
LOVELY
PROFESSIONAL
UNIVERSITY
Lecture #0
CSE 423
Virtualization &
Cloud Computing

Course details

- LTP – 3 0 0 [Three lectures per week]
- Credits : 3

Text Book

- Cloud Computing (Fundamentals Industry Approach and Trends)
  - *Rishabh Sharma*
  - 1st Edition, Wiley India Pvt. Ltd.

Reference Books

- Mastering Cloud Computing
  - *Rajkumar Buyya, Christian Vecchiola, S. Thamarai Selvi*
  - 1st Edition, Mc Graw Hill
- Cloud Computing : A hands on approach
  - *Arshdeep Bahga, Vijay Medisetti*
  - 1st Edition, Universities Press Pvt. Ltd

Course Assessment Model

- **MARKS BREAK UP**

- Class Participation/ Attendance 05

  Includes---- Punctuality, Active participation/quick response in the class

- CA (Two best out of Three CA) 20
  - ***CA consists of two MCQ based test and 1 term paper***
  - ***CA1 ---MCQ Based***
  - ***CA2---MCQ Based***

Course Outcomes

- CO1 :: illustrate the main aspects, key technologies and mechanisms of Virtualization technology
- CO2 :: examine the appropriate technologies, algorithms and approaches for the provisioning of various resources and implementation of cloud computing
- CO3 :: understand the main issues involved in cloud computing such as cloud architecture, capacity planning and service level agreement
- CO4 :: evaluate the economical cloud solution by considering appropriate cost estimation strategy and laws of cloudonomics
- CO5 :: enumerate the core aspects of cloud security, privacy and reliable cloud environment
- CO6 :: understand the emerging technologies of cloud computing and how it bring changes in the traditional cloud computing models

Program Outcomes

PO-1 Engineering knowledge::Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO-2 Problem analysis::Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO-3 Design/development of solutions::Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

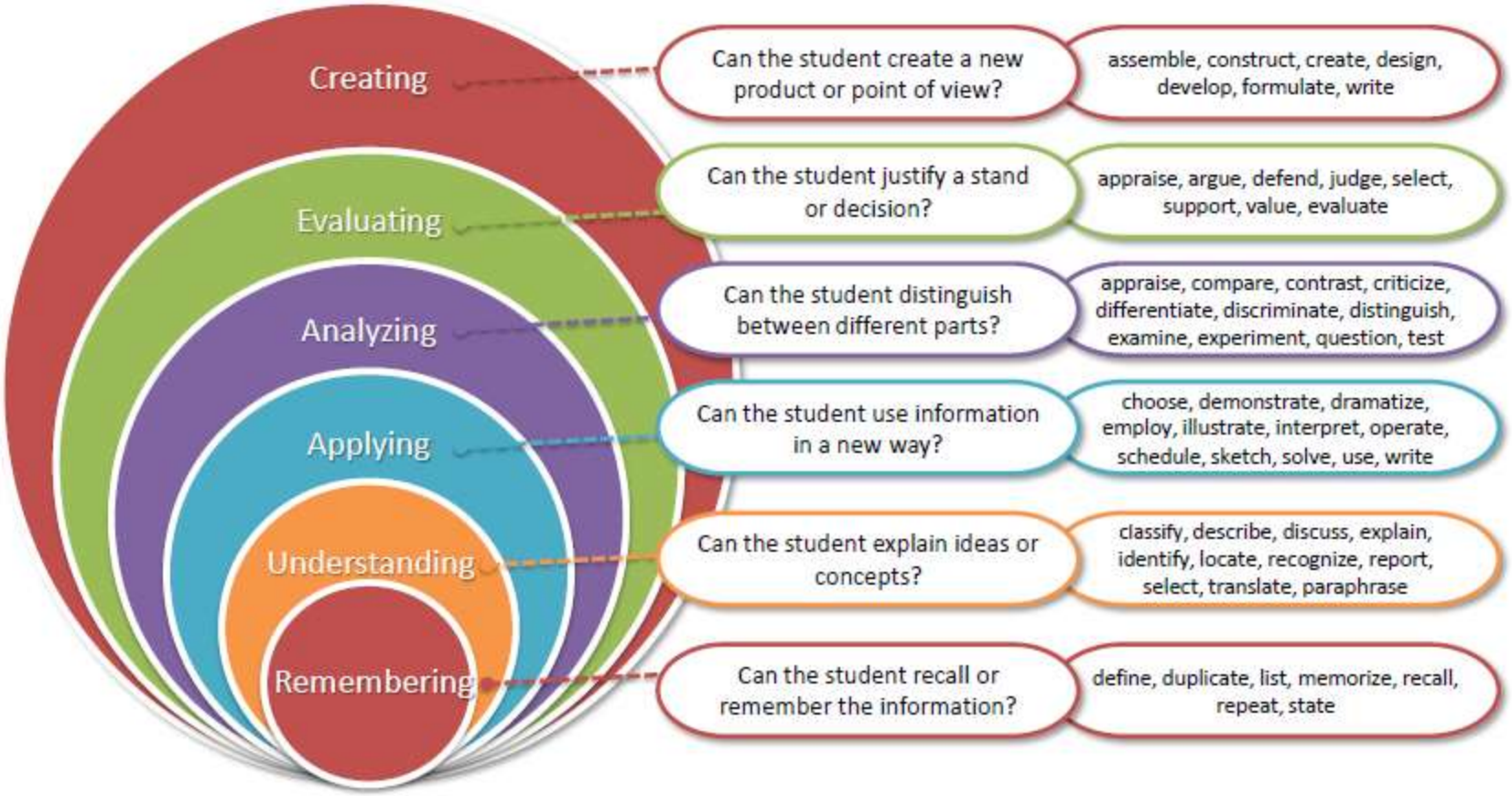
Program Outcomes

PO-6 The engineer and society::Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO-12 Life-long learning::Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PO-13 Competitive Skills::Ability to compete in national and international technical events and building the competitive spirit

Bloom's Taxonomy



Contents

Skill Set Attainment

- Knowledge of hypervisor tools
- Understanding Virtualization
- Understanding how to migrate the machines
- Knowledge of cloud computing
- Resource Planning

MOOCs

- **IBM Cloud Essentials**
- https://www.edx.org/course/ibm-cloud-essentials

- The certificate will be considered against the first CA

Why Virtualization and Cloud Computing

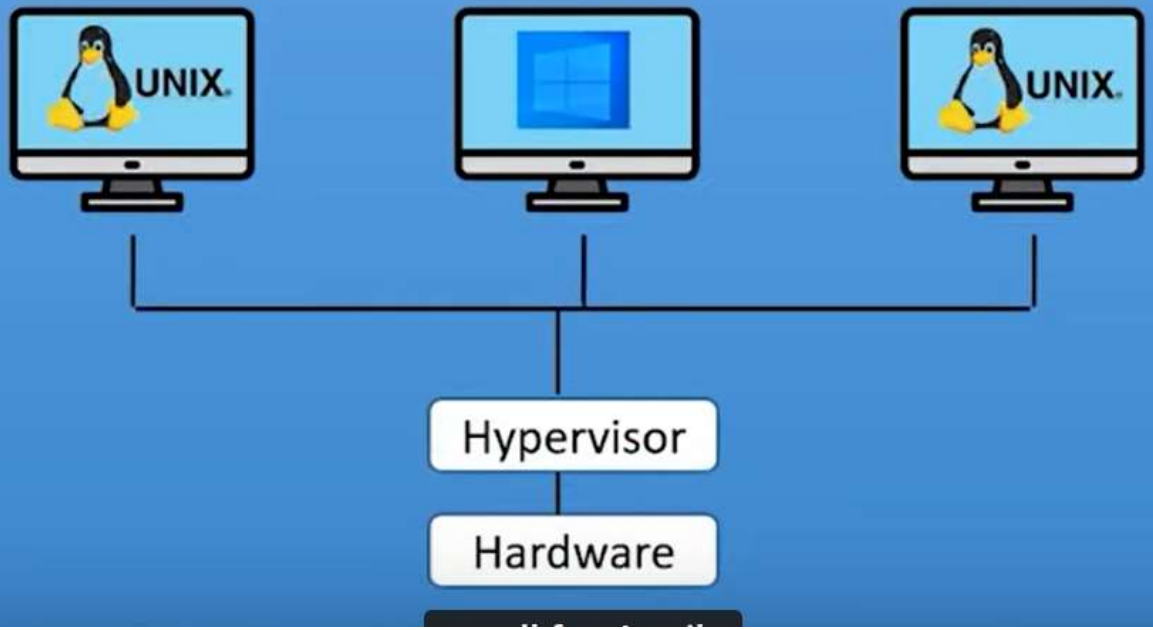
- **Virtualization:**

  The ability to run multiple operating systems on a single physical system and share the underlying hardware resources

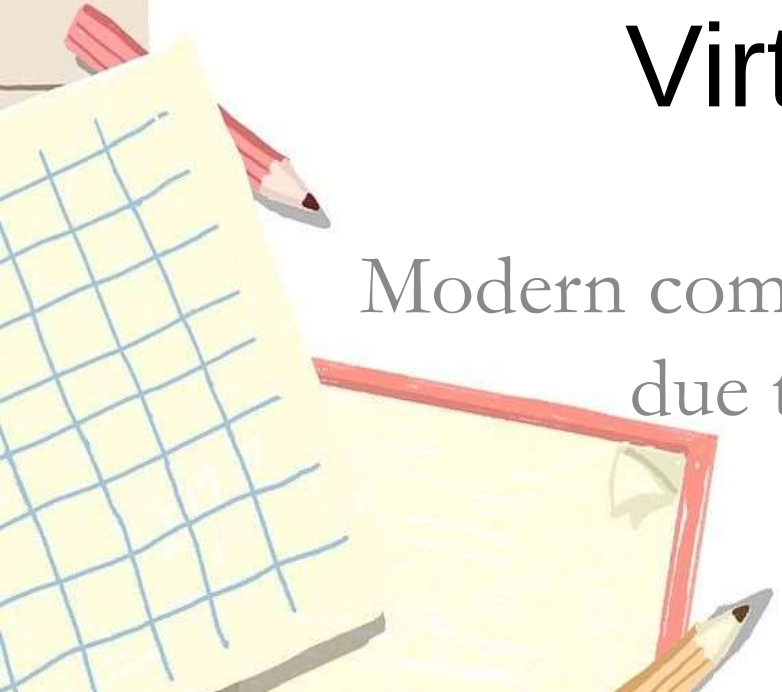
- **Cloud Computing:**

  "The provisioning of services in a timely (near on instant), on-demand manner, to allow the scaling up and down of resources"

- Hypervisor is a software that manages VMs.
- It acts as an interface between VM and physical hardware to ensure proper access to the resources needed for working.



- Virtualization
- https://www.youtube.com/watch?v=XItj08D5KPk



Virtualization

Modern computing is more efficient due to virtualization

Lets think like this

- Have you ever wished you could clone yourself?
- If you could, would you be more efficient? Would you do more?
- Virtualization enables computers to be more efficient in a similar fashion
- Computers that use virtualization optimize the available compute resources

Lets ponder on this...

- Do you use a smartphone, laptop or home computer?
- Smartphones, laptops or home computers are hardware
- Similar to how your brain controls your actions, software controls hardware
- There are different types of software that control computer actions

What is a VM

- Virtualization creates virtual hardware by cloning physical hardware
- The hypervisor uses virtual hardware to create a virtual machine (VM)
- A VM is a set of files
- With a hypervisor and VMs, one computer can run multiple OS simultaneously

Terminologies

- **Host Operating System:** The operating system via which the Virtual Machines are run. For Type 1 Hypervisors, as in Hyper-V, the hypervisor itself is the Host OS which schedules the virtual machines and allocates memory. For Type 2 hypervisors, the OS on which the hypervisor applications run is the Host OS.
- **Guest Operating System:** The operating system that uses virtualized hardware. It can be either Fully Virtualized or Para Virtualized. An enlightened guest OS knows that its a virtualized system which can improve performance.
- **Virtual Machine Monitor:** VMM is the application that virtualizes hardware for a specific virtual machine and executes the guest OS with the virtualized hardware.

Concepts

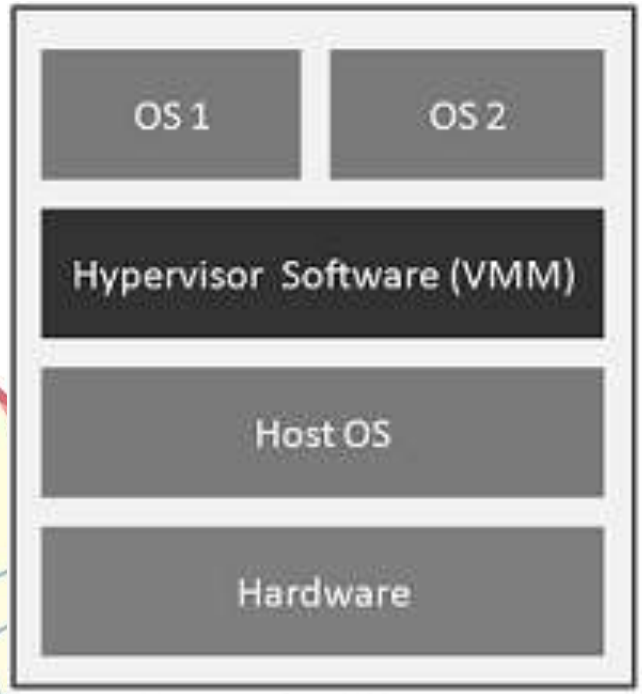
- Virtualization is technology that allows you to create multiple simulated environments or dedicated resources from a single, physical hardware system.
- Software called a hypervisor connects directly to that hardware and allows you to split 1 system into separate, distinct, and secure environments known as virtual machines (VMs).

Hypervisors

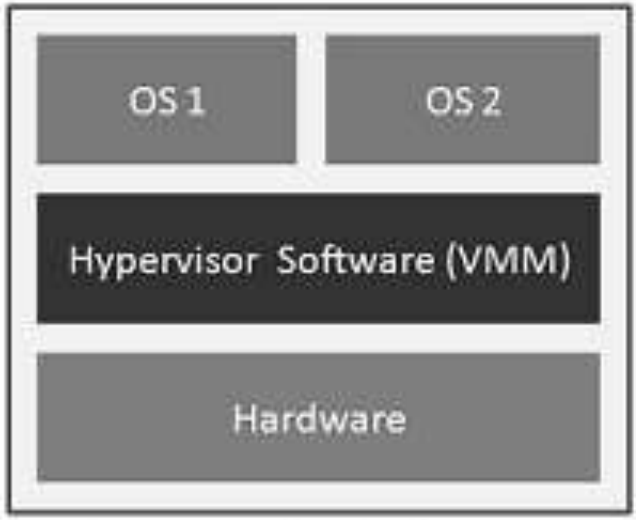
- A hypervisor is a process or a function to isolate operating system and applications from the underlying hardware.
- Though virtual machines operate on the same physical hardware, they are separated from each other. This also depicts that if one virtual machine undergoes a crash, error, or a malware attack, it doesn't affect the other virtual machines.
- Another benefit is that virtual machines are very mobile as they don't depend on the underlying hardware. Since they are not linked to physical hardware, switching between local or remote virtualized servers gets a lot easier as compared to traditional applications.

Types of Hypervisor

- A type-I hypervisor operates directly on the host's hardware to monitor hardware and guest virtual machines, and it's referred to as the bare metal.
- A type-II, also called a hosted hypervisor because it is usually installed onto an existing operating system. They are not much capable to run more complex virtual tasks. Used for basic development, testing, and emulation.



Hosted Architecture



Bare-Metal Architecture

Differences

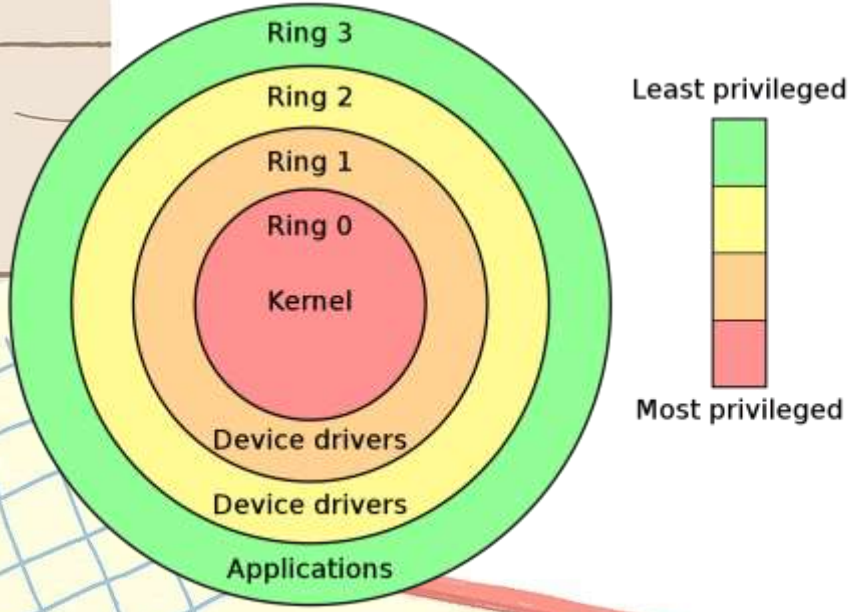
What's the difference between virtualization and cloud computing?

- It's easy to confuse the two, particularly because they both revolve around separating resources from hardware to create a useful environment. Virtualization helps create clouds, but that doesn't make it cloud computing. Think about it like this:
- Virtualization is a technology that separates functions from hardware
- Cloud computing is more of a solution that relies on that split

X86 Virtualization

- **x86 virtualization** refers to hardware and software-based mechanisms to support virtualization for processors based on the x86 architecture . Using a hypervisor , it allows several operating systems to be run in parallel on an x86 processor and resources to be distributed in an isolated and efficient manner between the operating systems running in parallel.

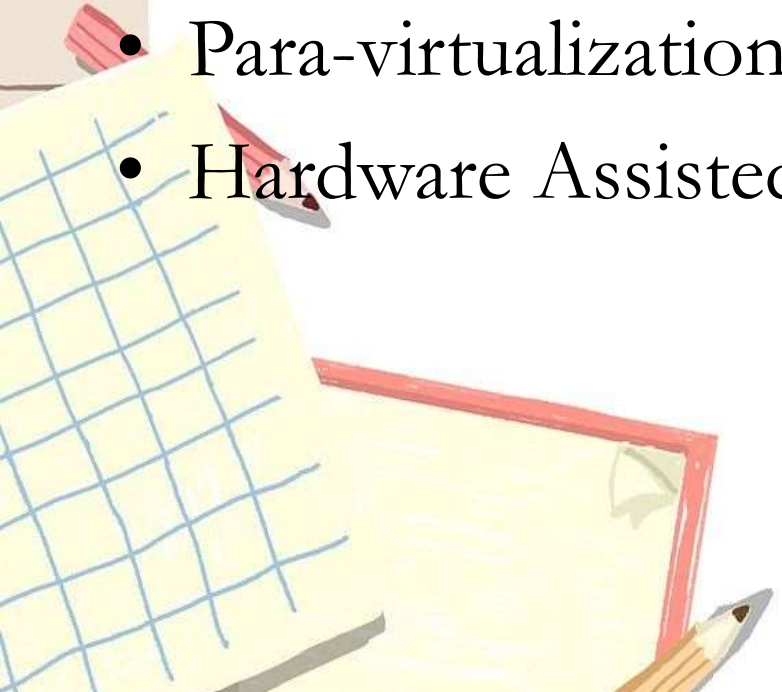
- In order to be able to allocate resources exclusively to the guest systems running in parallel, only the host operating system or the hypervisor may be granted direct access to the processor hardware, while the guest systems, like all other applications, may only have limited access rights to the hardware. In particular, it can be prevented that the guest systems can see or change memory areas that the hypervisor needs for management.
- The protected mode was introduced in the x86 world . With it, four different protection levels or *privilege levels, known* as rings, were introduced, which grant the code segments running on them different rights. Only with the introduction of this concept was it possible to implement virtualization based on the x86 architecture: In protected mode, the operating system kernel runs in a more privileged mode, called Ring 0 , and applications in a less privileged mode, in usually either ring 1 or ring 3.



- The hypervisor or the host operating system are executed with ring 0 authorization due to their privileged position in resource management. In order to guarantee the protection of the hypervisor resources, guest systems must therefore be run either at authorization level Ring 1 (in the so-called Ring 3.

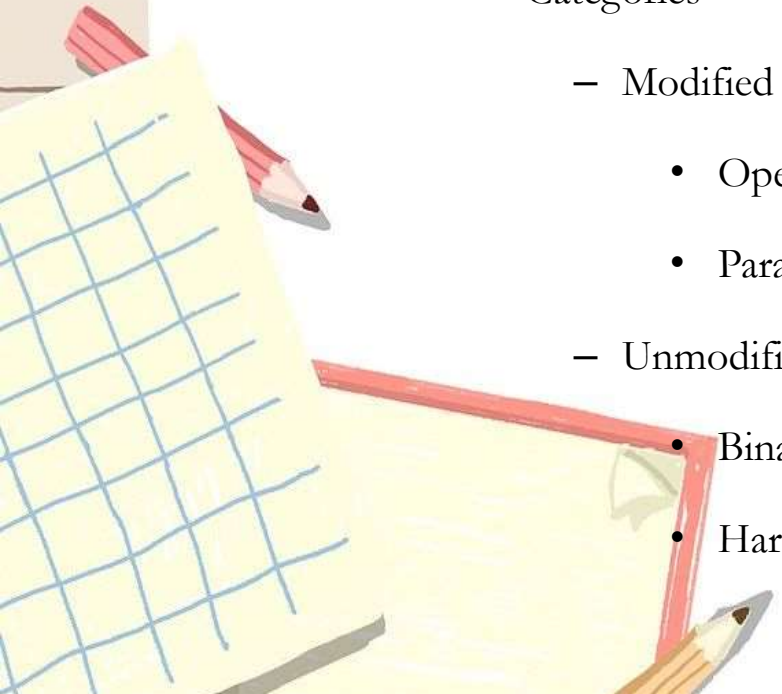
Types of Hardware Virtualization

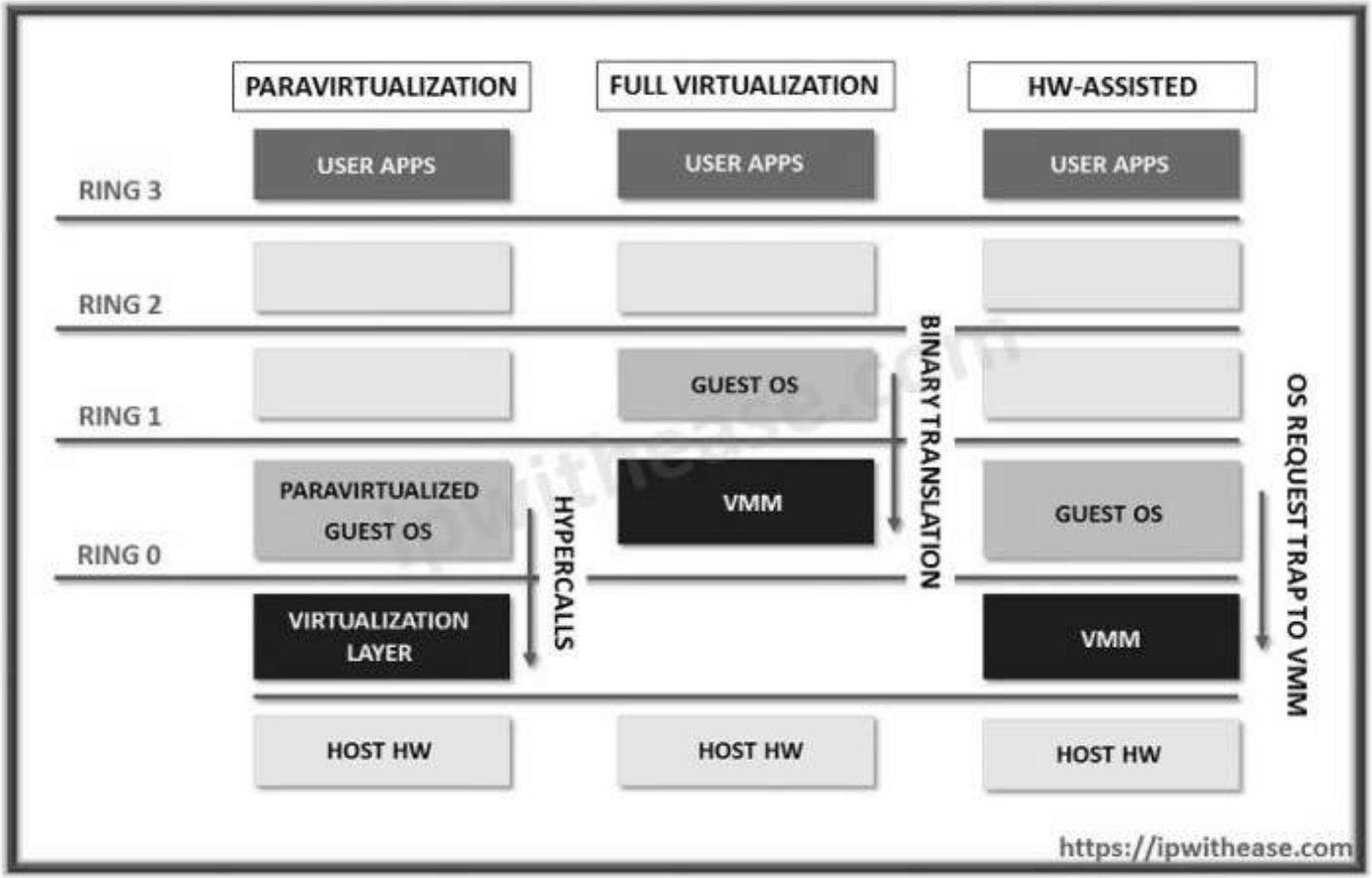
- Full Virtualization
- Para-virtualization
- Hardware Assisted Virtualization



What to change

- Based on how much change is required and at what level
- Categories
  - Modified Guest OS
    - Operating system level
    - Para-virtualization.
  - Unmodified Guest OS
    - Binary Translations
    - Hardware assisted




PARAVIRTUALIZATION
FULL VIRTUALIZATION
HW-ASSISTED
RING 3
RING 2
RING 1
RING 0
USER APPS
USER APPS
USER APPS
GUEST OS
PARAVIRTUALIZED GUEST OS
VMM
GUEST OS
VIRTUALIZATION LAYER
VMM
HOST HW
HOST HW
HOST HW
HYPERCALLS
BINARY TRANSLATION
OS REQUEST TRAP TO VMM
https://ipwithease.com

Full virtualization

- In this scenario, data is completely abstracted from the underlying hardware by the virtualization layer. In this technique guest, OS is unaware that it is a guest and hypervisor translate all OS calls on-the-fly. It provides flexibility and no hardware assistance or modification is required.
- The advantages of full virtualization are that the emulation layer isolates VMs from the host OS and from each other. It also controls individual VM access to system resources, preventing an unstable VM from impacting system performance.
- It also provides the total VM portability by emulating a consistent set of system hardware, VMs have the ability to transparently move between hosts with dissimilar hardware without any problems. The products support this virtualization are VMware, Microsoft, and KVM.

