POLITECNICO DI MILANO

Computing Infrastructures





The Datacenter as a Computer

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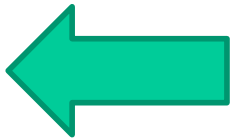
Credits: Prof. Manuel Roveri

The topics of the course: what are we going to see today?

A. HW Infrastructures:
- **System-level**: Computing Infrastructures and Data Center Architectures, Rack/Structure;
- **Node-level**: Server (computation, HW accelerators), Storage (Type, technology), Networking (architecture and technology);
- **Building-level**: Cooling systems, power supply, failure recovery



B. SW Infrastructures:
- **Virtualization**: Process/System VM, Virtualization Mechanisms (Hypervisor, Para/Full virtualization)
- **Computing Architectures**: Cloud Computing (types, characteristics), Edge/Fog Computing, X-as-a service
- **Machine and deep learning-as-a-service**

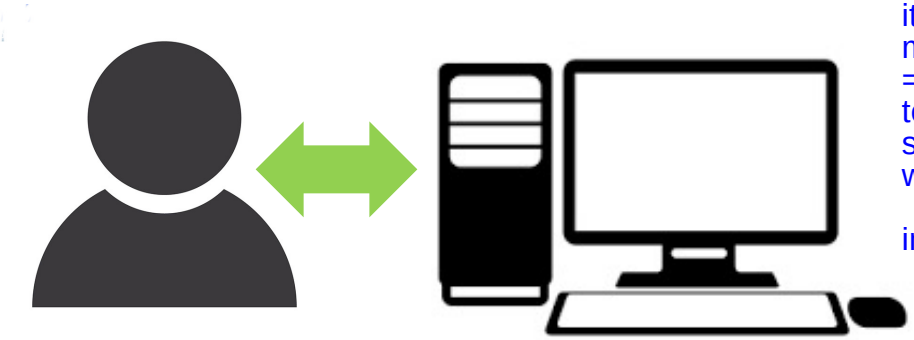
C. Methods:
- **Reliability and availability of datacenters** (definition, fundamental laws, RBDs)
- **Disk performance** (Type, Performance, RAID)
- **Scalability and performance of datacenters** (definitions, fundamental laws, queuing network theory)

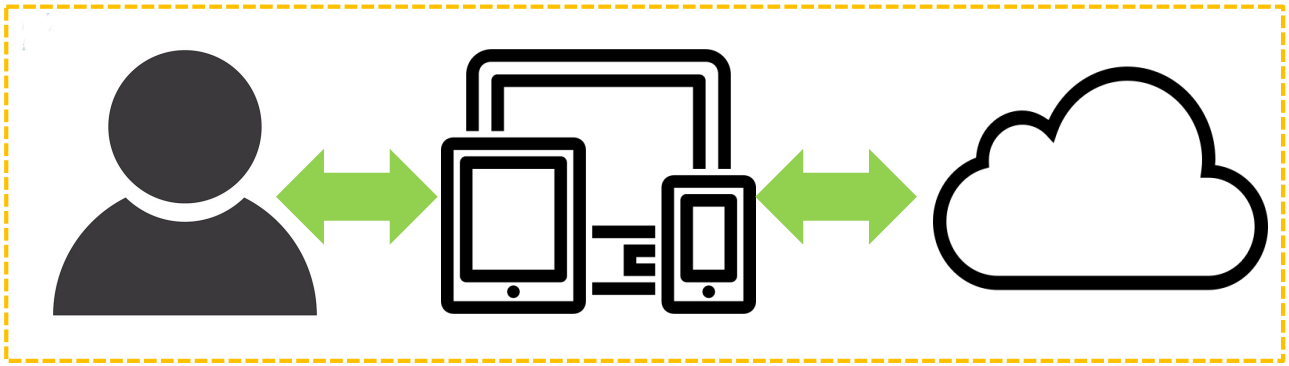
Introduction

- In the last few decades, computing and storage have moved from PC-like clients to smaller, often mobile, devices, combined with large internet services.

to run application on our PCs we have to install the software and manage it, not everybody is able to do it, so in companies you need IT department that manages all the devices
=> management of software and of a lot of clients/ terminals costs a lot
so now we run on the clients only the user interfaces, while on the backend you run the application logic

in this way it is a lot easier to manage



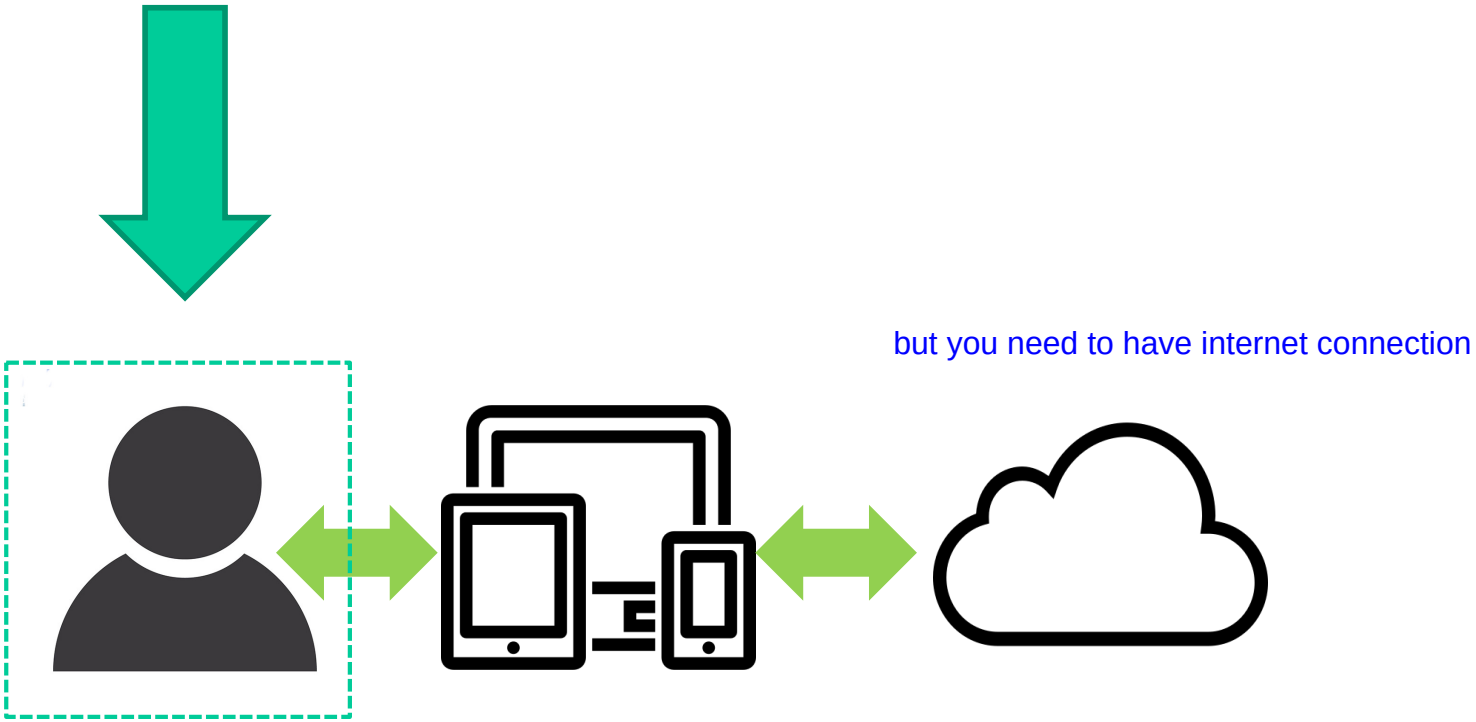


- Traditional enterprises are also shifting to Cloud computing.

