1

IST 615 – CLOUD MANAGEMENT

CLOUD AND NETWORKING TECHNOLOGY FUNDAMENTALS 1

Carlos E. Caicedo, Ph.D.

Associate Professor
Director – Center for Emerging Network Technologies (CENT)
School of Information Studies
Syracuse University

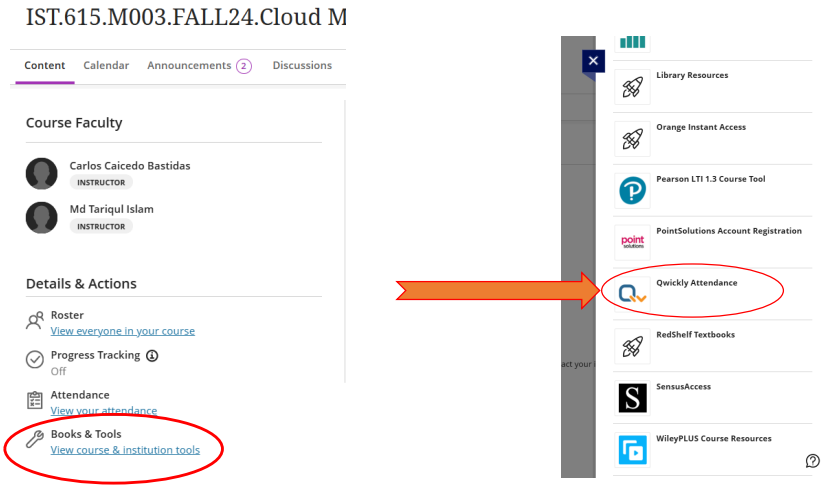
Outline

2

- Announcements
- Recap
- Cloud and Computing Concepts
  - Servers
  - Operating Systems
    - Linux
  - APIs
- Virtualization and Containers

Attendance

- We will use the Qwickly attendance tool to register attendance for each session of the course.
  - Go to Blackboard and click on the "View course and Institutions tools" link
  - On the list of tools, click on "Qwickly Attendance" and follow the instructions provided in class to register your attendance



Announcements (1)

4

- Laboratory exercises
  - Will be performed **outside** of class
    - There will also be *hands-on* activities in class
  - Lab #1 will be posted next week
    - Virtual Machines in Azure
  - For other labs you will need to create accounts on several other services
    - As students you get a lot of stuff for FREE (up to a limit)
    - We will leverage industry partnerships that the iSchool has with several companies
    - AWS Lab (Lab #2)
      - Accounts will be setup this week and the next (Keep an eye on your e-mail)
  - Lab report due in a week after its assignment
    - Must contain answers to the questions related to the lab assignment and/or report on measurements that verify that you completed the lab

Microsoft Azure

5

- Access to Microsoft Azure resources – two options
  - **Preferred option**: The Visual Studio Enterprise (VSE) Subscription
    - Provides $150 in Azure credits per month !! (for 1 year)
    - Additional benefits https://visualstudio.microsoft.com/subscriptions/
    - VSE subscription can now be purchased by IST 615 students through the bookstore. The process to acquire it and use it is described here: https://su-jsm.atlassian.net/wiki/x/QA3zC
    - Focus on completing the steps mentioned in the "Getting started" section. The rest of the sections in the webpage are just informational. The "Getting started" section and the Campus bookstore link is where students will need to go to complete their purchase. It will likely take 1 to 3 days for the subscription to become active.
  - Complete the process to get your subscription on or before September 10

Microsoft Azure (2)

6

- **Alternative option**: Azure for Students (NOT RECOMMENDED)
  - Provides $100 in Azure credits to be used over 12 months ***if you have not used this subscription for another course in the past !!***
    - Once the $100 credit is consumed you have to move to pay-as-you-go option
  - Details: https://azure.microsoft.com/en-us/free/students/
  - NOTE 1: This option is not recommended for IST 615 !!
    - The VSE subscription gives access to more Azure services than the Azure for Students account
    - You can have both VSE and Azure for Student subscriptions with no conflicts
  - NOTE 2: This option is *different* from the *Azure Free Account*
    - The Azure Free Account has many service restrictions
    - Make sure you subscribe to the option you really want to work with
- Complete the process to get access to Azure resources on or **before Tuesday, September 10**

Announcements (2)

7

- Information on Microsoft Certifications
- https://docs.microsoft.com/en-us/learn/certifications/student-discounts

- At the end of today's session I will provide information on additional material available to students for:
  - Strengthening knowledge on key network technology concepts
  - Preparing for certifications and/or expanding your knowledge on cloud (and data science) concepts

Announcements (3)