Para Virtualization

- It is an enhancement of virtualization technology in which a guest OS is recompiled prior to installation inside a virtual machine. In para-virtualization, the guest OS is modified to enable communication with the hypervisor to improve performance and efficiency.
- Its advantages are that the guest system comes closer to native performance than a fully virtualized guest and also it does nor require the latest virtualization CPU support. It also allows for an interface to the virtual machine that can differ somewhat from that of the underlying hardware.
- VMware and Xen are supported by this type of virtualization.

Hardware-assisted Virtualization

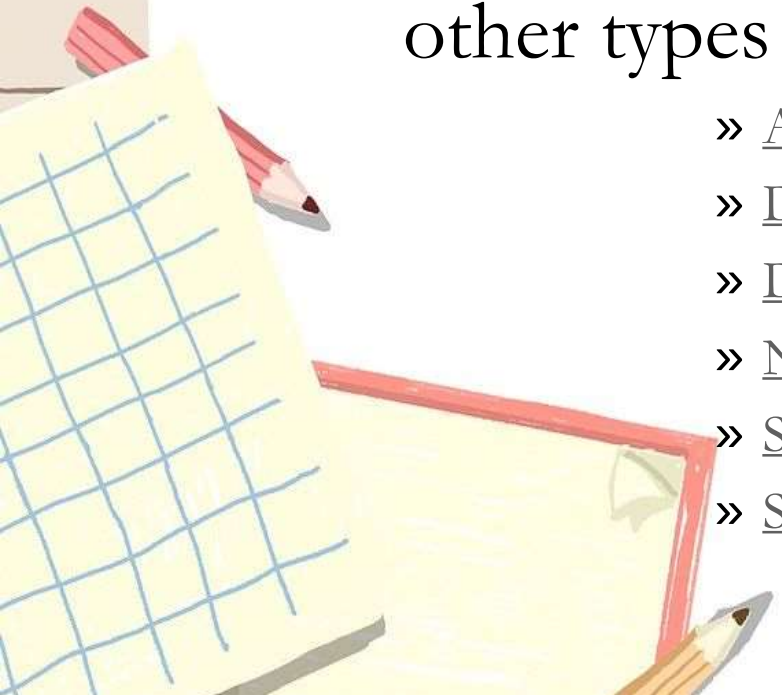
- In enables full virtualization with help of utilizing of a computer's physical components to support the software that creates and manages virtual machines. In this technique of virtualization unmodified guest is OS and no API are made. The sensitive calls are trapped by the hypervisor and in 2006 it was added to x86 processors (Intel VT-x or AMD-V).
- The products supporting hardware-assisted virtualization are VMware, Xen, Microsoft, and Parallels.
- There is additionally a mix of para-virtualization and full virtualization called **Hybrid Virtualization** where parts of the visitor working on paravirtualization for certain hardware drivers, and the host utilizes full virtualization for different highlights. This frequently delivers prevalent execution on the visitor without the requirement for the visitor to be totally par-virtualized.

Comparisons

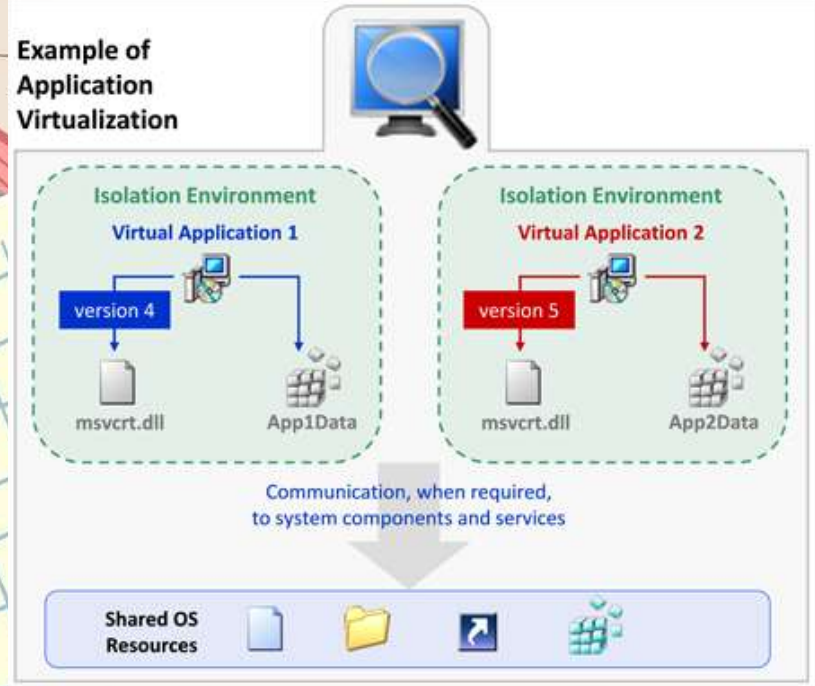
PARAMETER	FULL VIRTUALIZATION	PARA VIRTUALIZATION	HARDWARE ASSISTED VIRTUALIZATION
Generation	1st	2nd	3rd
Performance	Good	Better in certain cases	Fair
Used By	VMware, Microsoft, KVM	VMware, Xen	VMware, Xen, Microsoft, Parallels
Guest OS modification	Unmodified	Codified to issue hypercalls	Unmodified
Guest OS hypervisor independent?	Yes	XenLinux runs only on Hypervisor	Yes
Technique	Direct execution	Hypercalls	Exit to root mode on privileged instruction
Compatibility	Excellent	Poor	Excellent

Types of Virtualization

- Apart from hardware virtualization, other types of virtualization include:
  - » Application Virtualization
  - » Data Virtualization
  - » Desktop Virtualization
  - » Network Virtualization
  - » Server Virtualization
  - » Storage Virtualization



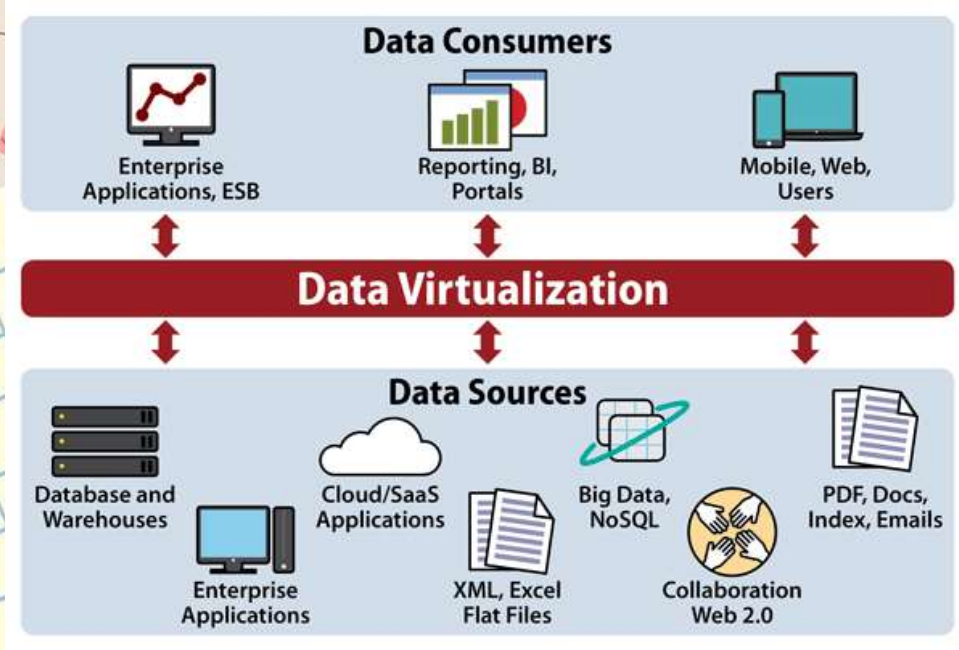
Application virtualization



- The process of installing an application on a central server (single computer system) that can virtually be operated on multiple systems is known as application virtualization. For end users, the virtualized application works exactly like a native application installed on a physical machine. With application virtualization, it's easier for organizations to update, maintain, and fix applications centrally. Admins can control and modify access permissions to the application without logging in to the user's desktop.

- Virtualizing an app allows for seamless use for the end-user, making it possible for the employee to work remotely with the same key programs installed in the office. When virtualized, apps work in what is called a sandbox, an environment that runs separately from the operating system. While operating in this sandbox, any changes will appear to run in the operating system, though the app is pulling operating power from the sandbox.
- There are two distinct kinds of application virtualization:
  - **Remote** applications run on a server that mimics the user desktop and can be accessed by authorized users regardless of their location.
  - **Streaming** apps run just one instance on the server and provide local access to the app.
- Remote app streaming is the more popular approach, thanks to the extended reach it grants.
- With just one instance of the app to manage and fix, an organization's IT professionals can save time and effort through app virtualization compared to installing the app on each user's computer.

Data Virtualization

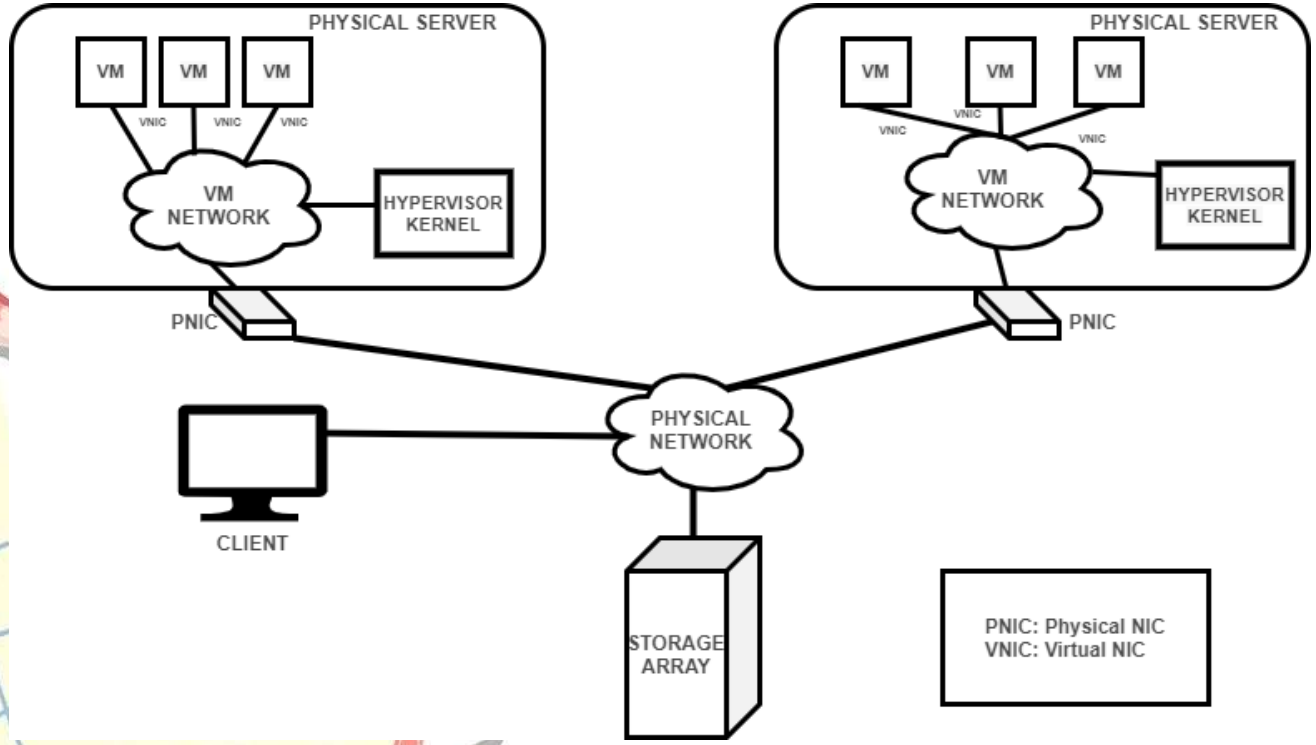


- Data virtualization is a data management approach. It retrieves, segregates, manipulates, and delivers data without any data specifications.
- Any technical details of the data like its exact location and formatting information are not needed to access it. It allows the application to get a singular view of the overall data with real-time access.
- Data virtualization software helps with data warehouse management and eliminates latency. It also provides users with on-demand integration, quick analysis, and real-time search and reports capabilities.

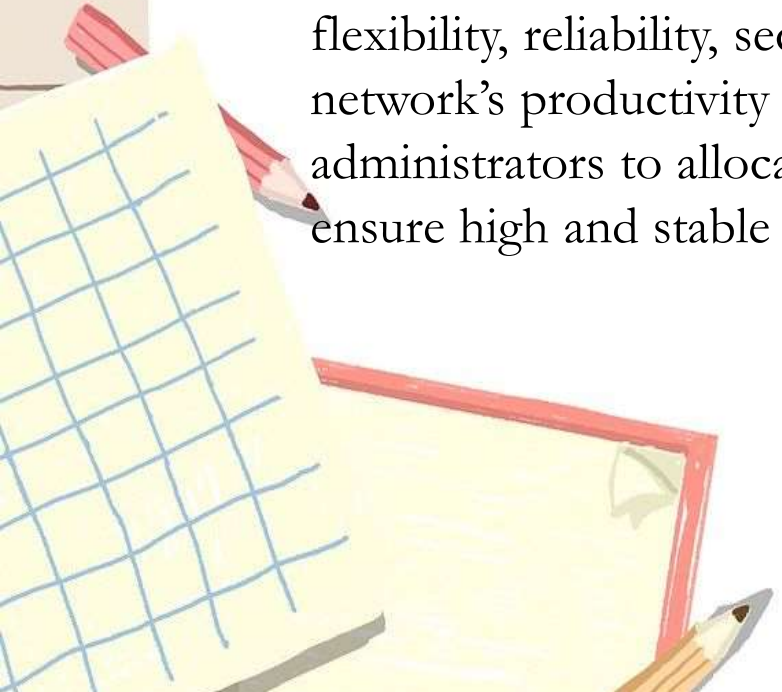
Desktop virtualization

- Creating a virtual desktop infrastructure, or VDI, makes it possible to work and store files in locations that everyone in your team can easily access no matter where they work.
- Desktop virtualization allows people to access multiple applications and operating systems (OS) on a single computer because the applications and OSs are installed on virtual machines that run on a server in the data centre.
- **When it comes to desktop virtualization, there are two main methods: local and remote. Local and remote desktop virtualization** are both possible depending on the business needs.
- Remote desktop virtualization is more robust and popular in the marketplace, with users running operating systems and applications accessed from a server located inside a secure data center.

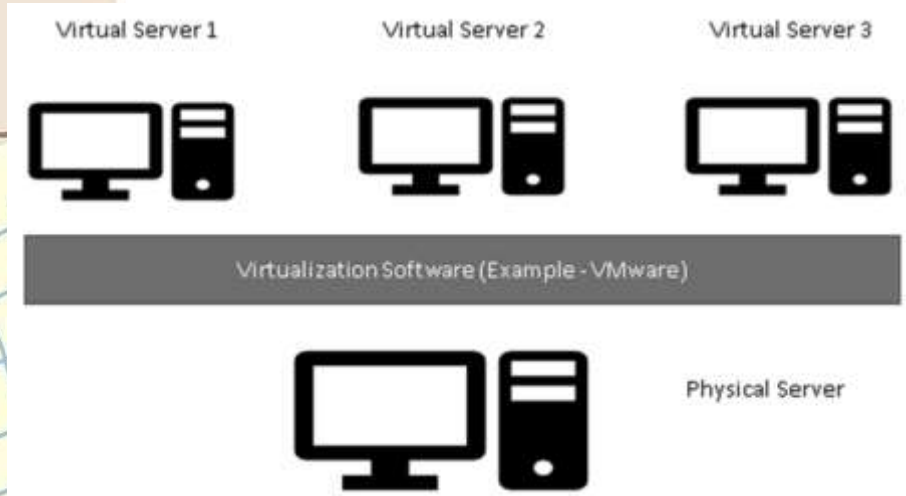
Network virtualization



- Network virtualization helps manage and monitor the entire computer network as a single administrative entity. Admins can keep a track of various elements of network infrastructure such as routers and switches from a single software-based administrator's console. Network virtualization helps network optimization for data transfer rates, flexibility, reliability, security, and scalability. It improves the overall network's productivity and efficiency. It becomes easier for administrators to allocate and distribute resources conveniently and ensure high and stable network performance.

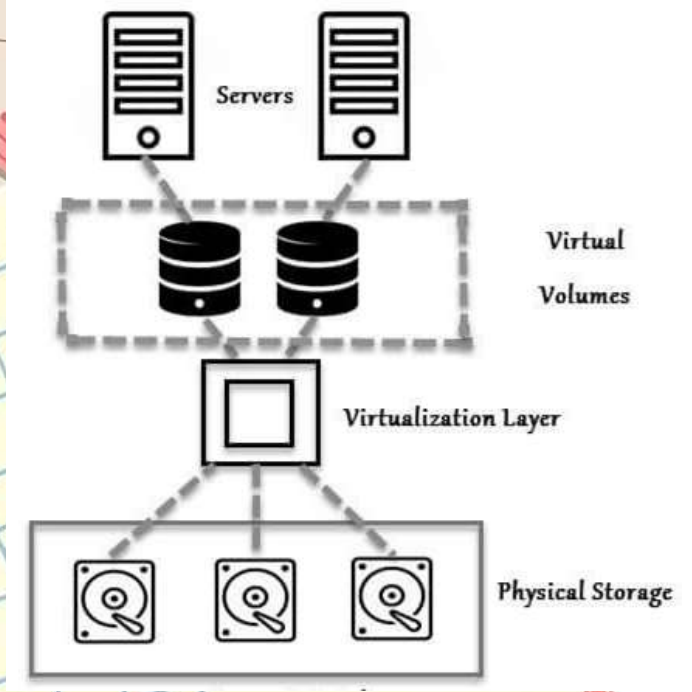


Server virtualization



Server virtualization is a process of partitioning the resources of a single server into multiple virtual servers. These virtual servers can run as separate machines. Server virtualization allows businesses to run multiple independent OSs (guests or virtual) all with different configurations using a single (host) server. The process also saves the hardware cost involved in keeping a host of physical servers, so businesses can make their server infrastructure more streamlined.

Storage virtualization



- Storage virtualization performs resource abstraction in a way that the multiple physical storage arrays are virtualized as a single storage pool with direct and independent access.
- The storage virtualization software aggregates and manages storage in various storage arrays and serves it to applications whenever needed.
- The centralized virtual storage increases flexibility and availability of resources needed. This data virtualization and centralization is easily manageable from a central console. It allows users to manage and access multiple arrays as a single storage unit.

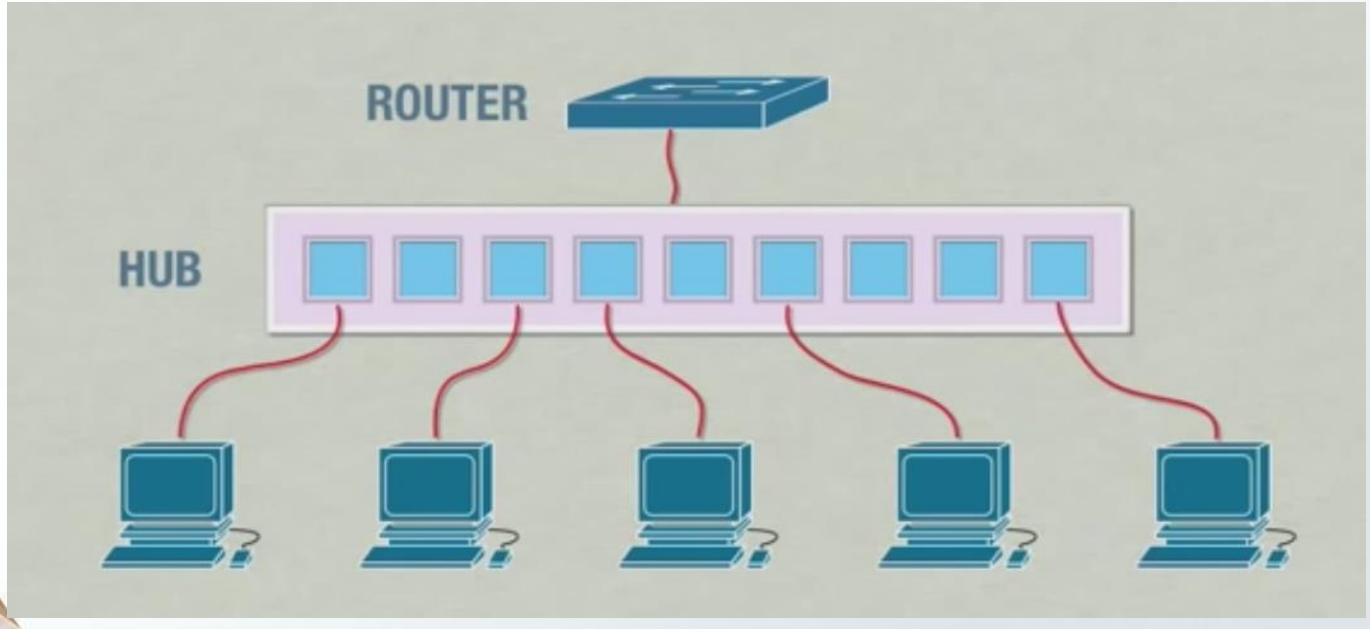
Concepts covered

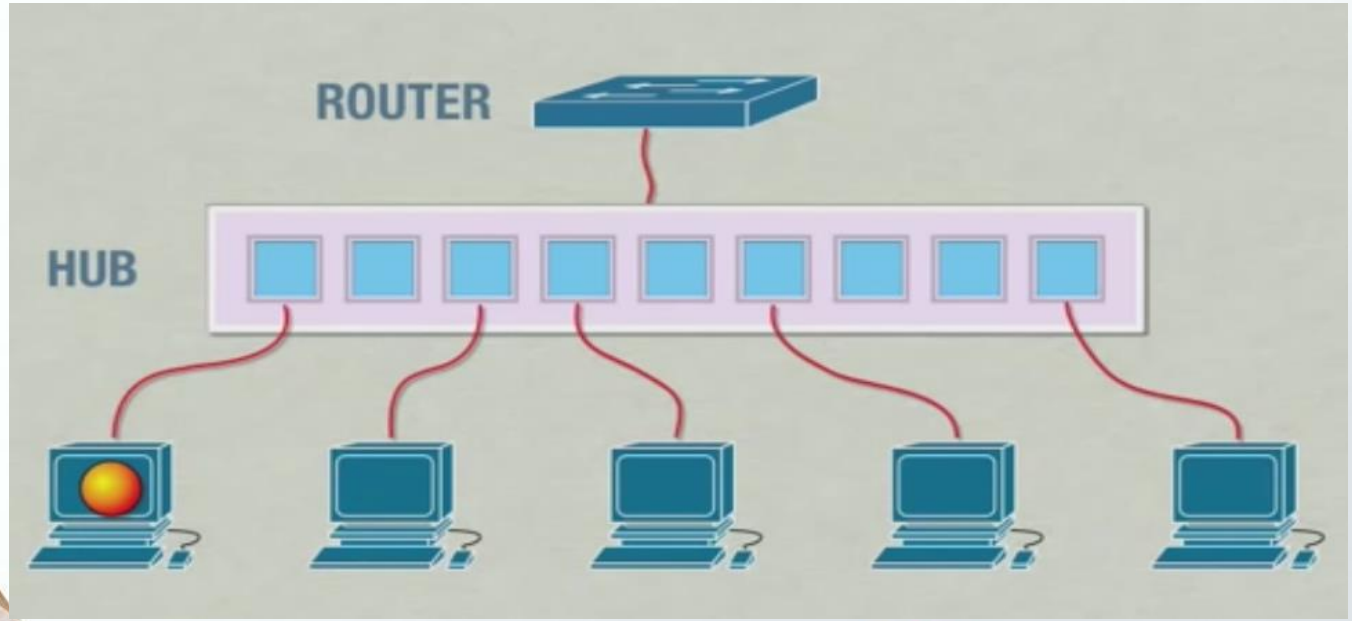
- Static LAN [SLAN]
- Concept of VLAN
- VSAN
- VSAN and benefits

