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Université Internationale de Rabat
L'UNIVERSITÉ INNOVANTE

Ecole Supérieure d'Informatique et du Numérique
COLLEGE OF ENGINEERING & ARCHITECTURE

# Cloud Foundations

## Chapter 4: Data center Infrastructure

PR. OUASSIM KARRAKCHOU

UNIVERSITE INTERNATIONALE DE RABAT

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# Data center Infrastructure

## What's inside a data center?

- Physically, a data center consists of a building, or part of a building, that houses the equipment. Often, a data center occupies a single large open area without walls. Like a giant retail store, columns are spread throughout the area to support the ceiling.

How is the equipment in a data center organized?

# Data center Infrastructure

## What's inside a data center?

- Physically, racks holding equipment are placed side by side in rows, leaving aisles between them.

- Logically, however, a data center is not merely composed of long rows of racks. Instead, a data center is built by replicating a basic set of equipment known as a pod.

# Data center Infrastructure

## What's a pod?

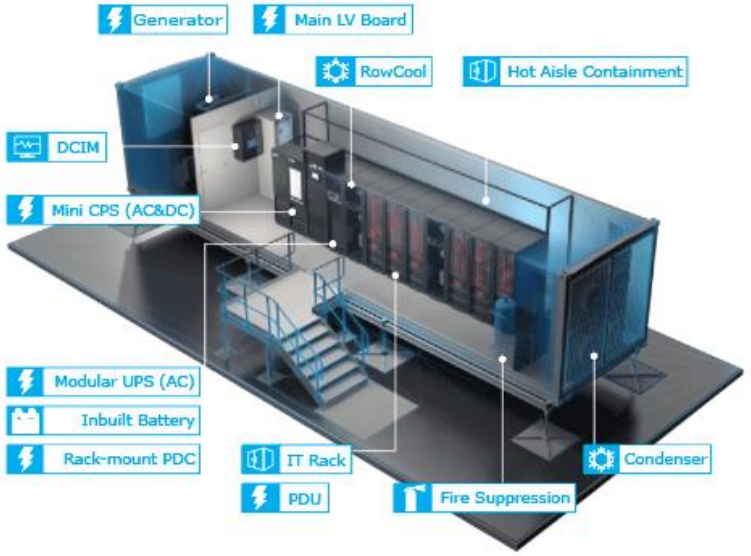
- A pod is a pre-built set of racks that additionally to servers, also contain storage, networking facilities, as well as Power Distribution Units (PDU), and Uninterruptible Power Supplies (UPS).

- The owner just needs to connect power, air conditioning, and network connections to the pod for it to function.

# Data center Infrastructure

## What's a pod?

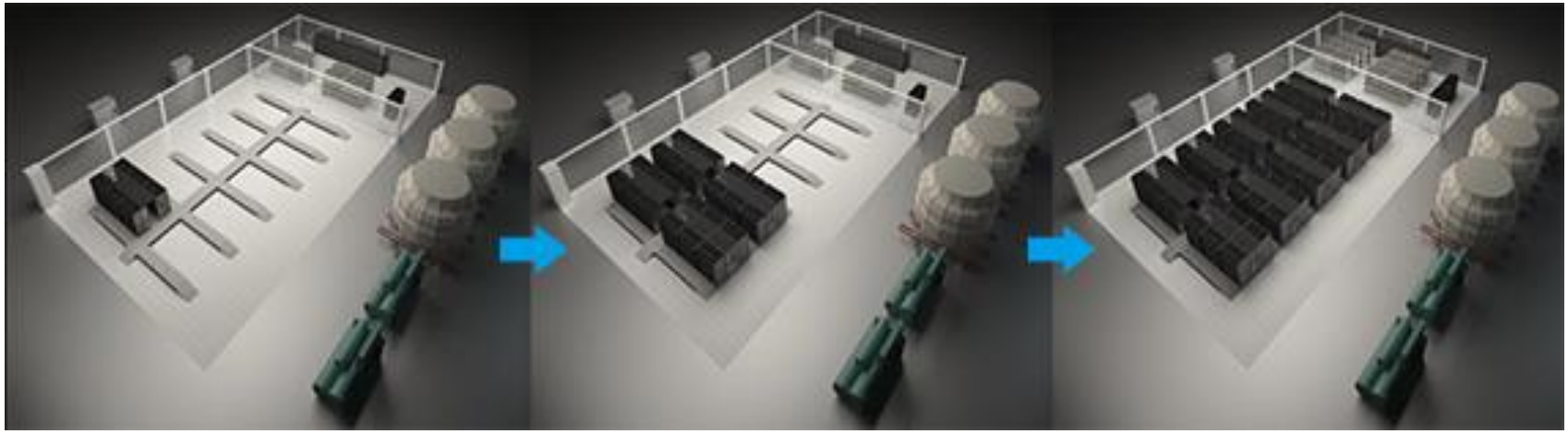
- Pods can contain a variable number of racks, but the average is around 12 to 16 racks.
- Some pods are referred to as containerized pods because they have a standard shipping container size, and thus can be shipped pre-built easily:

# Data center Infrastructure

## What's the advantage of using pods?

- The main advantage of pods is that they allow incremental growth of the data center, thus making the data center modular:



# Data center Infrastructure

## The problem of power and cooling

- Power consumption and cooling dominate many aspects of data center design because data centers consume huge amounts of power.
- For example, the Inner Mongolia Information Park owned by China Telecom consumes over 150 Megawatts of electric power. This is approximately the amount of electrical power consumed by a city of a million people.
- Cooling is the counterpart to power. As it consumes power, electronic equipment produces heat. To prevent it from malfunctioning and eventually burning out, the equipment must be cooled.
- Because the electronic systems in a data center generate substantial amounts of heat, the systems that remove heat have become major parts of the data center infrastructure.

Do you know of some solutions to cool down data centers?

# Data center Infrastructure

## Raised floor pathways and air cooling

- Data centers have a raised floor: a metal support structure supports a floor from one to four feet above the concrete floor of the building. The space between the real floor and the raised floor can be used to hold power cables and for air cooling.

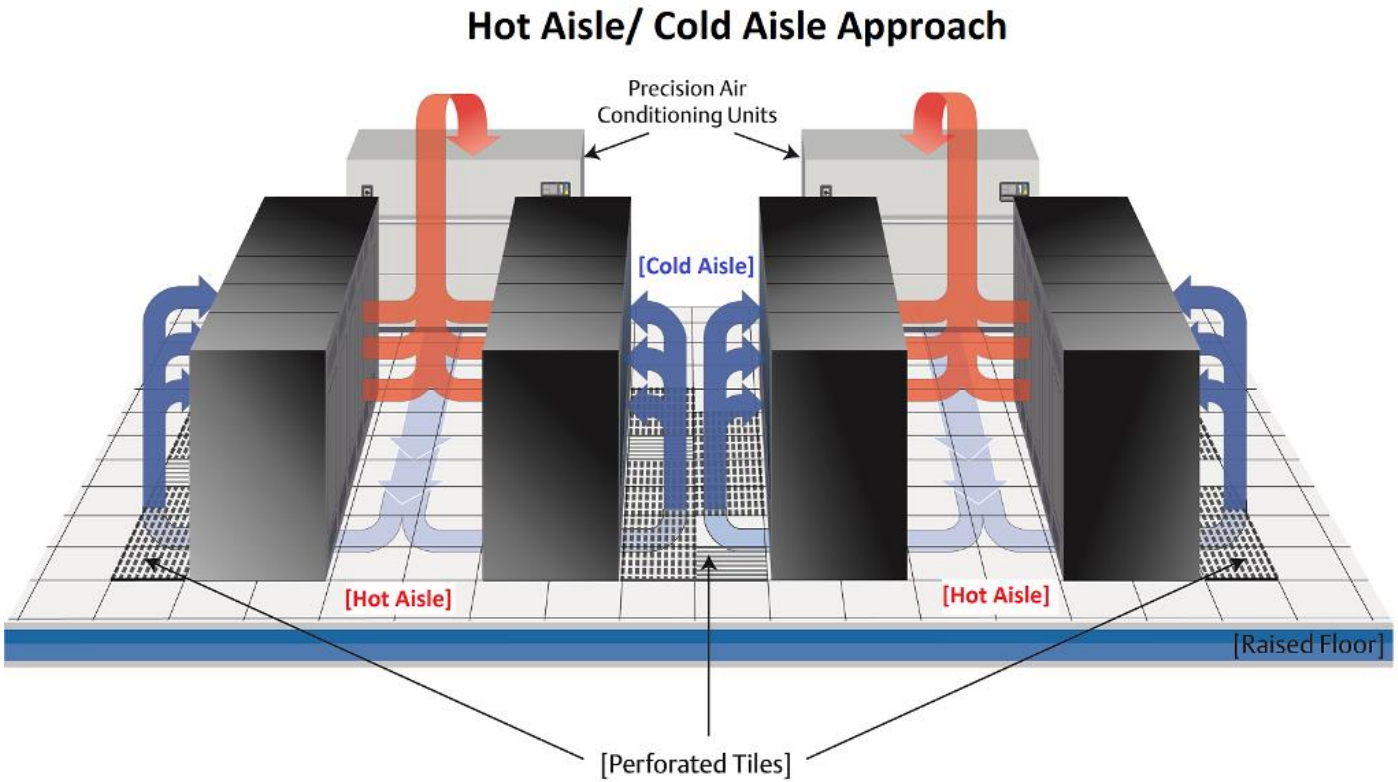
# Data center Infrastructure

## Thermal Containment And Hot/Cold Aisles

- Current data center designs push chilled air under a raised floor. Perforated floor tiles under each rack allow the chilled air to flow up- ward through the rack to cool equipment.
- Overall air flow in the data center must be designed carefully to move hot air away from the racks, ensuring that it cannot be accidentally drawn back into another piece of electronic equipment.
- A technique known as thermal containment offers one solution. The idea is to direct heat to contained areas where it can be pulled using fans in the ceiling and cooled again.
- Racks collect air from their front side and exhaust it from their back.
- So by orienting racks to create an aisle with the fronts of racks facing each other and then an aisle with the backs of racks facing each other., we can create hot and cold aisles.

# Data center Infrastructure

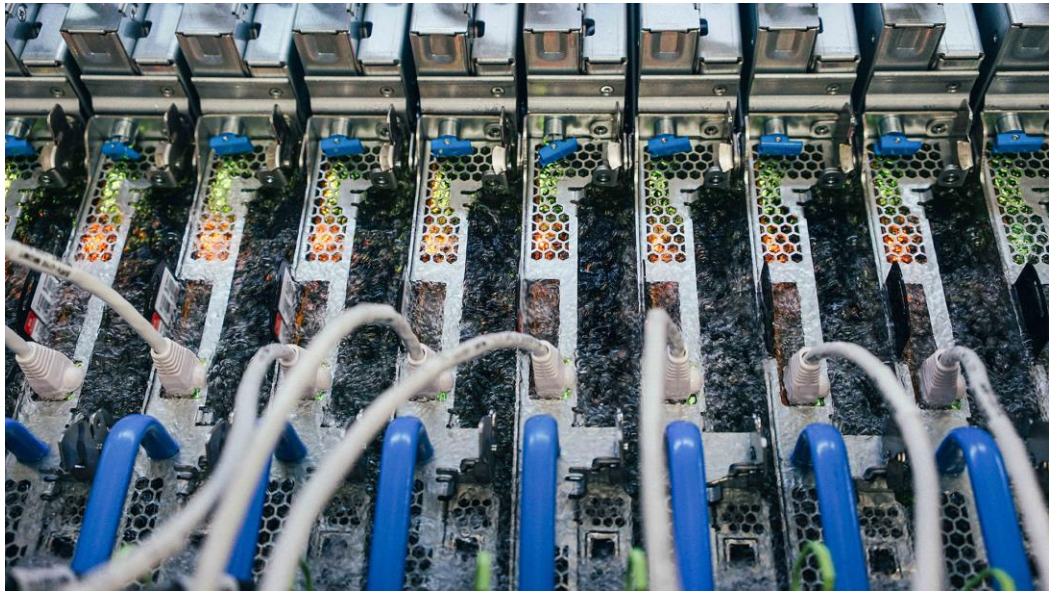
## Thermal Containment And Hot/Cold Aisles




- The center of a hot aisle, which is usually the center of a pod, is a hot spot where a chimney (i.e., a ceiling fan with an exhaust duct in the ceiling) is put to collect hot air efficiently.