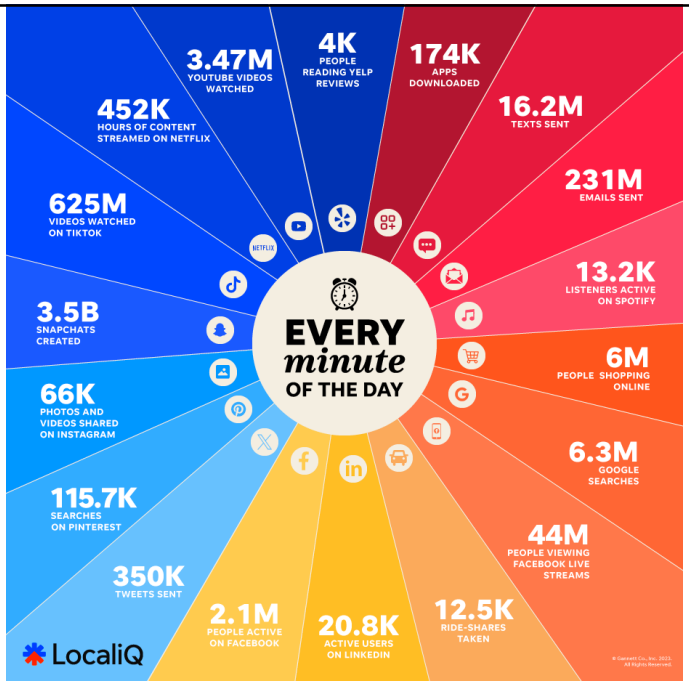
8

- Cloud News
  - *Top 10 cloud computing trends*
    - *https://www.youtube.com/watch?v=dbVAJ3QBAsU*

9

Recap

10



Source: https://localiq.com/blog/what-happens-in-an-internet-minute/

The "Cloud"

11

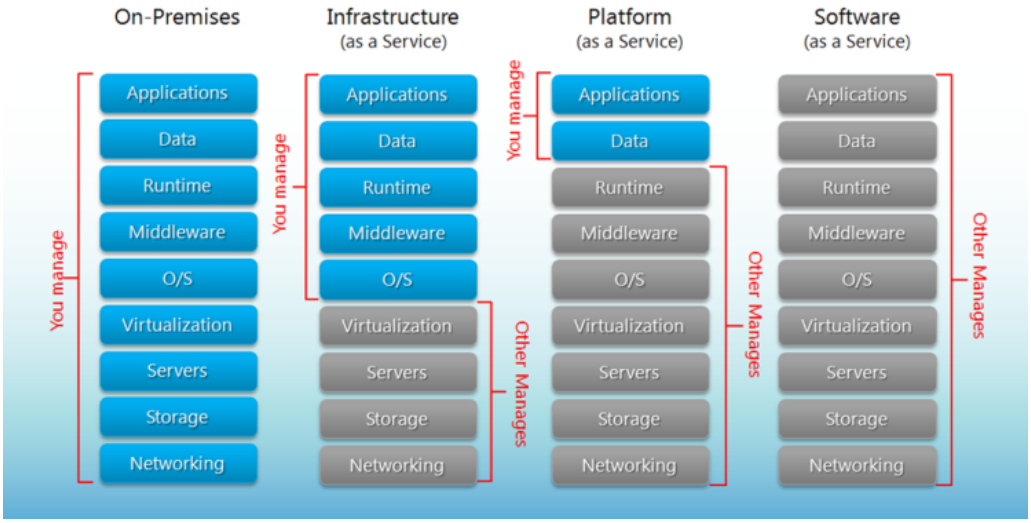
- Short for 'Cloud Computing'
  - Commercial services that evolved from scientific grid computing & enterprise-scale distributed computing
- Definition by NIST (National Institute of Standards and Technology)
  - Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

Basic (Cloud) Service Models

12

- IaaS: Infrastructure as a Service
  - Provider hosts hardware, servers, storage on behalf of the users
    - Scalable resources on demand
    - Pay for what you use
- PaaS: Platform as a Service
  - User has control over the deployed applications and possibly configuration settings
- SaaS: Software as a Service
  - SaaS uses web to deliver applications to user that are managed by the cloud service provider on infrastructure controlled by provider

Computing infrastructure / Virtualization / Cloud



https://blogs.technet.microsoft.com/kevinremde/2011/04/03/saas-paas-and-iaas-oh-my-cloudy-april-part-3/