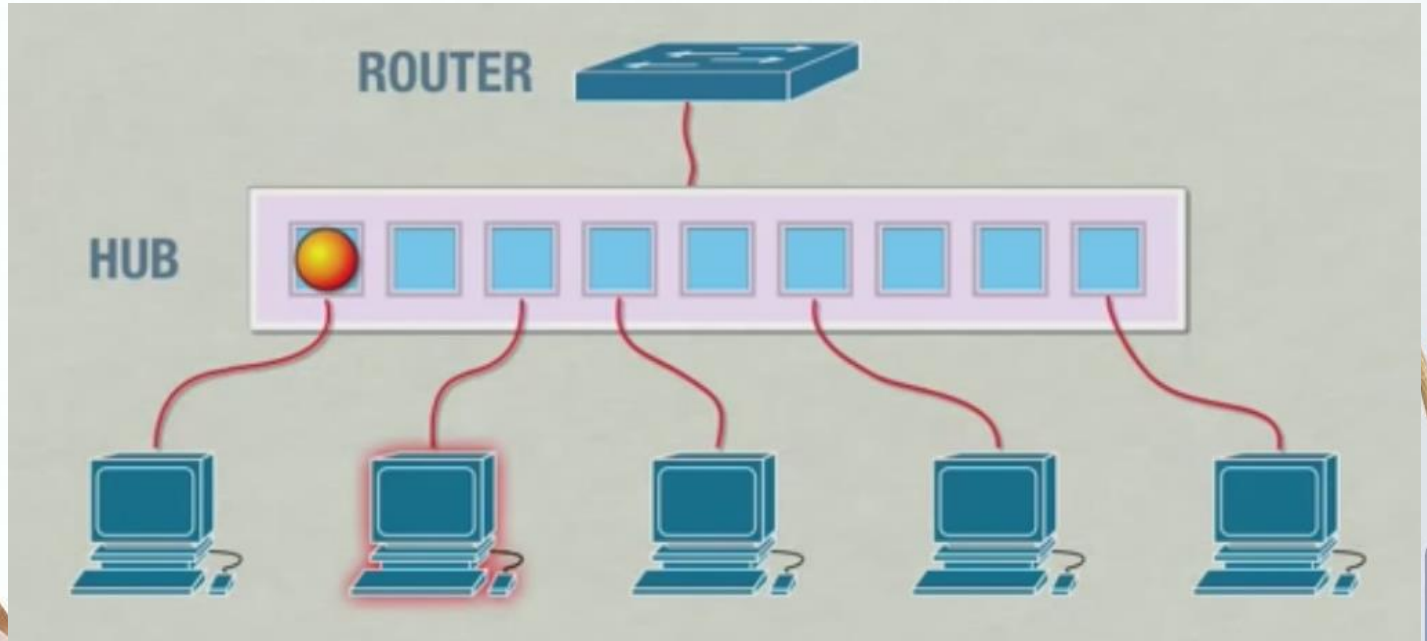

Static LAN

- A LAN is a computer network that consists of access points, cables, routers, and switches that enable devices to connect to web servers and internal servers within a single building, campus, or home network, and to other LANs.
- A router assigns IP addresses to each device on the network and facilitates a shared Internet connection between all the connected devices. A network switch connects to the router and facilitates communication between connected devices, but does not handle Local Area Network IP configuration or sharing Internet connections. Switches are ideal tools for increasing the number of LAN ports available on the network.

Flow of packets in Static LAN




ROUTER
HUB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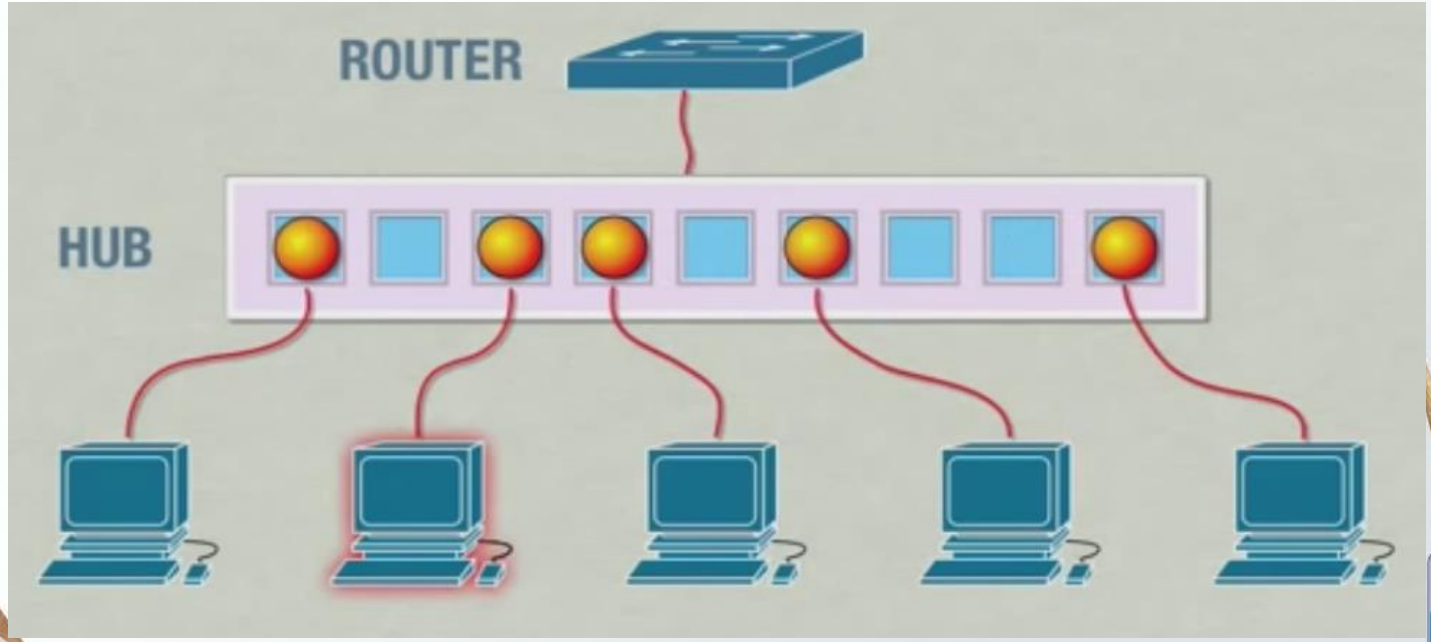
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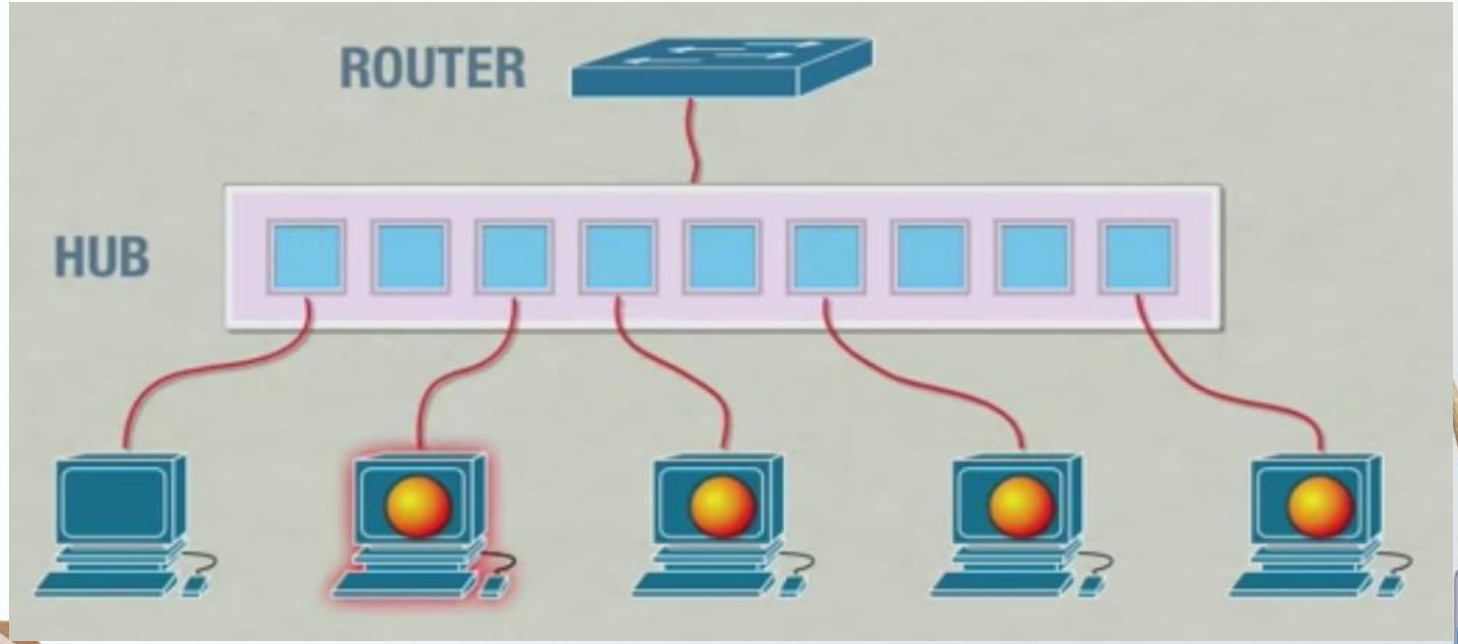
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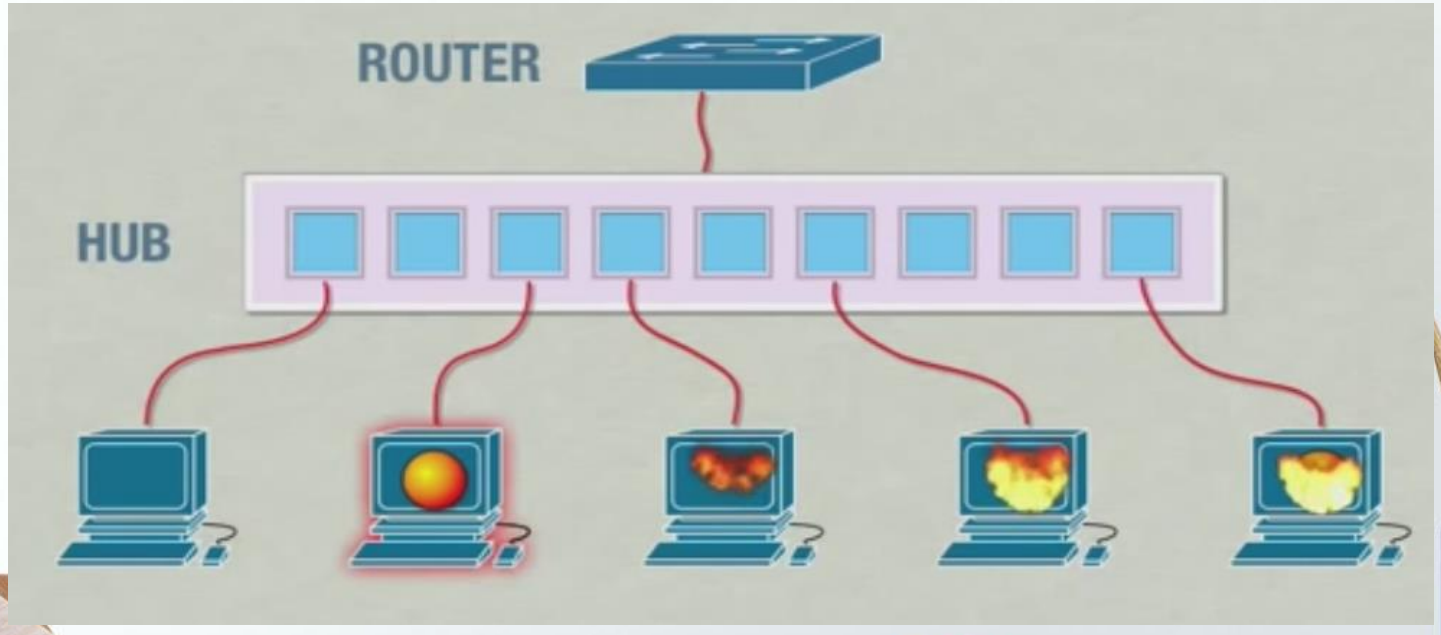
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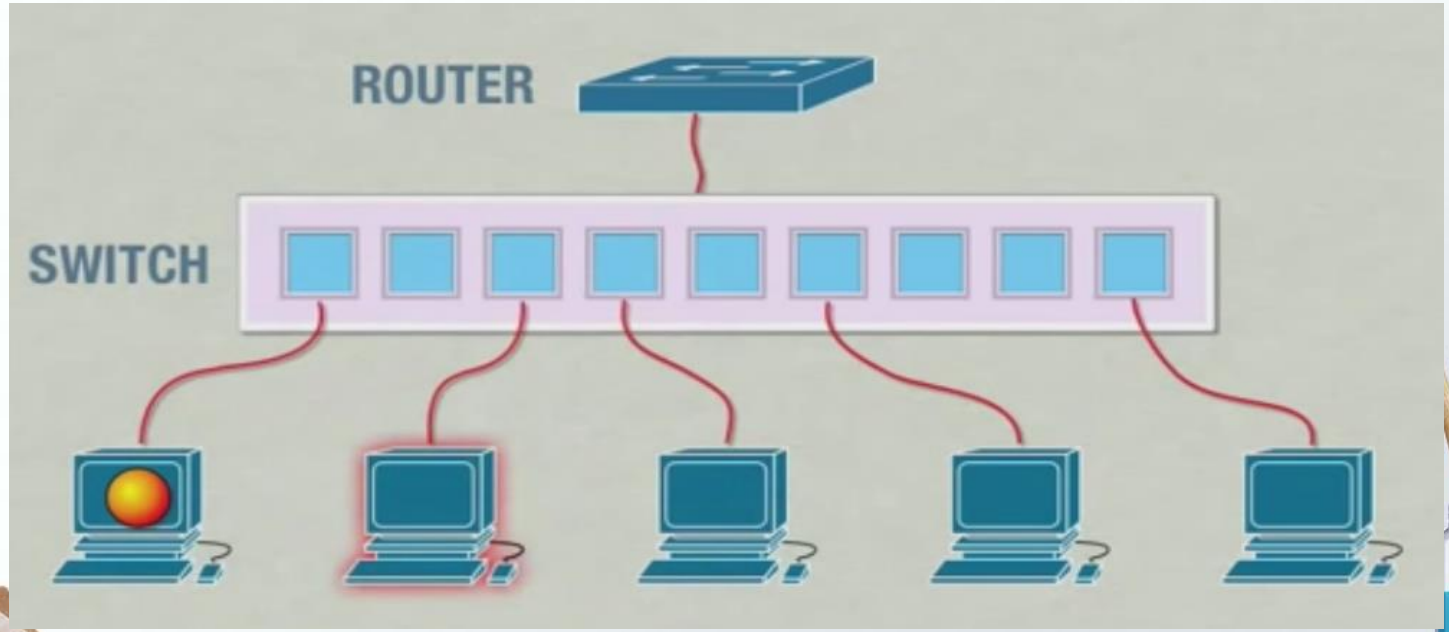
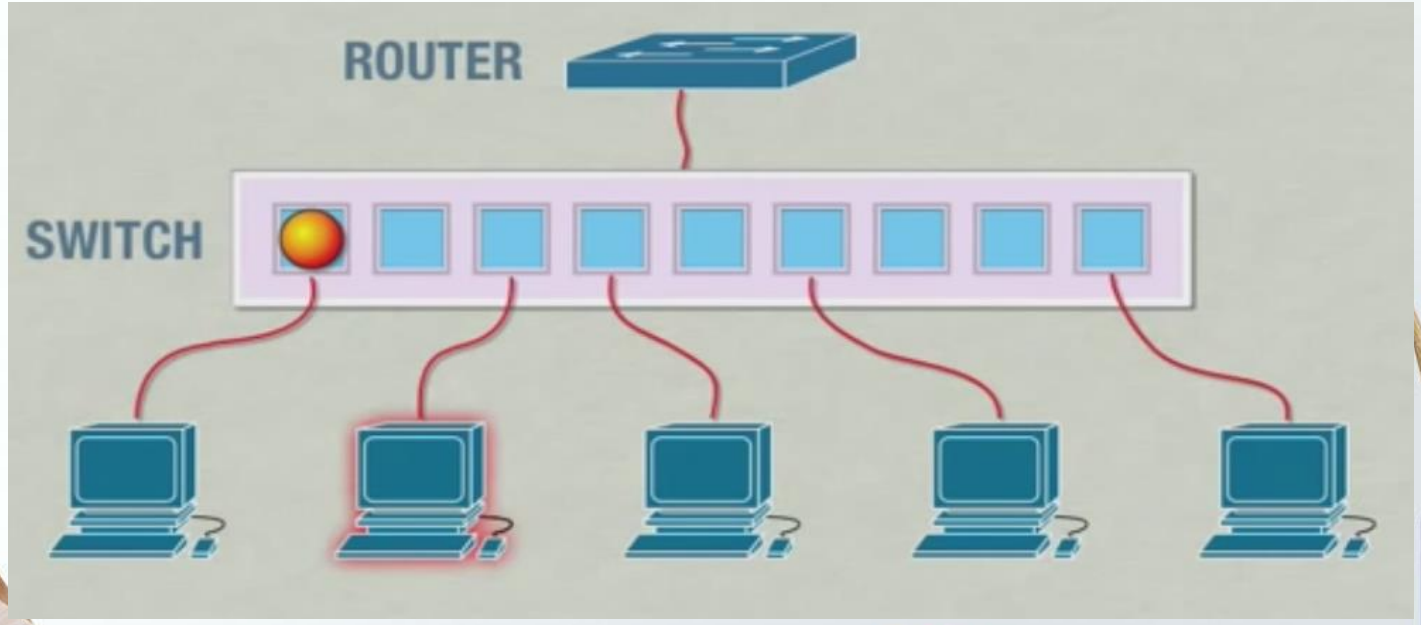

ROUTER
SWITCH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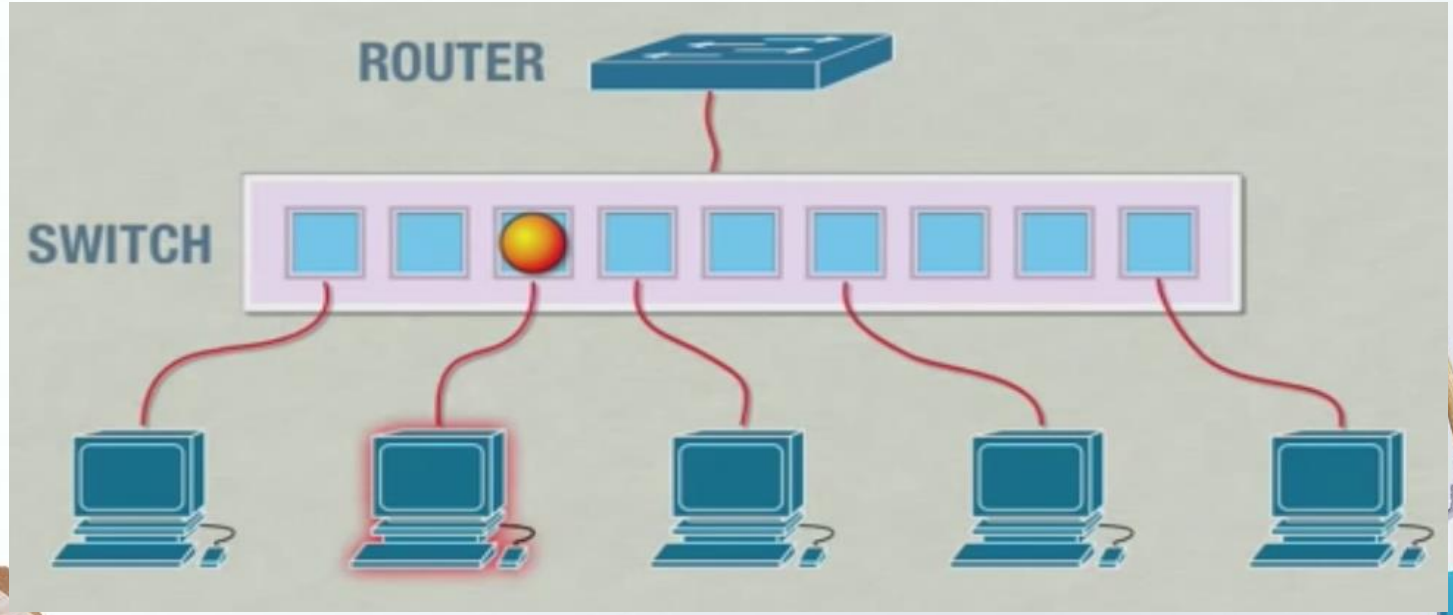
SWITCH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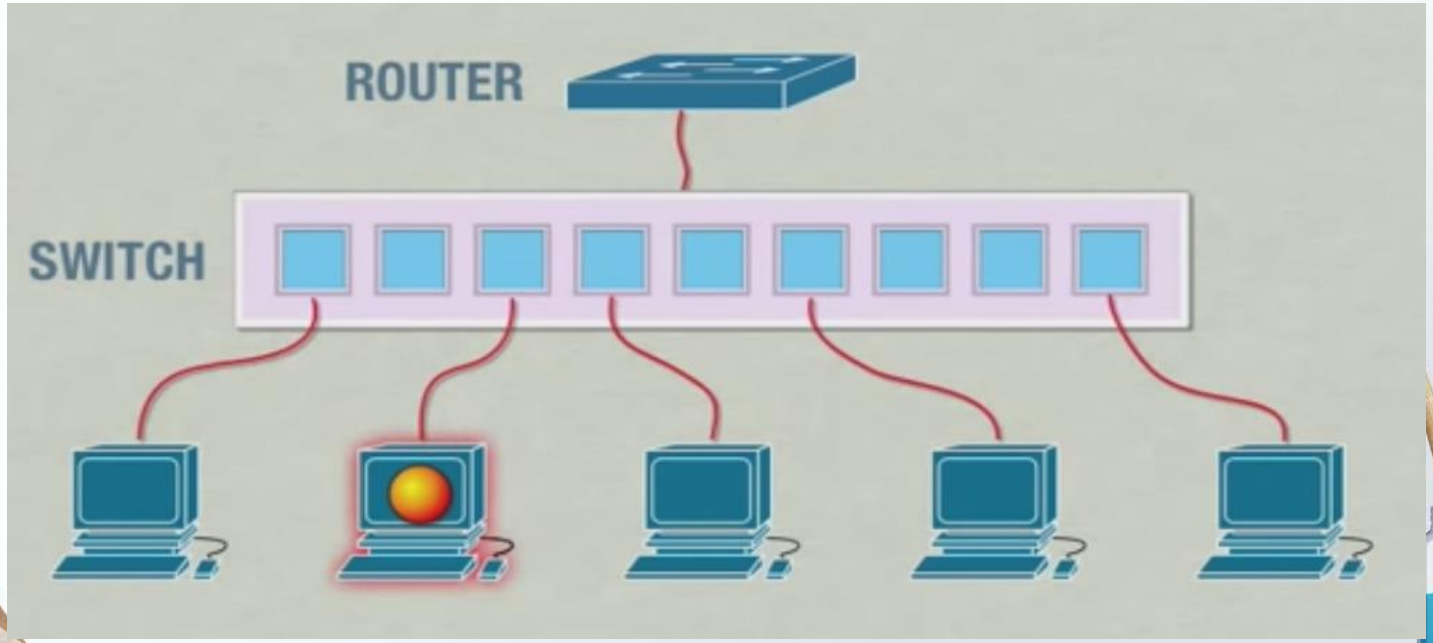
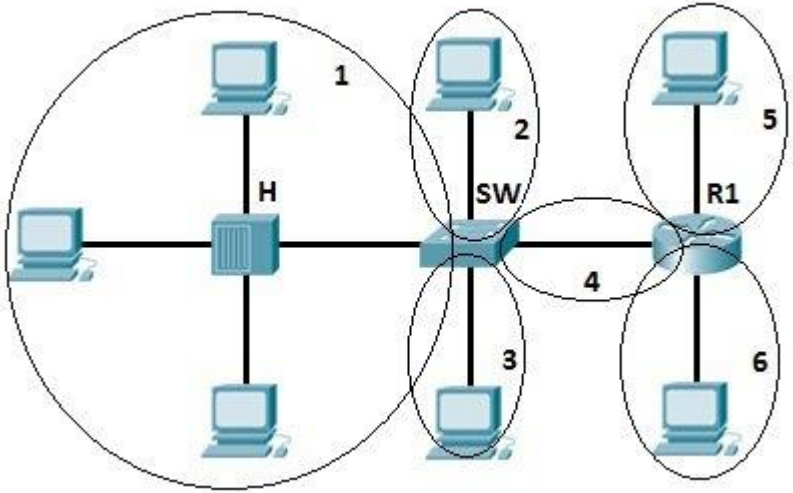
SWITCH


ROUTER
SWITCH

Collision Domain

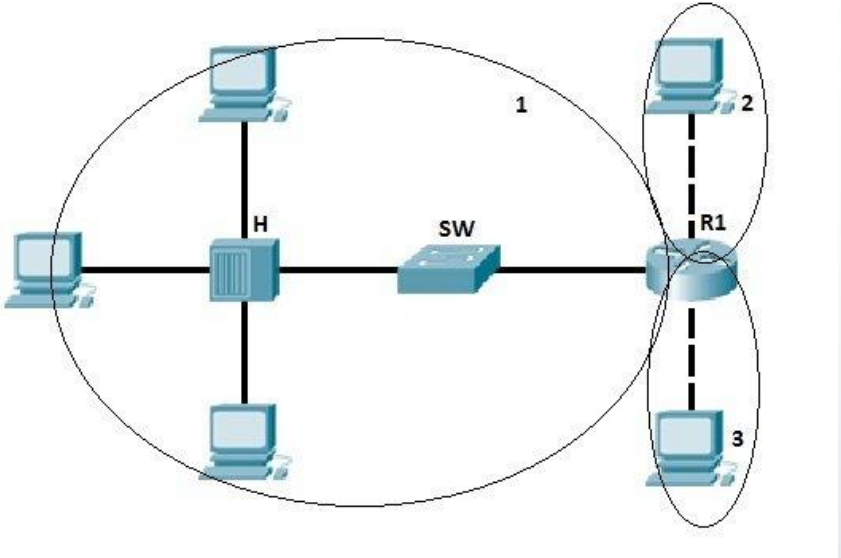
- A collision domain is, as the name implies, the part of a network where packet collisions can occur. A collision occurs when two devices send a packet at the same time on the shared network segment. The packets collide and both devices must send the packets again, which reduces network efficiency. Collisions are often in a hub environment, because each port on a hub is in the same collision domain. By contrast, each port on a bridge, a switch or a router is in a separate collision domain.



