LAN Design for our
Apartment Complex
In Muscat, Oman

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Description of the Area (Refer the end for birdsview layout)

- The area for which we will be designing the LAN consists of a huge apartment complex of 9 floors with 15 apartments each.
- There are six lifts per building.
- Each floor has 6 security cameras.
- Each apartment has 3 smoke machines.
- Each apartment has a builtin device via which it can connect to the LAN.
- There is also a common area that has a swimming pool, tennis court, table tennis court, and a grocery store.
- The grocery store is present on the ground floor.
- There is a distance of 20 m between two consecutive apartments.
- There is also a security guard and a server room on the ground floor.

Use Cases of the LAN

1. There are security cameras placed at various locations on each floor. This audio and video from these cameras need to be continuously streamed to the guards on the ground floor.
2. Each home has a fire alarm. In case the alarm goes off in any apartment, all other apartments in the building must get alerted as well.
3. If anyone wishes to order groceries, they should be able to ping the server in the grocery store and browse to find out what quantities and items are available, then place an order.

4. There should be a broadcast message facility available to each home. There should be the ability to multicast a message according to the floor number.
5. Booking of slots to use the tennis court and table tennis court.

Topological Design

Smoke Detectors:

Each apartment has 3 smoke detectors. Each smoke detector of each apartment will be connected to a switch via a star topology. For every 5 apartments there will be a switch. This means 3 such switches per floor, with 5*3 = 15 connections to each switch.

Cameras:

Each floor has 6 cameras. We already have 3 switches per floor to which the smoke detectors are connected via star topology. We also connect two cameras per floor to each of the three switches. Thus now each switch is connected to 15 + 2 = 17 devices.

Builtin devices:

There will be a builtin device in each apartment. The functionality of this is that users can use it to be able to access the LAN via which they can send messages to other users and also connect to the server on the ground floor which facilitates slot booking. There are 3 switches per floor as described above. Each of these will be connected to the builtin devices of 5 apartments (the same to which the smoke detector ports are connected). Thus now each switch is connected to 17 + 5 = 22 devices.

Now we have 3 switches per floor, which makes 3*9 = 27 switches per building. These switches are connected via mesh topology.

On the ground floor the guard will have a video which is streaming the video feeds of all cameras. There is also a server room on the ground floor which takes care of the slot booking, and a server for the grocery store. These 3 additional devices are connected to the mesh of switches.

Network Topologies available to connect the devices are:

1. **Bus Topology:** In this topology, all the nodes are connected to a single physical cable which becomes the backbone of the network. While this type of topology may be simpler to implement and uses minimal physical resources, the drawback is that the entire network would fail if there is a break in this mail cable.

2. **Ring Topology:** In this topology, each node is connected to two other nodes creating a ring type structure. Although this network does not have a central server and is highly scalable, this too will fail if one of the nodes stop working.

3. **Tree Topology:** In this topology, the nodes form a tree like structure. The network begins at the root and expands to the end nodes. This type of network is highly scalable. However, this topology is also prone to the failure of a single node.

4. **Star Topology:** In this topology, all the nodes are connected to a central point like a hub or a switch. The advantage of this system is that it will not go down if one of the nodes fails. Adding a node is also easy as we just have to add it to the central connection point instead of disrupting the entire network (unlike the previous 2 cases). Due to these advantages, we will be using this topology. One slight disadvantage is that this topology is still prone to failure of the central connection. However it is not necessary to connect all the peripheral devices via mesh since that would increase the cost.

5. **Mesh Topology:** In this topology, all the nodes are connected to one another. With this topology, we overcome all the disadvantages faced with the topologies above. However, one drawback is that it requires a lot of cables to connect all the nodes which is expensive and cumbersome to set up along with its maintenance.