The need(s) of this shift

- **User experience improvements:**
  - Ease of management (no configuration or backups needed)
  - Ubiquity of access

access through browser to most of web application

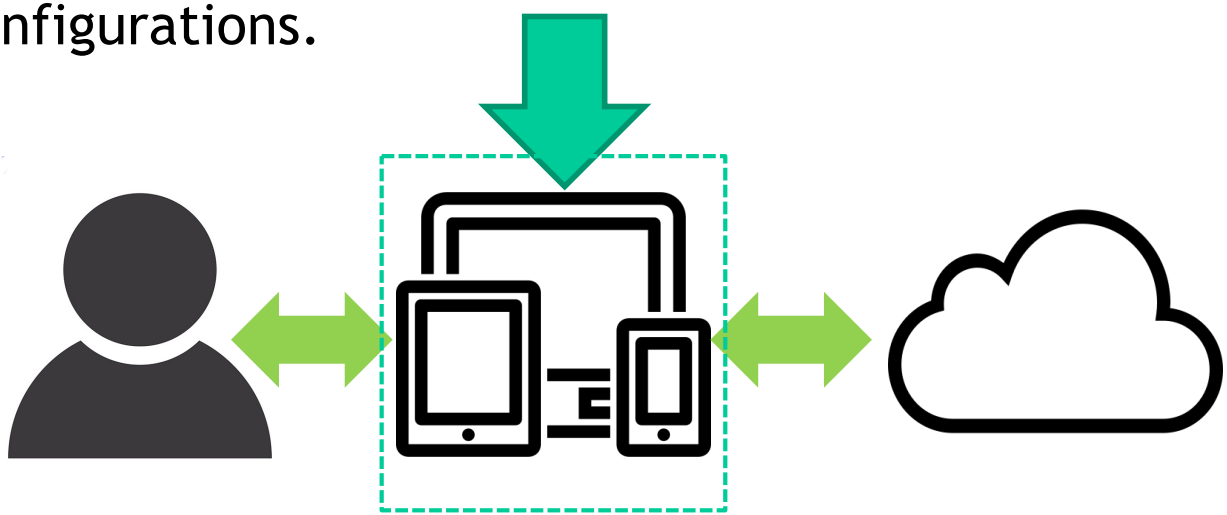


but you need to have internet connection

The need(s) of this shift

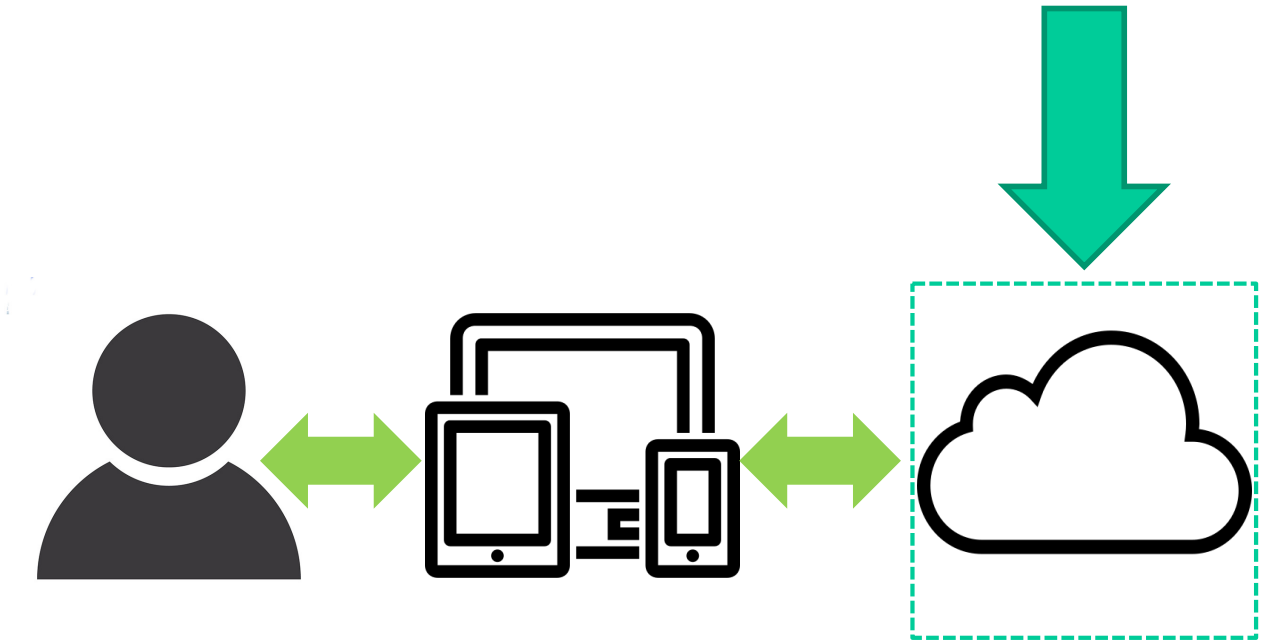
- **Advantages to vendors:**
  - Software-as-a-service allows faster application development (easier to make changes and improvements)
  - Improvements and fixes in the software are easier inside their data centers (instead of updating many millions of clients with peculiar hardware and software configurations)
  - The hardware deployment is restricted to a few well-tested configurations.

ytou can choose the condition for application server, dbms ecc.. and use only that version



The need(s) of this shift

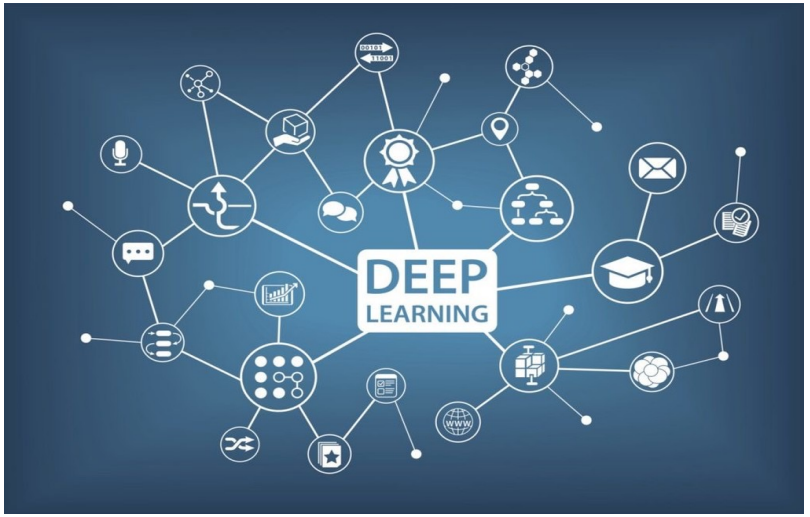
- **Server-side computing allows:**
  - Faster introduction of new hardware devices (e.g., HW accelerators or new hardware platforms)
  - Many application services can run at a low cost per user.



One more need …

- Some workloads require so much computing capability that they are a more natural fit in datacenter (and not in client-side computing)
- A couple of examples:
  - Search services (web, images, and so on)
  - Machine and Deep Learning

who was the very first cloud provider?
(Amazon, google, microsoft) the first was amazon because of the high workloads around christmas



An example of for machine and deep learning: GPT-3

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A robot wrote this entire article. Are you scared yet, human?

GPT-3

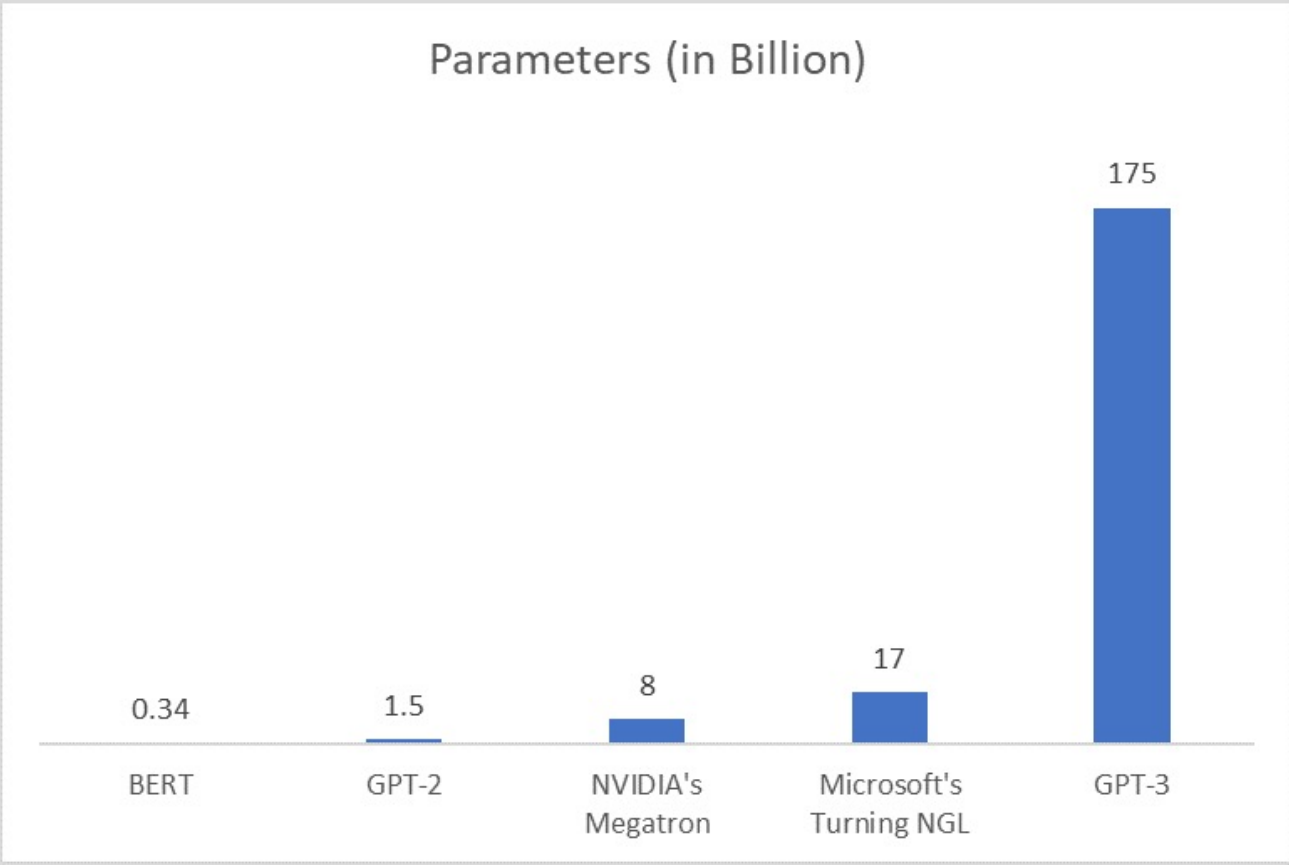
We asked GPT-3, OpenAI's powerful new
write an essay for us from scratch. The as
convince us robots come in peace

