Virginia Tech ❖ Bradley Department of Electrical and Computer Engineering

ECE 5984 Virtualization Technologies
Spring 2018, Course Syllabus

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1 Course Reference Number (CRN)

- VT Blacksburg campus: **19638**
- Off-campus/WebEx: **19904**

2 Instructors

Dr. Pierre Olivier
Postdoctoral Associate
ECE Dept., Virginia Tech
Office: 453 Durham Hall, Blacksburg, VA 24061

Dr. Mohamed Karaoui
Postdoctoral Associate
ECE Dept., Virginia Tech
Office: 454 Durham Hall, Blacksburg, VA 24061

Dr. Sang-Hoon Kim
Postdoctoral Associate
ECE Dept., Virginia Tech
Office: 453 Durham Hall, Blacksburg, VA 24061

Dr. Olivier will perform the lectures from 01/16 to 02/19, Dr. Karaoui from 02/21 to 03/28, and Dr. Kim from 04/02 to 05/02.

2.1 Instructors office hours information

- *Date and time*: every Tuesday from 11 AM to 12
- *Location*: Whittemore 344
- *E-mail*:
  - `polivier@vt.edu`
  - `karaoui@vt.edu`
  - `sanghoon@vt.edu`

Additional office hours will be performed by the course TA, as indicated below.

3 Graduate Teaching Assistant (GTA) and GTA office hours

GTA: Beichen Liu, ECE Dept., Virginia Tech

GTA office hours:

- *Date and time*: every Monday from 9 AM to 11 AM;
- *Email*: `bcliu430@vt.edu`
- *Location:* Whittemore 344

Additional office hours with the instructors or TA will be scheduled according to the course attendance.

4 Course objectives

Virtualization technologies are today ubiquitous in all computing domains: embedded systems (such as mobile phones), personal workstations, data-centers, HPC, etc. In particular, virtualization is one of the pillars powering cloud computing. These technologies allow to share the resources of a single physical machine (the host) among multiple Virtual Machines (VMs, the guests). These systems were at first designed to allow applications with different needs in terms of software and hardware dependencies, initially running on multiple physical machines, to be consolidated on a single host. This was achieved in order to save operating and administration costs as well as space, energy, and increase hardware utilization. Today, additional virtualization applications have emerged and these technologies power multi-tenant infrastructures, service-oriented architectures, ease software development, debugging, testing and deployment, etc.

In that context, understanding current virtualization technologies principles and knowing how to operate the related software and hardware components is an invaluable asset for industry application designers, programmers, system administrators, etc. In addition, considering the academic world, virtualization is a very popular and contemporary research topic.

The course will start with an introductory section covering general concepts about virtualization, concerning high-level/general definitions and constituting an overview of virtualization usage in today's computing systems and its different applications. The main part of the course will concern hardware and software support for virtualization technologies. The topics considered here will be: technical definitions (virtualization, virtual machine, hypervisor, etc.), the Popek/Goldberg theorem formally defining the properties needed by an ISA to be virtualized, virtualization without architectural support (Disco, Xen, VMware Workstation), x86-64 CPU/Memory/IO virtualization, ARM support for virtualization, and a comparison between x86 and ARM virtualization performance. Finally, various trending topics about virtualization will be covered: operating system level virtualization (containers), unikernels, storage virtualization, and cloud computing.

Upon completion of the course, the student will be able to:

- Distinguish and describe the functionality, architecture, and implementation of virtualized environments and the related components, including system-level virtualization, hypervisor-based CPU/Memory virtualization, lightweight virtualization (containers and unikernels), I/O and storage virtualization, cloud environments;
- Design, implement, and modify virtualization systems software including containers, hypervisors, I/O domain kernels, guest domain kernels, and split device drivers;
- Test, debug, and evaluate the performance of virtualized systems software at various abstraction levels and in various environments, including full-virtualization and paravirtualized environments, I/O domains, type I/II hypervisors, commercial cloud services, etc., as well as manage the potentially large codebases of virtualized software;
- Describe the current state of virtualization research.

