COURSE DESCRIPTION
CLOUD AND NETWORK INFRASTRUCTURES

SSD: SISTEMI DI ELABORAZIONE DELLE INFORMAZIONI (ING-INF/05)

DEGREE PROGRAMME: INGEGNERIA INFORMATICA (M63)
ACADEMIC YEAR 2022/2023

COURSE DESCRIPTION

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GENERAL INFORMATION ABOUT THE COURSE

INTEGRATED COURSE: NOT APPLICABLE
MODULE: NOT APPLICABLE
CHANNEL: FG A-Z
YEAR OF THE DEGREE PROGRAMME: I
PERIOD IN WHICH THE COURSE IS DELIVERED: SEMESTER II
CFU: 6

REQUIRED PRELIMINARY COURSES

None

PREREQUISITES

Computer Networking, Operating Systems, Computer Programming

LEARNING GOALS

The aim of the course is to provide a thorough understanding of the main methodologies and techniques adopted in (public, private or hybrid) Cloud Computing contexts for the dynamic dimensioning, configuration and management of virtualized infrastructures. In particular, the course covers:
- the engineering aspects of design and implementation of a modern datacenter and the main IT technologies adopted in this specific context;
- the peculiar architectural solutions and protocols used in the context of datacenter networking;

- the main virtualization techniques currently adopted for the various components of a Cloud-based IT system and how these are exploited to create scalable, elastic, flexible and reconfigurable systems through deployment and orchestration of VMs, containers and serverless components;
- the automation techniques that, according to the DevOps paradigm, allow the automation of deployment, configuration and management procedures of cloud and network systems.
The course includes practical and laboratory classes functional to the development of a course project.

EXPECTED LEARNING OUTCOMES (DUBLIN DESCRIPTORS)

Knowledge and understanding

The student needs to show a full comprehension of the main characteristics of virtualization techniques adopted in cloud systems and how they need to be employed and managed to create scalable systems.

Applying knowledge and understanding

The student needs to show ability to apply the learned techniques to the solution of typical design problems for cloud scalable applications and to configuration of the infrastructural components of a cloud datacenter.

COURSE CONTENT/SYLLABUS

Part I - Cloud Computing: enabling technologies

Virtualization technologies. The virtualization concept. Different approaches to IT resource virtualization. Type-1 and Type-2 hypervisors. Linux KVM. Container-based virtualization. Docker. Docker Image Layers. Container image repositories. Switched networks. Switching systems. Input-queued crossbar switches and Head-of-Line blocking. Virtual output queues. Multi-stage interconnection networks. Clos theorem. Spanning Tree Protocol (STP). TRILL. Virtual networking. Ethernet VLANs. Virtual network interfaces: TUN/TAP, MacVLAN, and MacVTap. Virtual Ethernet Port Aggregator (VEPA). Software switches: Linux Bridge, Open vSwitch. VM networking. Docker networking. SR-IOV NICs. Virtual routers. Virtualized network functions. Network Function Virtualization (NFV). Virtual Network Functions chaining and orchestration. Lab #1: Docker. Creation of Docker containers. Multi-stage docker build.

Part II - Cloud Computing: the user perspective

Cloud Computing: foundational concepts. Cloud service models (IaaS, PaaS, SaaS). Cloud deployment models (public, private, hybrid, community). Elastic computing. Horizontal vs vertical scalability in the cloud. Cloud resources and identity. Service Level Agreements. Billing models for cloud services. Cloud APIs and interoperability. Serverless computing. Cloud edge computing. Public cloud services. A review of main IaaS public cloud services. Lab #2: Creation of a scalable infrastructure in a private cloud.

Part III - Datacenter engineering

Datacenter architecture and organization. General architecture and organization of a datacenter. Main datacenter facilities. Rack layouts. Rackable servers. Blade servers. ANSI/TIA-942 standard.

Data Center Infrastructure Management (DCIM). Data center power management. Cooling solutions for datacenters. Power Usage Effectiveness (PUE). Datacenters for HPC applications. Datacenter networking. Transmission media for datacenter links. UTP cabling. Optical fibers. Optical transceivers. Datacenter network architectures and topologies. Access layer organization: Top-of-Rack vs. End-of-Row. Leaf-Spine datacenter networks. Multipath in datacenter networks. ECMP and TRILL. Flowlets. TCP Incast and TCP variants for datacenter networks. Other datacenter networking technologies. Storage networking technologies. SANs. Fiber Channel. ATA over Ethernet (AoE). Fibre Channel over Ethernet (FcoE). iSCSI and its Linux implementation. Infiniband. Multi-tenancy in cloud networking. IEEE 802.1ad Q-in-Q. Overlay networking. NVGRE. VxLAN. Ethernet over MPLS. Ethernet over IP. MP-BGP. EVPN. Lab #3: Emulation of a multitenant cloud in GNS3.

Part IV - Cloud management and automation

Private cloud platforms. OpenStack. OpenStack general architecture and fundamental services. Kubernetes. Resource management and configuration in private cloud infrastructures. The CloudSim simulator. The CloudSimNFV simulator. The VM placement problem and solution methods. The NFV placement problem and solution methods. Green datacenters and green cloud computing. DevOps and Cloud automation. Basic DevOps concepts. CI/CD. Frameworks for automatic deployment and configuration of cloud components. Ansible. YAML. Lab #4: Use of YAML for automatic deployment of cloud components.

READINGS/BIBLIOGRAPHY

- Lecture slides and notes
- Further teaching material provided by the instructor
- *Cloud Native Data Center Networking: Architecture, Protocols, and Tools (1st Edition).* Dinesh G. Dutt. O'Reilly Media, 2019
- *Network Programmability and Automation.* Jason Edelman, Scott S. Lowe, Matt Oswalt. O'Reilly Media, 2018

TEACHING METHODS OF THE COURSE (OR MODULE)

The course will consist of: a) lectures for approx. 80% of total hours; b) laboratories and/or practical lessons for the remaining 20% of total hours.

EXAMINATION/EVALUATION CRITERIA

a) Exam type

- ☐ Written
- ☑ Oral
- ☑ Project discussion
- ☐ Other

In case of a written exam, questions refer to

- ☐ Multiple choice answers

☐ Open answers

☐ Numerical exercises

b) Evaluation pattern

The oral exam will include the presentation and discussion of a course project previously prepared by the student.