Computer Networks
Assignment 1 - LAN Design Exercise

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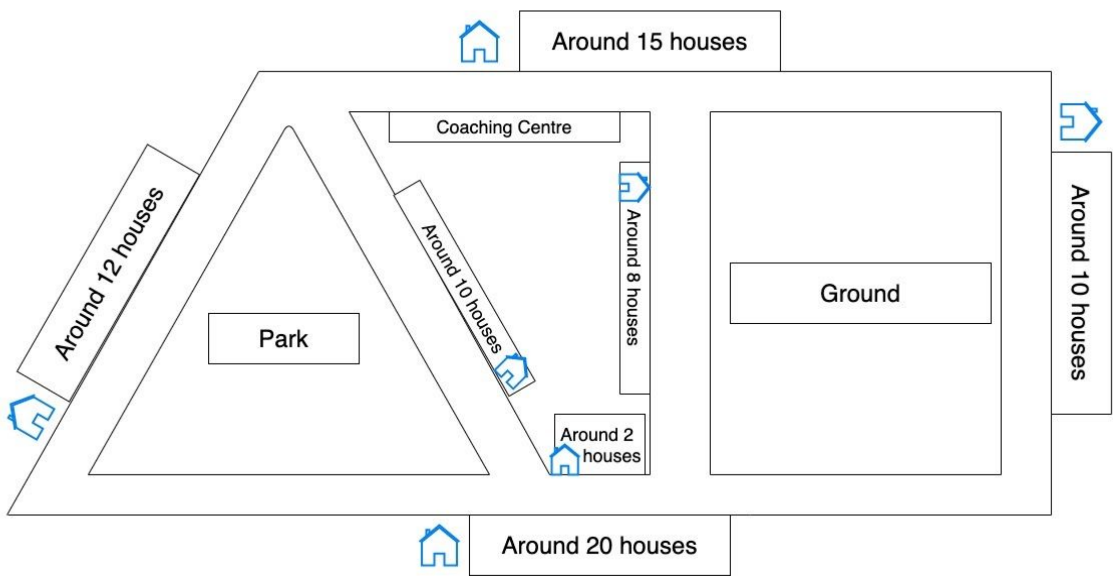
Locality Design



- This is a simplified design of my locality.
- There are around 80 houses in total.
- A few houses are unoccupied.
- So let's say there are 4-5 members per family/house and let's say there are around 8 devices per family. The total number of devices required would be around 900 (including around 220 - 250 devices for the coaching center).

Design Goals

We would like to achieve the following goals in our design, also keeping in mind that the design is made considering precisely my locality:

- High Speed: The network should provide high bandwidth to all the users connected to the network.

- Fair: Every user should have equal access to the bandwidth, and no one user should have any prioritized access to the network.

- Available: The network should be up and running most of the time. Users should be notified of any maintenance much earlier, and maintenance should be done at odd hours.

- Scalable: Since there are some unoccupied houses, the design should be able to adapt to increased nodes and extend without any problems.

- Secure: Each user's data should only be available only to itself and not to anyone else. Data meant to a destination should only be accessed by that destination and not any other device.

- Low Maintenance - The network should not need much maintenance. Failure of a component somewhere should not affect the entire network. Faults should also be manageable to get fixed without much delay. There should not also be much need to replace many components very frequently.

- Low cost: Needless to say, the design should not be much expensive and be accessible at lower prices.

Topological Design

A network topology describes the layout of the wire and devices as well as the paths used by data transmissions.

