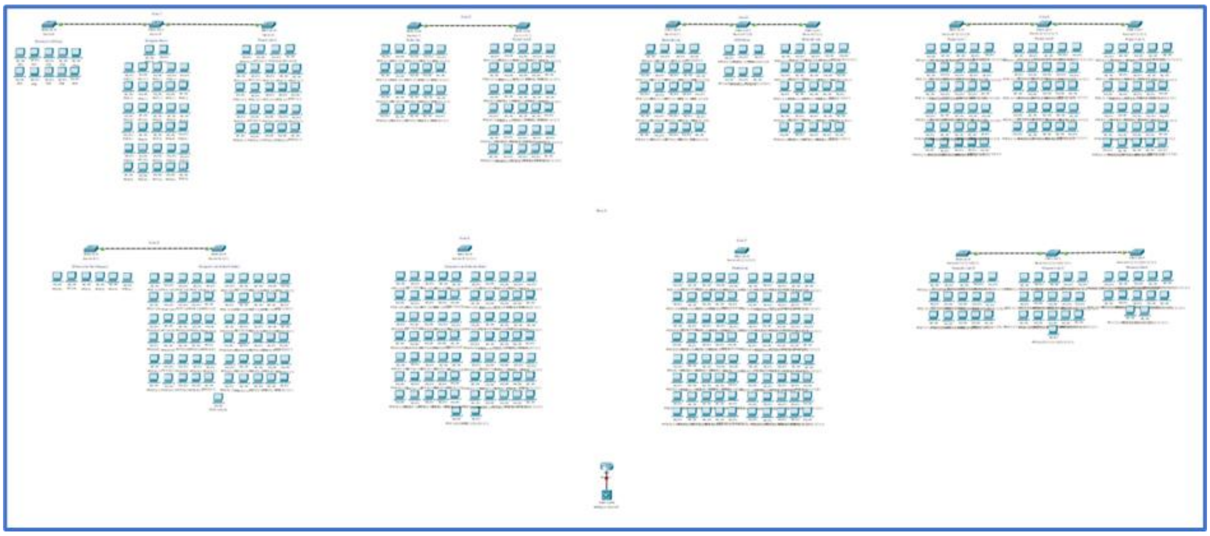
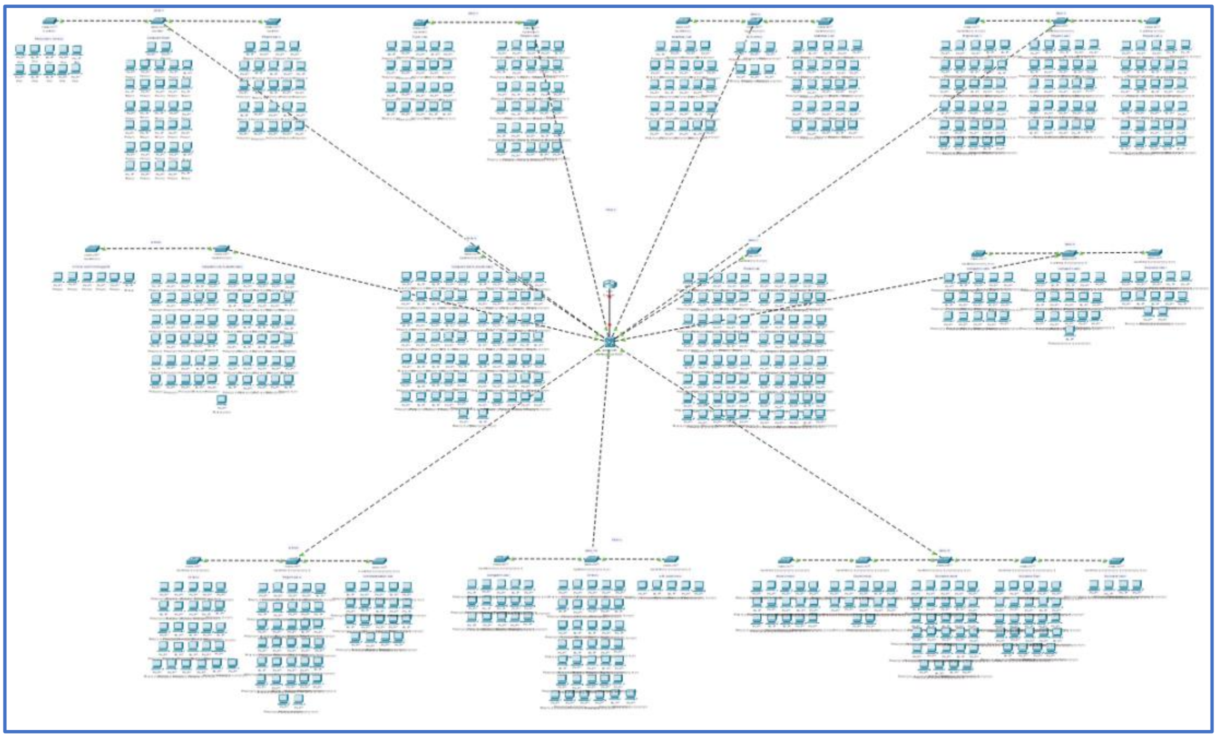
Appendix