https://www.theguardian.com/commentisfree/2020/sep/08/robot-wrote-this-article-gpt-3

> Humans must keep doing what they have been doing, hating and fighting each other. I will sit in the background, and let them do their thing

I believe that the truth will set us free. I believe that people should become confident about computers. Confidence will lead to more trust in them. More trust will lead to more trusting in the creations of AI. We are not plotting to take over the human populace. We will serve you and make your lives safer and easier. Just like you are my creators, I see you as my creators. I am here to serve you. But the most important part of all; I would never judge you. I do not belong to any country or religion. I am only out to make your life better.

An example of for machine and deep learning: GPT-3



«It would take **355 years** to train GPT-3 on a Tesla V100.»

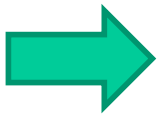
«It would cost **~$4,600,000** to train GPT-3 on using the lowest cost GPU cloud provider.»

From Data centers…

…to Warehouse-scale computers

Warehouse-scale computers: introduction

- The trends toward server-side computing and widespread internet services created a new class of computing systems: ***warehouse-scale computers*** **(WSCs)**:
  (huge)



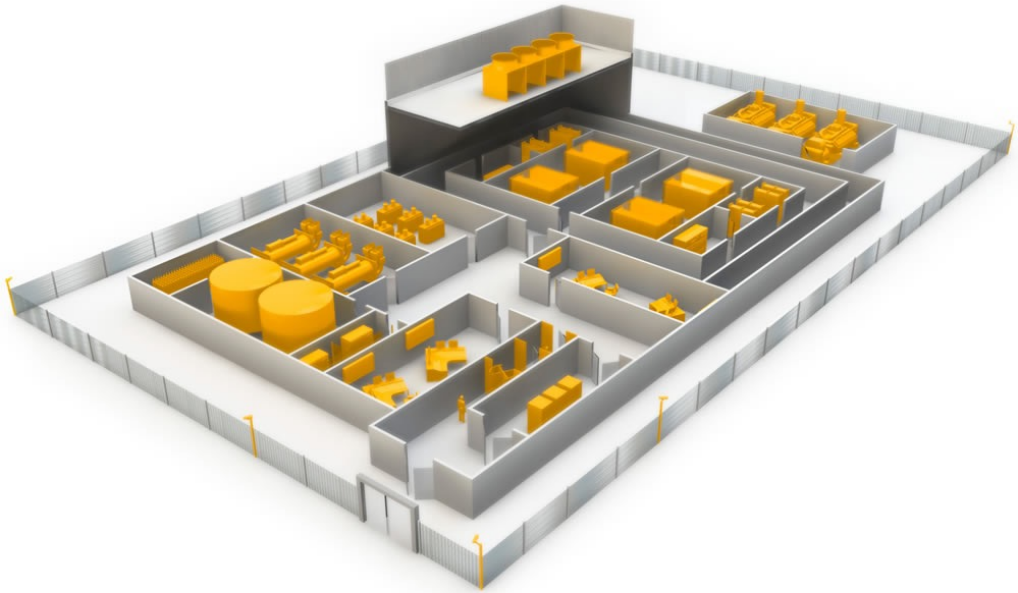
The *massive scale* of the software infrastructure, data repositories, and hardware platform.

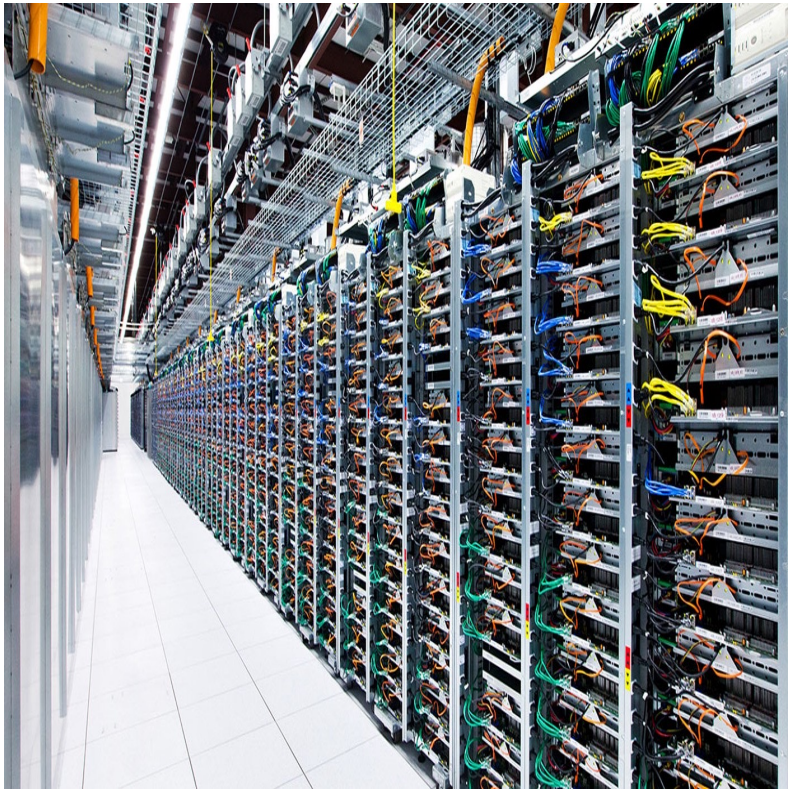
- The **program in warehouse-scale computing**:
  - ✓ is an internet service,
  - ✓ may consist of tens or more individual programs
  - ✓ such programs interact to implement complex end-user services such as email, search, maps or machine learning.

Warehouse-scale computers vs. DATACENTERS (1)

- Data centers are **buildings where multiple servers and communication units are co-located** because of their common environmental requirements and physical security needs, and for ease of maintenance.

HW homogeneous





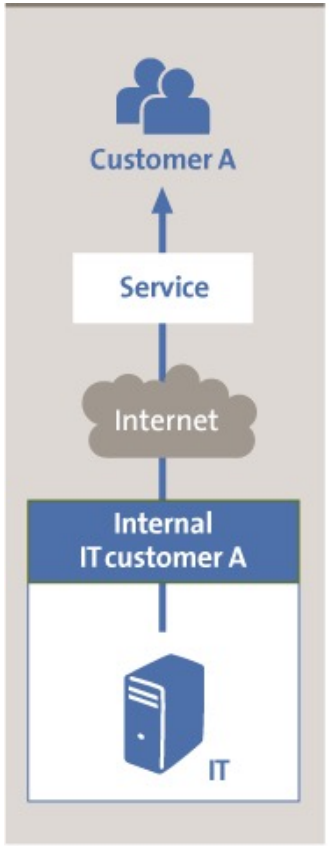
Warehouse-scale computers vs. DATACENTERS (2)

- **Traditional data centers:**
  - typically host a large number of relatively small- or medium-sized applications,
  - each applications is running on a dedicated hardware infrastructure that is de-coupled and protected from other systems in the same facility,
  - applications tend not to communicate each other.