Cables used

Cables available to connect the devices are:

1. **Twisted Pair Cables:** These type of cables consist of two insulated copper wires twisted in a regular spiral/helical form. Here, one wire carries the signal while the other is used as ground reference. If we do not twist the wires, one of the wires will act as an antenna while the other acts as a receiver thus causing interference.
    a. **Shielded Twisted Pair:** In this type of twisted pair cable, the wires are covered with a conductive layer (like a foil) to absorb EM waves from both inside the wire and outside the wire. Due to this, the wires become bulky and costly (which is undesirable). Since these wires are used in harsh climates and my apartment does not have harsh climates, we will not be using this.
    b. **Unshielded Twisted Pair:** In this, we do not use any additional shielding. Due to this, the bulk and cost of the wires is greatly lower (which is desirable). Due to these advantages, we will be using these cables for one of our purposes.

2. **Coaxial cables:** Coaxial cables consist of a copper core surrounded by an insulating material, encased by a cylindrical conductor covered in a protective plastic sheet. Althougth they are not very bulky and have reasonable costs, we will not be using them as they can be slightly insecure and the number of nodes we can connect to them is limited.

3. **Fibre Optic cable:** Fibre optic cables, like electrical cables are used to carry various signals. However, they are made out of optical fibres which are structures containing a glass core surrounded by a glass cadding of lower index. This is the best type of cable when compared to the other cables when it comes to bandwidth (light has a higher frequency), security (the wires cannot be bent easily and thus cannot be fiddled with a lot).
    One of the drawbacks of optical fibres is the installment cost, and the complexity of the installment. For example, I recently upgraded by internet connection to fibre optic and the installment cost was 10 OMR (~2000 INR), which is relatively expensive. A

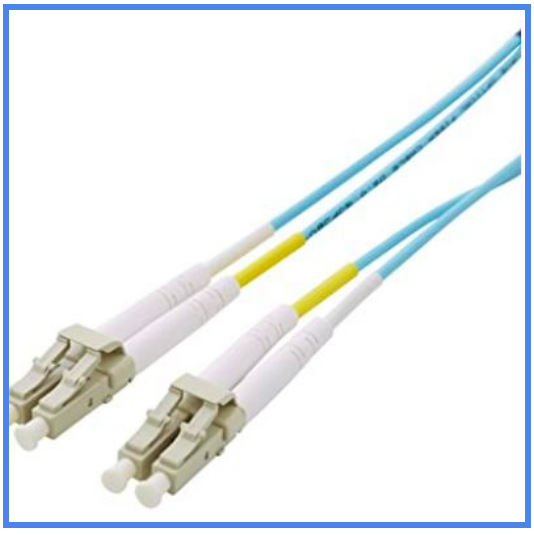
certified technician was also required for the installation. There are two type of optical fibre cables-

a. **Single mode fibre cable**: In this, there is only a single ray in the cable. It acts like a waveguide. Due to the single ray, there is lesser attenuation and thus the ray can travel for longer distances. The cable is cheaper as well due to bulk production. However, the cost of the port is expensive.

b. **Multimode Fibre Cable:** In this, there are multiple waves within a single cable. Due to this, there is interference between these multiple rays and this the rays travel for shorter distances. The cost of the cable is also costlier. However, the cost of the port is lesser when compared to single mode fibre.

To connect the cameras to the switches, we use multimode fibre optic cable. This is because fibre optic cables provide high bandwidth, and security is of utmost importance in the complex. We have decided to use multimode fibre optic cable due to the low cost of the ports. Due to the large number of cameras, we will have a large number of ports. Thus, it is crucial for the cost of the ports to be low. It is okay if the cost of the cable is relatively higher. The audio and video needs to be transferred in real time. For the same purpose, we use optical fibres in connecting the switches across floors when making the mesh topology, and in connecting the guard's computer to the mesh.