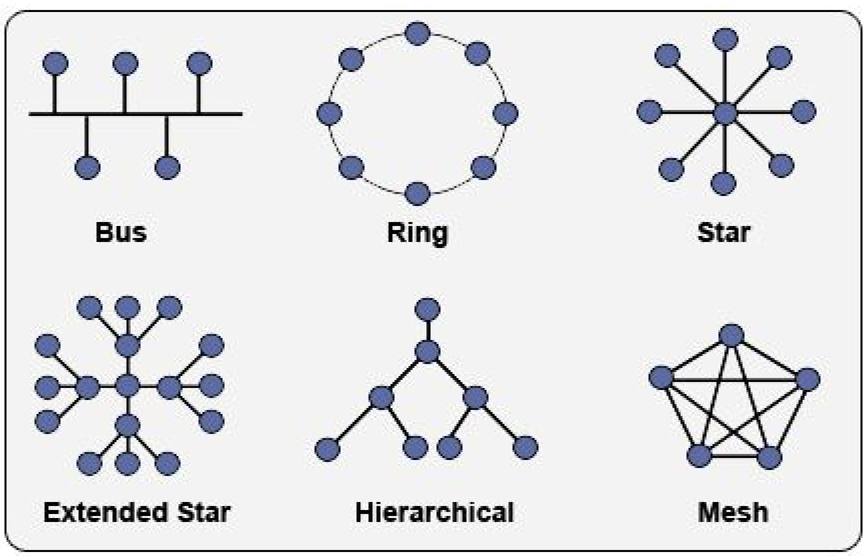
Some of the popular network topologies are:

- Bus Topology
  In Bus Topology, all the devices are connected by one single cable. The media is shared. It requires termination at the end of the link because the signal can get reflected back from the end of the medium. We cannot use this because it is not scalable, and the addition of a new node requires

cutting the cable and disrupting the transmission. Also, if the cable fails, the whole network goes down and that is an unacceptable situation.

- Ring Topology
  Here too, the media is shared. We cannot use this because if one of the nodes goes down, the whole network goes down unless it smartly decides to convert into a bus topology, which is still undesirable and may increase costs.

- Star Topology
  Here, the media is not shared, and all nodes are connected to a central node. Failure of a node will not break down the entire network, but failure of the central node will. It is scalable though, as the addition of a new node is easy. We will not use it as it is highly dependent on the central node, and it is also unfeasible to connect every node to the central node.



- Tree Topology
  Tree topology is like an extended star topology where all nodes are connected in a hierarchical fashion (each node in itself can also be a star topology). The cost is high, but when it is used with network devices that filter frames or packets, like bridges, switches, and routers, it significantly reduces the traffic on the wires by sending packets only to the wires of the destination host.

- Mesh Topology
  In Mesh Topology, every node is connected to every other node. As can be imagined, it requires a large number of cables and thus the cost and maintenance are very high and hence it is only suitable for small networks. Therefore, we will not use this.

As can be seen, each topology has its own advantages and disadvantages. Tree topology seems to be the most convincing. The only issue with that since there is only a single path between any nodes, the failure of a cable can affect communication between those nodes where the failed cable lies in the path between them. We can even overcome this by connecting each node to multiple nodes so that there is more than one path between any two nodes, kind of a partial mesh structure. But we will keep it simple and not go that far. Failure of a single cable is not the end of the world for us. We can fix the cables when any failures occur in a decent period of time. So we decide to keep a tree topology where every node in itself is a star topology.

Moving on to the architecture, there are two choices:

- A three-tier architecture with edge switches, distribution switches, and a core switch.
  It involves many more cables, switches and is much more expensive than the two-tier architecture. It is generally used when there are a large number of end-users in the locality, which in our case, aren't.