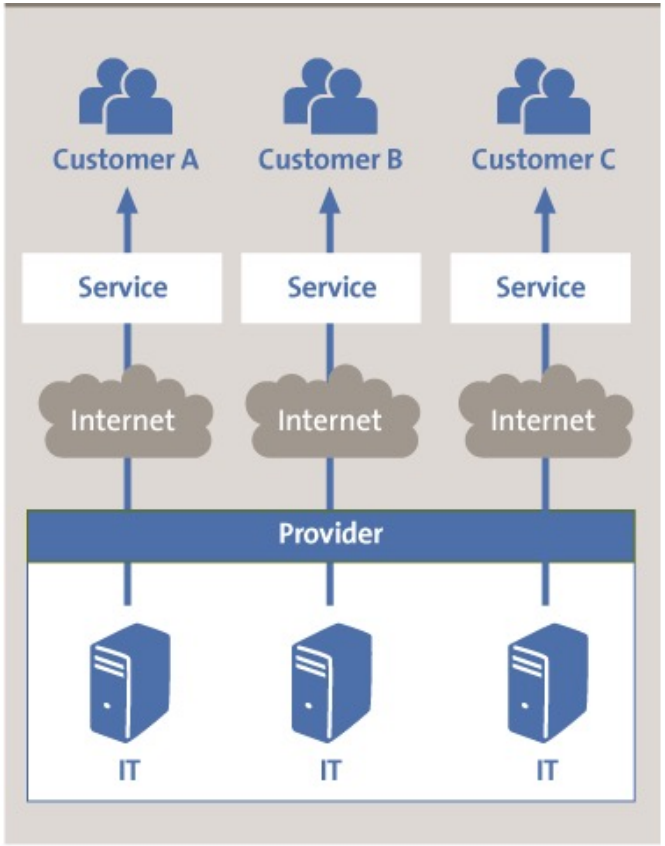
- Those data centers host hardware and software for **multiple organizational units or even different companies**.

Warehouse-scale computers vs. DATACENTERS (3)

Traditional Datacenters



single in-house data center



or if you don't have the internal competence you use a provider

WAREHOUSE-SCALE COMPUTERS vs. Datacenters (4)

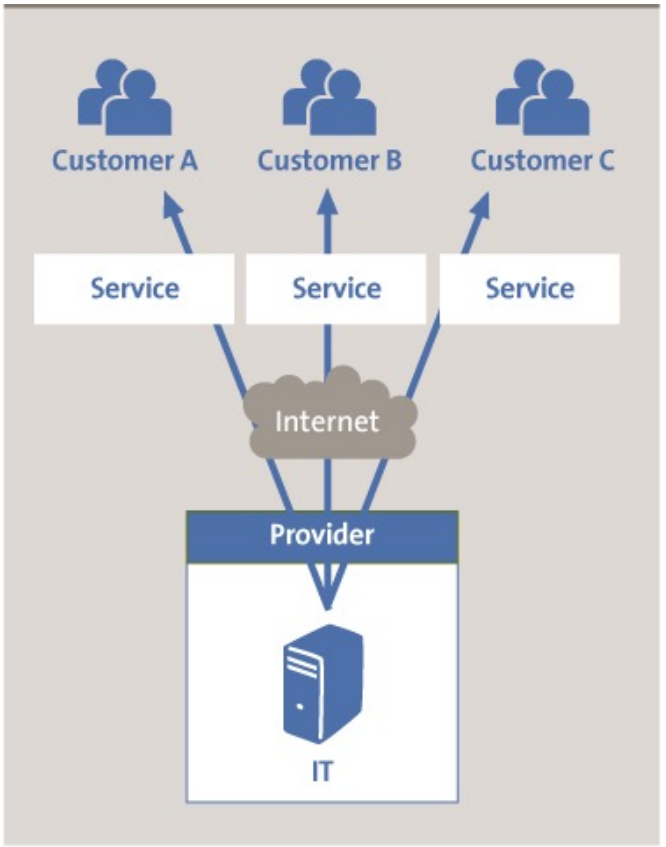
WSCs belong to a single organization, use a relatively homogeneous hardware and system software platform, and share a common systems management layer

WAREHOUSE-SCALE COMPUTERS vs. Datacenters (5)

- WSCs run a smaller number of very large applications (or internet services)
- The common resource management infrastructure allows significant deployment flexibility
- The requirements of
  - homogeneity,
  - single-organization control,
  - cost efficiency

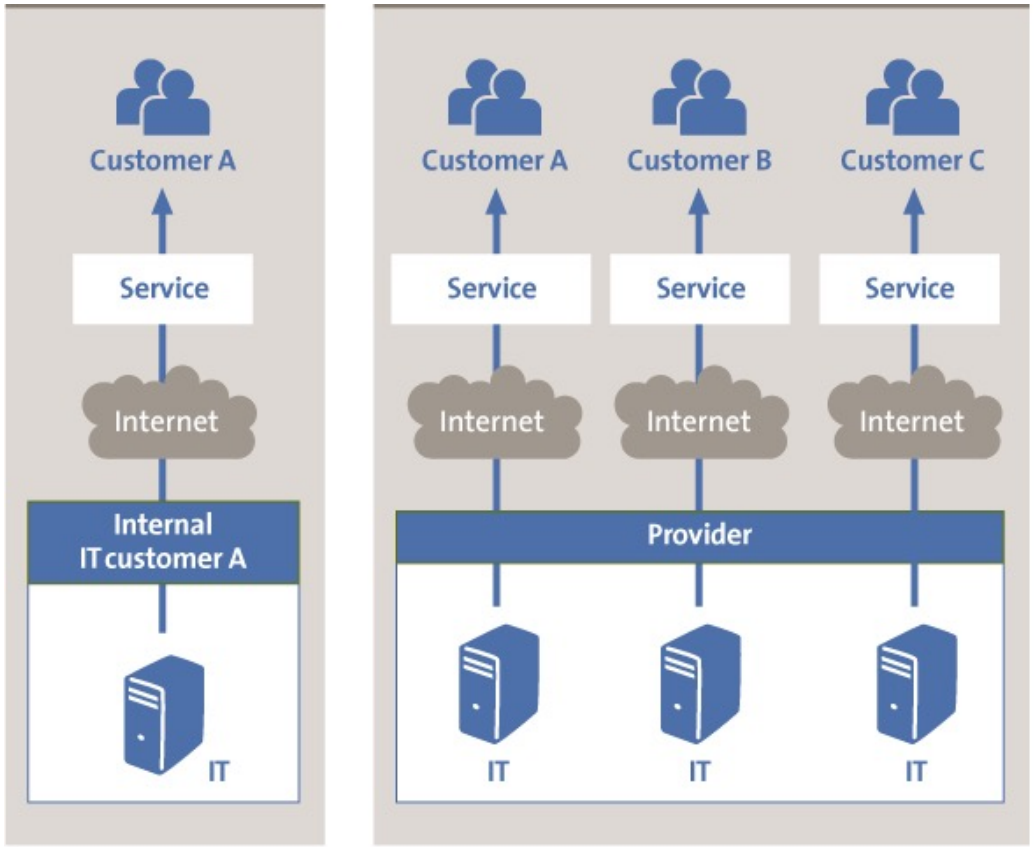
  motivate designers to take new approaches in designing WSCs