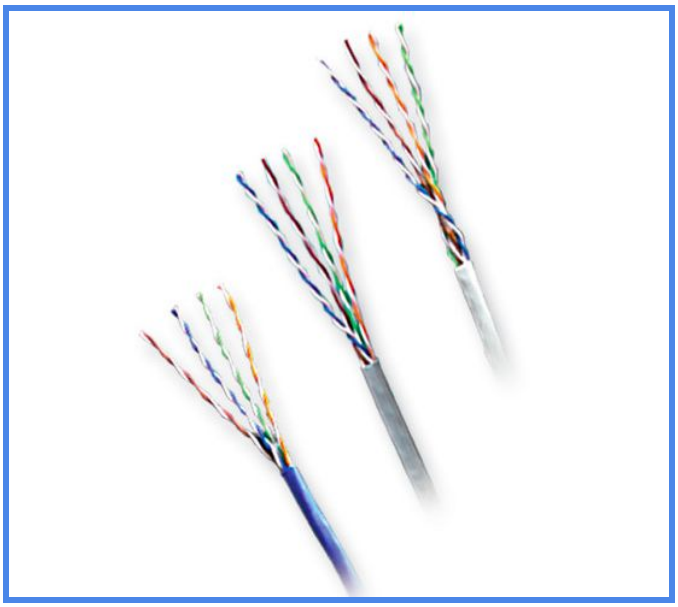
Choice of Device for Fibre Optic Cable



- We have chosen to use the **AmazonBasics 10Gb 40Gb Multimode OM3 Duplex 50/125 OFNP Fiber Patch Cable** for our purpose.
- It supports 10 gigabits or 40 gigabits speed. We will be using the 10 gigabits option as it is supported by our switch as well.

However when it comes to connecting the builtin devices and smoke alarms to the switches, the cable used will be unshielded twisted pair cables. This is because it is cheaper and more flexible. It is suitable for indoor environments, and it will not be used for lengths more than 100m. The data transferred will not be heavy, it will just be a few bytes of message. That is why we will use twisted pair cable for the builtin devices and smoke alarms. We also use twisted pair to connect the grocery store server and the server for slot booking to the switches.

Choice of Device for Twisted Pair Cable



- We have chosen to use the **Honeywell Genesis 4 Unshielded Twisted Pair (UTP) Cat 5e Cable** for our purpose.

Networking Devices

1. **Hub:** The hub operates at the physical layer and does not understand ethernet frames or MAC addresses. It creates the network with a physical star topology but a logical bus topology.
2. **Switch:** The switch operates at the data link layer. It, on the other hand, does understand the ethernet frame and the MAC address. It creates a network with a physical star topology and a logical star/tree topology.

We prefer the switch over the hub mainly due to two reasons. The first reason being that the switch offers MAC addresses. This is crucial to us as we need to identify the camera from which we are getting the video/audio stream or the fire alarm that has gone off. The second reason being that the switch operates on a logical star/tree topology whereas the hub uses a logical bus topology. The bus topology is prone to failure if the main cable fails.

Choice of Device for Switch

- The switch we have decided to use is the **NETGEAR 10-Port Gigabit/10G Ethernet Unmanaged Switch (GS110MX)**.
- Since this device has only 3 ports, we will be stacking 3 sets of these at a particular switch location (displayed in the image on the last page). That is, we will be using switch cascading.
- It supports speeds of **(100M/1G/2.5G/5G/10G) bits/sec**. Since the fibre optic cable I have chosen above uses 10 Gbits/sec, we will use 10 Gbits/sec setting for this switch.

IP Addressing Schema

IP address is a distinct symbol assigned to each device in order to avoid any ambiguity between devices. For our LAN design, we are going to use IPv4 addressing. We will now see which addressing (classless vs classful) is better for our purpose.

1. **Classless vs Classful**

   Classless: The main features of classless addressing is that there is no restriction on the length of the network and host addresses. We are free to choose any number of bits. Classless addresses are represented as a.b.c.d but followed by an ‘e’ to denote classless addressing. e denotes that the first e bits of our address represent the network address and the remaining bits represent the host address.
   Classful: In classful, the addresses are divided into 5 classes A,B,C,D and E. We divide the addresses into these classes based on the starting bits of the address (Example- 10 belongs to class B). For classes A,B and C the number of addresses are predefined allowing a maximum of 16777214, 65534 & 254 addresses respectively.

   We have decided to use Classless addressing for the following reason: we have a total of 594 devices in our building (explained below). If we were to consider classful addressing, we cannot use class C as it is too less and class B contains way more addresses than we require. Thus, to avoid the wastage of addresses, we use classless addressing.