- In this figure you can see 6 collision domains highlighted

Broadcast Domain

- A broadcast domain is the domain in which a broadcast is forwarded. A broadcast domain contains all devices that can reach each other at the data link layer (OSI layer 2) by using broadcast. All ports on a hub or a switch are by default in the same broadcast domain. All ports on a router are in the different broadcast domains and routers don’t forward broadcasts from one broadcast domain to another.



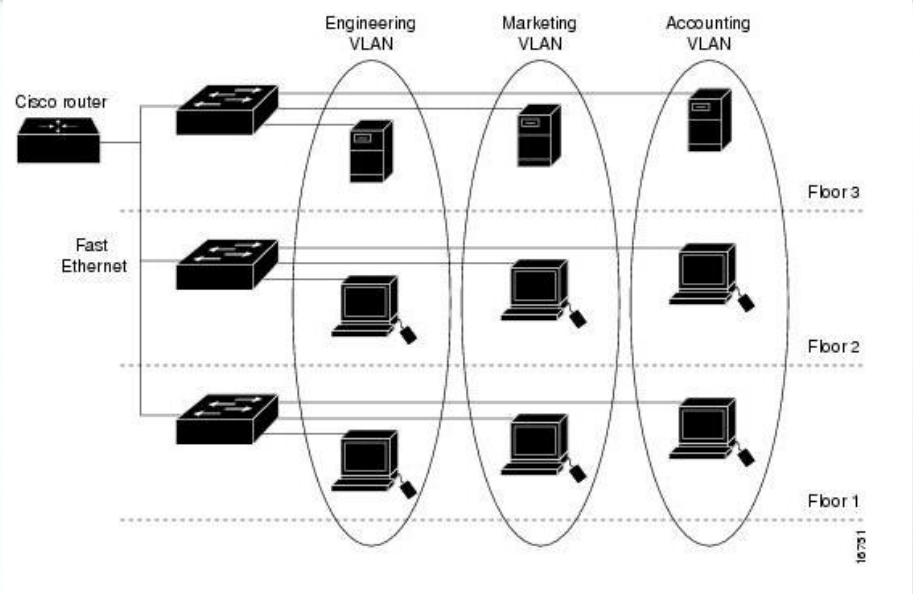
- In the picture above we have three broadcast domains, since all ports on a hub or a switch are in the same broadcast domain, and all ports on a router are in a different broadcast domain.

Issues

- As the number of devices in the Broadcast Domain increases, number of Broadcasts also increases and the quality of the network will come down because of the following reasons.
  - **Decrease in available Bandwidth:** Large number of Broadcasts will reduce the available bandwidth of network links for normal traffic because the broadcast traffic is forwarded to all the ports in a switch.
  - **Decrease in processing power of computers:** Since the computers need to process all the broadcast packets it recieve, a portion of the computer CPU power is spent on processing the broadcast packets.


Why VLAN ?

- A VLAN shares similar characteristics to a LAN, but a VLAN allows different computers and devices to be connected virtually to each other as if they were in a LAN sharing a single broadcast domain. In a way, a VLAN acts mini separate networks within a LAN. A VLAN is helpful for organizational use mainly because it can be used to segment a larger network into smaller segments. As shown in the figure below, different VLANs can be used for different groups of users, departments, functions, etc., without needing to be in the same geographical area.



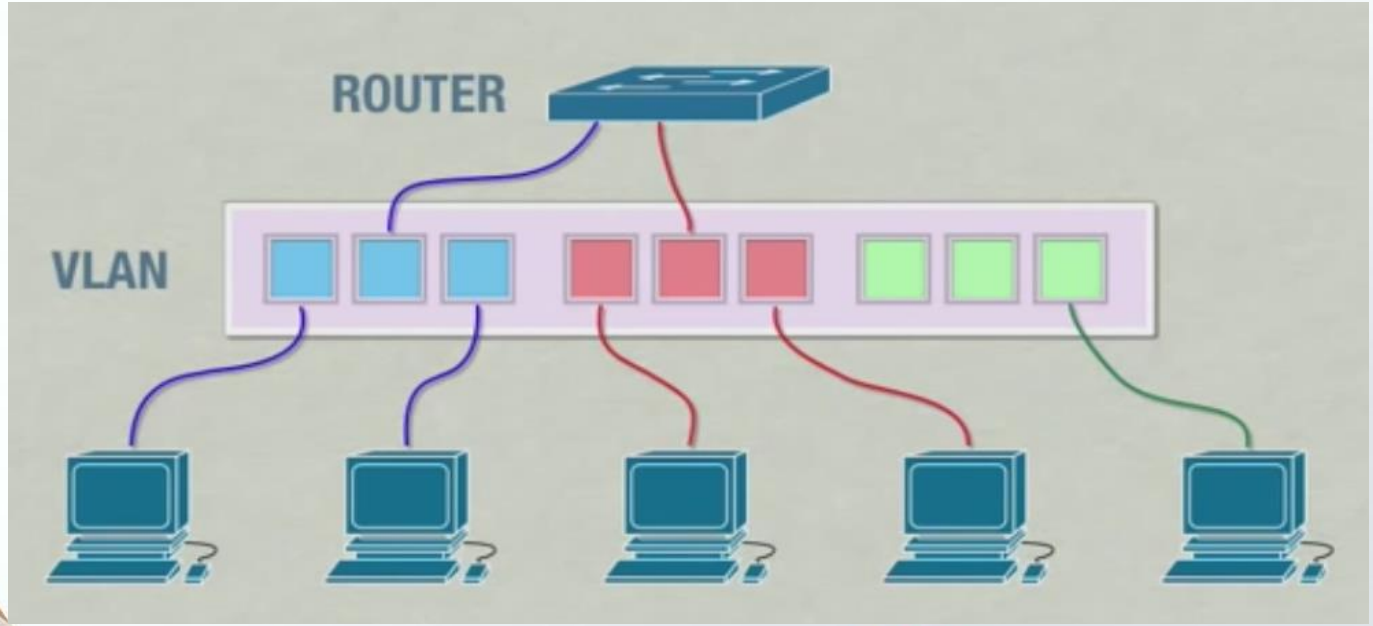
- Segmentation of a network helps to increase security, reliability, and efficiency of a network. There are a variety of ways a VLAN can be utilized to fit an organization’s needs.

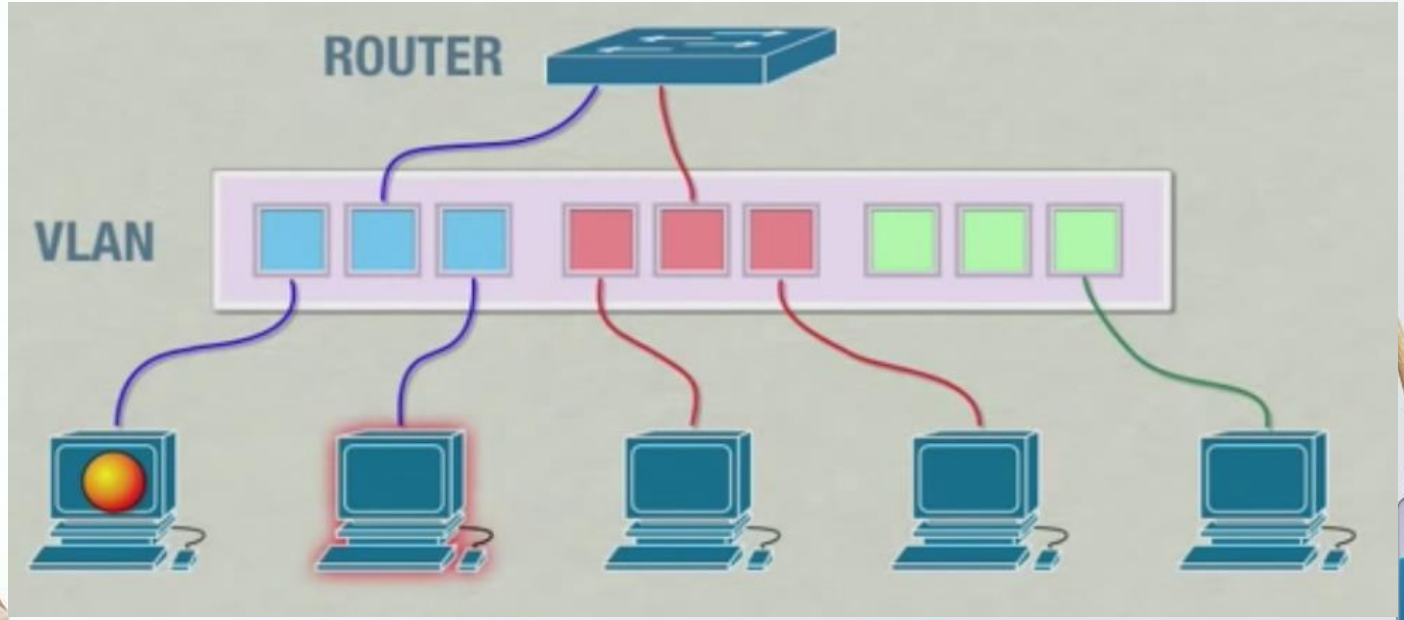
- A VLAN allows different computers and devices to be connected virtually to each other as if they were in a LAN sharing a single broadcast domain.
- A VLAN is helpful for organizational use mainly because it can be used to segment a larger network into smaller segments.
- VLANs can limit user access to a certain VLAN, which then allows only authorized users to have access to networks with highly sensitive information.
- VLANs can be used for different groups of users, departments, functions, etc., without needing to be in the same geographical area.
- VLANs can help reduce IT cost, improve network security and performance, provide easier management, as well as ensuring network flexibility.

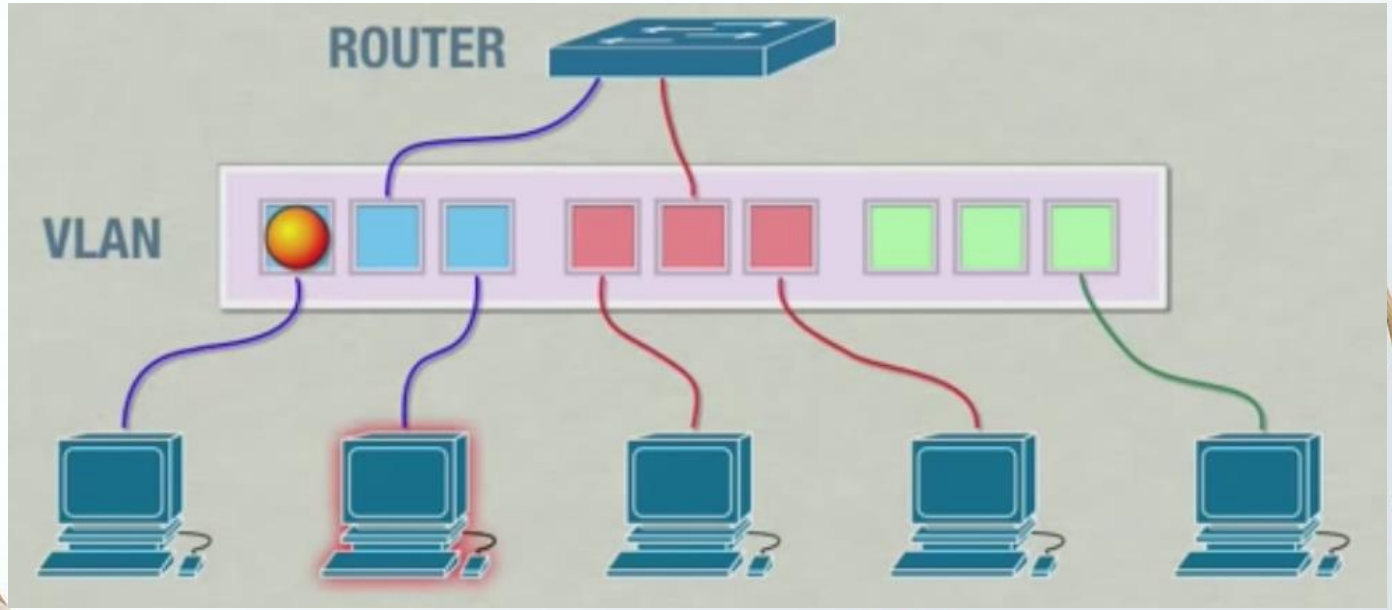
Points to ponder…

- Why not create a large subnet instead of smaller VLANs or LANs? A single subnet is simple to understand and implement but creates problems as the network grows. By creating smaller subnets, this **limits the broadcast domain traffic**. Think of broadcast traffic as one device making an announcement to the rest of the devices in the network like a person speaking to a large audience, but in networking every device can speak at the same time.