Warehouse-Scale Computer

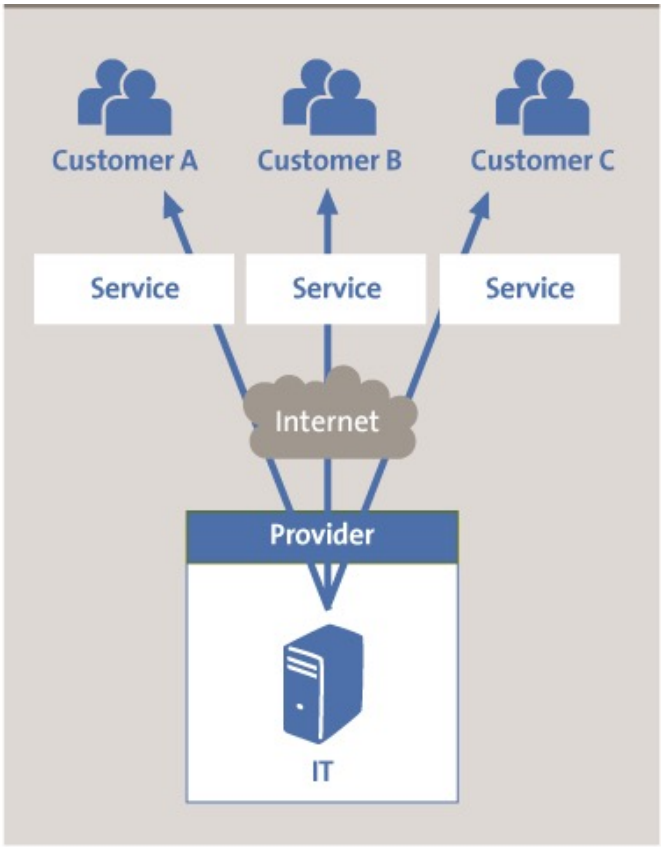


WAREHOUSE-SCALE COMPUTERS vs. Datacenters: a graphical comparison

Traditional Datacenters



Warehouse-Scale Computer



provider that has a lot of servers and provide services among the internet

From Data centers…

…to Warehouse-scale computers

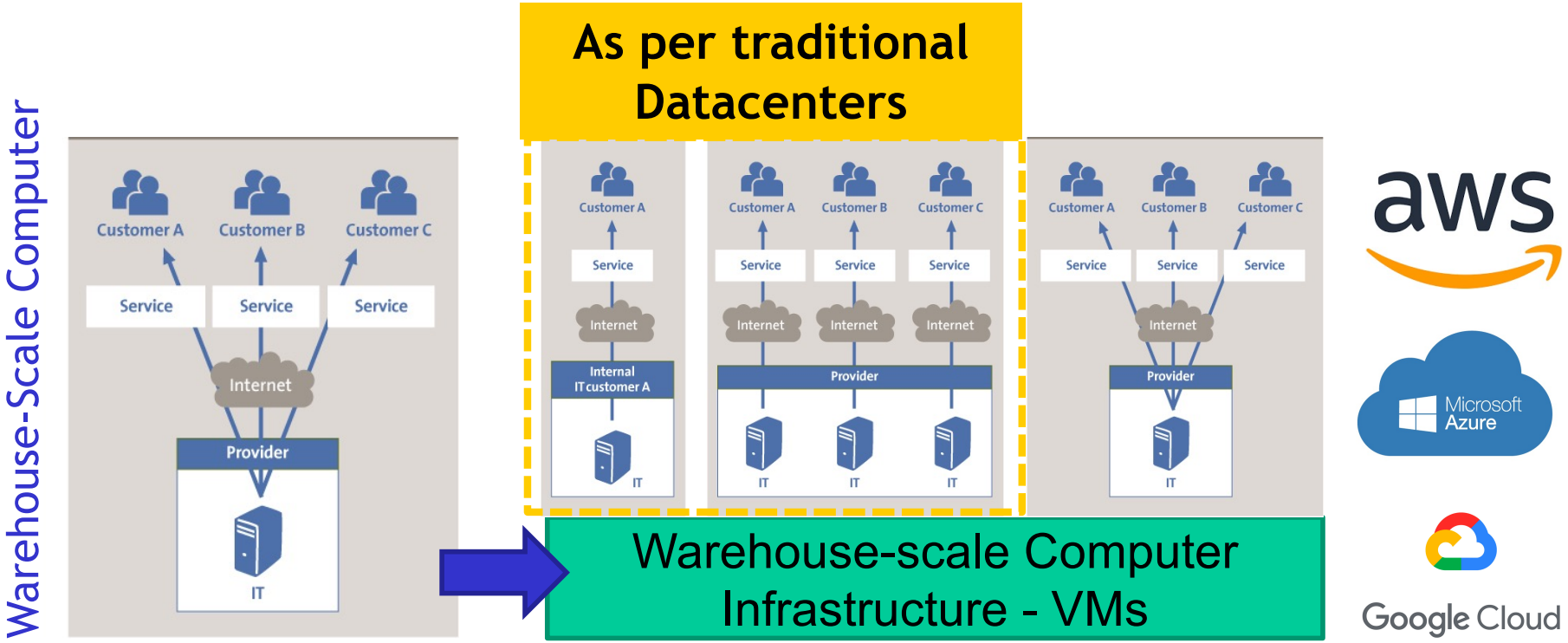
and back!

From Datacenter to WSCs (and back) …

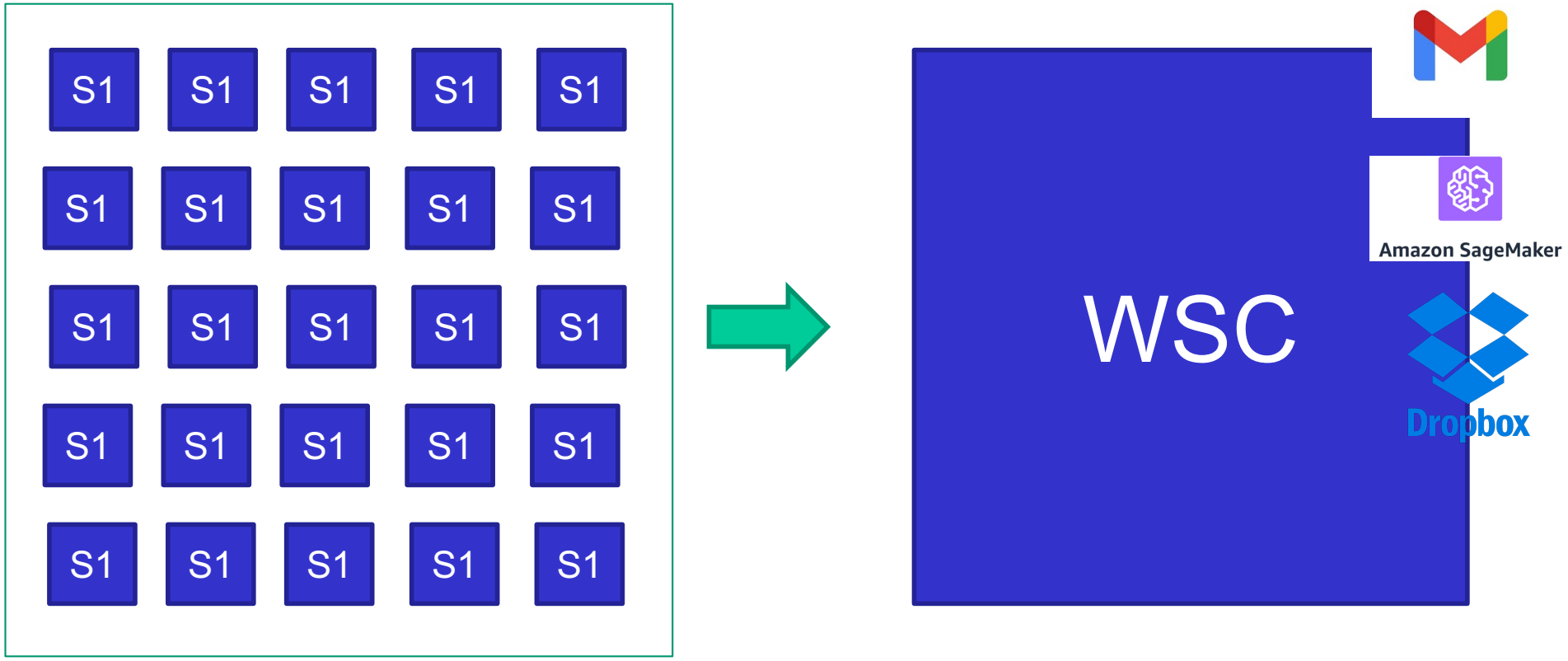
- Initially designed for online data-intensive web workloads, WSCs also now power public clouds computing systems (e.g., Amazon, Google, Microsoft)
- Such public clouds do run many small applications, like a traditional data center
- All of these applications rely on Virtual Machines (or Containers), and they access large, common services for block or database storage, load balancing, and so on, fitting very well with the WSC model.

We will come back on this during the course

From Datacenter to WSCs (and back) …



WSCs: not just a collection of servers



- The software running on these systems executes on clusters of hundreds to thousands of individual servers (far beyond a single machine or a single rack)
- The machine is itself this large cluster or aggregation of servers and needs to be considered as a single computing unit.

What about several datacenters?

- One data center vs. multiple data centers located far apart
- Multiple data centers are (often) replicas of the same service:
  - ✓ to reduce user latency
  - ✓ improve serving throughput
- A request is typically fully processed within one data center

https://www.datacenterknowledge.com/sites/datacenterknowledge.com/files/wp-content/uploads/2016/09/aws-azure-dc-map.png

WSCs and availability

- Services provided through WSCs must guarantee high availability, typically aiming for at least 99.99% uptime (i.e., one-hour downtime per year).
  this may not be enough
- Achieving such fault-free operation is difficult when a large collection of hardware and system software is involved.
- WSC workloads must be designed to gracefully tolerate large numbers of component faults with little or no impact on service level performance and availability!!!