Cloud Provider – Major Activities

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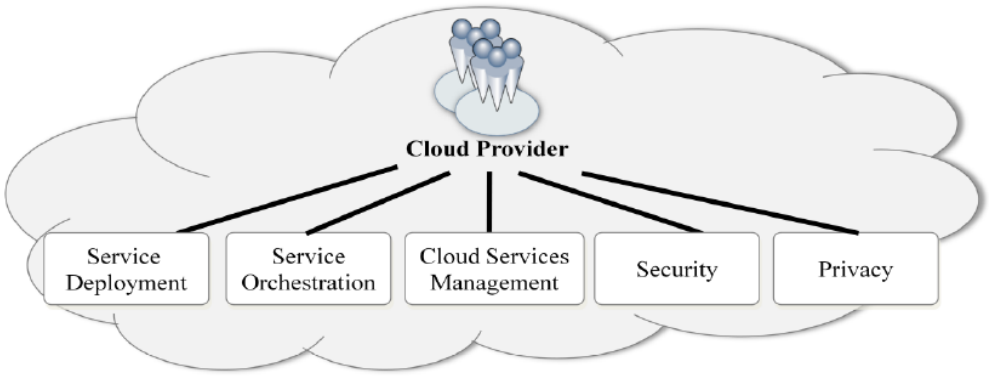
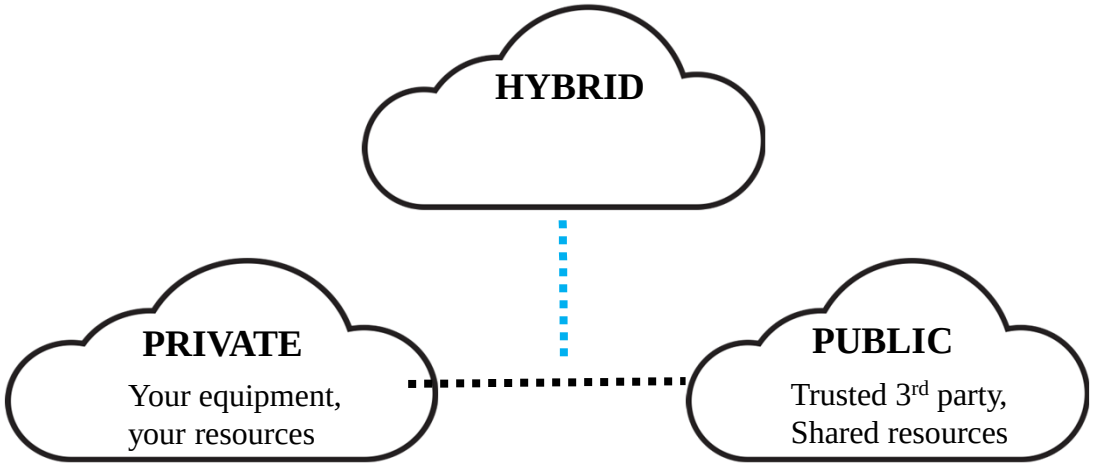


Source: NIST

Cloud computing environments



APPLICATIONS & SERVICES
COMPUTE NETWORK STORAGE

Compute (Computational Resources)

17

- CPU (Central Processing Unit)
  - Executes the instructions of a computer program
  - Performs computations, memory management, control of computer hardware (input/output devices)
    - Sometimes uses specialized processing units to perform these functions
      - Delegates but supervises
- Characterization
  - Clock speed
  - Cache
  - Cores (Number of "internal" processor)
  - Others:
    - Density (fabrication process), system bus speed
- Do not confuse with GPU

Network (Networking services)

18

- Network infrastructure provides connectivity between systems
- Network services facilitate connectivity in different ways and may also provide security
  - IP address assignment
  - DNS
  - Proxy
  - Firewalls
- Characterization:
  - Speed (connectivity speed / data rate)
  - Security (encrypted traffic, private routing, etc).
  - …

Storage

19

- Storage capabilities provide a mechanism to have "persistent" bundles of information
  - Database records
  - Photos, documents, music, video, etc.
- Characterization:
  - Size (amount of storage space)
  - Input/Output (Read/Write) speed
  - Technology (FCP, SSD, etc)

20

Cloud and Computing Concepts 1

Main resources provided by cloud services and/or datacenters

21

- Compute (Computational Resources)
  - The capability to process information and perform computations
- Network (Networking services)
  - Access via a network (public/private) to the resources in the cloud/datacenter
  - The capability to "expose" customized applications and or services to external or internal users
- Storage
  - The capability to have information accessible at any time in the future until it is intentionally deleted

What is a server?

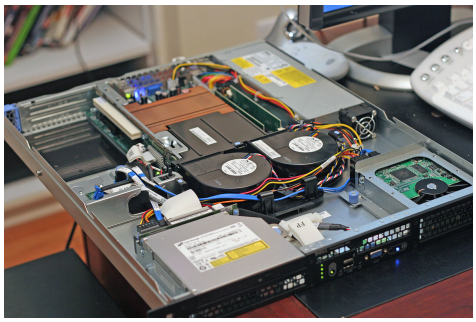
22

- A **server** is a device that accepts and responds to requests made over a network. The device that makes the request, and receives a response from the server, is called a **client**.
  - Web Server: Stores and delivers web pages
    - Web client = browser *in most cases*
  - E-mail Server
  - File Server
- Servers typically need to always be on since they are used to deliver services that are constantly requested
  - Need to plan for fault tolerance

What is a server? (2)

23

- Servers can be hardware based (bare-metal server) or virtual



Note: In some situations, a machine can take the role of being a **server** for a specific application

Video: https://www.youtube.com/watch?v=UjCDWCeHCzY

What is an Operating System?

24

- An operating system, or "OS", is software that communicates with the hardware in a computer system and allows other programs (other software) to run (use the capabilities of the hardware to accomplish the tasks the software is structured to complete/serve).
- Every computing device (desktop computer, tablet, smartphone, server, etc.) has an operating system that provides basic functionality for the device.
- Common operating systems:
  - Desktop: Windows 11, MAC OS
  - Server: Windows Server, **Linux**

Operating Systems - Classification

25

Operating systems provide a software based platform over which application programs, can run (execute processing tasks) and make use of hardware resources (storage, networking, interrupts, etc.)