Scenario for VLANs




ROUTER
VLAN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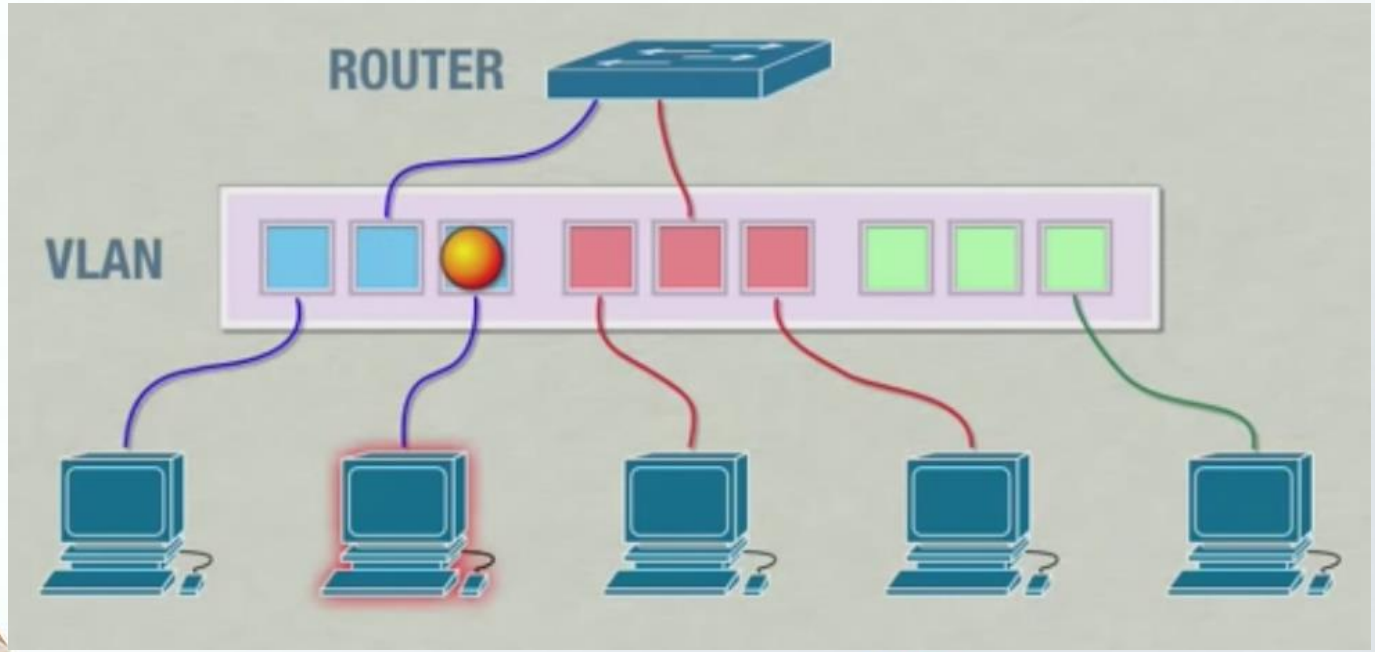
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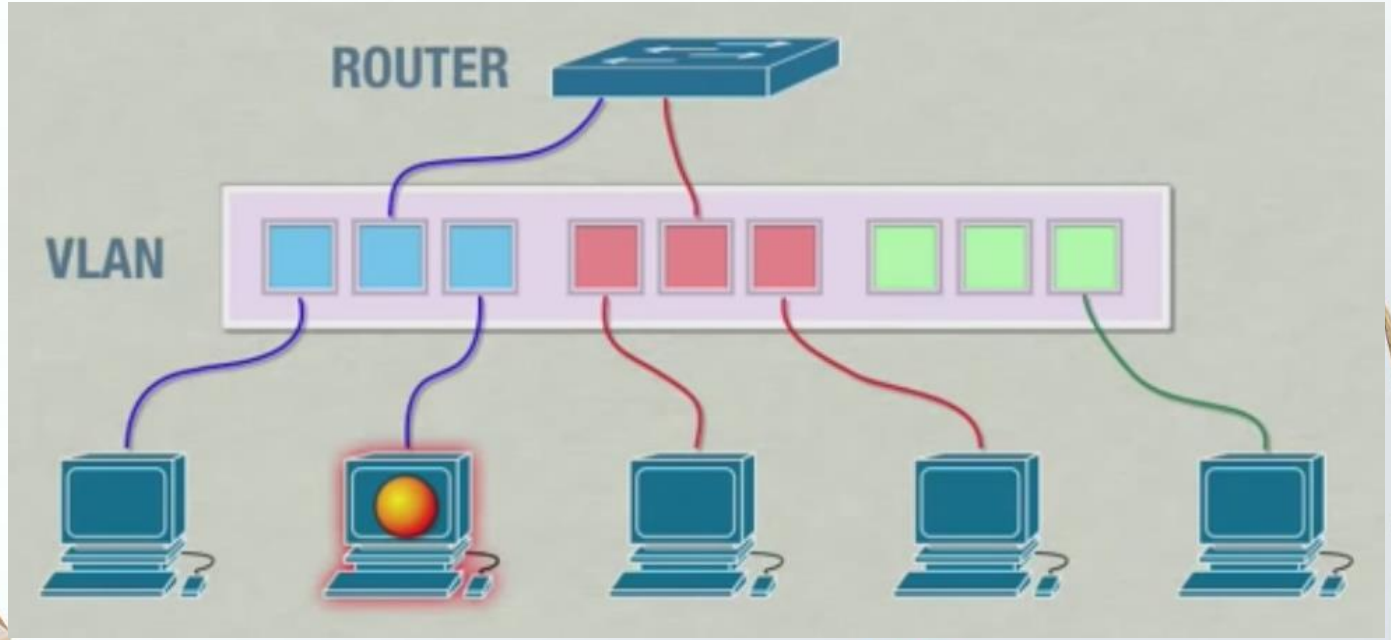
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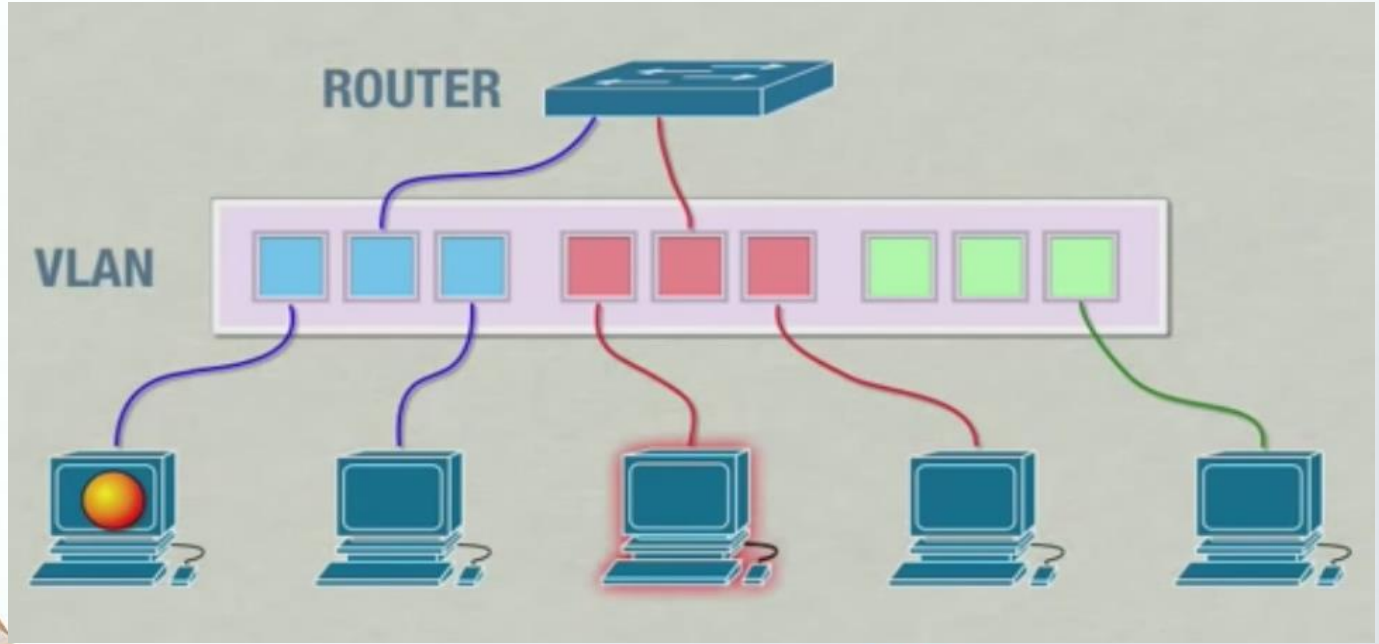
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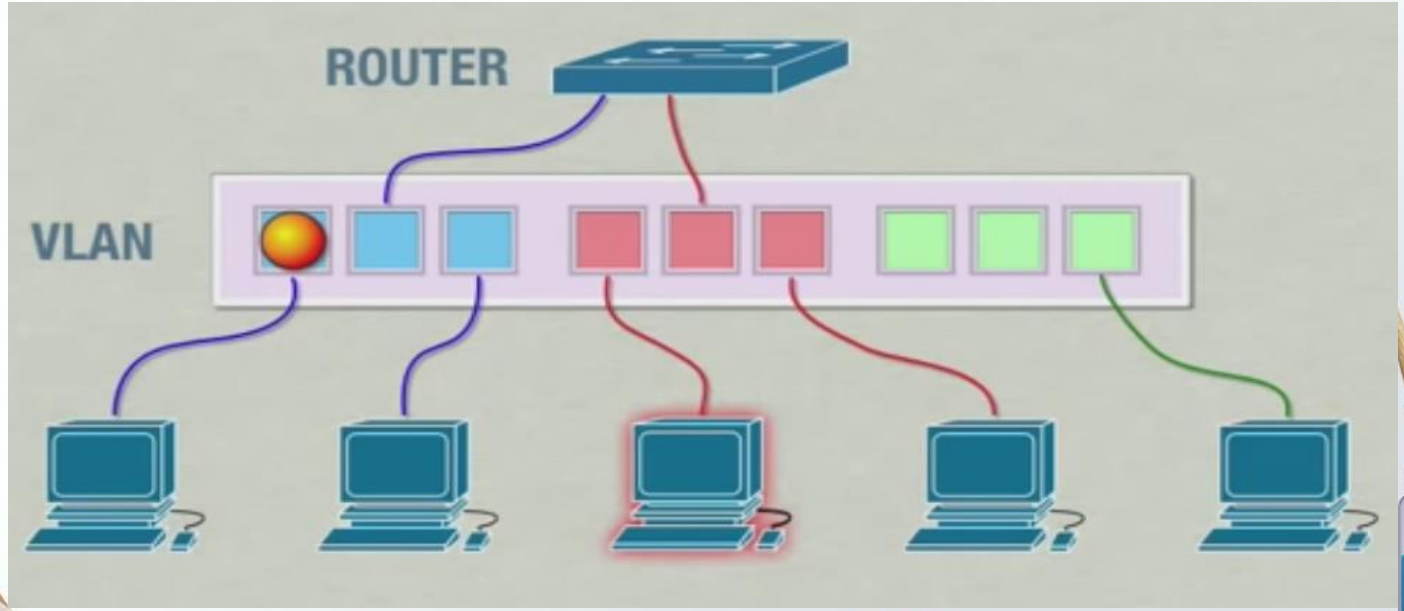
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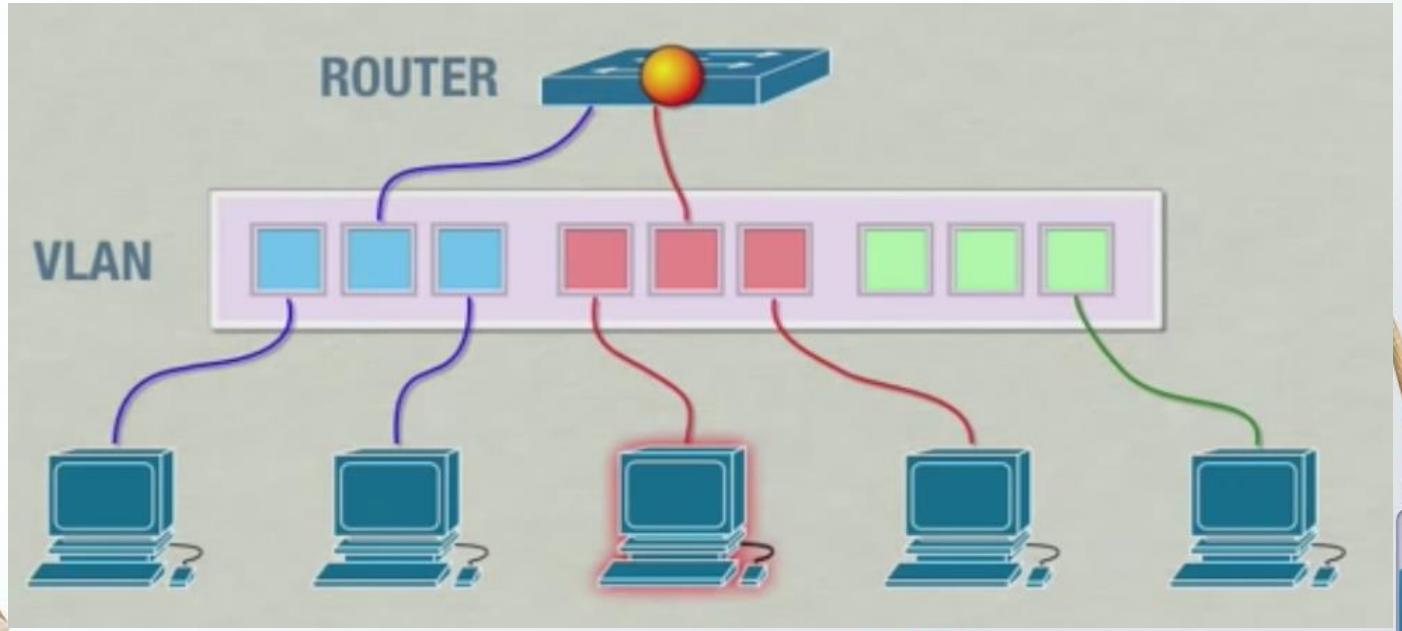
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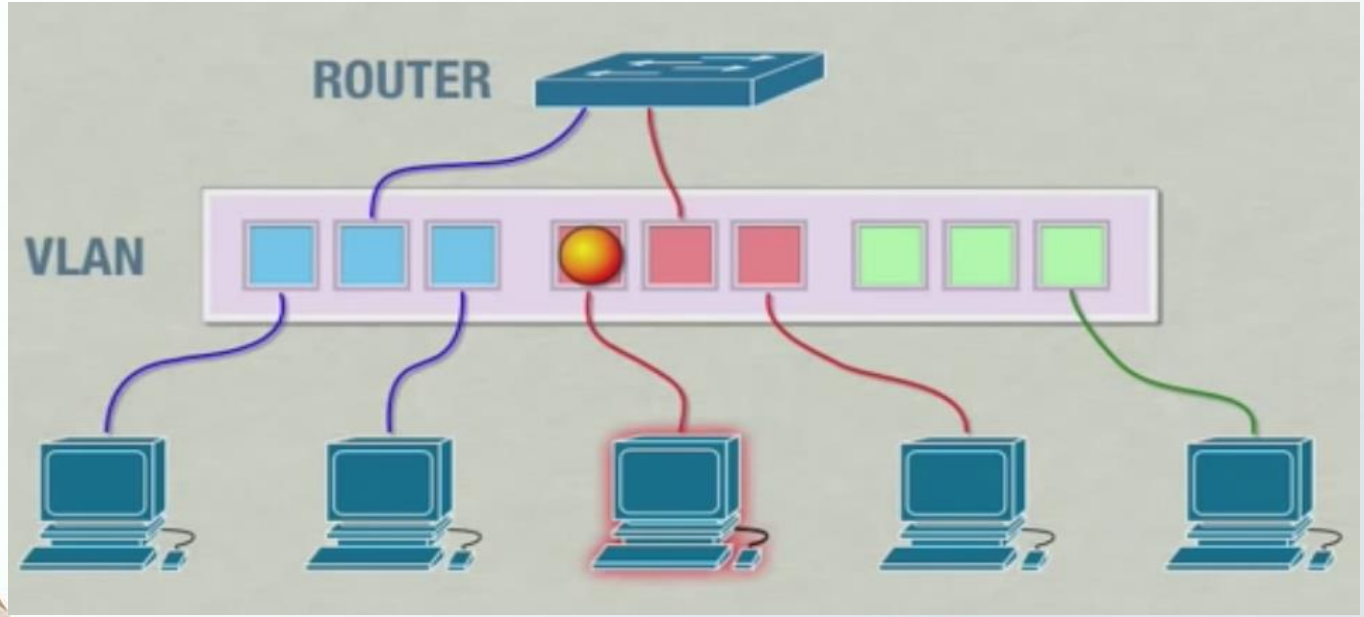
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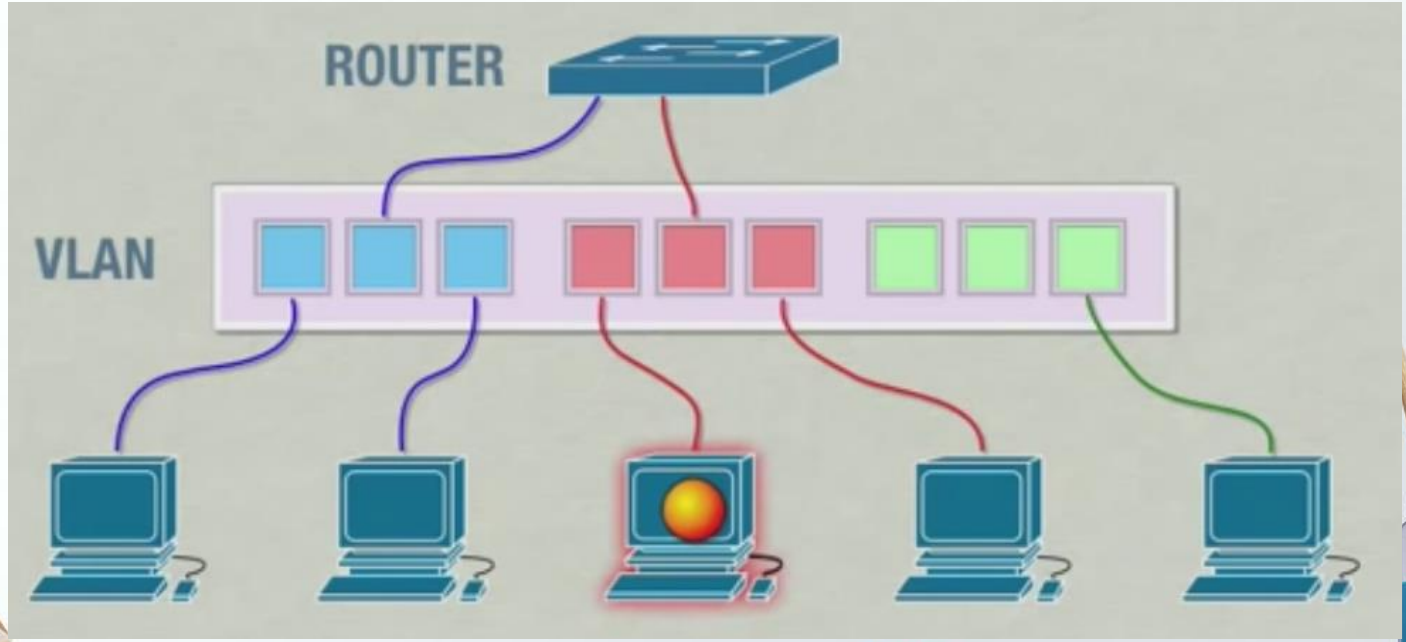
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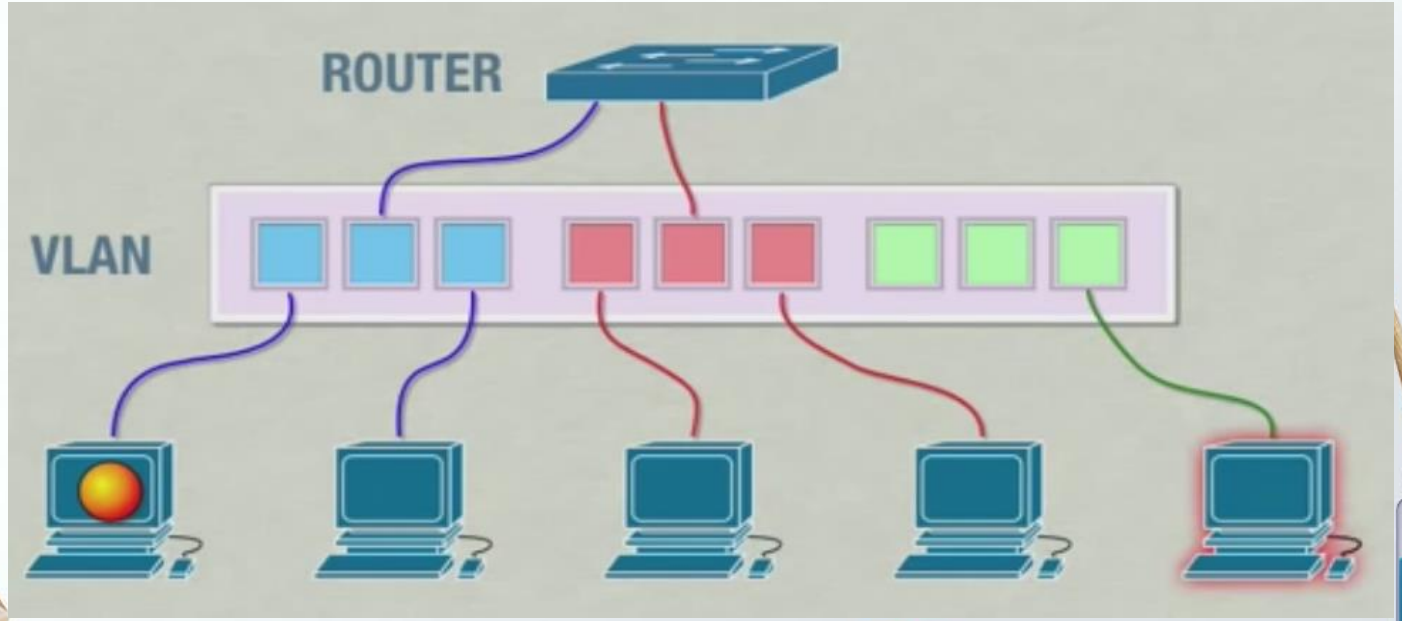
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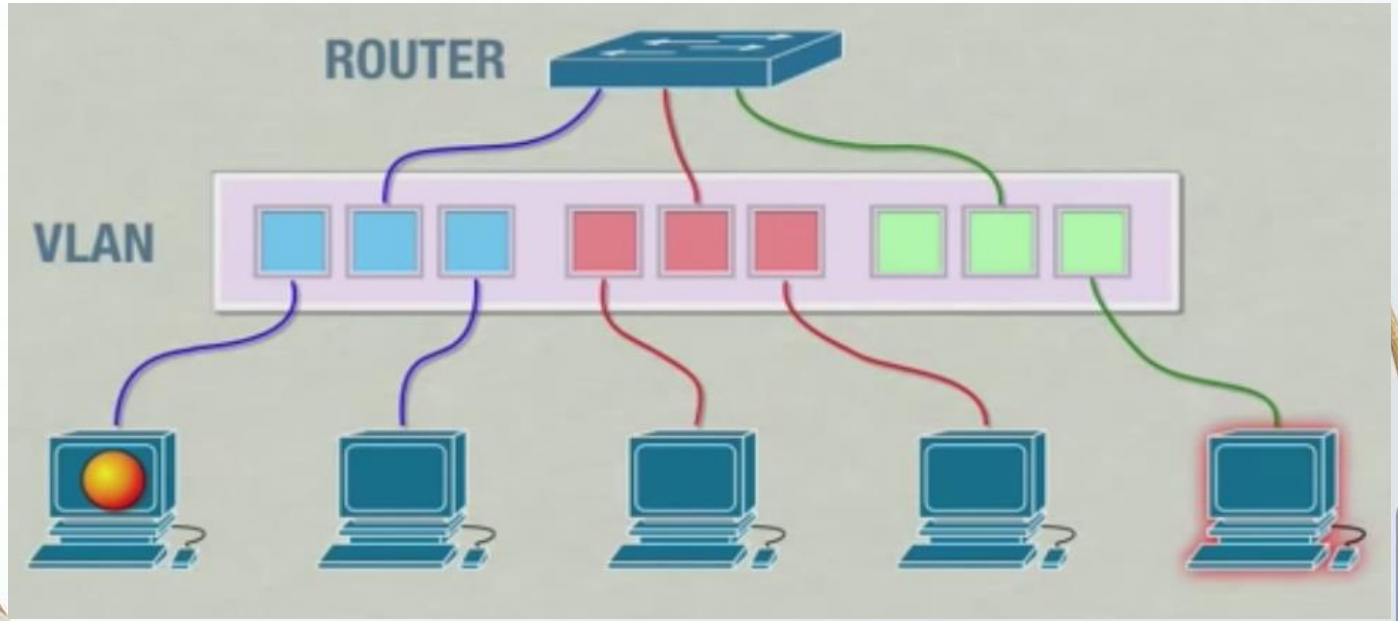
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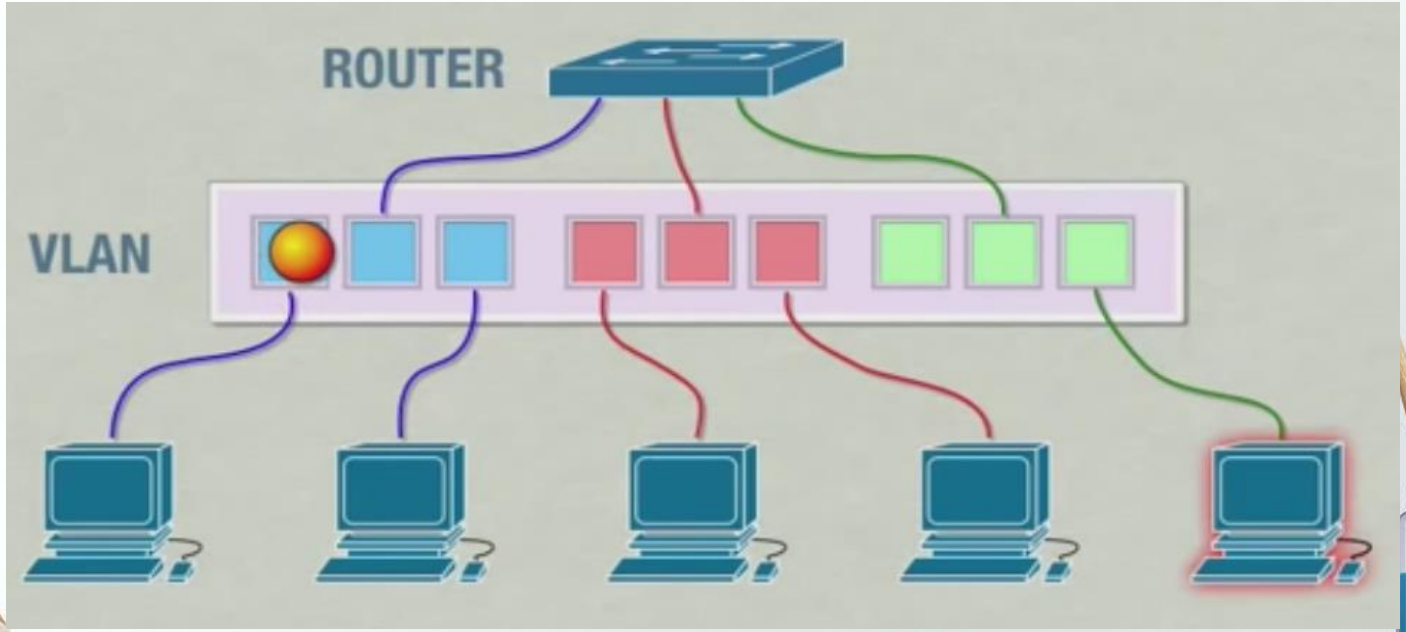
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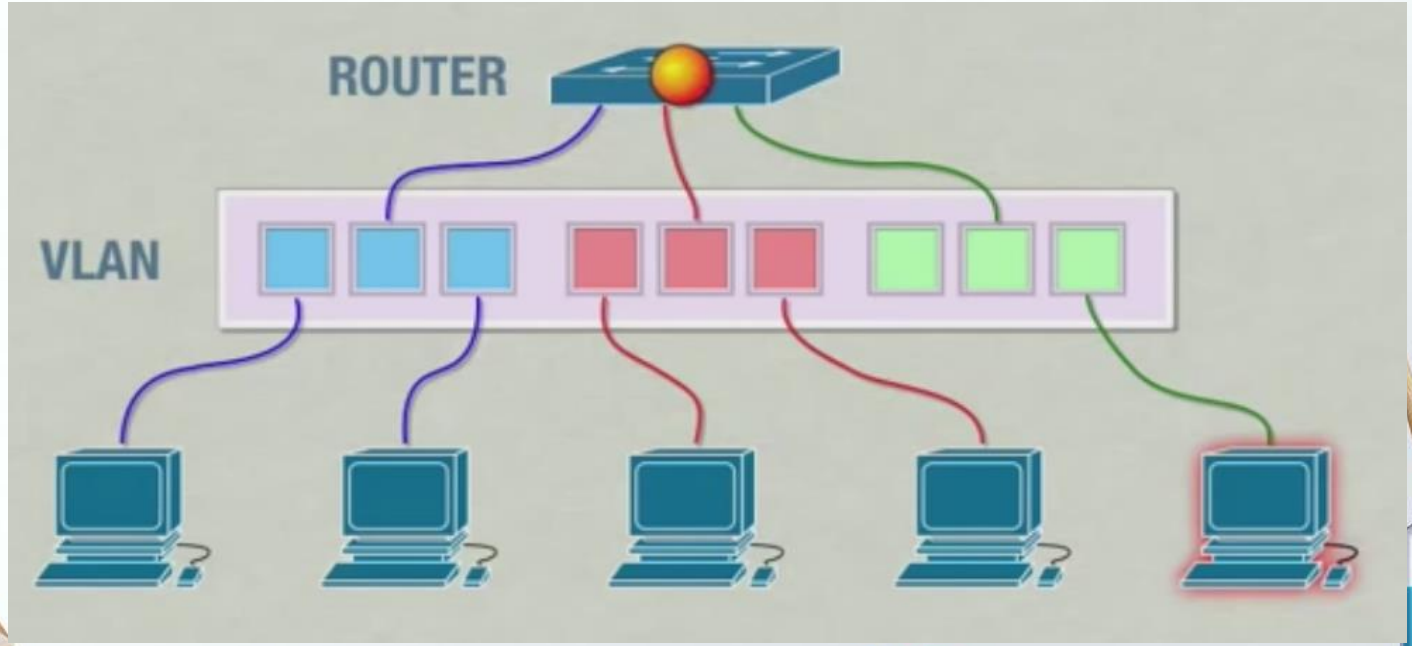
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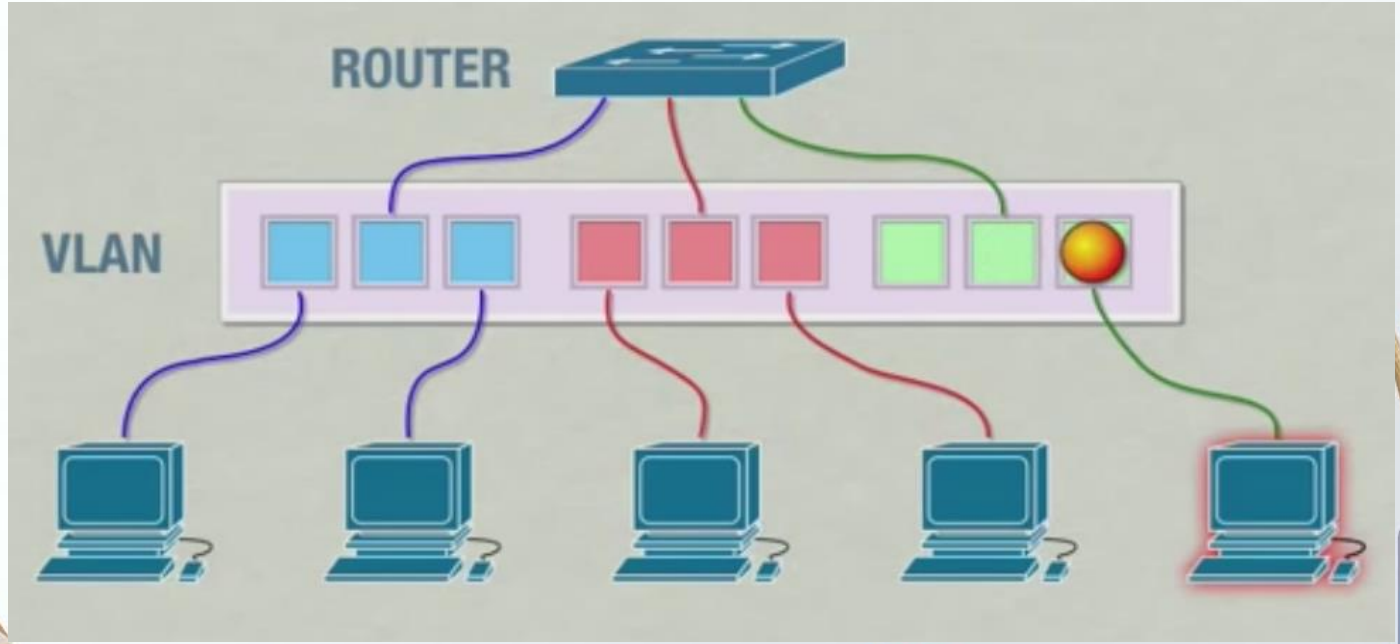
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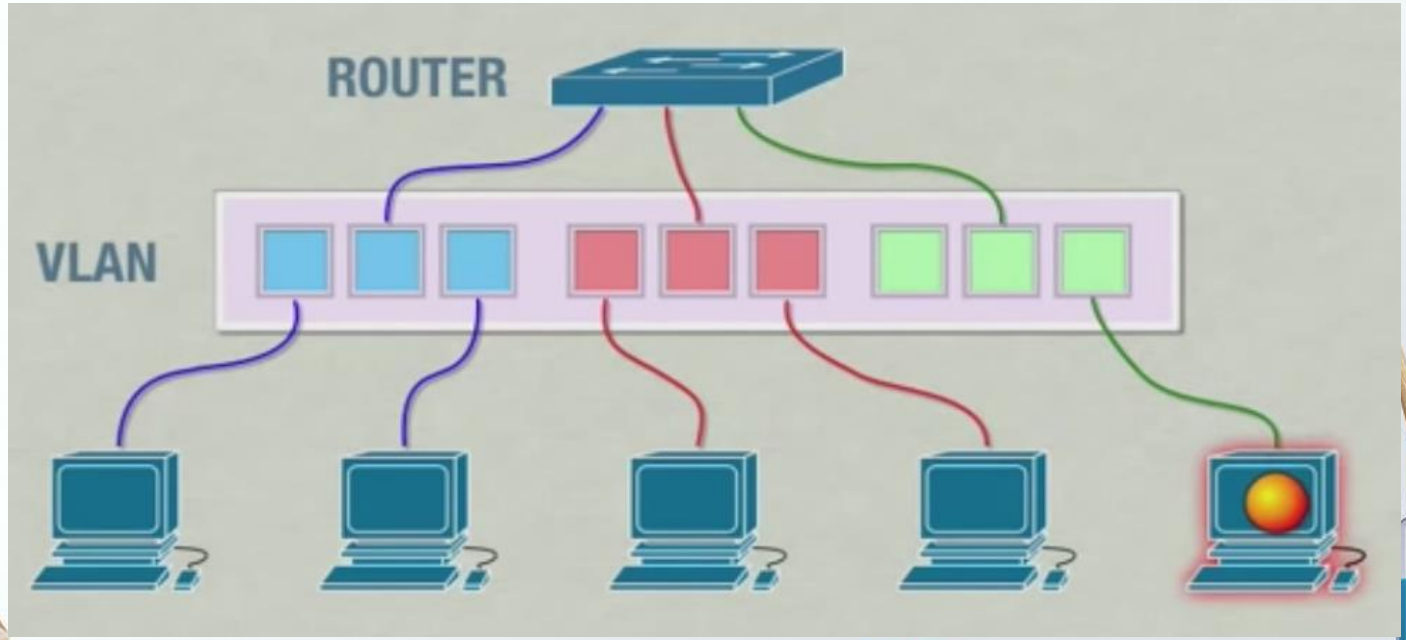
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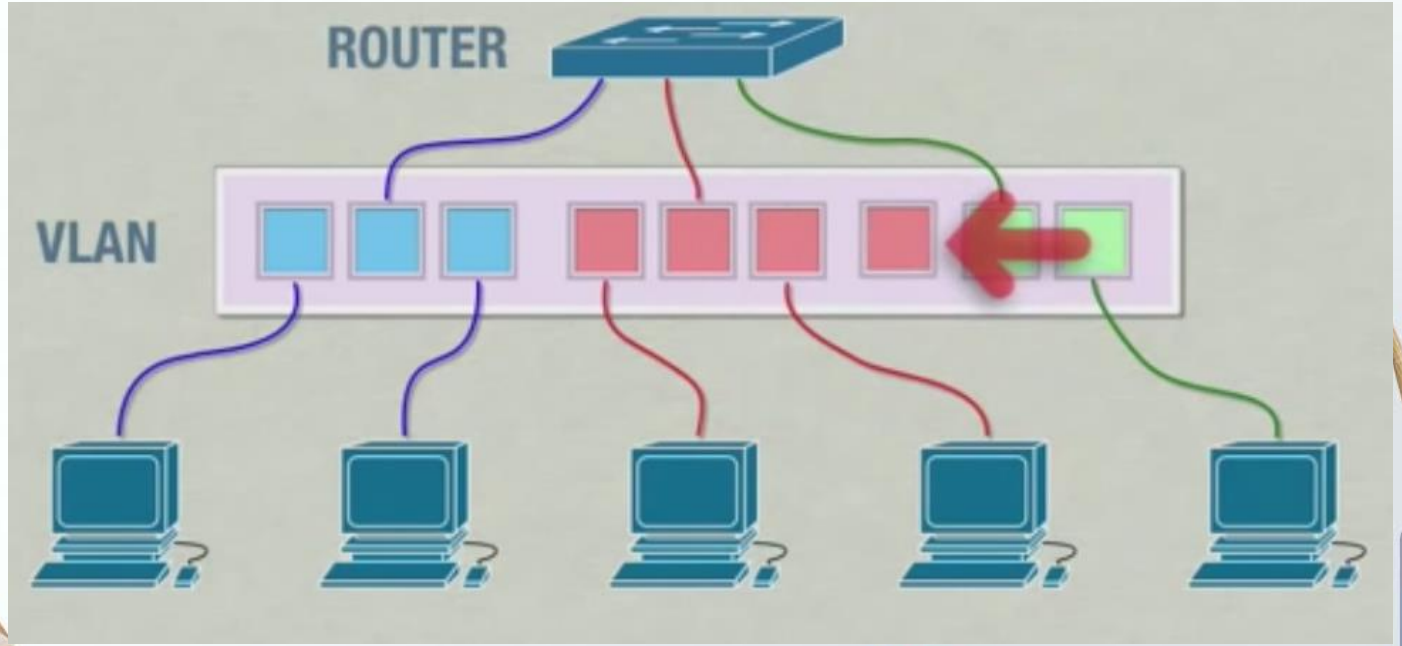
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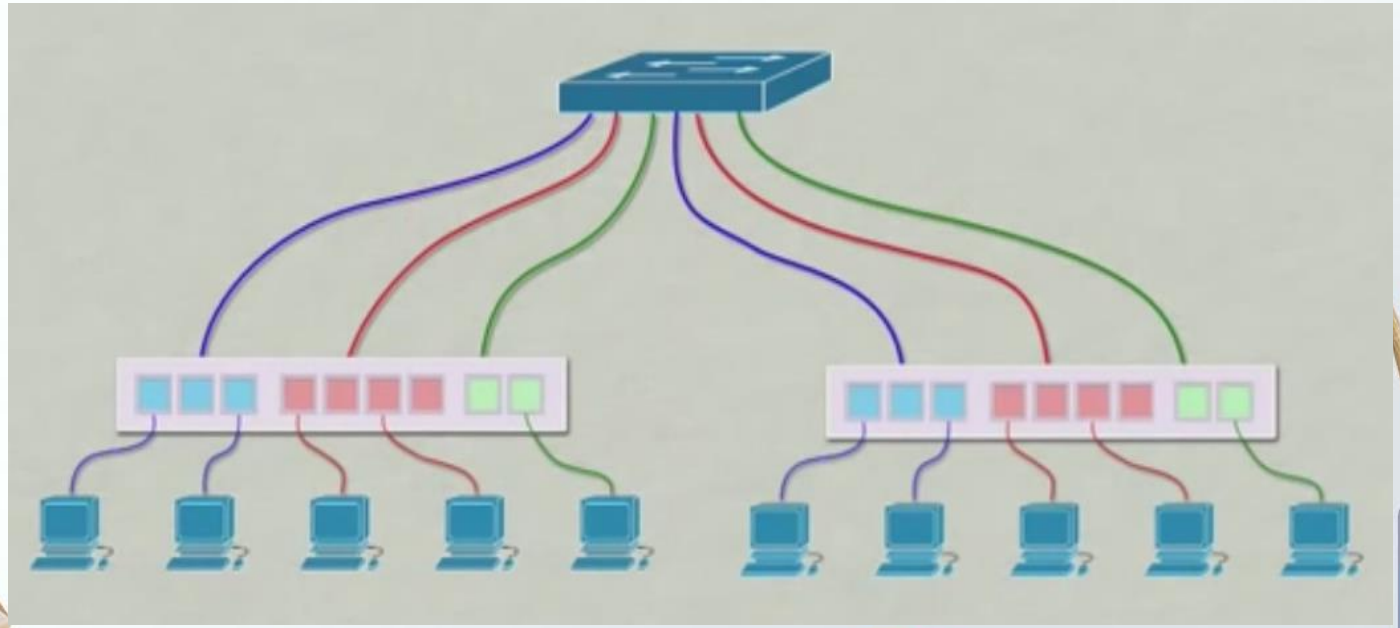
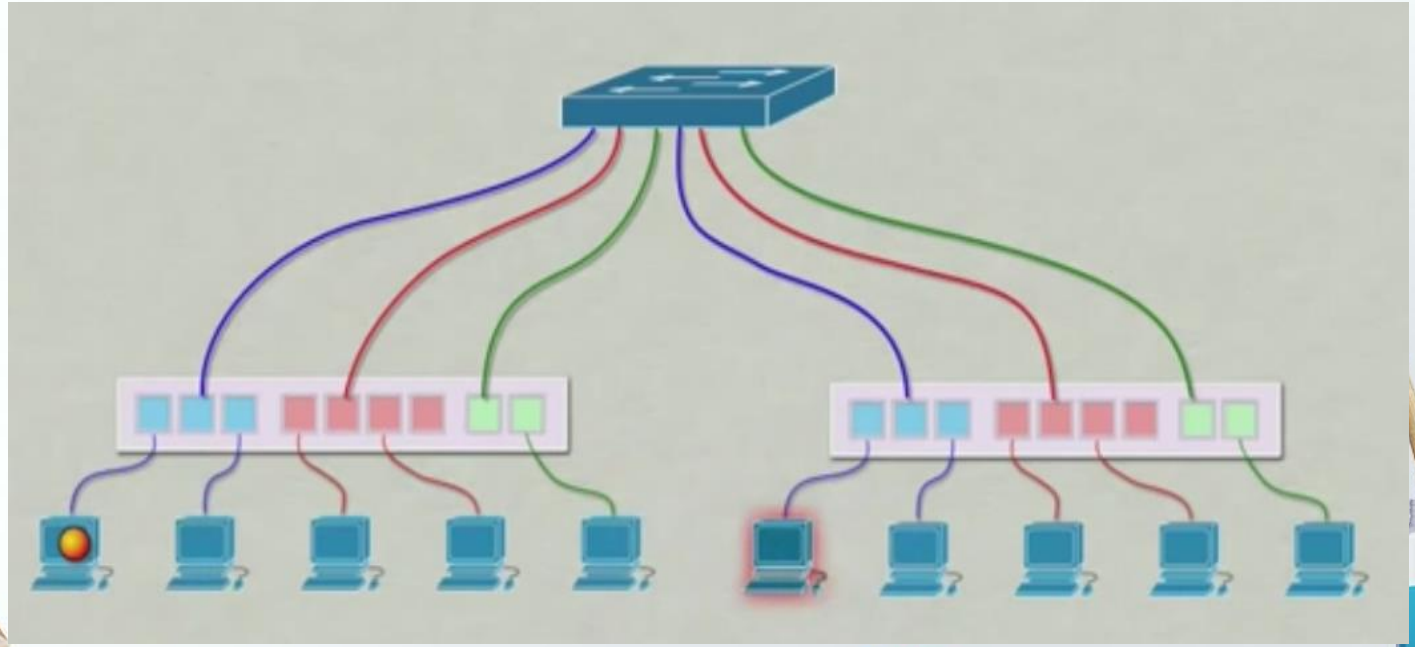
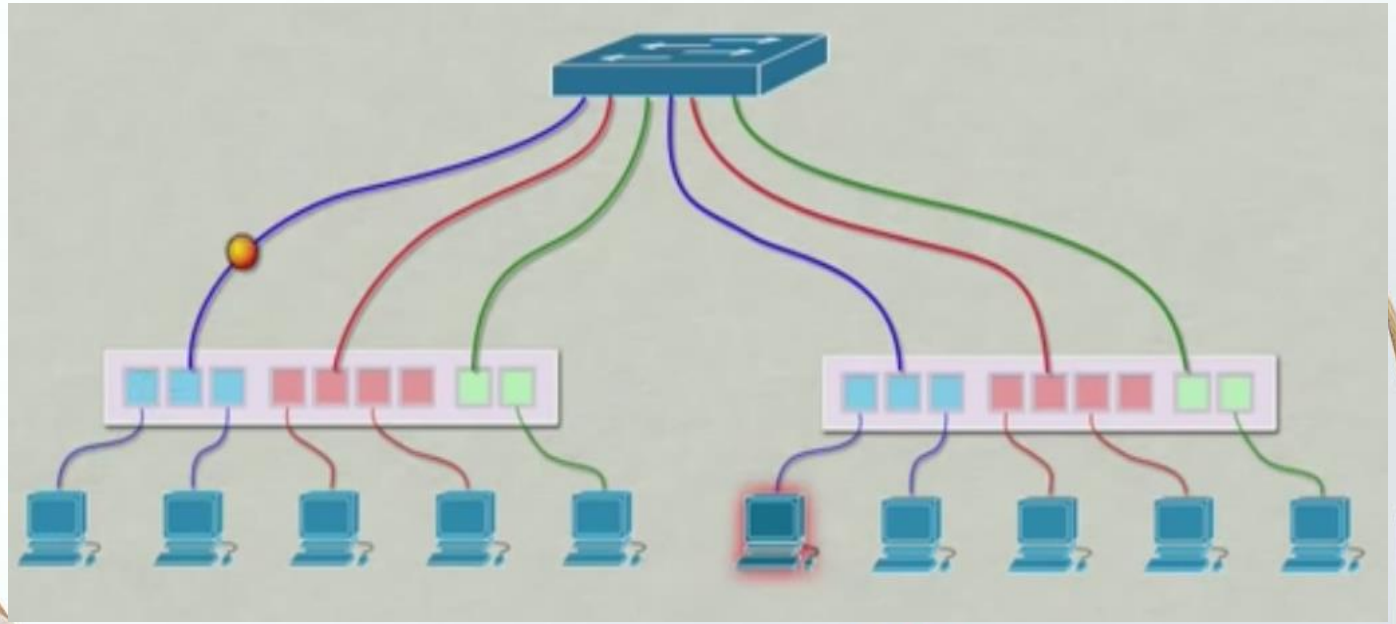
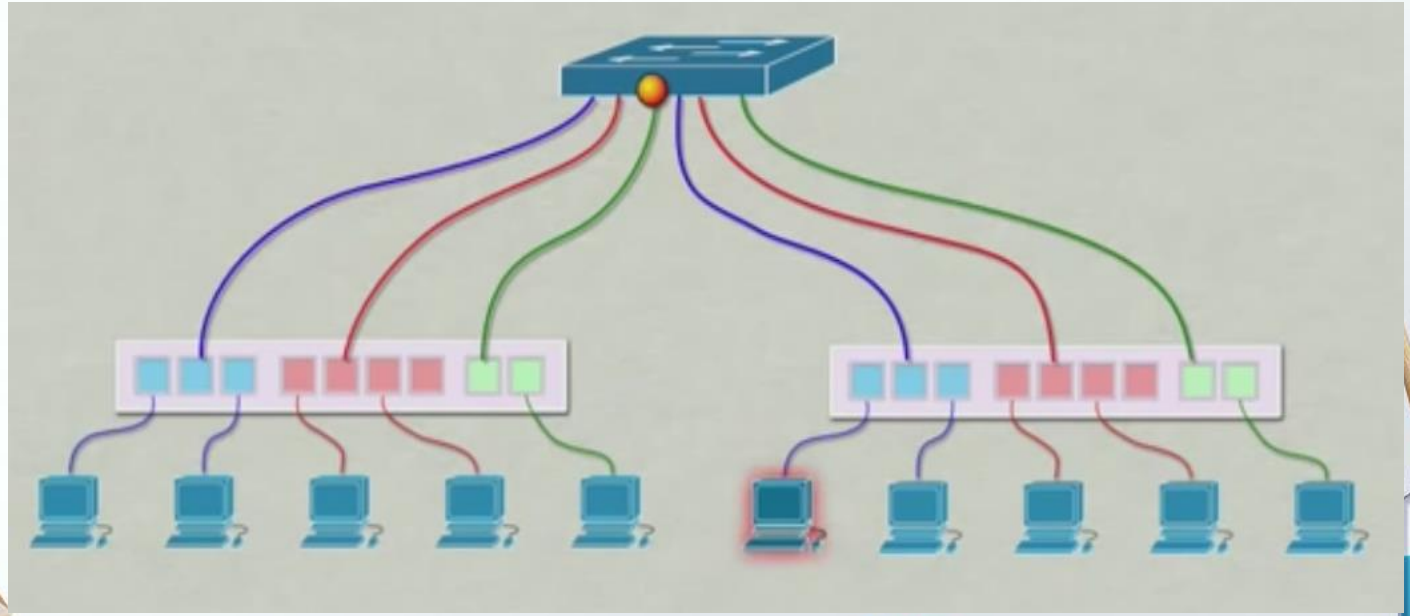
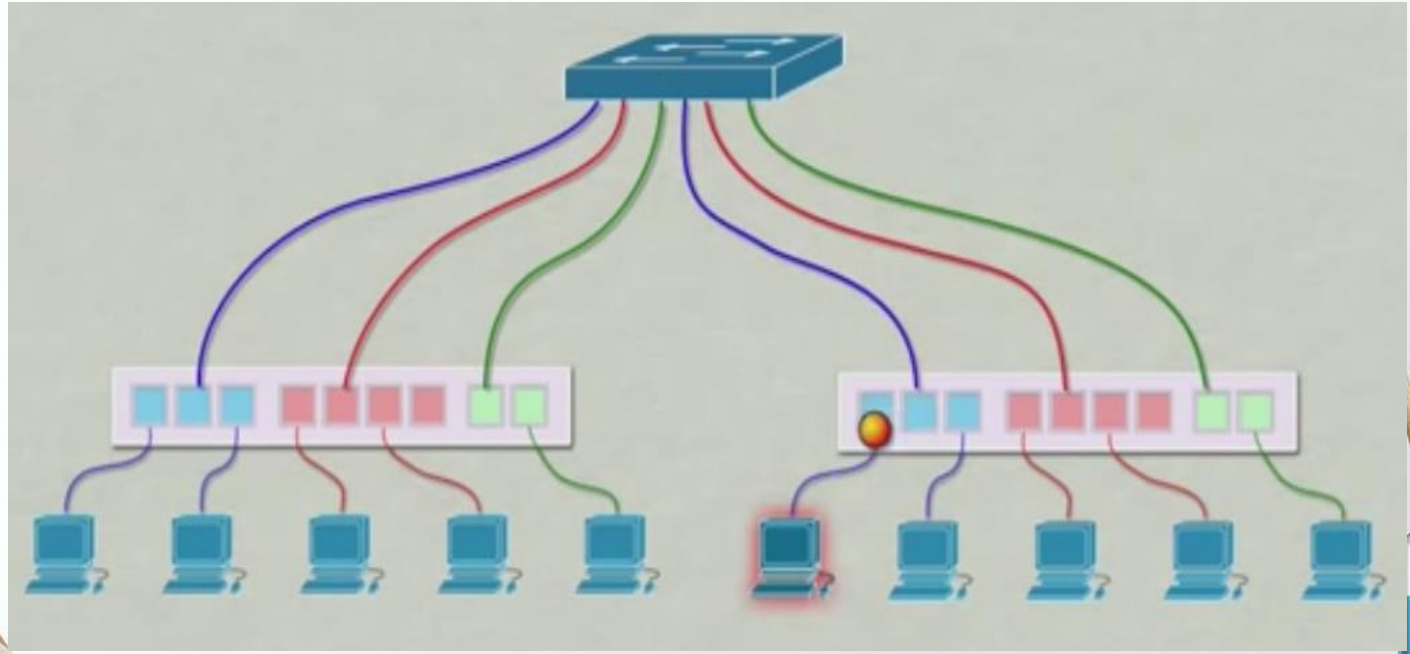
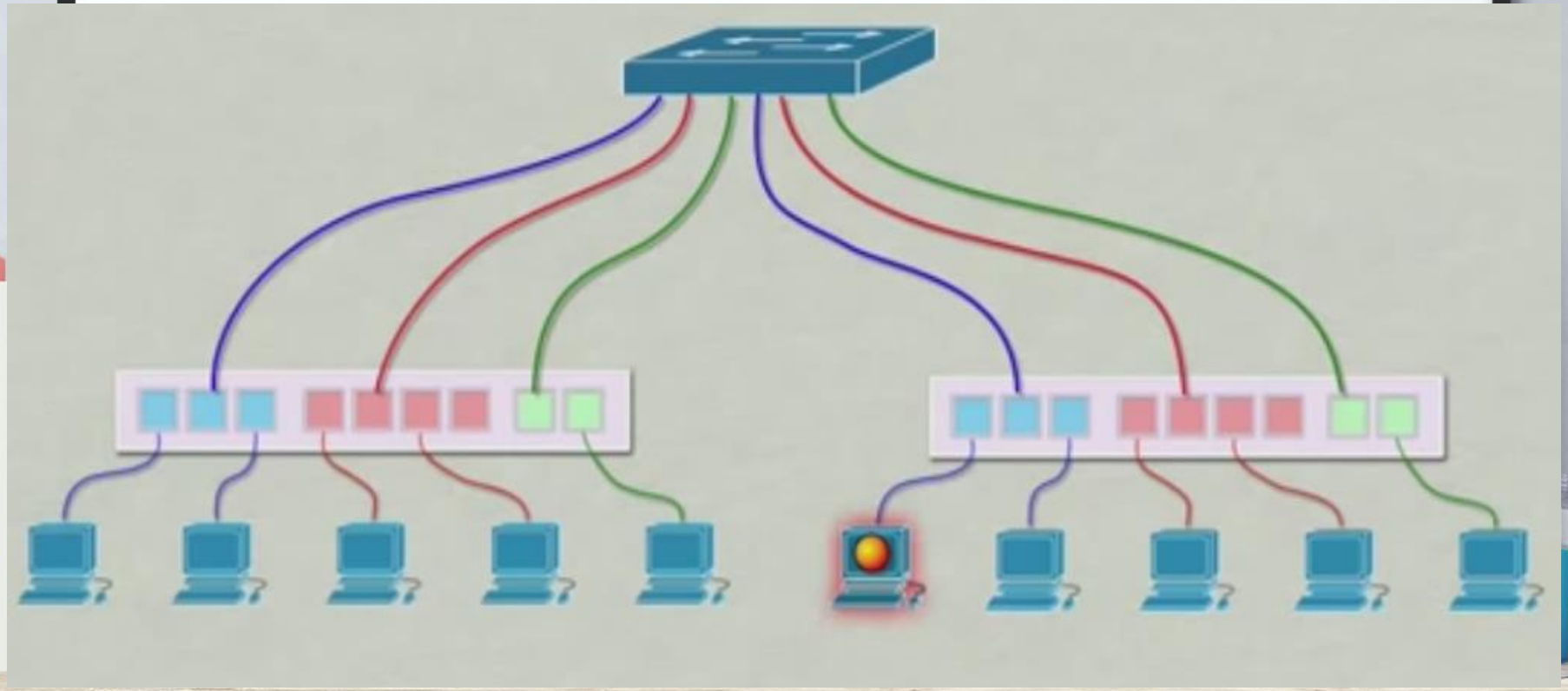