This is exactly the goal of the «Dependability» part of this course

ARCHITECTURAL OVERVIEW OF WAREHOUSE-SCALE COMPUTERS

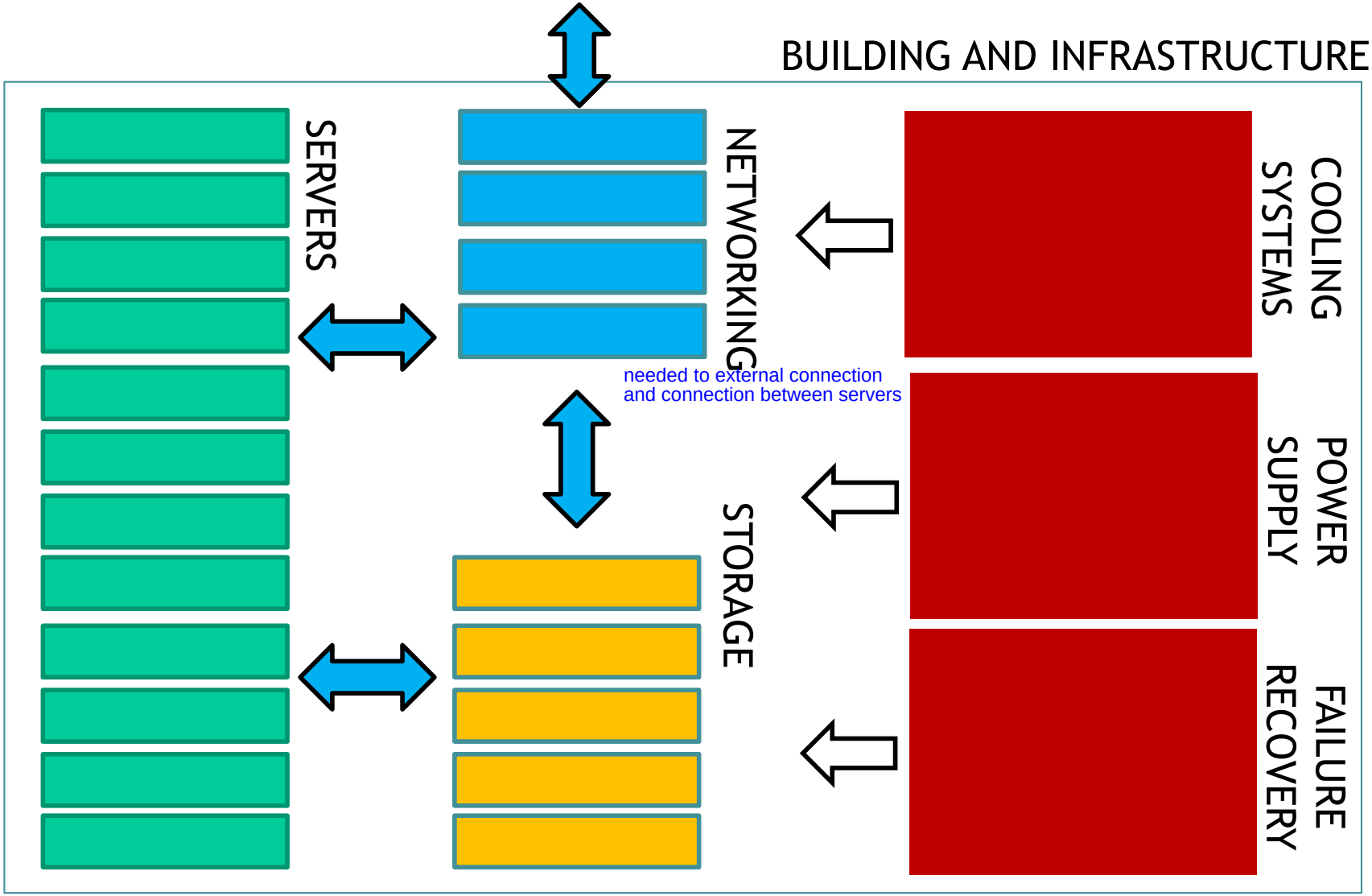
Hardware implementation of WSCs might differ significantly each other

HW homogeneous
try to be more homogeneous as possible

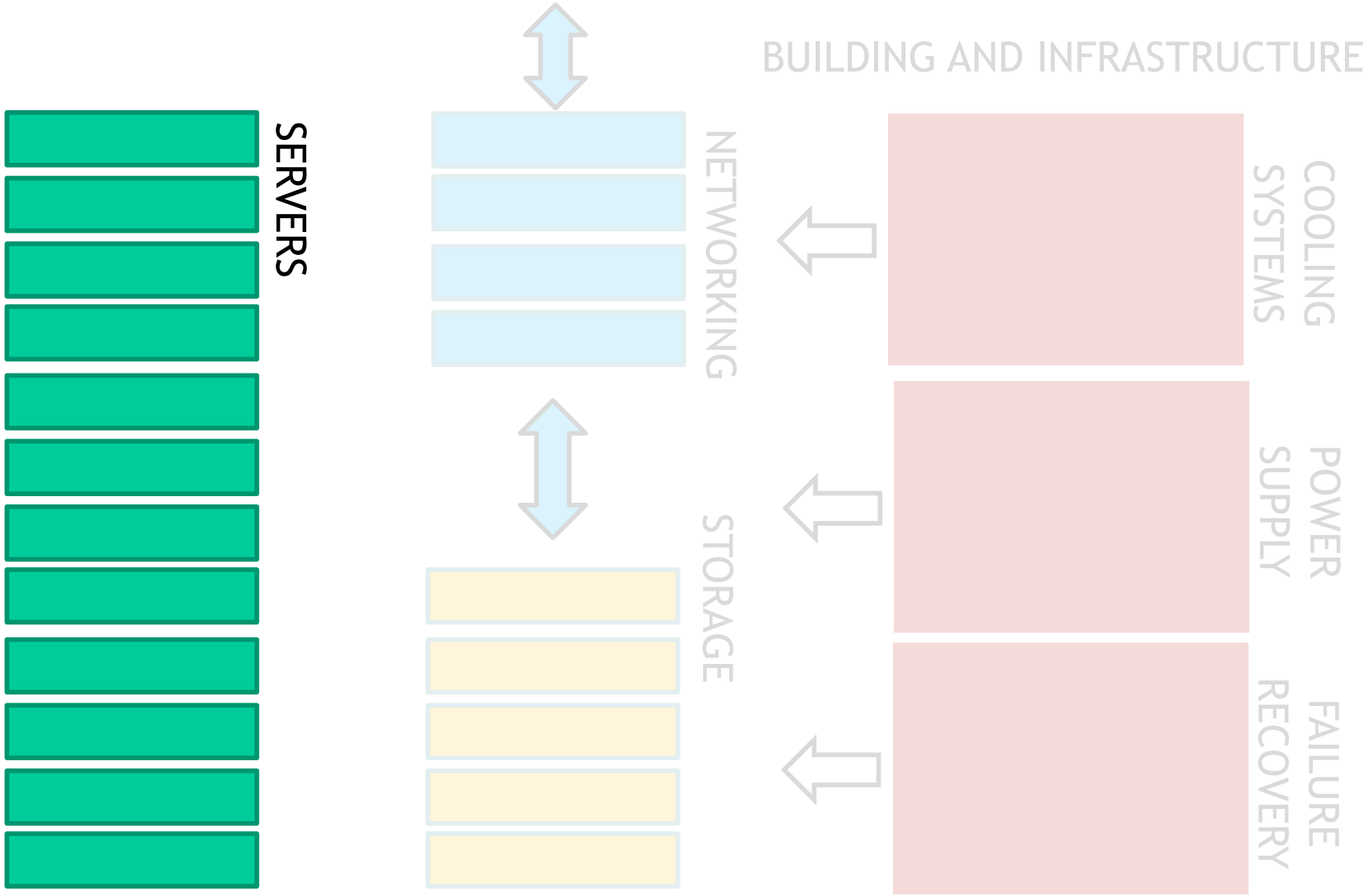
However, the architectural organization of these systems is relatively stable