Classification of Operating Systems (OSs)

- Multi-user: Allows two or more users to run programs at the same time
- Multiprocessing: Supports running a program on more than one CPU
- Multitasking: Allows more than one program to run concurrently
- Multithreading: Allows different parts of a single program to run concurrently
- *Real time: Responds to input instantly*

UNIX

26

- A multi-tasking and multi-user Operating System
- Developed in 1969 at AT&T's Bell Labs by
  - Ken Thompson (Kernel)
  - Dennis Ritchie (C)
  - Douglas McIlroy
  - Joe Ossana
- Variants: System V, Solaris, SCO Unix, SunOS, 4.4BSD, FreeBSD, NetBSD, OpenBSD

Operating Systems in the 80's:

- Microsoft's DOS was the dominant OS for PC
- UNIX – powerful OS used mainly for minicomputers in commercial applications
- There was interest in a UNIX based OS that could run on a PC (and was cheap)
- Both DOS and UNIX were proprietary
  - the source code of their kernel is protected

Beginnings of Linux

- In 1987 Andrew Tanenbaum developed Minix, a simplified version of UNIX that runs on PC
  - OS for educational purposes
- In Sept 1991, Linus Torvalds, a second year student of Computer Science at the University of Helsinki, developed the preliminary kernel of Linux (Linux v.0.0.1)
  - Inspired by Minix
  - It was later licensed under the GNU General Public License, thus ensuring that the source code will be free for all to copy, study and to change.

Linux

29

- Main components
  - Linux Kernel
  - GNU (GNU is Not Unix) Software
  - Software Package management
  - Other packages

- Has been ported from Intel x86 architecture processors to many others
  - Alpha, VAX, PowerPC, IBM S/390, MIPS, IA-64,…
  - "Embedded" in many commercial devices
    - Wearables, cameras, etc.

Linux Distributions

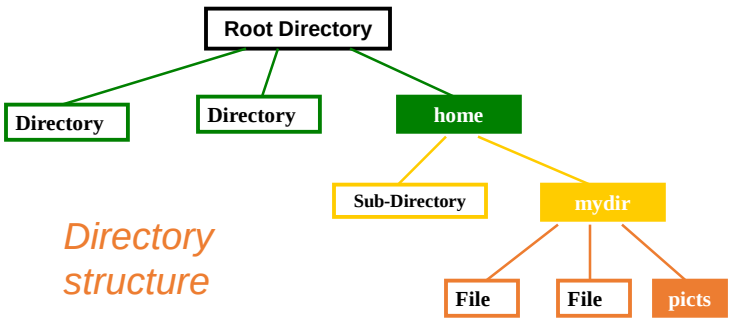
30

- Many "distributions" (300 +)
  - Red Hat
    - RHEL (commercially support)
    - **Fedora** (free)
  - Debian
  - **Ubuntu**
  - SuSe
  - Amazon Linux 2
  - …

Files and directories

31

- A directory is similar to a folder: it contains files or other directories
- The collection of directories and files is called the file system
  - The base directory is called the "**root**" directory
  - The file system follows a tree-like structure



Directory structure

Basic Commands (1)

32

- ls
  - $ ls -l
  - $ ls -a
  - $ ls -la
  - $ ls -l --sort=time
  - $ ls -l --sort=size -r
- cd
  - $ cd /usr/bin
- pwd
  - $ pwd
- ~
  - $ cd ~
- echo
  - $ echo "Hello World"
  - $ echo -n "Hello World"
- cat
  - $ cat /etc/motd
  - $ cat /proc/cpuinfo
- cp
  - $ cp foo bar
  - $ cp -a foo bar
- mkdir
  - $ mkdir foo

And many more… see Homework 1

Application Program Interface (API)

33

- An ***a**pplication **p**rogram **i**nterface* (**API**) is a set of routines, protocols, and tools for building software applications.
  - Specifies how software components should interact
  - Simplifies application development by abstracting the underlying implementation details and only exposing information (objects) or actions that the developer needs.
  - Includes specifications for some or all of:
    - software routines (functions)
    - data structures
    - object classes
    - variables
    - remote procedure calls
  - https://www.youtube.com/watch?v=s7wmiS2mSXY

Application Programming Interfaces: The Bezos API mandate

34

- Issued in 2002 by Jeff Bezos (Amazon Founder)

1. All teams will henceforth expose their data and functionality through service interfaces.
2. Teams must communicate with each other through these interfaces.
3. There will be no other form of interprocess communication allowed: no direct linking, no direct reads of another team's data store, no shared-memory model, no back-doors whatsoever. The only communication allowed is via service interface calls over the network.
4. It doesn't matter what technology they use. HTTP, Corba, Pubsub, custom protocols — doesn't matter.
5. All service interfaces, without exception, must be designed from the ground up to be externalizable. That is to say, the team must plan and design to be able to expose the interface to developers in the outside world. No exceptions.
6. Anyone who doesn't do this will be fired.
7. Thank you; have a nice day!