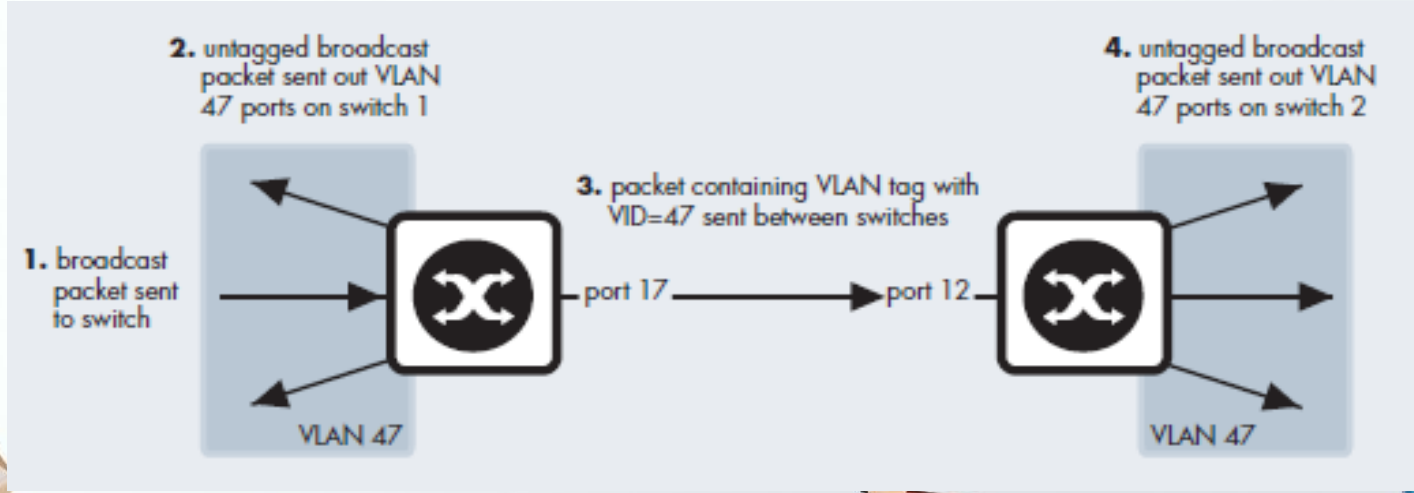






VLAN implementation

- Port Based VLAN
  - Ports of switch are simply assigned to VLANs, with no extra criteria.