# Data center Infrastructure

## Liquid cooling for datacenters



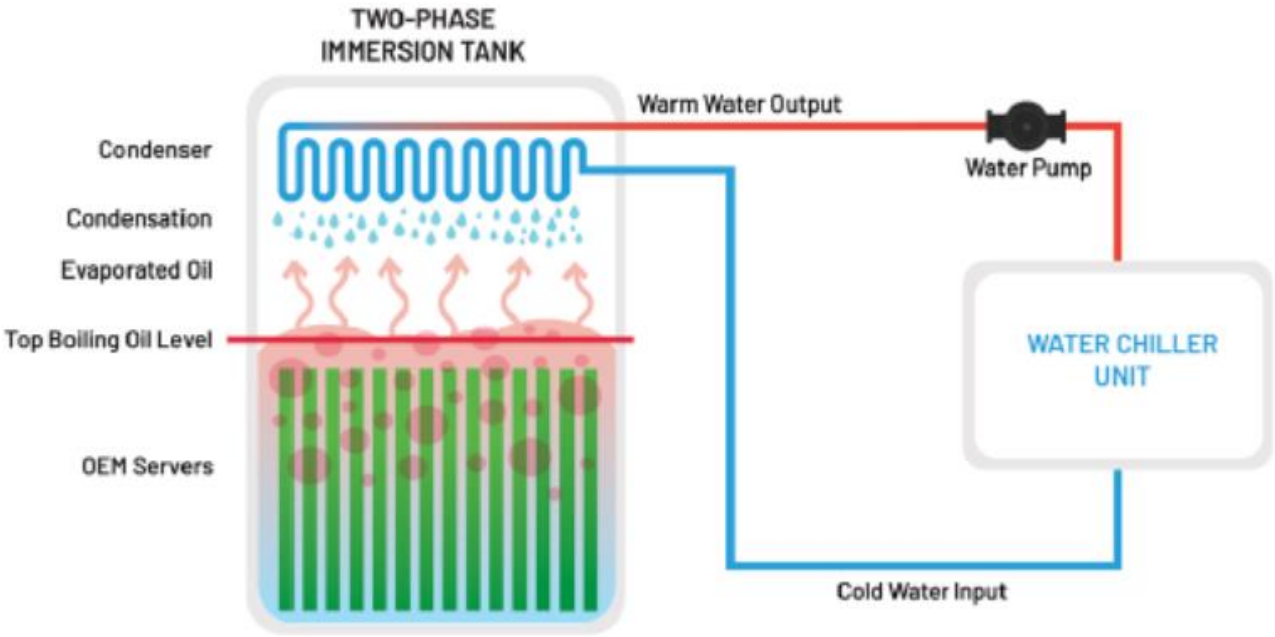
- To increase the efficiency of cooling, some data centers switched to liquid cooling.

- In this case, a non-conducting liquid is made into contact with all the electronic equipment of the rack. Sometimes, this liquid has a low boiling point, and by boiling takes away some heat from the servers.

# Data center Infrastructure

## Liquid cooling for datacenters

- When using the boiling process to cool, the technology is called two-phase immersion cooling:

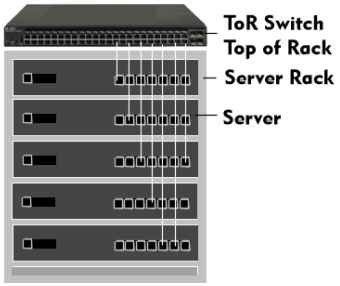


# Data center Infrastructure

## Network connectivity

- Network connectivity forms the second most important consideration in data center design.

- A network switch in each rack connects to each server in the rack and provides communication among the servers as well as communication to the rest of the data center and the Internet. The switch in each rack is usually placed near the top, giving rise to the term Top of Rack (ToR) switch.