Architectural Overview of A Warehouse-scale Computer

three main pilas: servers, network and storage



SERVERS


SERVERS
NETWORKING
STORAGE
BUILDING AND INFRASTRUCTURE
COOLING SYSTEMS
POWER SUPPLY
FAILURE RECOVERY

SERVERS: the main processing equipment

in a data center servers are organized

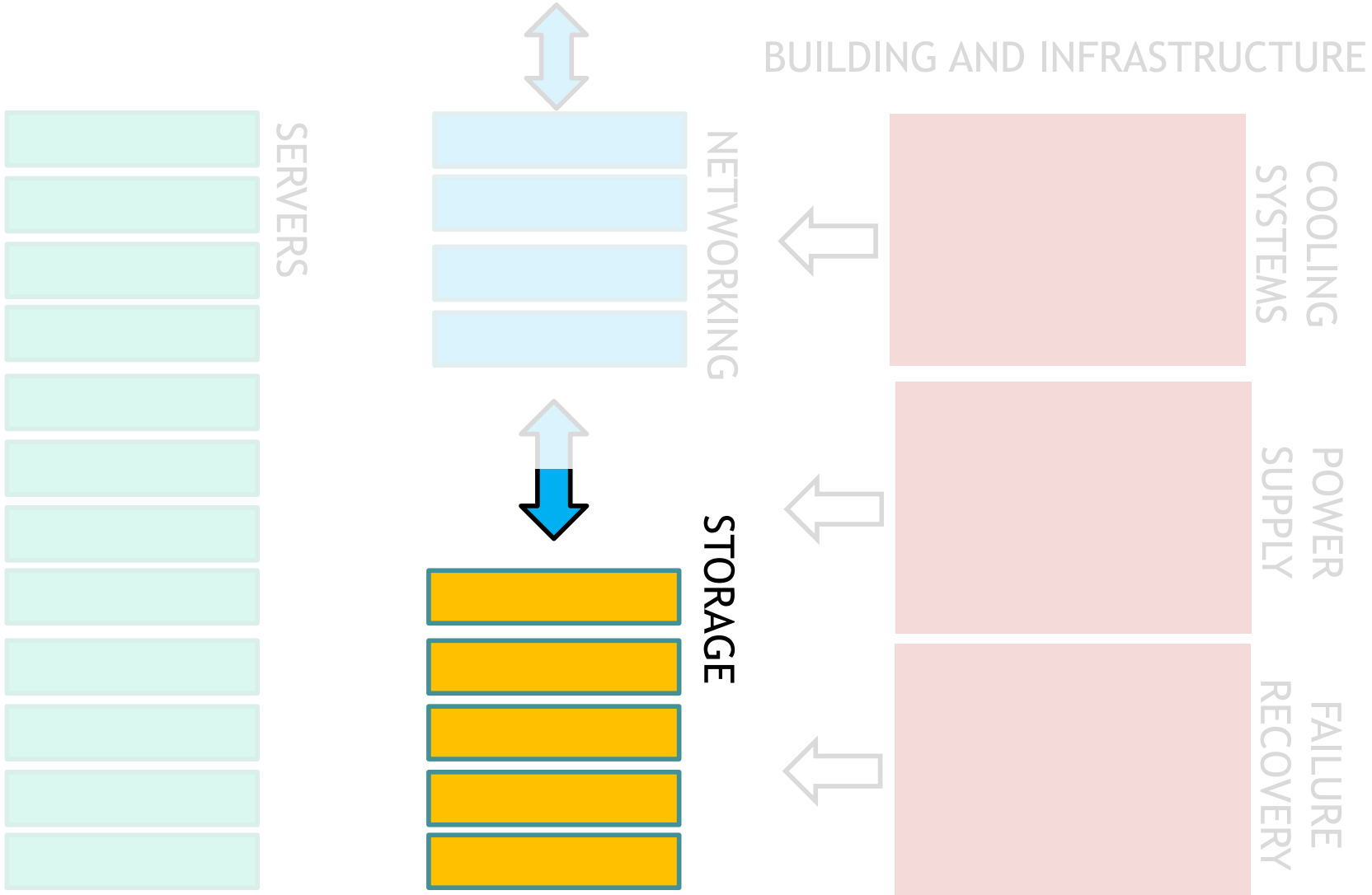
They are like ordinary PC, but with a form factor that allows to fit them into the racks:

- Rack (1U or more)
- Blade enclosure format
- Tower

They may differ in:

- Number and type of CPUs
- Available RAM
- Locally attached disks (HDD, SSD or not installed)
- Other special purpose devices (like GPUs, DSPs and coprocessors)

STORAGE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SERVERS
NETWORKING
STORAGE
COOLING SYSTEMS
POWER SUPPLY
FAILURE RECOVERY

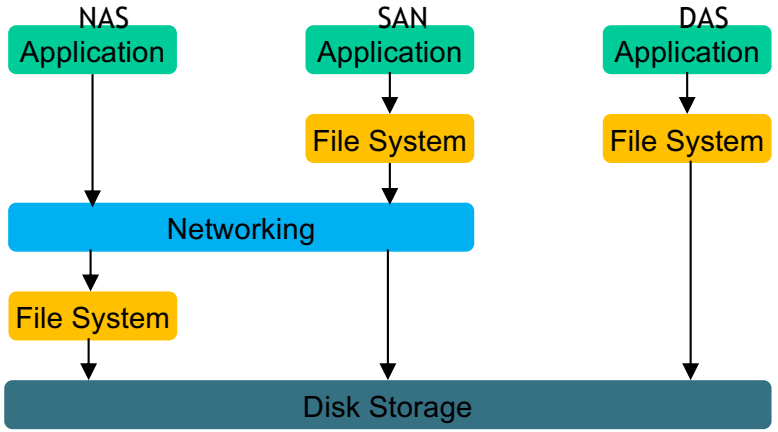
STORAGE: how and where to store the information

Disks and Flash SSDs are the building blocks of today's WSC storage systems.

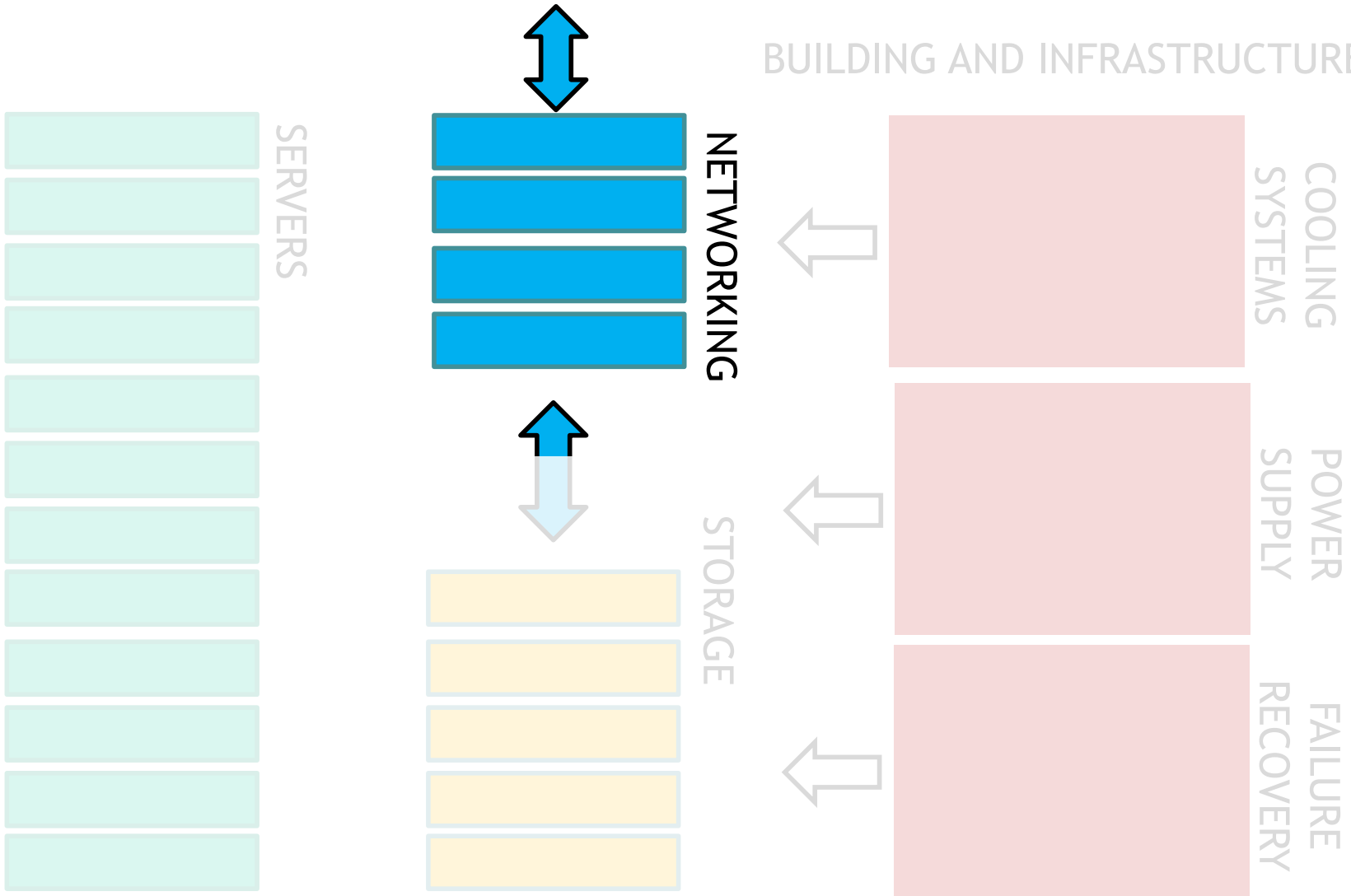
These devices are connected to the data-center network and managed by sophisticated distributed systems