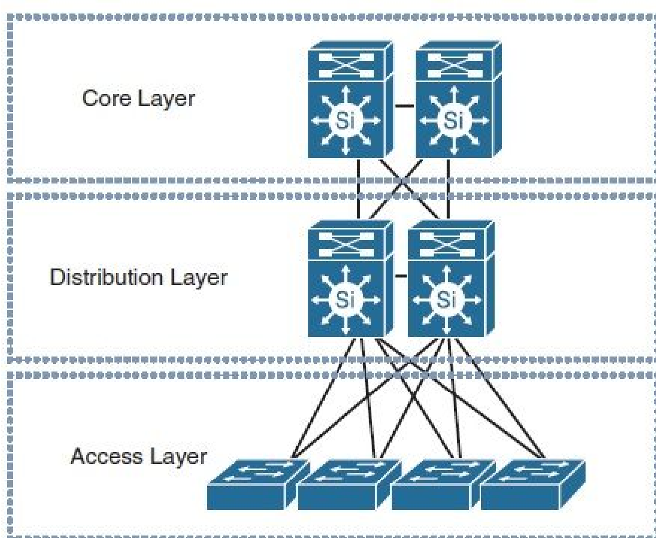


Figure 3-1 *Three-Tier Network Design Model*

- A two-tier architecture with only edge switches and distribution switches (the core switch is collapsed into the distribution switches)
  It involves much lesser cables, switches and is relatively inexpensive than the three-tier architecture. We don't have that many devices and hence we can easily prefer to use two-tier architecture. Since there are users that are far apart, hence we would have to cascade multiple distribution switches. Using a two-tier architecture will save us a lot of costs and hence we will use this.

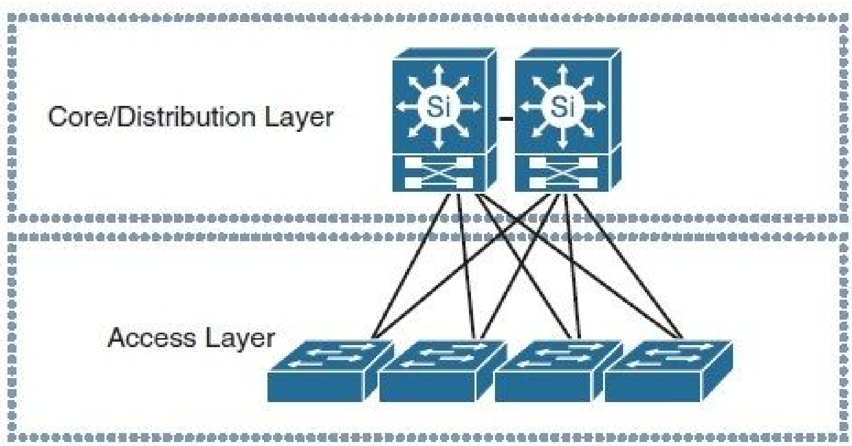


Figure 3-2 *Two-Tier Network Design Model*

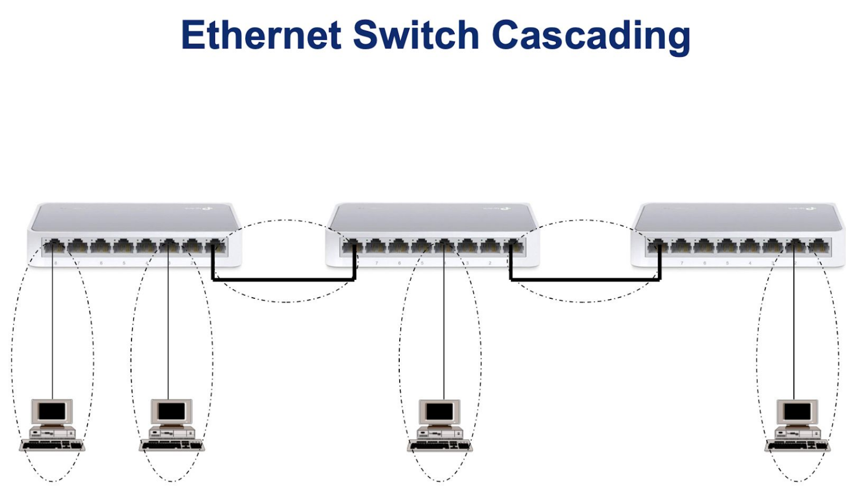
Why is there a different name for edge switches, distribution switches, and core switches? What is the difference between them?

- Edge switches (also called Access switches) are the switches in the lowest level of the hierarchy. They are called edge switches because they are connected to the edge of the network (the user nodes).

- Distribution switches are the switches that connect the edge switches with the core switch and provide a path between two users not in the same switch. Distribution switches should have higher bandwidth capacity than the edge switches because multiple ports from the edge switches may want to transfer data, and if it goes from the uplink port to the distribution switch port, then the distribution switch must be able to hold all that data. It should also be noted that the uplink port in the edge switch should also be able to contain all that data.

