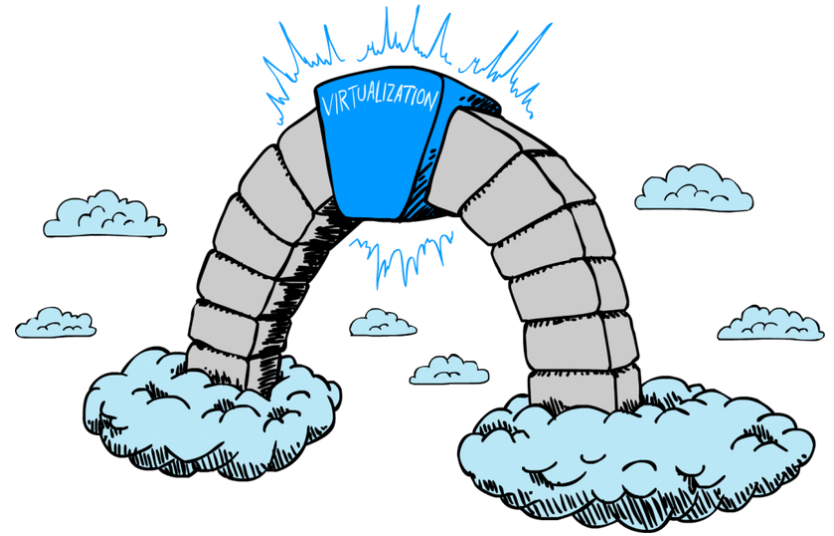


Virtualization in the cloud: techniques and technologies



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Notions

- **Technologies** that run the cloud
 - Virtualization, virtual machines (QEMU/KVM)...
 - Containers (Docker), orchestrators (Kubernetes), micro-services...
 - Serverless, Function-as-a-Service (Apache OpenWhisk)...
- **Techniques** to run on the cloud
 - Application architecture
 - Availability, scalability, security...
- **Systems** point of view

Outline

1. Hardware virtualization

1. What is virtualization?
 2. VMs and hypervisors
 3. *Demo*: QEMU/KVM
 4. VM management with libvirt
 5. Virtualization for the cloud
 6. Internals of an hypervisor
- *Lab*: VM management with libvirt

2. Operating System-level Virtualization

1. VMs are hard
2. Containers and container engines
3. *Demo*: Docker
4. Dockerfile
5. Internals of Docker Engine
6. *Demo*: namespaces & cgroups
7. Containers for the cloud: micro-services
8. Containers for the cloud: orchestration
9. *Demo*: Kubernetes
10. `deployment.yaml`
 - *Lab*: Simple Container Engine

3. Serverless Computing

1. Containers are hard
 2. Backend-as-a-Service
 3. Function-as-a-Service
 4. *Demo*: Apache OpenWhisk
 5. Application architecture
 6. Internals of Apache OpenWhisk
 7. Limits
- *Lab*: Initiation to Apache OpenWhisk
 - *Lab*: Scaling Horizontally a Web Service, Revisited

Resources

- **Class website:** <https://www-inf.telecom-sudparis.eu/COURS/CSC5004/>
 - Sources of demos
 - Labs
 - Lectures
- References:
 - Hardware virtualization: *Mastering KVM Virtualization, 2nd edition*. Dakic et al., 2020.
 - Operating system-level virtualization: *Docker: Pratique des architectures à base de conteneurs*. Cloux et al., 2016. [Fr.]
 - General: *Linux Containers and Virtualization: A Kernel Perspective*. Jain, 2020.

Further readings

Hardware virtualization

- *Memory resource management in VMware ESX server*. Waldspurger. In OSDI 2002.
- *Xen and the Art of Virtualization*. Barham, Dragovic, Fraser, Hand, Harris, Ho, Neugebauer, Pratt, Warfield. In SOSP 2003.
- *kvm: the Linux Virtual Machine Monitor*. Kivity, Kamay, Laor, Lublin, Liguori. In Linux Symposium 2007.
- *Unikernels: library operating systems for the cloud*. Madhavapeddy, Mortier, Rotsos, Scott, Singh, Gazagnaire, Smith, Hand, Crowcroft. In SIGARCH 2013.
- *My VM is Lighter (and Safer) than your Container*. Manco, Lupu, Schmidt, Mendes, Kuenzer, Sati, Yasukata, Raiciu, Huici. In SOSP 2017.
- *GiantVM: a type-II hypervisor implementing many-to-one virtualization*. Zhang, Ding, Chen, Jia, Yu, Qi, Guan. In VEE 2020.
- *Firecracker: Lightweight Virtualization for Serverless Applications*. Agache, Brooker, Florescu, Iordache, Liguori, Neugebauer, Piwonka, Popa. In NSDI 2020.

Serverless

- *SAND: Towards High-Performance Serverless Computing*. Akkus, Chen, Rimal, Stein, Satzke, Beck, Aditya, Hilt. In USENIX ATC 2018.
- *From Laptop to Lambda: Outsourcing Everyday Jobs to Thousands of Transient Functional Containers*. Fouladi, Romero, Iyer, Li, Chatterjee, Kozyrakis, Zaharia, Winstead. In USENIX ATC 2019.
- *Faasm: Lightweight Isolation for Efficient Stateful Serverless Computing*. Shillaker, Pietzuch. In USENIX ATC 2020.
- *SONIC: Application-aware Data Passing for Chained Serverless Applications*. Mahgoub, University; Shankar, Mitra, Klimovic, Chatterji Saurabh Bagchi. In USENIX ATC 2021.
- *Nightcore: efficient and scalable serverless computing for latency-sensitive, interactive microservices*. Jia, Witchel. In ASPLOS 2021.
- *BeeHive: Sub-second Elasticity for Web Services with Semi-FaaS Execution*. Zhao, Wu, Tang, Zang, Wang, Chen. In ASPLOS 2023.

Other topics

- Memory management, storage, networking, power management...
- Operating systems, distributed systems...
- Security, reliability, availability...
- Programming models, orchestration...