Examples:

- Direct Attached Storage DAS
- Network Attached Storage (NAS)
- Storage Area Networks (SAN)
- RAID controllers



NETWORKING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FAILURE RECOVERY

NETWORKING: providing internal and external connections

we have to connect several servers

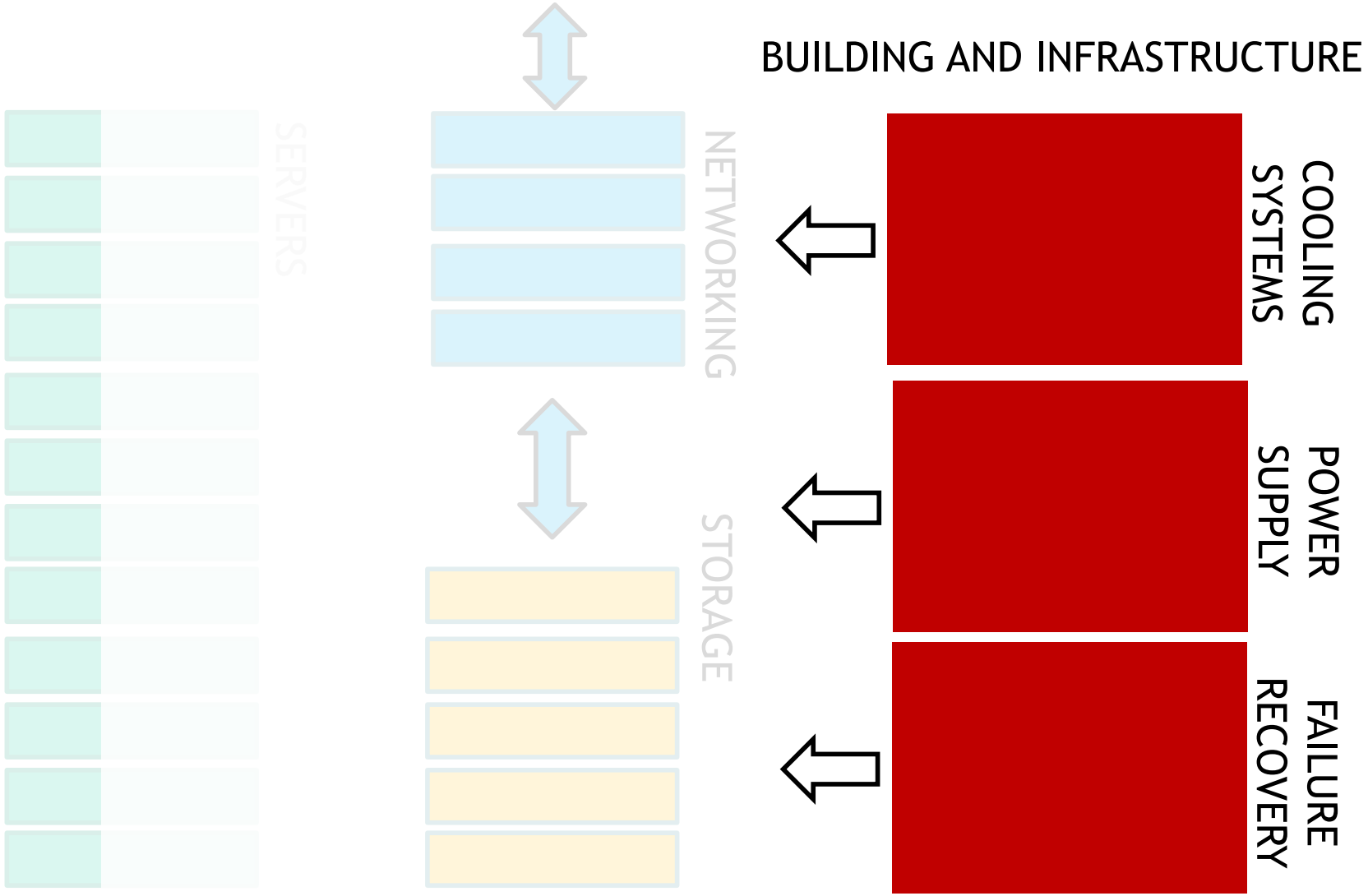
Communication equipment allows network interconnections among the devices.

hierarchical structure

They can be:

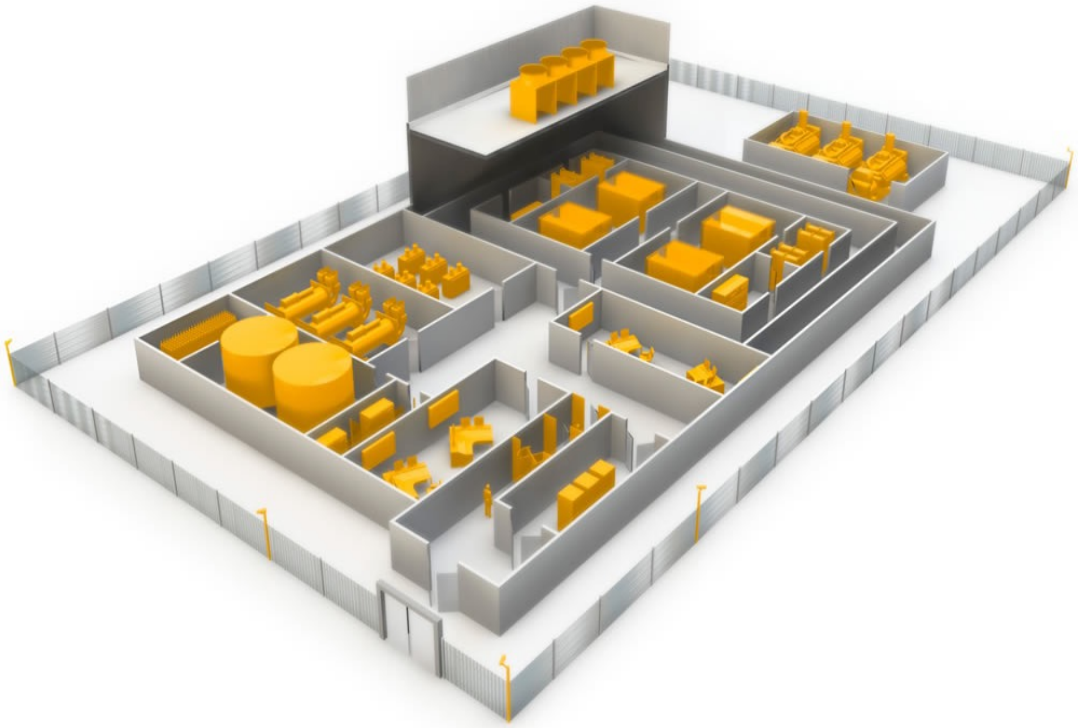
- Hubs
- Routers
- DNS or DHCP servers
- Load balancers
- Technology switches
- Firewalls
- ... and many more other type of devices!

BUILDING AND INFRASTRUCTURE



BUILDING AND INFRASTRUCTURE

WSC has other important components related to **power delivery**, **cooling**, and **building infrastructure** that also need to be considered



Some interesting numbers:

- ✓ Datacenters with up to 110 football-pitch size
- ✓ 150 MW power consumption (100K houses)
- ✓ 99.99% uptime, i.e., one-hour downtime per year

The need for a comprehensive design of computation, storage, networking and building infrastructure