Types of VLAN

Port-Based VLAN

- Port-based VLANs groups virtual local area network by port. In this type of virtual LAN, a switch port can be configured manually to a member of VLAN.
- Devices that are connected to this port will belong to the same broadcast domain that is because all other ports are configured with a similar VLAN number.
- The challenge of this type of network is to know which ports are appropriate to each VLAN. The VLAN membership can’t be known just by looking at the physical port of a switch. You can determine it by checking the configuration information.

Protocol Based VLAN

- This type of VLAN processes traffic based on a protocol that can be used to define filtering criteria for tags, which are untagged packets.
- In this Virtual Local Area Network, the layer-3 protocol is carried by the frame to determine VLAN membership. It works in multi-protocol environments. This method is not practical in a predominately IP based network.

MAC Based VLAN

- MAC Based VLAN allows incoming untagged packets to be assigned virtual LAN and, thereby, classify traffic depending on the packet source address. You define a Mac address to VLAN mapping by configuring mapping the entry in MAC to the VLAN table.

Advantages of VLAN

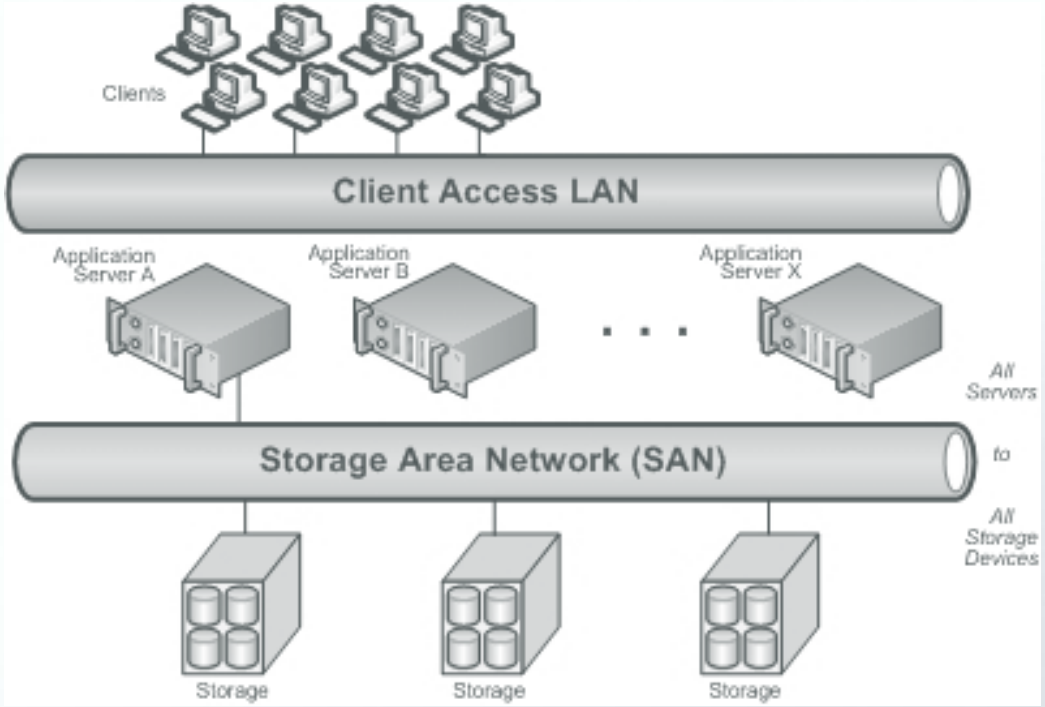
+ Performance.
+ Formation of virtual Workgroups.
+ Flexibility.
+ Ease of partitioning of resources.


Storages

- Computer memory and local storage might not provide enough storage, storage protection, multiple-user access, or speed and performance for enterprise applications. So, most organizations employ some form of a SAN in addition to network-attached storage (NAS) for improved efficiency and better data management.

Storage Area Network

- A storage area network is a dedicated, high-performance storage system that transfers block-level data between servers and storage devices. SAN is typically used in data centers, enterprises or virtual computing environments. It offers the speed of DAS with the sharing, flexibility and reliability of NAS. SAN storage is a very sophisticated option that’s meant to support complex, mission-critical applications.


Clients
Client Access LAN
Application Server A
Application Server B
Application Server X
All Servers
to
Storage Area Network (SAN)
All Storage Devices
Storage
Storage
Storage

- **Best Use Case Scenario:** SAN is best for block-level data sharing of mission- critical files or applications at data centers or large-scale enterprise organizations.
- **Worst Use Case Scenario**: SAN can be a significant investment and is a sophisticated solution that's typically reserved for serious large-scale computing needs. A small-to-midsize organization with a limited budget and few IT staff or resources likely wouldn't need SAN.

Why storage area networks are important

- SAN introduces networking flexibility enabling one server, or many heterogeneous servers across multiple data centers, to share a common storage utility. The SAN also eliminates the traditional dedicated connection between a file server and storage—and the concept that the server effectively owns and manages the storage devices—eliminating bandwidth bottlenecks.

Advantages of SAN

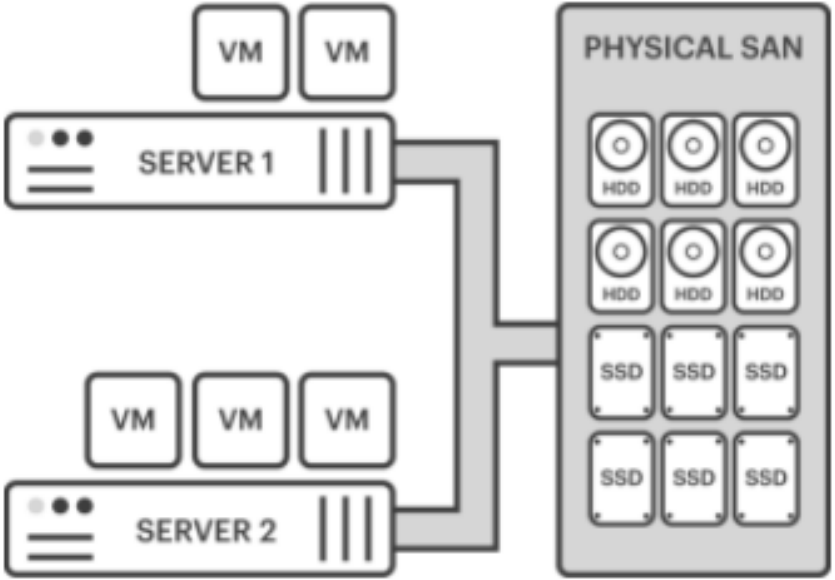
- **Improved application availability**
  Storage exists independently of applications, and it's accessible through multiple paths for increased reliability, availability and serviceability.
- **Better application performance**
  SANs offload and move storage processing from servers onto separate networks.

- **Central and consolidated**
  SANs make simpler management, scalability, flexibility and availability possible.
- **Remote site data transfer and vaulting**
  SANs protect data from disaster and malicious attacks with a remote copy.
- **Simple centralized management**
  SANs simplify management by creating single images of storage media.


Virtual SAN

- A virtual storage area network (SAN) is a software-based component that provides a virtualized ‘pool’ of storage to multiple virtual machines (VMs) and applications. In order to achieve this, data is passed (shared) between servers over a network using a protocol such as iSCSI or fibre channel.

- A virtual SAN enables organizations to eliminate the dedicated storage hardware and associated networking within their physical infrastructure.



- Instead, the virtual SAN is installed on commodity x86 servers, often (but not always) the same servers that generally handle the organization’s compute functionality.
- A virtual SAN converges traditional datacenter hardware components into a single virtualized appliance, controlled by a software layer. It can either be installed as a software program that runs on a virtual machine (VM), or be incorporated into a storage vendor's firmware and sold as a single, consolidated solution.

LOVELY PROFESSIONAL UNIVERSITY

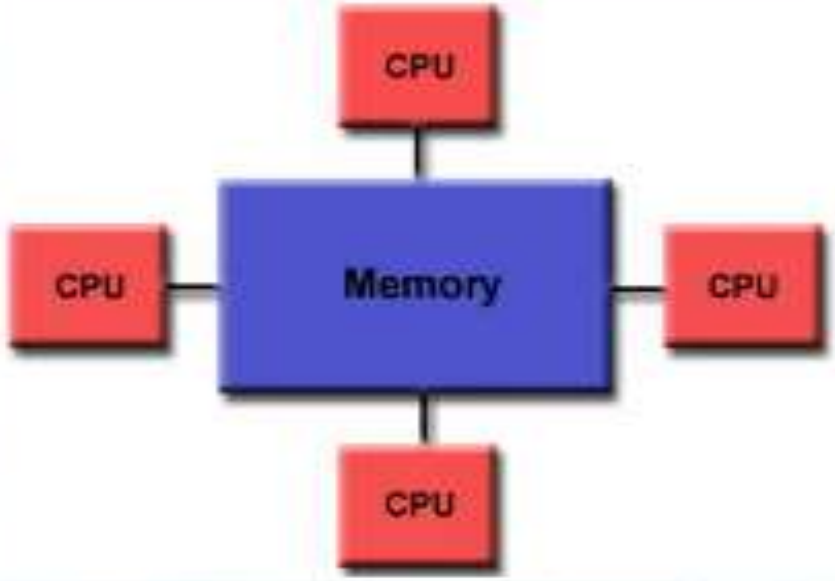
CSE 423

Parallel And Distributed Systems

Parallel Systems

- **DEFINATION:** A system is said to be a parallel system in which multiple processor have direct access to shared memory which forms a common address space.
- Usually tightly-coupled system are referred to as parallel system. In this systems there is a single system wide primary memory that is shared by all the processors.
- Parallel computing is the use of two or more processors in combination to solve a single problem.

Parallel System



Applications of Parallel System

- An example of parallel computing would be two servers that shares the workload of routing mail, managing connections to an accounting system or database etc.
- Supercomputers are usually placed in parallel system architecture.
- Terminals connected to single servers.

Advantages of Parallel System

- Provide concurrency (do multiple things at the same time)
- Taking advantage of non local sources
- Cost savings
- Save time and money
- Overcoming memory constraints
- Global addresses space provides a user friendly programming perspective to memory

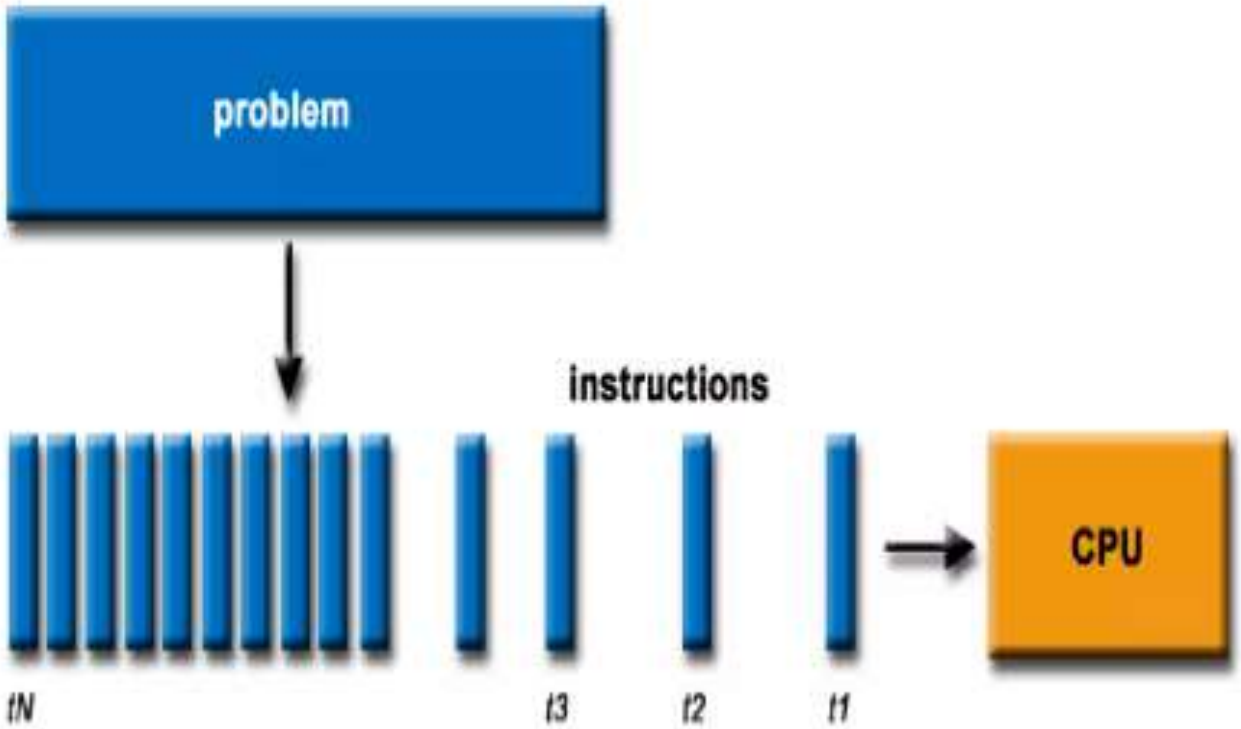
Disadvantages of Parallel System

- Primary disadvantage is the lack of scalability between memory and CPUs.
- Programmer responsibility for synchronization constructs that ensure “correct” access of global memory.
- It becomes increasingly difficult and expensive to design and produce shared memory machines with ever increasing number of processors.
- Reliability and fault tolerance.

Why Parallel Computing ?

- Traditionally, software has been written for serial computation:
  - To be run on a single computer having a single CPU;
  - A problem is broken into a discrete series of instructions.
  - Instructions are executed one after another.
  - Only one instruction may execute at any moment of time.

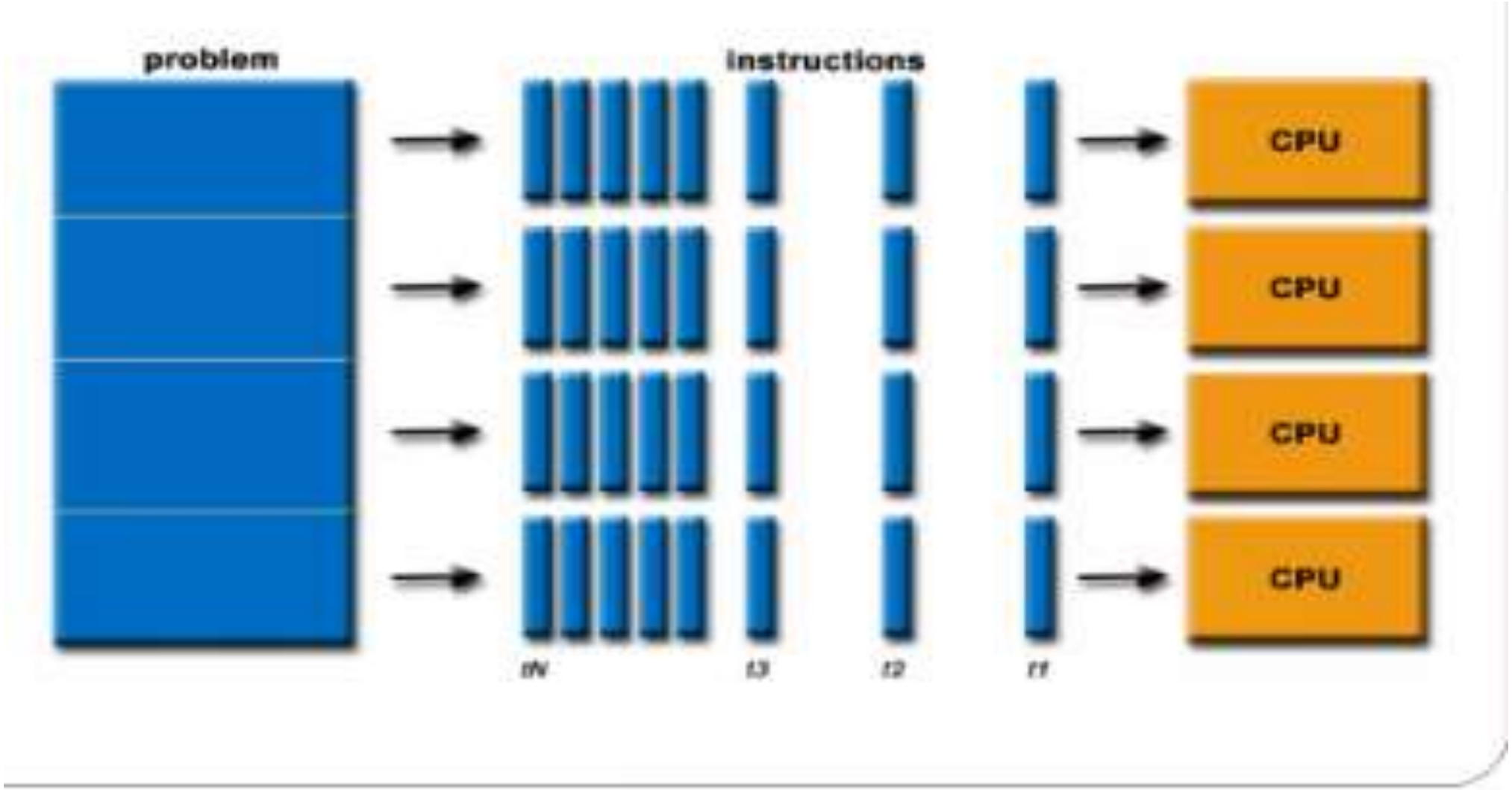
Serial Problem…



Parallel Computing…

- Parallel computing is a form of computation in which many calculations are carried out simultaneously.
- In the simplest sense, it is the simultaneous use of multiple compute resources to solve a computational problem:
  - To be run using multiple CPUs
  - A problem is broken into discrete parts that can be solved concurrently
  - Each part is further broken down to a series of instructions
  - Instructions from each part execute simultaneously on different CPUs.

Parallel Problem



Why use Parallel Computing?

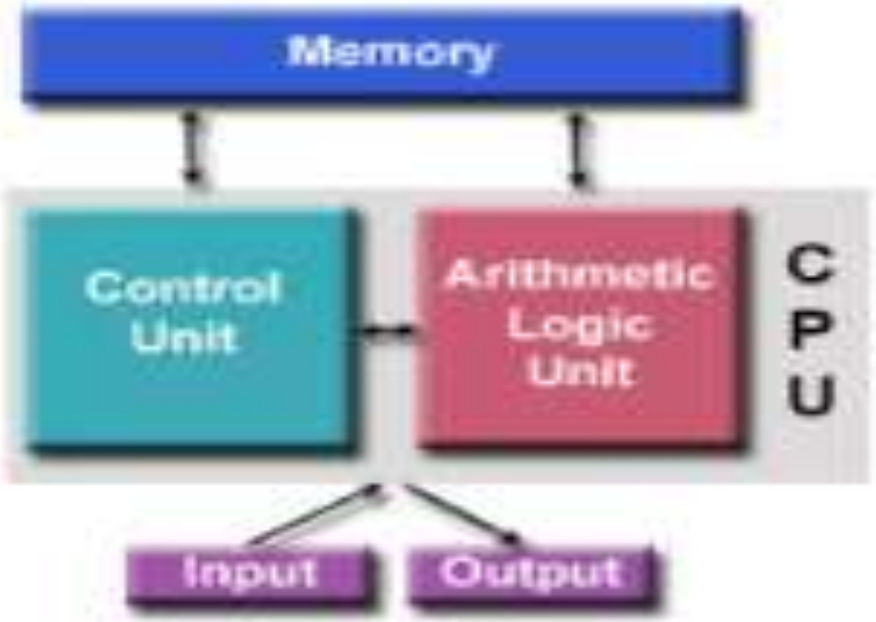
- Save time and/or money
- Solve large problems: e.g. – Web search engines/ databases processing millions of transactions per second.
- Provide concurrency;
- Use of non-local resources;

Why use Parallel Computing?...

- Limits to serial computing:
  - Transmission speeds
  - Limits to miniaturization
  - Economic limitations
- Current computer architecture are increasingly relying upon hardware level parallelism to improve performance:
  - Multiple execution units
  - Pipelined instructions
  - Multi- core

Parallel Computer Architecture

- von Neumann Architecture



Comprised of four main components:

Memory
Control Unit
Arithmetic Logic Unit
Input / Output

Parallel Computer Architecture…

- **Memory** is used to store both program instructions and data
  - **Program instructions** are coded data which tell the computer to do something
  - **Data** is simply information to be used by the program
- **Control unit** fetches instructions/data from memory, decodes the instructions and then sequentially coordinates operations to accomplish the programmed task.

Parallel Computer Architecture…

- **Arithmetic unit** That performs basic arithmetic operations
- **Input/Output** is the interface to the human operator

Parallel Computer Architecture…

Flynn's classical Taxonomy:

Single Instruction, Single Data (SISD):

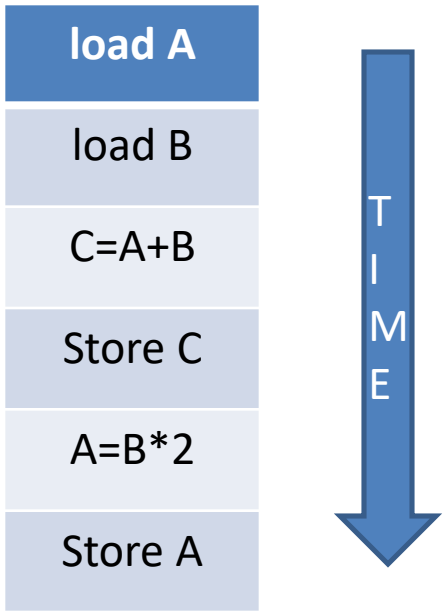
- A serial (non parallel) computer

Single Instruction:

- Only one instruction stream is being acted on by the CPU during anyone clock cycle.

Single Data :

- Only one data stream is being used as input during any one clock cycle.
- Deterministic execution.



Single Instruction, Multiple Data (SIMD):

prev instruct
load A(1)
load B(1)
C(1)=A(1)*B(1)
store C(1)
next instruct

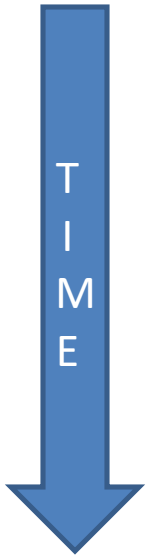
P1

prev instruct
load A(2)
load B(2)
C(2)=A(2)*B(2)
store C(2)
next instruct

P2

prev instruct
load A(n)
load B(n)
C(n)=A(n)*B(n)
store C(n)
next instruct

Pn



Single Instruction, Multiple Data (SIMD):

A type of parallel computer

Single instruction:

- All processing units execute the same instruction at any given clock cycle

Multiple data:

- Each processing unit can operate on a different data element.
- Best suited for specialize problems characterized by a high degree of regularity, such as graphics/image processing.
- Two varieties processor arrays and vector pipelines.

Multiple Instruction, Single Data (MISD):

prev instruct
load A(1)
C(1)=A(1)*1
store C(1)
next instruct

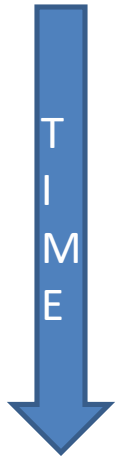
P1

prev instruct
load A(1)
C(2)=A(1)*2
store C(2)
next instruct

P2

prev instruct
load A(1)
C(n)=A(1)*n
store C(n)
next instruct

Pn



Multiple Instruction, Single Data (MISD):

- A single data stream is fed into multiple processing units.
- Each processing unit operates on the data independently via independent instruction streams.
- Some conceivable usage might be:
  - Multiple frequency filters operating on a single signal stream

Multiple Instruction, Multiple Data (MIMD):

prev instruct
load A(1)
load B(1)
C(1)=A(1)*B(1)
store C(1)
next instruct

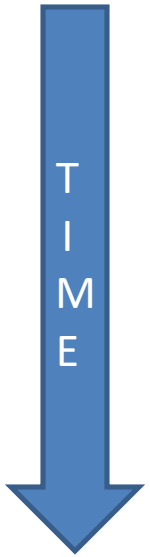
P1

prev instruct
call func D
x=y*z
sum= x*2
Call sub 1(i,j)
next instruct

P2

prev instruct
Do 10 i=1,N
Alpha= w**3
Zeta=C(i)
10 continue
next instruct

Pn



Multiple Instruction, Multiple Data (MIMD):

- **Multiple Instruction:** Every processor may be executing a different instruction stream.
- **Multiple Data:** Every processor may be working with a different data stream.
- **Execution** can be synchronous or asynchronous, deterministic or non- deterministic.