5 Prerequisites

Graduate standing is required, as well as a good knowledge of (1) computer architecture, (2) operating systems concepts, (3) the C programming language and (4) the Linux command line.

6 Course meeting time and location

Meeting time: Every Monday and Wednesday, 5:30 PM - 6:45 PM.
Location: Randolph 121.

7 Required and recommended texts

7.1 Required

- Bugnion, Edouard, Jason Nieh, and Dan Tsafrir. *Hardware and Software Support for Virtualization.* Synthesis Lectures on Computer Architecture 12.1 (2017): 1-206. ISBN-10: 1627056939.

7.2 Recommended:

- Chisnall, David. *The definitive guide to the Xen hypervisor*. Pearson Education, 2008. ISBN-10: 013234971X.
- Tanenbaum, Andrew S., and Herbert Bos. *Modern operating systems*. Prentice Hall Press, 2014. ISBN-10: 013359162X.
- Saltzer, Jerome H., and M. Frans Kaashoek. *Principles of computer system design: an introduction*. Morgan Kaufmann, 2009. ISBN-10: 0123749573.
- Love, R. (2010). *Linux Kernel Development*, 3rd Edition. Addison-Wesley Professional. Pp. xxv, 440. ISBN-10: 0672329468.

8 Development environment

Some of the programming projects will require the student to install one or several Linux distributions (**natively**, for example in a *dual boot* way) on their personal machines. Moreover, the student personal machine should support hardware virtualization. Here are some resources to check for hardware virtualization support on one's personal machine:

- *Windows*:
  - Intel CPU: `https://downloadcenter.intel.com/download/7838/Intel-Processor-Identification-Utility-Windows-Version`
  - AMD CPU: `http://support.amd.com/en-us/search/utilities?k=virtualization`
- *Linux*: `http://www.cyberciti.biz/faq/linux-xen-vmware-kvm-intel-vt-amd-v-support`
- *Mac*: `http://kb.parallels.com/en/5653`

Should the above points concerning the development environment be an issue, the student is encouraged to contact the instructors.

9 Grading:

The grade will be divided into 3 programming projects and a final exam. Each project will constitute 30% of the final grade, and the final exam will weight for 10% of the final grade. The final exam will be take-home and open-book.

After grades for a project/exam are released, if a student believes an error has been made during grading, it must contact the instructor *within 2 weeks of the grade release date*. Note that the final exam and potentially the last project will be graded on a date that will be very close to the final grade input in VT's system (less than 2 weeks): concerning these, any student having concern about his grade should contact the instructor *as soon as possible*.

10 Course website

`https://canvas.vt.edu/courses/63785/`.

11 Course topic outline (tentative)

Topic	Req. Book Chapters
Introduction, definitions and concepts about virtualization	1, 2
Virtualization without architectural support	3
Lightweight virtualization: unikernels, containers	-
x86-64 CPU virtualization with VT-X	4
x86-64 MMU virtualization with EPT	5
x86-64 IO virtualization	6
Virtualization support in ARM CPUs	7
ARM and x86 virtualization performance comparison	8
Storage virtualization	-
Introduction to cloud computing	-

12 Special Needs or Circumstances

Any student with special needs or circumstances should feel free to meet with or otherwise contact the instructors.

- *Disability accommodation*: Reasonable accommodations are available for students who have documentation of a disability from a qualified professional. Students should work through Virginia Tech's Services for Students with Disabilities (SSD). Any student with accommodations through the SSD Office should contact the instructors during the first two weeks of the semester;
- *Religious accommodation*: If participation in some part of this class conflicts with your observation of specific religious holidays during the semester, please contact the instructors during the first two weeks of class to make alternative arrangements;
- *Accommodations for medical or personal/family emergencies*: If you miss class due to illness, especially in the case of an exam or some deadline, see a professional in Schiffert Health Center. If deemed appropriate, documentation of your illness will be sent to the Dean's Office for distribution to the instructors. If you experience a personal or family emergency that necessitates missing class, contact the Dean of Students.