2. **Dynamic vs Static**

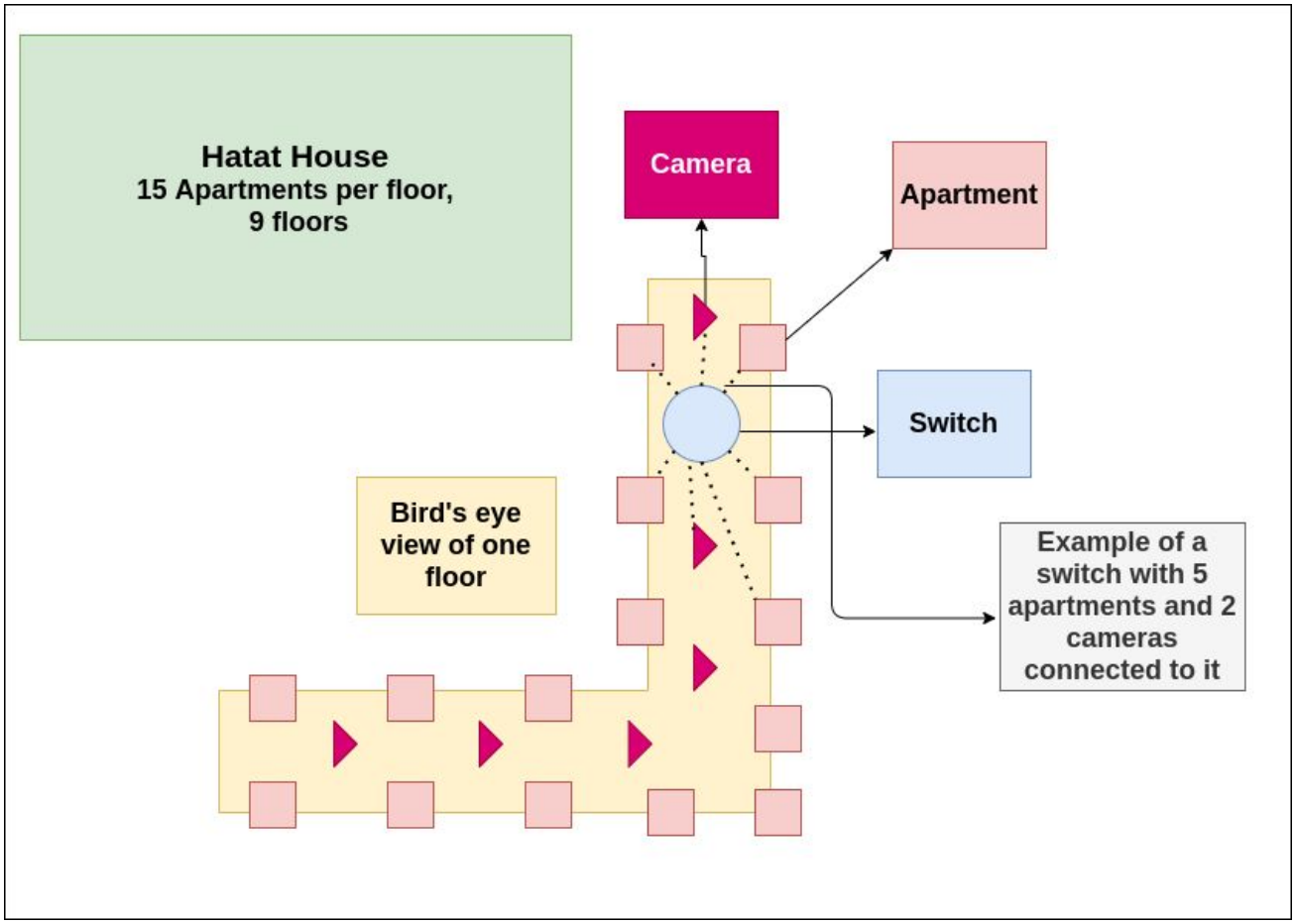
   Static IP addressing: Static addresses do not change over time (it cannot be modified once it is provided). This address is provided by the ISP. Naturally, this makes them less secure and more traceable as they do not change over time. This also makes them more costly. Static addressing is used more in business offices and servers. Thus, it does not make much sense for our use case.

   Dynamic IP addressing: In this case, each system gets a different IP address each time it comes online. This address is assigned by the DHCP server. Since the addresses change continuously, they are more secure and cost less as well. Due to these advantages, we will be using Dynamic IP addressing.