- https://nordicapis.com/the-bezos-api-mandate-amazons-manifesto-for-externalization/

Application Programming Interfaces (APIs)

35

- API classification:
  - Public APIs: Open to any developer or end consumer
  - Protected, Business APIs: API open to select business partners
    - Facilitate business transactions/services between partners
  - Private APIs: Accessible to developers within an enterprise only
    - Used for building corporate/enterprise applications

36 Virtualization and Containers

Introduction

37

- What is Virtualization?
  - Virtualization is the creation of a virtual resource or device on a platform where the operational environment of the platform divides the resource into one or more execution environments
- Examples of Virtualization
  - Virtual drives
  - Virtual memory
  - Virtual machines
  - Virtual servers

Traditional Architecture Virtual Architecture

History

38

- 1960s Machines
  - Did not scale well
  - Extremely expensive
  - Cost efficiency was desired
  - IBM-360 Operating System (1964)
    - Virtual Memory
  - IBM 370 Operating System (1972)
    - Virtual Machines
- Renaissance
  - VMware – Early 2000's
    - Server and Desktop virtualization products

Virtualization Software

39

- VMware, Microsoft (Hyper-V), Citrix (Xen)
- VMware (Company)
  - Produces the most popular line of commercial virtualization software
  - First company to utilize virtualization on x86 machines
  - Software runs on Linux, Windows, and MAC
- vSphere (aka ESX)
  - Costly
  - High overhead

VMware Architecture

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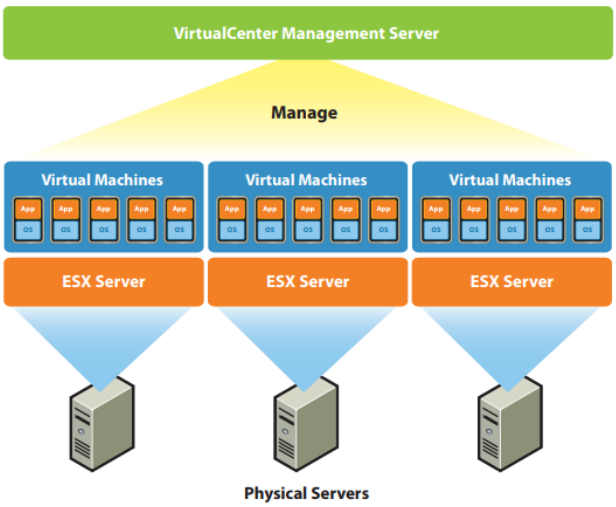


Hypervisor

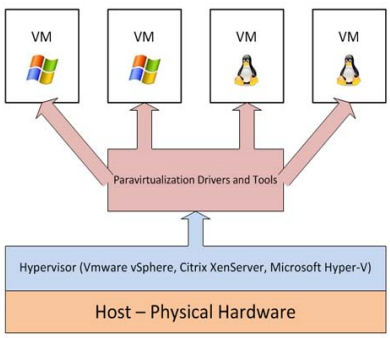
41

- Also called a virtual machine manager (VMM)
- Software that allows multiple operating systems to share a single hardware host
  - Each operating system appears to have the host's processor, memory, and other resources all to itself
- Controls the host system processor and resources (memory, disk, network), allocating what is needed to each operating system
- Makes sure that each guest system (each *virtual machine*) does not affect other guest systems