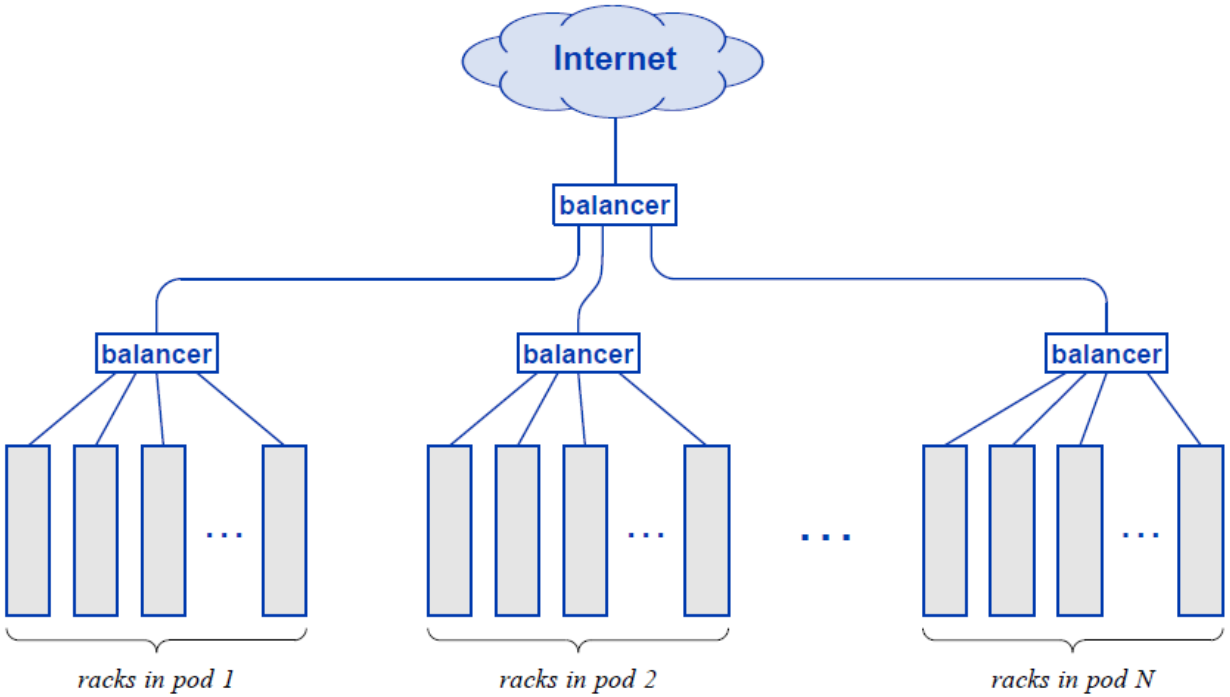



- To further increase the rate at which data can be sent, each server can use a multiport network interface card. Each of the ports connects to the ToR switch, and each operates independently and in parallel.

# Data center Infrastructure

## How are racks connected with each other?

- The simplest solution is to use a fat-tree design:

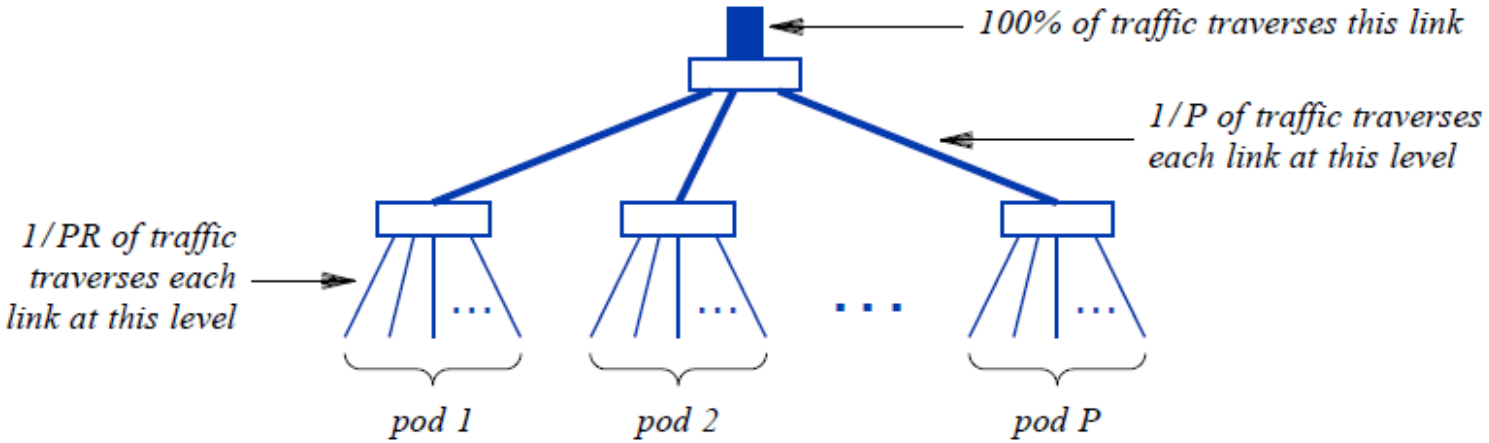



Can you see a downside to this solution?

