ICT Infrastructure - Appunti

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Course info

Don't be shy to send multiple emails, prof. Cisternino receives many emails, and he known he can't reply to each one. He is okay to be contacted through teams using the symbol to "mention" him.

He designed the UniPi datacenters.

"Italy is more about the multiple micro businesses than the few existing industries"

Exam

The exam is **oral**.

Prof. Cisternino expects students to get the full picture, and understand key concepts, not to remember everything —which still wouldn't be bad ☺—.

Chapter 1

Introduction

Prof. Cisternino dropped a lot of measures in terms of Watts, Dollars, Gigabits and so on.

He mentioned with emphasis the problem of energy consumption. To give an idea, a single rack of a datacenter designed ~ 10 years ago, absorbs $\underline{\text{up to } 15kW}$. The datacenter in *San Piero a Grado* is made up of 60 racks. It is not meant to provide the maximum energy possible for all racks simultaneously, but it still helps to get an idea of how things work in similar contexts.

1.1 Course map

1. Elements
   - i. Datacenters
     - (a) Power
     - (b) Cooling
   - ii. Cabling
   - iii. Networking
   - iv. Storage
   - v. Compute
   - vi. Virtualization
     - (a) Hypervisor
     - (b) Containers
2. Cloud
   - i. Reference architecture
   - ii. Resilience
   - iii. Security
   - iv. Legal aspects
     - (a) GDPR
     - (b) Security frameworks
   - v. Procurement aspects
   - vi. Operations

     i.e. Keep the system up and running while upgrading the system

Chapter 2

Datacenter

10 years ago datacenters were no more than a room with some computers, air conditioners and some plugs to power up the devices. Later on, customers started asking server vendors to include in the servers utilities to allow an *automated datacenter management*. Thus the trend moved towards **Software Defined Datacenter**, which currently is the only possible way to deploy a Datacenter.

An **Active Datacenter** allows for internet storage (?)

A Datacenter should be **future-proof**: servers may be replaced, but updating a whole datacenter is at least a 1-year project.

2.1 Structure

Racks are made of —$\sim$ 42— *units*.

Besides server theirselves, there is a **cooling system**. The first issue is the how to provide cool air. Then there is also how to define an evacuation plan, which must take into account dust.

However also the **floor** is not to be negliged.

- *Floating* floor or Ground floor
  - *"A "floating floor" in a data center, also known as a "raised floor", is a type of construction used in data centers to create a void between the actual concrete floor and the floor tiles where the servers and other equipment are located12. This space is typically used for routing cables and for air circulation, which helps with cooling the equipment1."*[1]
- *Resistance* usually around $1\frac{ton}{m^2}$

For example, in San Piero A Grado, there was a power cabin receiveing current from three lines. Now the whole power management components are in a container outside the building placed close to the facility.

Cables are not super-resistant to current. A lot of current passing through a copper wire will *exhaust* both the wire and the components receiving such current; hence the current should also be balanced among different cables, to avoid exhausting some components before the others.

A UPS —first of all— stabilizes the output current.

In theory $1V * 1A = 1W$, but in reality, performing such conversion something gets lost, so we have

$$I * V * cos\phi = W$$

2.2 Power Management

Electric panels (aka *switchboards*) allow segmenting the power supply in the various zones of the datacenter.

PDUs stands for *Power Distribution Units*, and allow to distribute power for a server units in a rack. Typically, for each PDU there is another one, providing redundacy and thus resilience/robustness.

Definition 2.1 (PUE) *Power Usage Effectiveness **PUE** measures the efficiency of a Datacenter.*

$$PUE = \frac{Total\ energy}{ICT\ energy}$$

[1]ChatGPT 4.0 - Generated

The reason for improving Datacenter design is to lower the PUE; basically to save money, but also for "green-environment" concerns.

But *when* should PUE be measured?

The PUE in January is very different from the one in August, so generally it is calculated as the average of one year.

Note that a poorly designed datacenter placed in Siberia with $-20°$ may have a lower PUE than a datacenter in Italy, for instance.
In particulare geographical zones with high temperature variations over the year (e.g. in Italy the temperature variates from 40 to 50 Celsius degrees), are strongly unrecommended to build datacenters in. A counterintuitive example is the desert, where the temperature is very high during the day and very low during the night, but in general the temperature over the year is **stable**; allowing for defining physical processes exploiting such stability.
Also the oceans have a very stable temperature; not on the surface, but deep down it is very stable.

2.3 Cooling

Note that racks are always placed back-to-back, because the front requires cool air, and the back outputs hot air.