1 - Initial Floor 2 Diagram



2 - Initial Floor 3 Diagram



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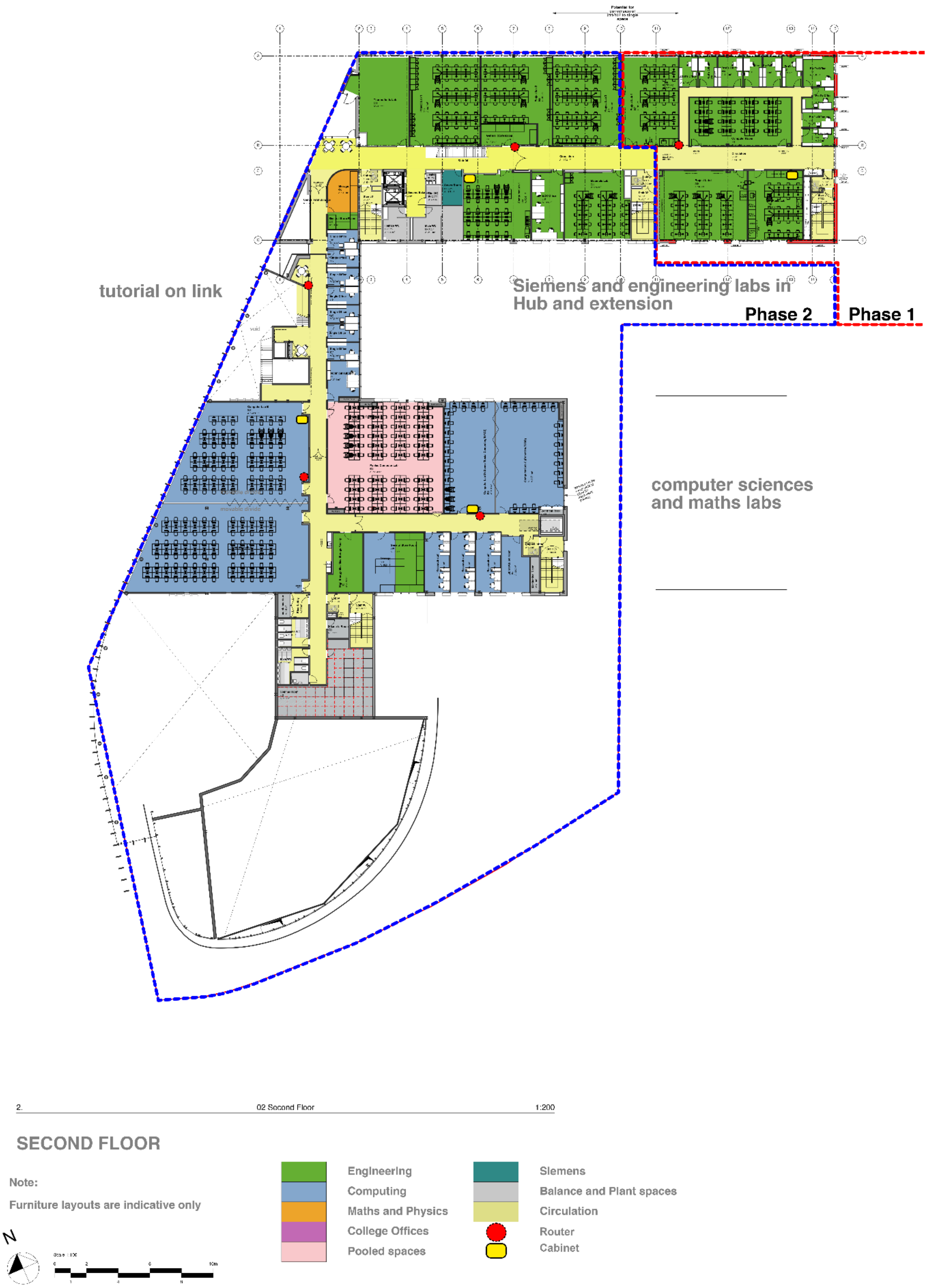
3 - Final Floor 2 Floorplan



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4 - Final Floor 3 Floorplan

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5 – Cat5e Length Calculation Spreadsheet (Workstations)

Area	Room/Sector	Cabinet	Cable Length	Quantity	Length Needed (m)
1	prof offices	1	20	10	30
	p lab 4	1	20	24	44
	c room	1	10	32	42
2	fuels lab	1	5	20	25
	p lab 5	1	15	30	45
3	mat lab	2	15	24	39
	c lab 1	2	5	25	30
	ecr	2	10	6	16
4	p lab 3	2	20	35	55
	p lab 2	2	15	25	40
	p lab 1	2	15	35	50
5	c lab b top	3	10	61	71
6	offices/tech support	3	15	9	24
	c lab b bottom	3	20	72	92
7	pooled lab	3	15	80	95
8	comp lab d	4	10	15	25
	comp lab c	4	10	16	26
	research	4	10	12	22
9	offices east	1	25	17	42
	offices west	1	45	9	54
	comms lab	1	20	19	39
	p lab 6	1	20	32	52
10	c lab 2	1	25	15	40
	hpl desks & office	1	15	5	20
	post grad	1	20	36	56
11	research workplace west	5	10	29	39
	west offices	5	20	15	35
12	east offices	5	25	12	37
	research staff	4	25	4	29
	research workplace east	4	35	24	59
				Total	1273
				Total Including WAPs	1405

6 – Cat5e Length Calculation Spreadsheet (WAPs)

WAP (Floor/Area/Side)	Cable Length (M)
2BE	2
2BW	5
2M	10
2TE	10
2TW	5
3BE	20
3BW	10
3M	35
3TE	10
3TW	25
	132

7 – Table of Costs

Product	Quantity	Cost Per Unit (£)	Total (£)
Router	1	4,335.78	4335.78
Switch 24P	6	217.54	1305.24
Switch 48P	17	283.96	4827.32
Core Switch	2	2068.26	4136.52
SFE+ Module	2	467.45	934.9
WAP	10	179.99	1799.9
4u Cab	2	55.98	111.96
9u Cab	2	87.08	174.16
12u Cab	1	109.85	109.85
Fibre	See Fig. 10	See Fig. 10	93.44
Cat5e	See App. 7	See App. 7	1405
			19234.07