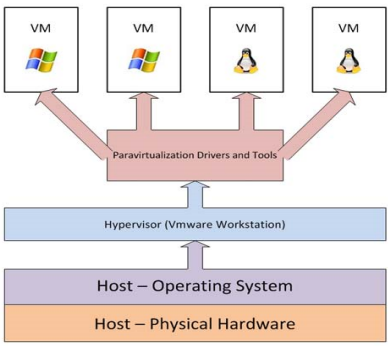
Hypervisor

42

Type I versus Type II Hypervisor



Type I



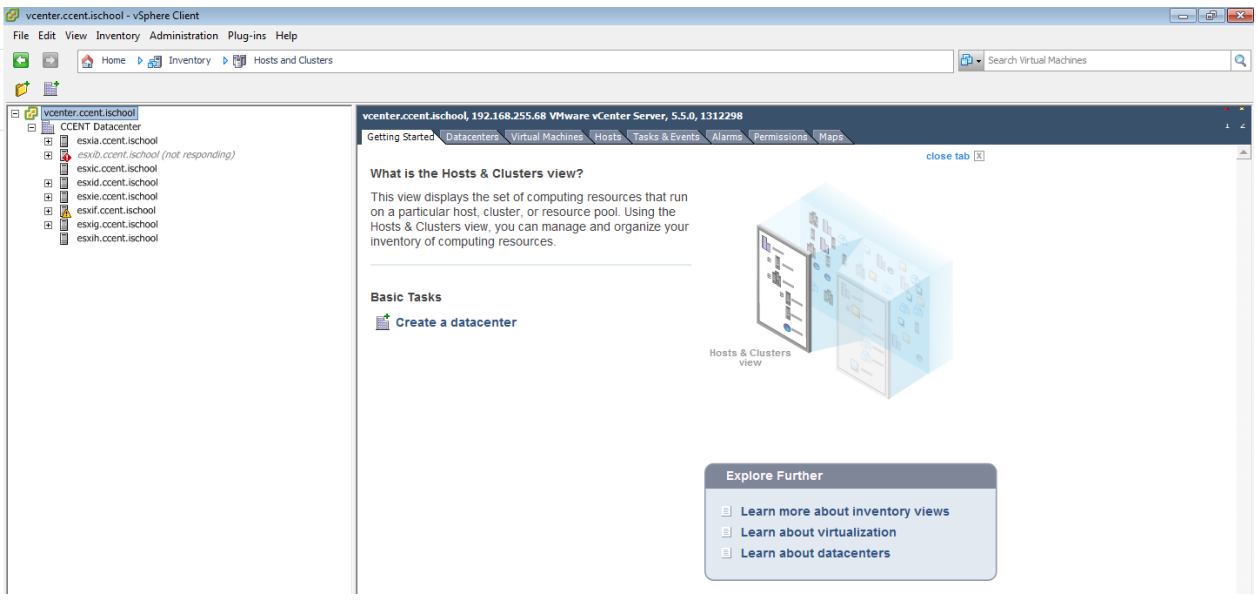
Type II

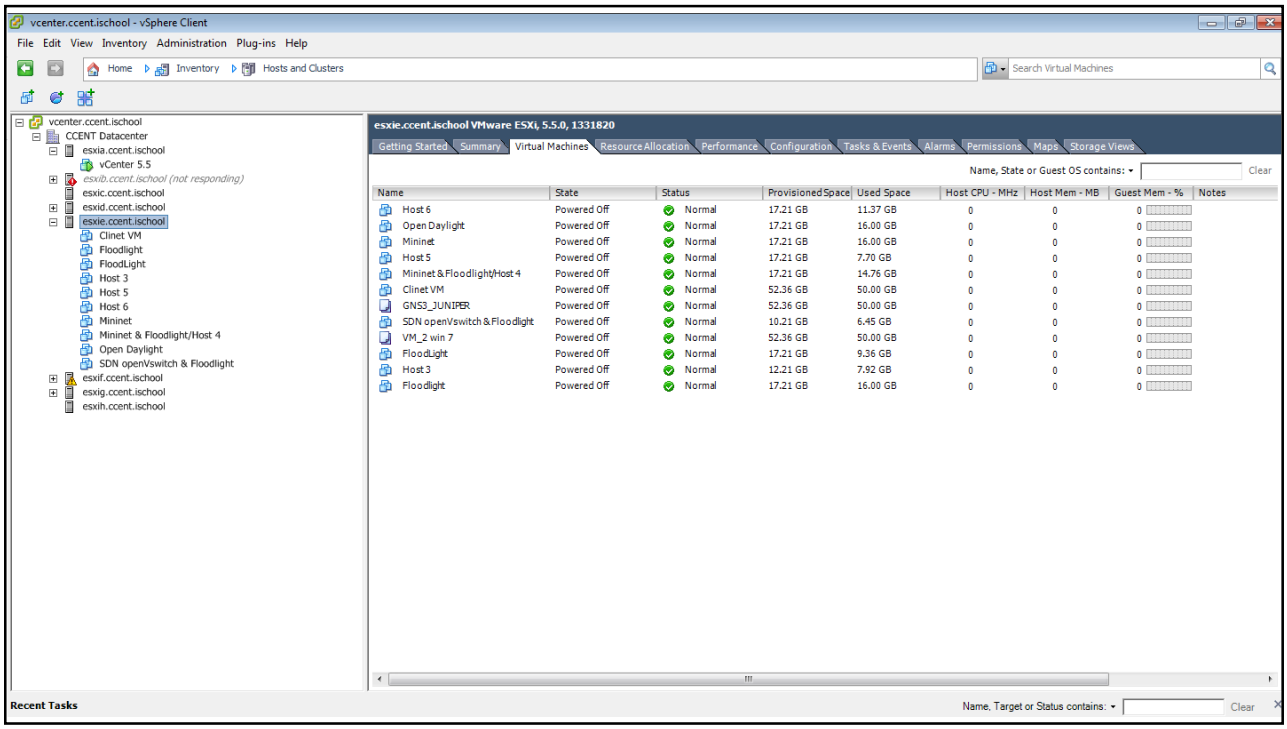
Pros and Cons of Server Virtualization

43

- Pros
  - Cost
    - Less physical servers
    - Less energy and space costs
    - Less maintenance
  - Efficient Administration
    - Easier management
    - Consolidate idle workloads
    - Smaller IT staff
  - Growth and Scalability
    - Easy growth
    - Increase server utilization
    - Easier automation
  - Security
    - Single server security maintenance
    - Hypervisor software often provides security benefits
- Cons
  - (If not designed properly) Slow Performance
    - High stress on single machine = Longer processing times
    - The network bottleneck
  - Single Point of Failure
    - Many servers on one host machine
    - Hardware or software failures can be critical
  - Cost
    - High initial investment
    - Software licensing costs
  - Security
    - All servers managed through one machine
  - Learning curve