# Data center Infrastructure

## How are racks connected with each other?

- Arranging a data center network as a hierarchy has a disadvantage: links near the top of the hierarchy carry more traffic than links farther away:

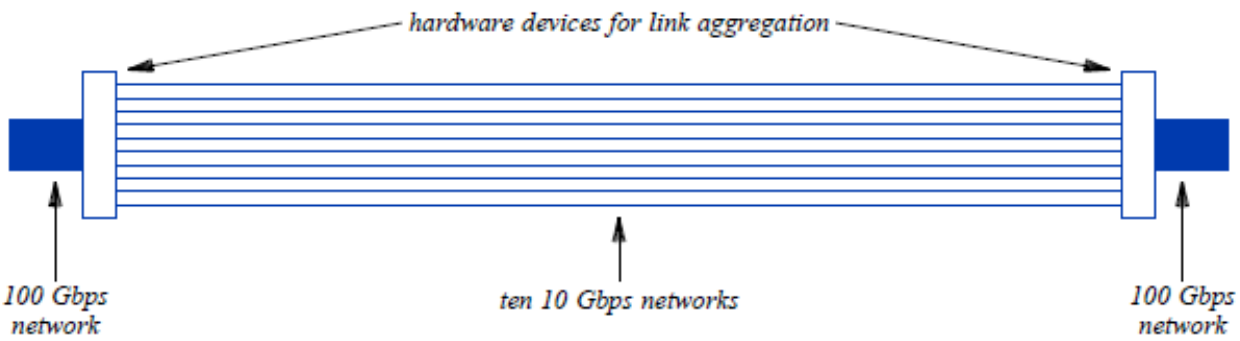



What is the challenge in implementing this approach?

# Data center Infrastructure

## How are racks connected with each other?

- The problem with the fat-tree approach lies in the high capacity needed for the top-level links.
- However, link capacities are standardized, so only certain ones are available (e.g., 10 Gbps and 100 Gbps Ethernet), and higher-speed equipment is expensive.
- To address this issue, a technique known as link-aggregation is used:

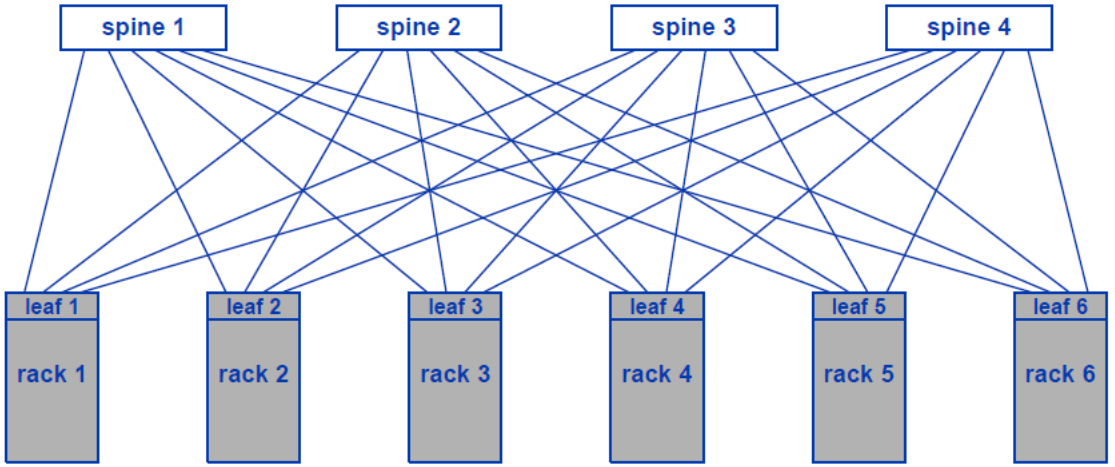



Can you find a better networking solution?

# Data center Infrastructure

## How are racks connected with each other?

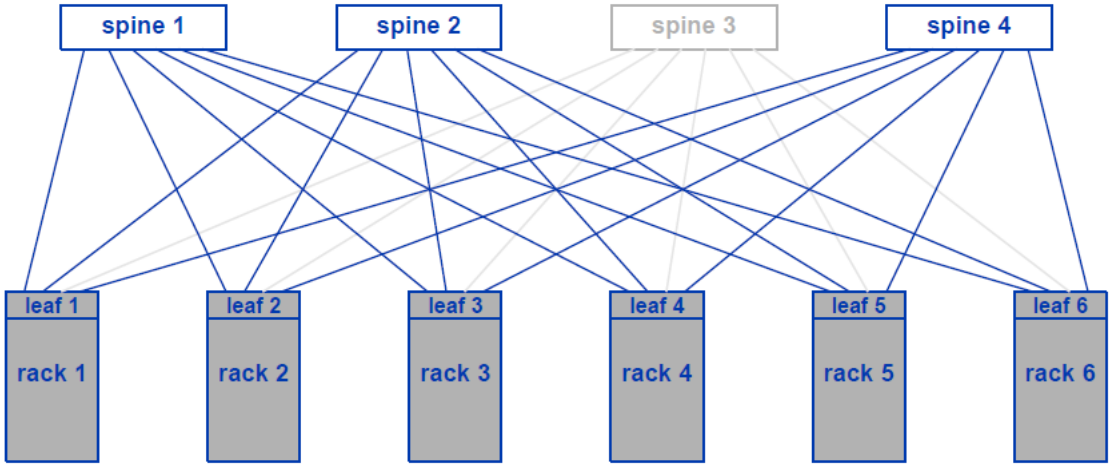
- How can a data center network be designed that handles large volumes of traffic without using a hierarchical design?
- The specific approach used in data centers is known as a leaf-spine network architecture.
- In leaf-spine terminology, each Top-of-Rack switch is called a leaf. The data center owner adds an additional set of spine switches and connects each leaf switch to each spine switch:



# Data center Infrastructure

## What are the advantages of leaf-spine network architecture?

- The leaf-spine architecture offers two main advantages over a hierarchical design:
  - Higher east-west traffic capacity: Because both the source and destination racks connect to all spine switches, several independent paths exist between each pair.
  - Redundant paths to handle failures :

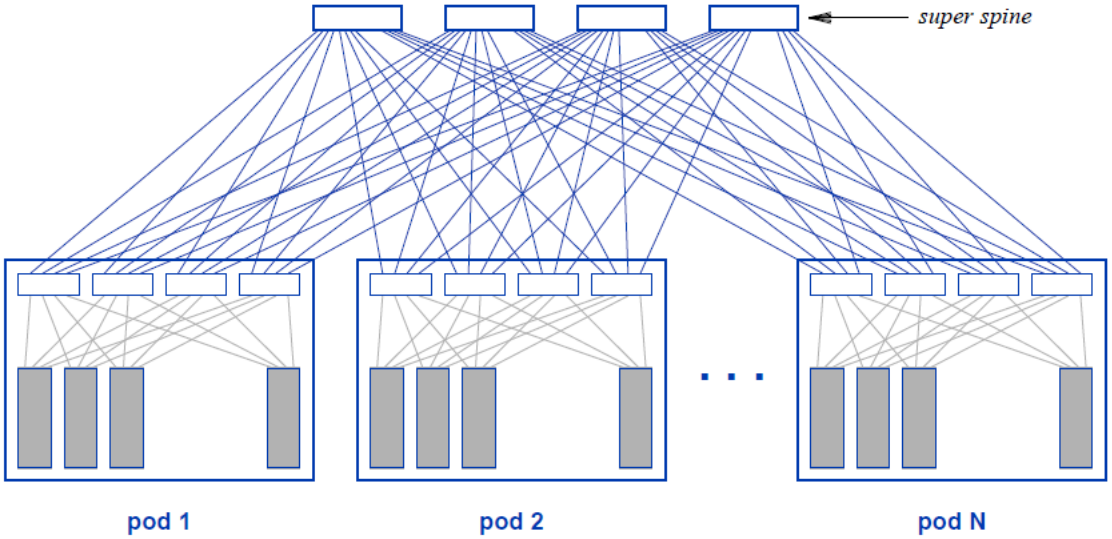


# Data center Infrastructure

## Super spines for scalability

- Although it works for small numbers of racks, connecting all racks to each spine switch does not scale to tens of thousands of racks because the largest switches do not have tens of thousands of ports.

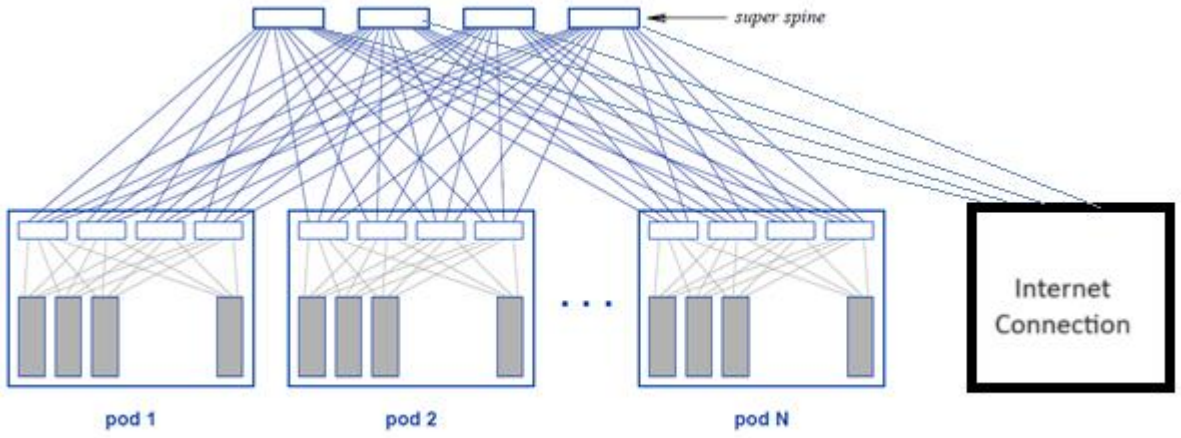
- To handle scaling, a data center uses a separate leaf-spine network to connect the racks in each pod, and a super-spine level is added to connect the pods together:



# Data center Infrastructure

## Where is the Internet connection in a super-spine architecture?

- The incoming Internet connection may pass through a router, a hardware firewall, or other equipment (e.g., VPN gateway), and eventually reaches a special switch.
- In fact, most data centers dedicate at least two switches to each Internet connection in case one switch fails.
- The two external connection switches each connect to all the super spine switches as if they are spine switches: they act like a miniature pod!



# Data center Infrastructure

## How is storage handled in a data center?

- Earlier data centers contained servers where all the storage was local.
- However, the introduction of multi-tenant cloud systems made local storage on servers problematic. Do you know why?
- The main issue comes from the fact that a given server runs virtualized servers from multiple customers at the same time, and so we run into the problem of limited storage space in a single server.
- To overcome the problems, data centers employ an approach for storage analogous to the approach used for computation: virtualized disks.
- In a small data center, the owner places all physical storage devices in a centralized location; in a larger data center, multiple locations are used.

# Data center Infrastructure

## How is storage handled in a data center?

- Software creates virtualized disks for customers: when a virtualized server is created, the virtualized server is granted access to a corresponding virtualized disk.

- As software on a virtualized server accesses or stores data on its disk, requests travel across the data center network to the storage facility and replies travel back over the network.

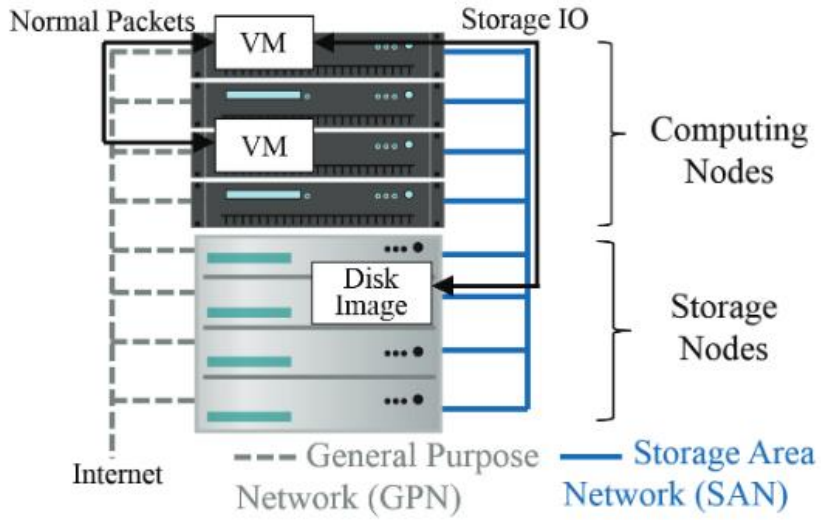
- Network communication introduces latency, which means that accessing virtualized storage over a network can take longer than accessing a local disk.

- To avoid long delays, a data center owner can create multiple storage facilities and place each facility near a group of racks. For example, some data centers place a storage facility with each pod.

# Data center Infrastructure

## How is storage handled in a data center?

- Usually, in a rack, some servers are dedicated to storage, and others are dedicated to computing (i.e., hosting the VMs):




- The storage and computing are also in different isolated networks.

- For better flexibility, new architectures use the same unified network for both storage and compute: they are called hyperconverged infrastructures.

# Data center Infrastructure

## Summary

- *A data center consists of racks arranged in aisles and divided logically into pods.*
- *Raised floor allows cool air to reach each rack, and techniques such as hot/cold aisles help manage cooling.*
- *Early data centers used hierarchical networks in a fat tree design that requires highest capacity near the top of the tree. Modern cloud centers use a leaf-spine network architecture that supports east-west traffic (i.e., traffic among racks in the data center).*
- *Early data centers used conventional computers that each had a local disk. A modern data center places all physical storage hardware in a centralized location and provides access to virtualized block storage over a network.*