- Core switches are like distribution switches but of higher capacity due to similar reasoning. They also provide fast transport between distribution switches spread across more considerable distances.

Why cascade a few distribution switches but not connect distribution switches to a core switch in a hierarchical fashion?
Using a core switch would make sense when we have many distribution switches and cascading them would not make much sense. In that case, using a core switch would be better. But since we don't have that many user nodes, we would just need two or at max three distribution switches and we are done.

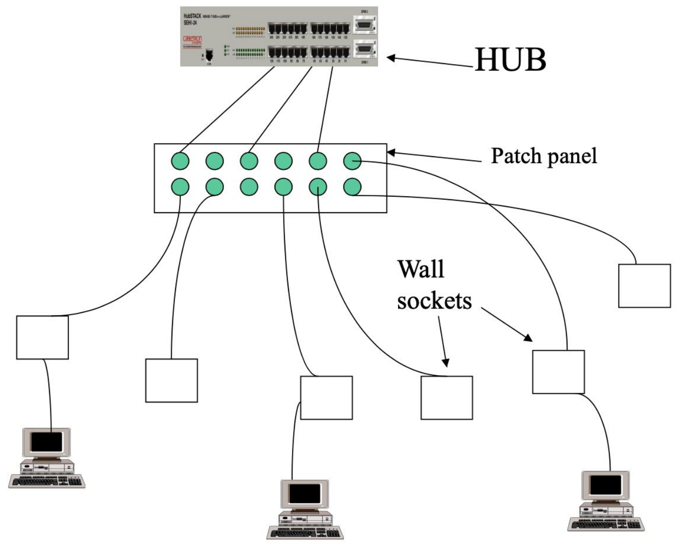


Choice of Cables

Since we have decided on a two-level architecture, there are quite a decent number of cables that will be required. So we need to be careful when choosing our cables as it can have a significant impact in the long run.
Each switch will be a Structured Cabling System.

What is Structured Cabling?
It is a planned approach to cabling. It brings some order to the way cabling is done in modern networks. There is a central device (can be a hub or a switch or something similar). There is also a patch panel, and there are some sockets, and each user is connected to one of the sockets.

STRUCTURED CABLING



So there are three levels of cabling done:

1. Between a user node and a wall socket. It is called a patch cable.
2. Between the wall socket and the patch panel. It is not visible to the user. It is protected. It is called the backbone cable.
3. Then the patch panel is connected to the switching device, which is another patch cable.

Why use structured cabling and not connect each end-user directly to the edge switch?

There are multiple reasons.

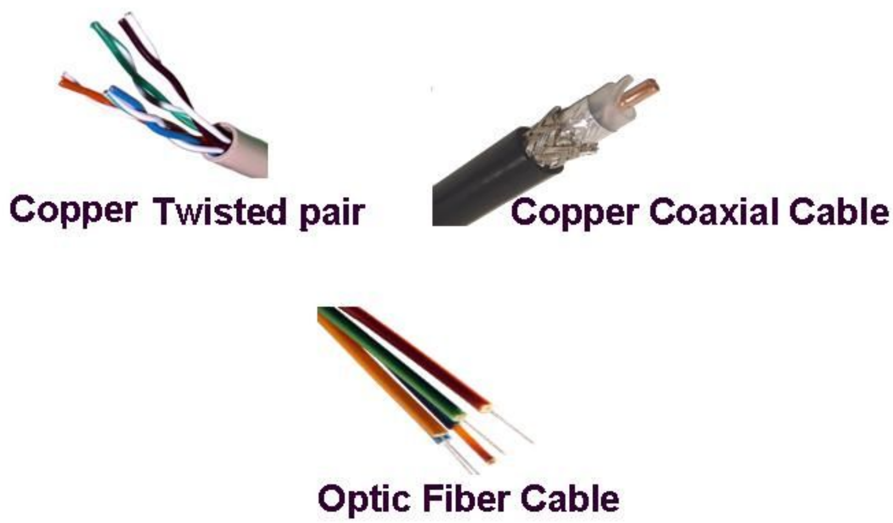
- **Enhanced flexibility**: Patch cables are just a few meters in length. If one of the patch cables is damaged, we can just buy another one. It will not cause any disruption to the network.