VMware - vCenter Example

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Clinet VM
Floodlight
FloodLight
Host 3
Host 5
Host 6
Mininet
Mininet & Floodlight/Host 4
Open Daylight
SDN openVswitch & Floodlight
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Getting Started Summary Virtual Machines Resource Allocation Performance Configuration Tasks & Events Alarms Permissions Maps Storage Views
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Name State Status Provisioned Space Used Space Host CPU - MHz Host Mem - MB Guest Mem - % Notes
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Open Daylight Powered Off Normal 17.21 GB 16.00 GB 0 0 0
Mininet Powered Off Normal 17.21 GB 16.00 GB 0 0 0
Host 5 Powered Off Normal 17.21 GB 7.70 GB 0 0 0
Mininet & Floodlight/Host 4 Powered Off Normal 17.21 GB 14.76 GB 0 0 0
Clinet VM Powered Off Normal 52.36 GB 50.00 GB 0 0 0
GNS3_JUNIPER Powered Off Normal 52.36 GB 50.00 GB 0 0 0
SDN openVswitch & Floodlight Powered Off Normal 10.21 GB 6.45 GB 0 0 0
VM_2 win 7 Powered Off Normal 52.36 GB 50.00 GB 0 0 0
FloodLight Powered Off Normal 17.21 GB 9.36 GB 0 0 0
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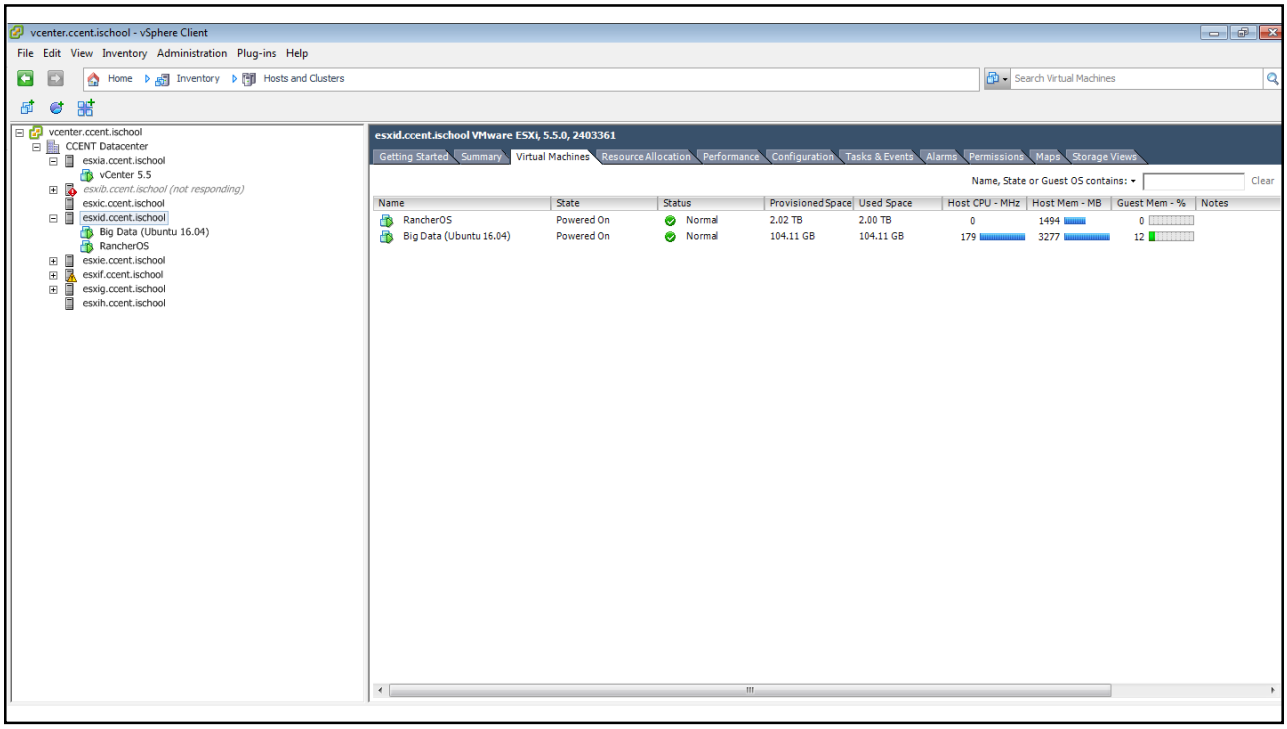
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esxic.ccent.ischool
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Big Data (Ubuntu 16.04)
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Big Data (Ubuntu 16.04) Powered On Normal 104.11 GB 104.11 GB 179 3277 12