THANK YOU

&

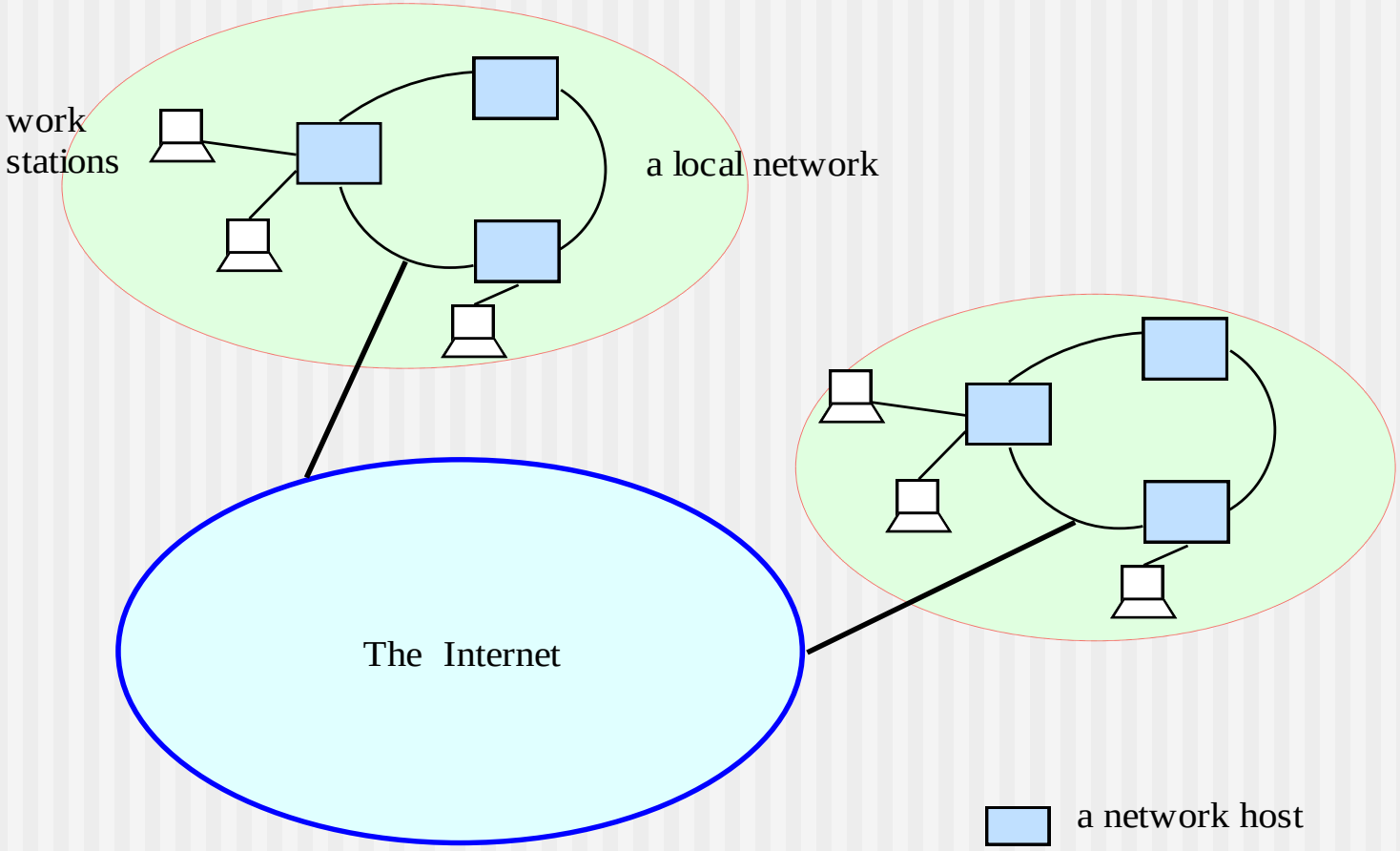
ANY QUERIES?

Distributed computing

Distributed system, distributed computing

- Early computing was performed on a single processor. Uni-processor computing can be called *centralized computing*.
- A *distributed system* is a collection of independent computers, interconnected via a network, capable of collaborating on a task.
- *Distributed computing* is computing performed in a distributed system.

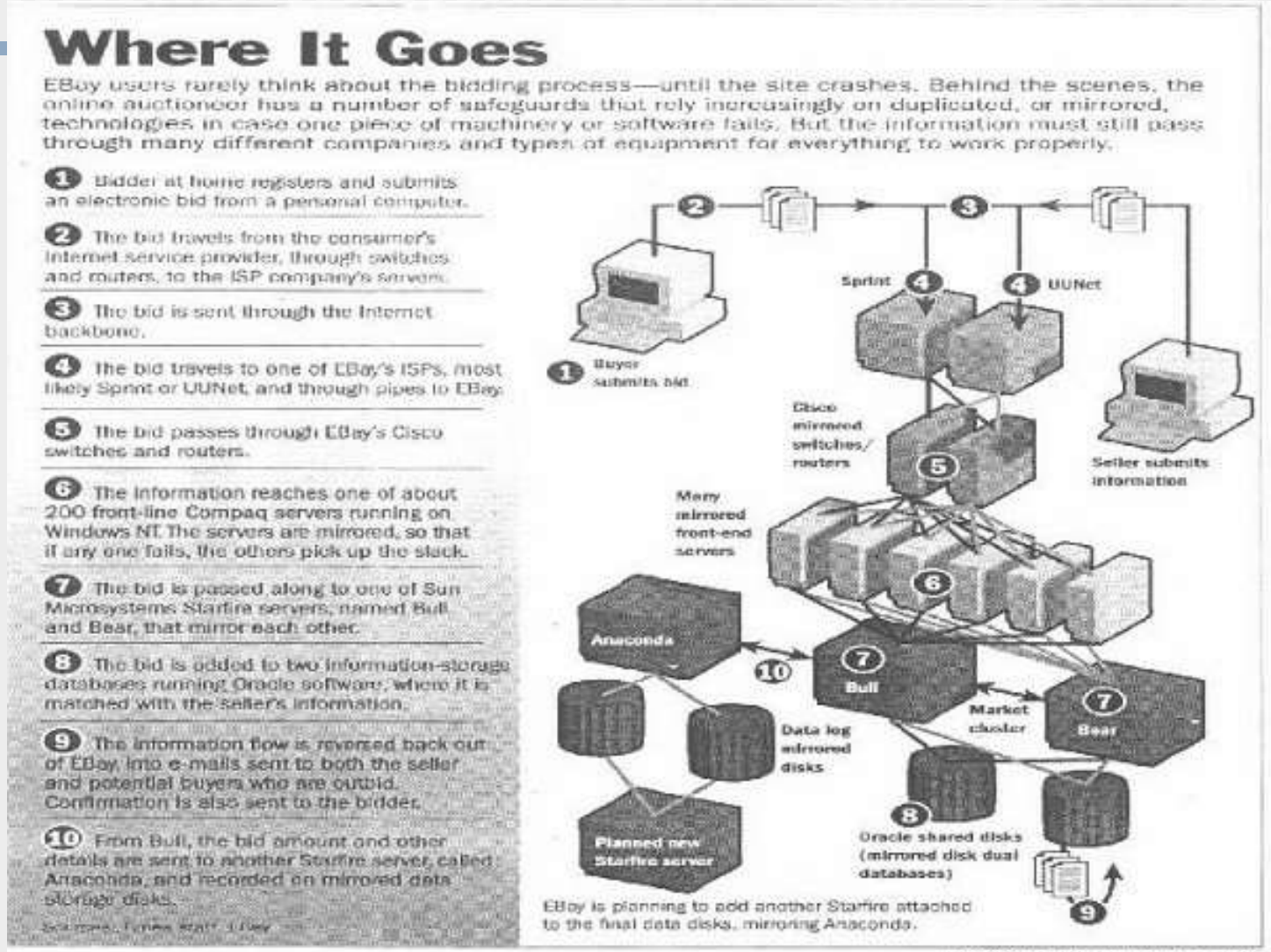
Distributed Systems



Examples of Distributed systems

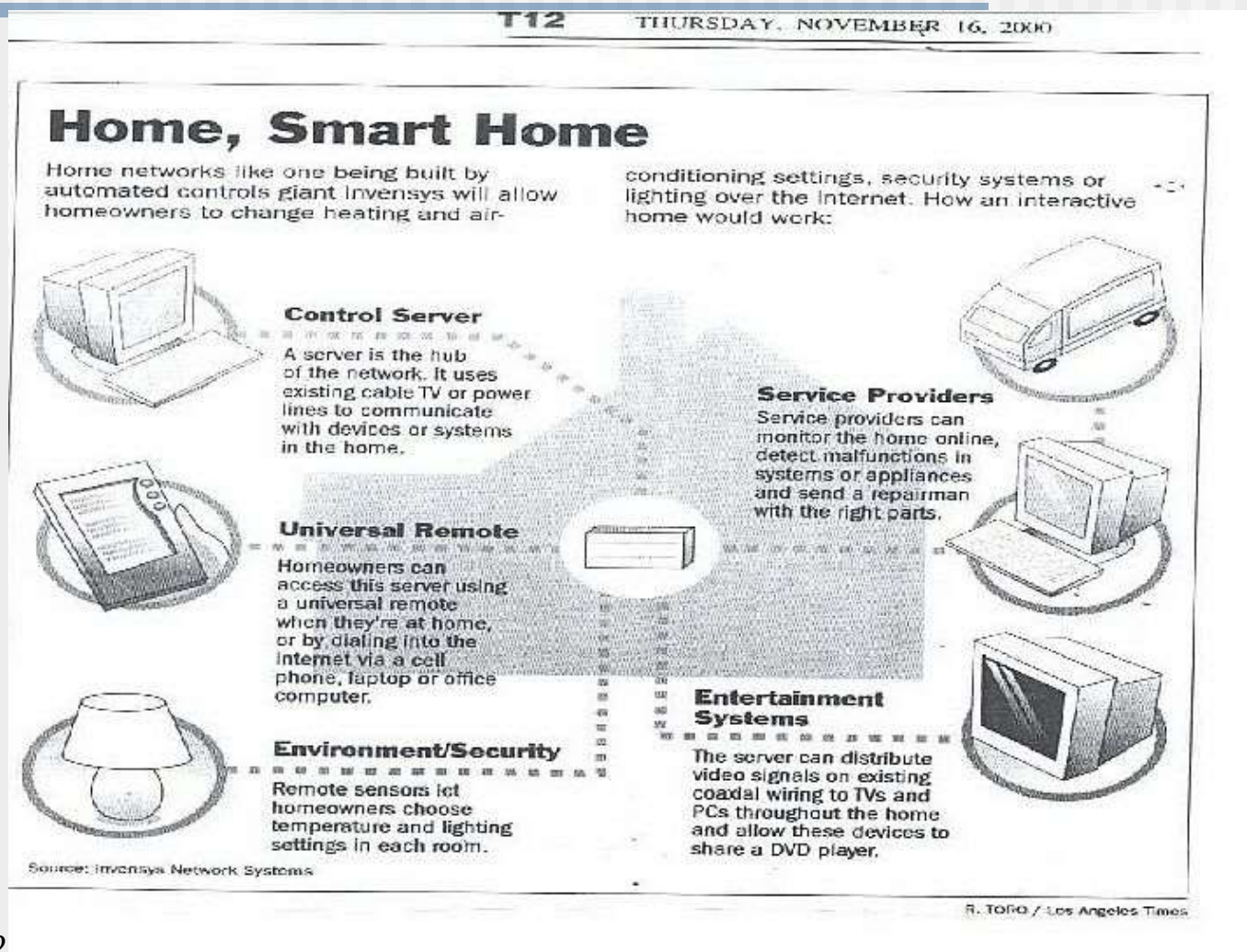
- Network of workstations (NOW): a group of networked personal workstations connected to one or more server machines.
- The Internet
- An intranet: a network of computers and workstations within an organization, segregated from the Internet via a protective device (a firewall).

Example of a large-scale distributed system – eBay **(Source: Los Angeles Times.)**



An example small-scale distributed system

(Source: Los Angeles Times.)



T12 THURSDAY, NOVEMBER 16, 2000

Home, Smart Home

Home networks like one being built by automated controls giant Invensys will allow homeowners to change heating and air-conditioning settings, security systems or lighting over the Internet. How an interactive home would work:

Control Server
A server is the hub of the network. It uses existing cable TV or power lines to communicate with devices or systems in the home.

Universal Remote
Homeowners can access this server using a universal remote when they're at home, or by dialing into the Internet via a cell phone, laptop or office computer.

Environment/Security
Remote sensors let homeowners choose temperature and lighting settings in each room.

Service Providers
Service providers can monitor the home online, detect malfunctions in systems or appliances and send a repairman with the right parts.

Entertainment Systems
The server can distribute video signals on existing coaxial wiring to TVs and PCs throughout the home and allow these devices to share a DVD player.

Source: Invensys Network Systems

R. Toro / Los Angeles Times

Computers in a Distributed System

- Workstations: computers used by end-users to perform computing
- Server machines: computers which provide resources and services
- Personal Assistance Devices: handheld computers connected to the system via a wireless communication link.

The power of the Internet

(Source: the Usability Professional Association's site.)

- 60 million American households use computers.*(The New York Times, 5/28/98)*
- The number of computer users in the workplace has increased from 600,000 in 1976 to 80 million today. *(San Francisco Examiner, 3/29/98)*
- 84% of Internet users say that the Web is indispensable. Nearly the same percentage find e-mail indispensable. 85% use the Internet every day. *(GVU, 1997)*

The Power of the Internet – 2

(Source: www.cisco.com)

- BACKBONE CAPACITY: The capacity of the Internet backbone to carry information is doubling every 100 days. (U.S. Internet Council, Apr. 1999).
- DATA TRAFFIC SURPASSING VOICE: Voice traffic is growing at 10% per year or less, while data traffic is conservatively estimated to be growing at 125% per year, meaning voice will be less than 1% of the total traffic by 2007. (Technology Futures, Inc March 2000).
- DOMAIN NAMES: There are 12,844,877 unique domain names (e.g. Cisco.com) registered worldwide, with 428,023 new domain names registered each week. (NetNames Statistics 12/28/1999).

The Power of the Internet – 3

(Source: www.cisco.com)

- DOMAIN NAMES: There are 12,844,877 unique domain names (e.g. Cisco.com) registered worldwide, with 428,023 new domain names registered each week. (NetNames Statistics 12/28/1999).
- HOST COMPUTERS: In July 1999 there were 56.2 million "host" computers supporting web pages. In July 1997 there were 19.5 million host computers, with 3.2 million hosts in July 1994, and a mere 80,000 in July 1989. (Internet Software Consortium – Internet Domain Survey).
- TOTAL AMOUNT OF DATA: 1,570,000,000 pages, 29,400,000,000,000 bytes of text, 353,000,000 images, and 5,880,000,000,000 bytes of image data. (The Censorware Project, Jan. 26, 1999).

The Power of the Internet – 4

(Source: www.cisco.com)

- EMAIL VOLUME: Average U.S. consumer will receive 1,600 commercial email messages in 2005, up from 40 in 1999, while non-marketing and personal correspondence will more than double from approximately 1,750 emails per year in 1999 to almost 4,000 in 2005 (Jupiter Communications, May 2000).
- 159 million computers in the U.S., 135 million in EU, and 116 million in Asia Pacific (as of April 2000).
- WEB HITS/DAY: U.S. web pages averaged one billion hits per day (aggregate) in October 1999. (eMarketer/Media Metrix, Nov. 1999).

The Power of the Internet – 5

(Source: www.cisco.com)

- NEW USERS Q1 2000: More than 5 million Americans joined the online world in the first quarter of 2000, which averages to roughly 55,000 new users each day, 2,289 new users each hour, or 38 new users each minute. (CyberAtlas / Telecommunications Reports International, May 2000).
- US INTERNET USAGE: Average US Internet user went online 18 sessions, spent a total of 9 hours, 5 minutes and 24 seconds online and visited 10 unique sites per month. (Nielsen NetRatings, June 2000).

The Power of the Internet – 6

(Source: www.cisco.com)

- E-MAIL 1998: The U.S. Postal Service delivered 101 billion pieces of paper mail in 1998. Estimates for e-mail messages sent in 1998 range from 618 billion to 4 trillion. (U.S. Internet Council, Apr. 1999).
- E-MAIL 1999: There are 270 million e-mailboxes in the U.S. -- roughly 2.5 per user. (eMarketer/ Messaging Online, Nov. 1999).
- HOURS ONLINE (Veronis, Suhler & Associates, Nov. 1999):

  1997 – 28 hours per capita

  1998 – 74 hours per capita

  2003 – 192 hours per capita

“The network really is the computer.”

Tim O’Reilly, in an address at 6/2000 Java One:

“By now, it's a truism that the Internet runs on open source. Bind, the Berkeley Internet Name Daemon, is the single most mission critical program on the Internet, followed closely by Sendmail and Apache, open source servers for two of the Internet's most widely used application protocols, **SMTP** (Simple Mail Transfer Protocol) and **HTTP** (HyperText Transfer Protocol).”

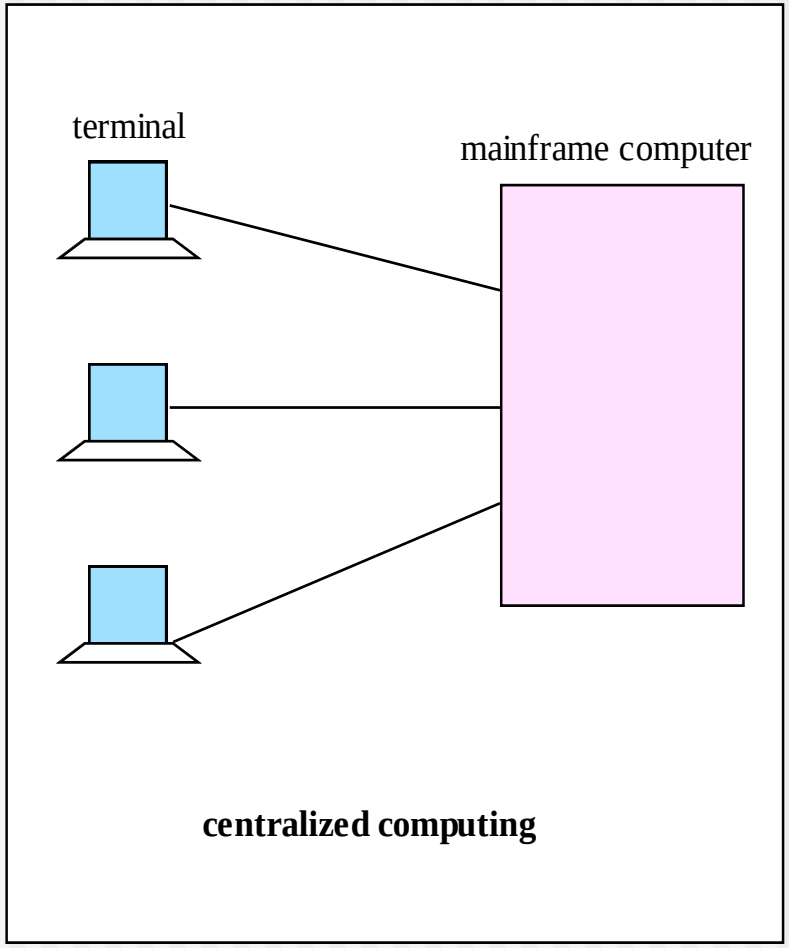
Early “killer apps”:

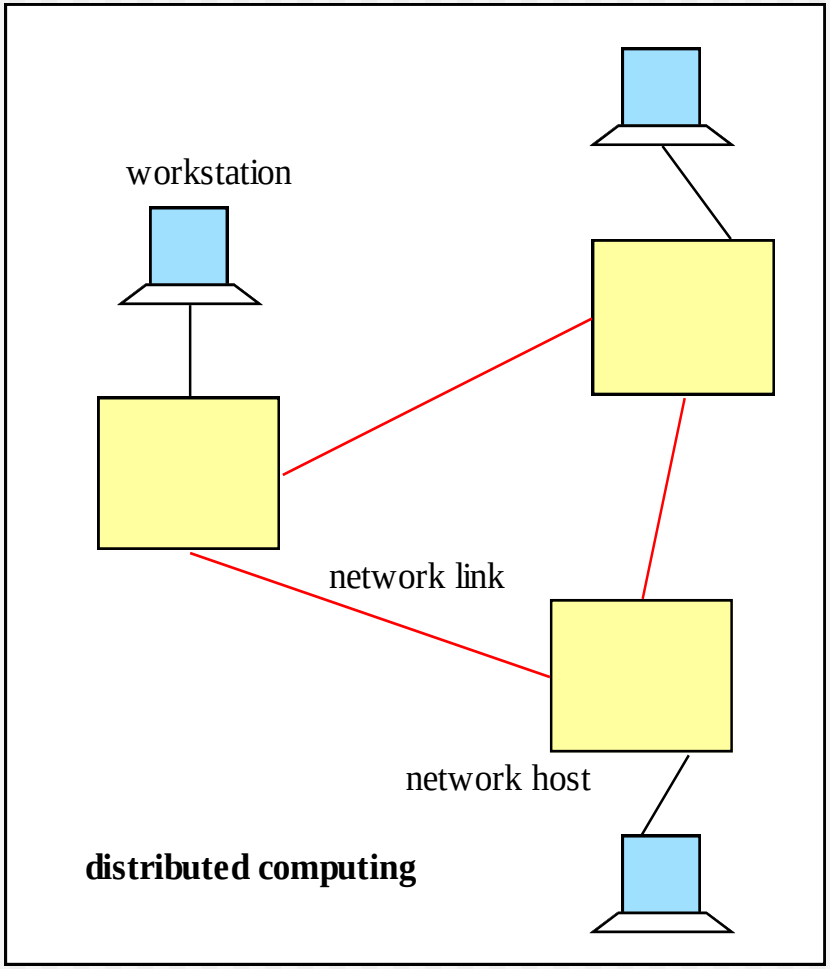
- usenet: distributed bulletin board
- email
- talk

Recent “killer apps”:

- the web
- Peer-to-Peer (e.g., Napster, Gnutella, KaZaA)
- collaborative computing (e.g., Java Shared Data Toolkit)

Centralized vs. Distributed Computing





Monolithic mainframe applications vs. distributed applications

based on http://www.inprise.com/visibroker/papers/distributed/wp.html

- **The monolithic mainframe application architecture**:
  - Separate, single-function applications, such as order-entry or billing
  - Applications cannot share data or other resources
  - Developers must create multiple instances of the same functionality (service).
  - Proprietary (user) interfaces
- **The distributed application architecture**:
  - Integrated applications
  - Applications can share resources
  - A single instance of functionality (service) can be reused.
  - Common user interfaces

Evolution of paradigms

- Client-server: Socket API, RMI (remote method invocation)
- Distributed objects
- Object broker: CORBA
- Network service: Jini
- Object space: JavaSpaces
- Mobile agents
- Message oriented middleware (MOM): Java Message Service
- Collaborative applications

Cooperative distributed computing projects

Cooperative distributed computing projects (also called distributed computing in some literature): these are projects that parcel out large-scale computing to workstations, often making use of surplus CPU cycles. Example: seti@home: project to scan data retrieved by a radio telescope to search for radio signals from another world.

Why distributed computing?

- Economics: distributed systems allow the pooling of resources, including CPU cycles, data storage, input/output devices, and services.
- Reliability: a distributed system allow replication of resources and/or services, thus reducing service outage due to failures.
- The Internet has become a universal platform for distributed computing.

The Weaknesses and Strengths of Distributed Computing

In any form of computing, there is always a tradeoff in advantages and disadvantages

Some of the reasons for the popularity of distributed computing :

- **The affordability of computers and availability of network access**
- **Resource sharing**
- **Scalability**
- **Fault Tolerance**

The Weaknesses and Strengths of Distributed Computing

The disadvantages of distributed computing:

- **Multiple Points of Failures:** the failure of one or more participating computers, or one or more network links, can spell trouble.
- **Security Concerns**: In a distributed system, there are more opportunities for unauthorized attack.

Summary - 1

We discussed the following topics:

- What is meant by distributed computing
- Distributed system
- Distributed computing vs. parallel computing
- Basic concepts in operating system: processes and threads

Summary - 2

- Basic concepts in data communication:
  - Network architectures: the OSI model and the Internet model
  - Connection-oriented communication vs. connectionless communication
  - Naming schemes for network resources
    - The Domain Name System (DNS)
    - Protocol port numbers
    - Uniform Resource Identifier (URI)
    - Email addresses

Summary-3

- Basic concepts in software engineering:
  - Procedural programming vs. object-oriented programming
  - UML Class diagrams
  - The three-layered architecture of distributed applications: presentation layer, application or business logic, the service layer
  - The terms toolkit, framework, and component