  Similarly, at the other end, there is a switching device. If there is a need to change the switching device, we can just replace it. If we did not use structured cabling, we would have to disconnect every cable from the old device and connect it to the new device.

- **Increased reliability**: It is a wire-once approach. The backbone cables have a lifetime of more than ten years. They are standardized and have a guaranteed performance.

- A few more reasons are that it is **application-independent**, it is **modular** (most components are out of bound from the end-users, and hence it is safe), and the **network control is easier**.

So, now we have to select the cables for the patch cable and the backbone cable. We have the following options:



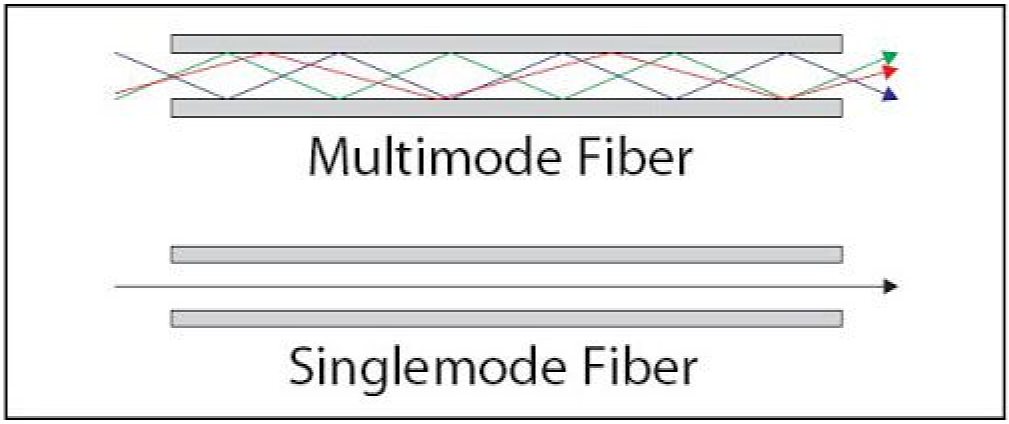
- Twisted Pair
  Here, two insulated copper wires are twisted in a spiral/helical form which is used as a single communication link. Cross-talk and attenuation are reduced because of twisting. They are generally used for shorter distances. There are two kinds of twisted pair cables:

- Shielded Twisted Pair (STP) Cable
  There is a shield of wire mesh around the insulated twisted pair. It will absorb any radiation from any neighboring wires or from its own wires. It does not carry any information and is just used for shielding purposes.

- Unshielded Twisted Pair (UTP) Cable
  Here, there is no such shielding, and hence there is no protection from radiation. It is hence cheaper than the STP cable.

- Coaxial Cable
  It has a copper core, surrounded by an insulating material, encased by a wire mesh, and covered in a protective plastic sheath. It has better shielding and less attenuation than twisted pair cables and it can be used for longer distances.

- Optical Fiber Cable
  It has a glass core surrounded by a glass cladding of a lower index and covered by a thin plastic jacket and protected by a sheath. Optical fiber cables are lightweight, offer very high bandwidth, and are immune to external noise. They can work for very long distances, and they are very secure. The only downside is that they are very costly.



We will use Category 5e Unshielded Twisted Pair cables for the patch cables and Multimode Optical Fiber Cables for the backbone. Twisted Pair cables are generally used for shorter distances and indoor applications and they seem the perfect choice for the patch cables. We choose UTP over STP because they don't offer much value over UTP to justify their high cost. We use the category 5e cables as they offer bandwidth up to 100 Mbps which is more than sufficient. But we need to use optical fiber cables for the backbone because they offer connectivity for distances longer than 50-100 meters, they can be used in outdoor environments, and they offer very high bandwidth. We use multi-mode because they are cheaper and they are better suited for mid-range distances.