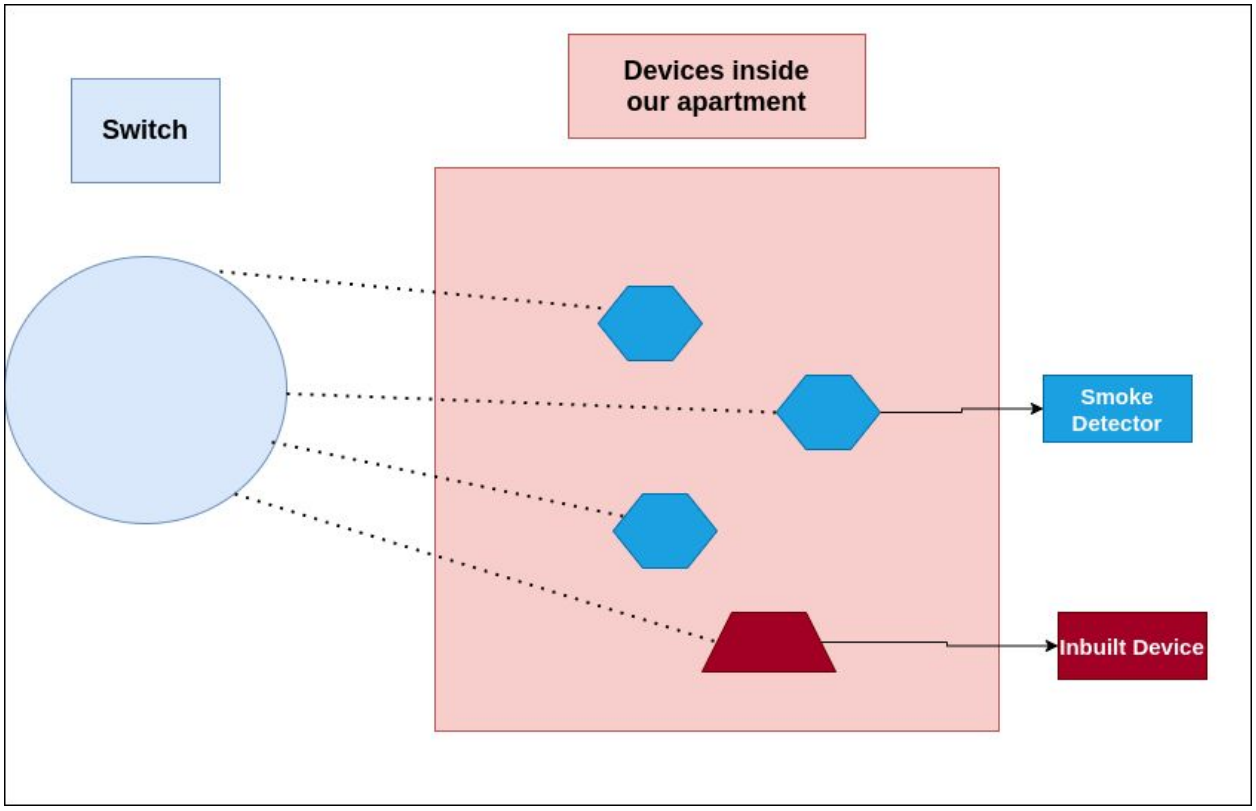
Each apartment has 3 smoke machines + 1 inbuilt device which amounts to 4 such devices per apartment. That means there are 4*15 = 60 such devices per floor. In addition to that we have 6 cameras per floor, which means a total of 66 devices per floor. A total of 9 floors means there are 66*9 = 594 devices. We also consider the system present with the guard, the server used for booking, and the server for booking slots. Together, this amounts to 597 devices. In order to give unique addresses to these devices, we need 10 bits (1024 addresses).

Thus the number of bits in the host address is 10, and the number of bits in the network address is 22. Hence addresses will be of the form 10.0.0.0/22 to 10.0.4.255/22.

Final LAN structure for our apartment Complex (Hatat House)



Connections from a single apartment to a switch (zoomed in version)



Mesh connection between switches of different floors