2.3.1 CRAC

Figure 2.1: CRAC/CRAH cooling architecture

Chillers take hot air from above and push cool air in the bottom. Then air pushed under the floating floor wants to exit, and does so going through the grates placed in front of the racks. The racks suck the cool air in front and output hot air from the back.

There are two **drawbacks**:
1. It is difficult to confine and keep separated hot air and cool air. The mixup between the two leads to cooling inefficiency, thus energy and money waste
2. In case a rack has a workload heavier than others and thus requires more cooling air, the chiller must provide more cool air to all the racks in the same row; this makes this architecture particularly inefficient for datacenter which have heterogeneous workloads.

2.3.2 Inrow Cooling

The fan "towers" are called *inrow cooling*.

The first advantage is that it allows for heterogeneous cooling in the datacenter. Secondarily, a fan outputs hot air directly where another fan expects it to be. This allows to confine hot air and to avoid wasting energy in outputting air and sucking it.

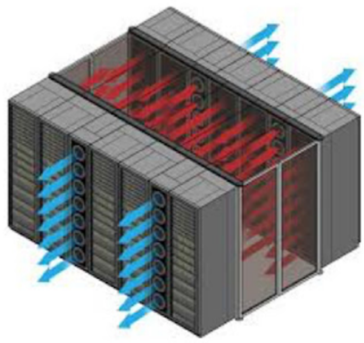

Figure 2.2: Inrow cooling architecture

2.3.3 Chilling water outside

Figure 2.2: Outside chillers

Outside of a datacenter there are chillers which cool down water which is then pumped into the datacenter, where it is used by CRAC/InRow chillers to cool down air.

It is important to ensure that the temperature does not heat up while travelling from the outside chillers to the datacenter, because it would mean wasting energy.

In SPG the outside chillers cool the water down to 18°, which seems high temperature, but in fact it is not: the datacenter is designed to work up to 26°.

The higher the "allowed" temperature is, the more is the energy saved.

Besides, **adiabatic** chillers —such as the ones in SPG— can use ***free cooling*** in case the outside temperature is lower than 18°[2], which basically exploits the lower outside temperature to *passively* chill water, without involving the compressor used in the standard cooling way.

Also **humidity** must be managed. An environment which is too dry leads to water condensation onto racks and plugs, possibly resulting in damage to devices and humans.

2.4 Redundancy for Resilience

Passive-Active means that aside from the active system, there is a mirrored one which is shut down waiting for failure and boots up *"just in case"*. This approach is usually not the ideal one, because the second system is very unlikely to be used and is costful.

Active-active systems are usually better, bust cost even more.

TODO

[2]common case in winter and autumn

2.5 Cooling CPU

High-end CPUs *heat up so much* that it has became *unreasonable* to cool them using air.

However, note that water conducts electricity, so a flaw in a waterpowered cooling system may lead to consistent damange and possible fires.

Oil instead doesn't conduct electricity, and there are some systems which are *submerged* in oil, but there are two drawbacks:

1. **Price**: oil is way more expensive than water
2. **Servicing**: it is impossible to maintain the system's hardware.

Distilled water is not conductive, but even not considering that distilling it is expensive, it is impossible to guarantee that is stays pure when travelling in pipes, chillers, and so on.

Most datacenters tend to have an hybrid approach to cooling, called **air-to-liquid**. The idea is simple: It is acceptable to use cool air to chill water, which is then used to chill the air by InRow coolers, which chills the liquid which chills the CPUs.

(Woa! We need a schema...)

This is *not* the most efficient approach.

A nice question would be, *"Cant́ we simply chill the liquid and send it directly onto the CPUs?"* **No** ☺.

- Required pressure is different
- Required temperatures do not match
- ... TODO

2.5.1 Spilling Pipes

Liquid cooling systems manufacturers allow customers to ensure that their pipes are not spilling by injecting in the pipes a known gas at a known pressure. The customer can measure the pressure when the product is shipped and check whether it is the expected one, and if not, send back the device.

Handling spills

Handling spills is an **open problem**. Theorically, the idea would be to check for pressure variations, but this is currently *impossible* to be done on each entrance of each rack. Too much actuaction and sensoring would be required.

Besides, in case a pipe is spilling, the operators must act *quickly*, before the water spills onto other racks and cause critical damage.

2.5.2 Chassis

Chassis are needed for various reasons:

- 2.4GHz is the frequency at which water in our cells resonates, and circuits generate electromagnetic fields, so it may be unsafe to directly expose humans to circuitry
- Act as Faraday cages
- TODO

Chapter 3

Cabling

Cabling is of paramount importance.

1. Maintenance
2. Cooling
   i. Cables may heat up
   ii. Cables may obstruct air flow
3. Determines which machines interact with each other