Choice of Networking Devices

What are hubs and switches?

- A hub is a device that operates at the physical layer. It can only understand 0 and 1 and not frames, preambles, and MAC addresses. When some data reaches any port in the hub, it relays this data to all the ports in the hub. It has a single broadcast domain and a single collision domain. Single Broadcast Domain means that if any node transmits some information, that is broadcasted to all the other nodes in the hub. Single Collision Domain means that if more than one node wants to transmit information, it is not possible, and there would be a collision.

- A switch is a device that operates at the data link layer, and hence it can understand frames, preambles, and learn MAC addresses. It has multiple broadcast domains and multiple collision domains as each port is a separate collision domain.

We sometimes cascade hubs and switches when there are more nodes than available ports or the distance between a pair of nodes is more than what twisted pair cables can offer.

Why do we prefer a switch over a hub?
There are multiple reasons to prefer a switch over a hub:

- A switch is more secure as it delivers data only to the destination it was actually intended, whereas a hub broadcasts data to all the nodes, and a node can sniff the data if it is not encrypted.

- A switch can have n/2 (where n is the number of ports) parallel transmissions in the best case (multiple broadcast and collision domains). In contrast, a hub can have only a single transmission of data at a time (single collision and broadcast domains).

- A switch has error detection (even correction in some kinds of switches), and it won't transmit the data to the destination if it detects an error or an inconsistency. In contrast, a hub broadcasts every bit as soon as it reaches the hub.

- If a switch senses that a collision can occur, it buffers the frame in its memory and sends it to the destination when that node becomes free. In this way, the sender does not need to worry, and it can rest. In contrast, a hub does not have any memory at all.

So, we need to select the choice for our edge switches, and distribution switches.

- **Edge Switch**
  I have chosen TP-Link TL-SL1218MP Poe Switch Unmanaged 16 Port 10/100Mbps + 2 Port Gigabit Uplink + 2 SFP | Up to 250M Transmission, 802.3AT/Af Compliant, 192W.

There will be one edge switch for every 8 houses. So we will have to buy around 10 edge switches.

I chose this particular model because of the following reasons:

- Auto-negotiation: If the user is not capable of transferring at 100 Mbps, then the switch will configure to transfer at 10 Mbps.
- 16 ports: Since there is one edge switch for every 8 houses, so each house will get 2 ports. We will use one port for the Wireless Access Point and we will keep 1 port if someone wants to use a faster and wired network.
- Cheaper but unmanaged: We will keep the distribution switches managed and keep edge switches unmanaged and hence it will be cheaper.
- SFP Ports to support Optical Fibers.

- **Distribution Switch**

  I have chosen [Cisco SG350-10SFP Managed Switch | 10 Ports of Gigabit Ethernet (GbE) Ports | 8 SFP Slots Plus | Gigabit Ethernet Ports SFP Combo (SG350-10SFP-K9-IN)](#).

Ideally, since there are only 10 edge switches, we would have needed only a single 12 or 16 port Distribution switch, but it would be better to keep 2 distribution switches and cascade them and the distance is quite large. So we would buy two 10-port distribution switches. One switch would be at the top left in our locality design and the other one at the bottom right.

I chose this particular model because of the following reasons:

- Auto-negotiation: If any edge switch is not capable of transferring at 1 Gbps, then the distribution switch can configure it to transfer at 10 or 100 Mbps.
- 10 ports: Every 5 edge switches will be connected to a distribution switch and hence we have 5 ports left empty and we can use them if necessary for port mirroring or debugging or something else.
- Managed: Though a bit expensive, but it is necessary because we would want to troubleshoot errors with much ease in a distribution switch as it can have a significant impact on the availability of the network.
- SFP Ports to support Optical Fibers.
- High Bandwidth: Bandwidth should be higher than that of edge switches due to reasons mentioned when we talked about the two tier architecture.

We also need a **Wireless Access Point** since we are giving only 2 ports to every house. Hence we need to have some wireless connectivity.

I have chosen [TP-Link 300Mbps Wireless N Ceiling Mount Access Point – Supports Passive PoE, Free PoE Injector, Long Range Coverage, Secure Guest Network, Centralized Management (EAP110)](#).

I chose this particular model because of the following reasons:

- A family has 8-10 devices. A WAP should be able to support it. This one does.
- We would have to buy this for every house. 1 port from the edge switch would be connected to WAP.
- Cheap: Always an added bonus if the device is cheap :)
- We don't need outdoor support. So this once is mid range and sufficient for a single house.

We also need to select a **Router** to connect to a WAN to get internet connection. Both the distribution switches would be connected to this router.

I have chosen [TP-Link Archer C5400 AC5400 5400 Mbps Wi-Fi Speed Wireless Tri-Band MU-MIMO Gigabit WiFi Router]().

I chose this particular model because of the following reasons:

- 1 port for WAN and 4 ports for LAN. We need just 2 LAN ports for the 2 distribution switches and WAN port for internet connectivity.
- High speed: can provide 1 Gbps speed to both the distribution switches.
- There are many more reasons listed on the product page but we primarily needed the above two only.
- It is not cheap, but is worth the cost. It is the only router we have and we would want it to be as good as possible.

IP Addressing Schema

Assuming that we are using the IPv4 protocol, we have a couple of options:

- Classful Addressing
    - We have around 900 devices, so we would have to use Class B addressing (16 bits for Host addresses and 14 + 2 bits for Network addresses).
    - Total hosts allowed will be 2^16 - 2 = 65534 (2 subtracted for network address and broadcast address). But we need only 900. As can be seen, it is a huge waste of space and hence we will not use this.

- Classless Inter-Domain Routing (CIDR)
  Since we are not using Classful Addressing, we will use CIDR.
    - In our design, there have to be at least 2 subnets. A separate subnet for the coaching centre is absolutely necessary because of various security issues. The broadcast from the coaching centre should not be received by any other device other than those in the coaching centre.
    - And then we will keep only 1 subnet for all the other devices. So around 220-250 devices in the Coaching Center Subnet and around 650 devices in the Personal Users Subnet.
    - So we will need 10 bits for the host address space and since there are two subnets, we will need to have 2 bits for the subnet number because we cannot keep all zeros and all ones.
    - All zeros subnet will have the same network address as the original network address and All ones subnet will have the same broadcast address as the original network's broadcast address and hence we cannot use them.
    - So 2 bits for the subnet number and 10 bits for host addresses, hence we need a total of 12 bits.
    - So the network address will consist of 32 - 12 = 20 bits.
    - We will have 1024 - 2 = 1022 hosts space available for 250 coaching centre devices and 1022 hosts available for 650 personal devices. Yes, some addresses are getting wasted, but scalability is there.

More devices in the coaching center can be added, the unoccupied houses can be occupied without any hassle, etc.

The scheme

- Let's say the Network Address is 103.252.160.0/20 (01100111.11111100.10100000.00000000)

- Broadcast Address: 103.252.175.255/20 (01100111.11111100.10101111.11111111)

- Netmask: 255.255.240.0 (11111111.11111111.11110000.00000000)

- Address Space: 103.252.160.0 to 103.252.175.255

- Subnet 01: Coaching Centre Subnet
    - Subnetwork Address: 103.252.164.0/22 (01100111.11111100.10100100.00000000)

    - Subnet Broadcast Address: 103.252.167.255/22 (01100111.11111100.10100111.11111111)

    - Subnet Address Space: 103.252.164.0 to 103.252.167.255

- Subnet 10: Personal Users Subnet
    - Subnetwork Address: 103.252.168.0/22 (01100111.11111100.10101000.00000000)

    - Subnet Broadcast Address: 103.252.171.255/22 (01100111.11111100.10101011.11111111)

    - Subnet Address Space: 103.252.168.0 to 103.252.171.255