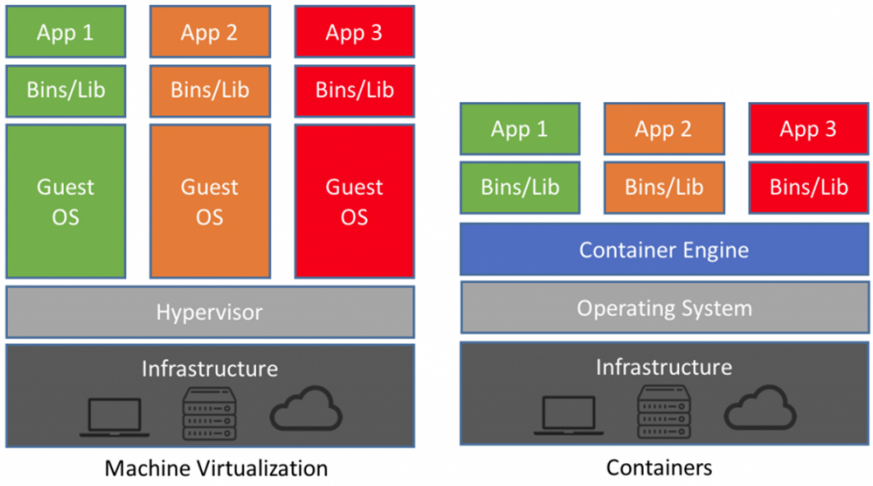
Containers – Introduction

47

- Containers virtualize the OS just like hypervisors virtualizes the hardware
- Containers wrap up a piece of software in a complete filesystem that contains everything it needs to run such as : code, runtime, system tools, libraries etc.
- Containers share the OS kernel, binaries and/or libraries where needed
  - Any differences are limited to each container

VMs vs. Containers

48



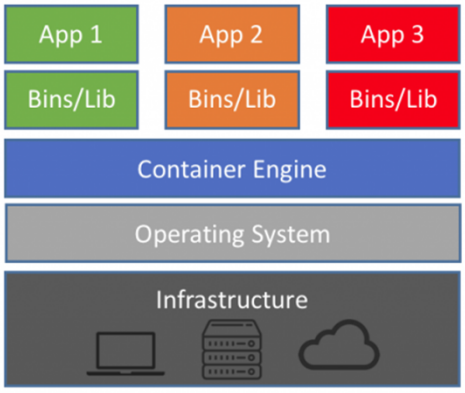
Containers

49

- Docker, CRI-O and LXCs are some of the most popular implementations of containers
  - They can be run on any Linux Server
- Can move around between machines without any modification
  - *Without any modification – if machines have the same processor architecture*

How do containers work?

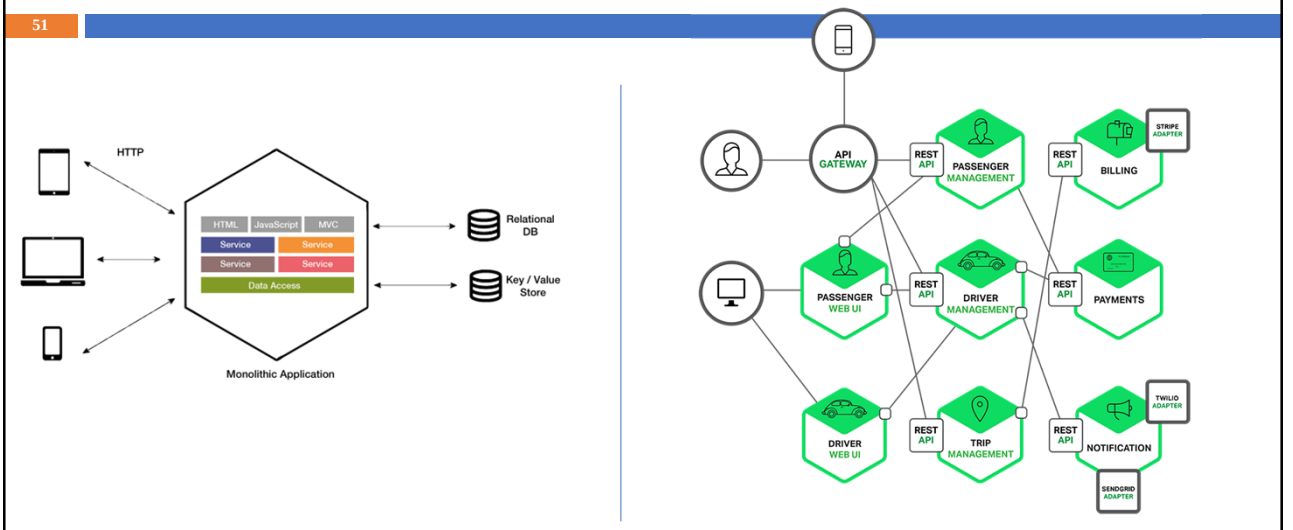
50



Containers allow users to easily launch applications on any virtual or physical infrastructure, **integrating all its dependencies such as code, runtime, system tools and system libraries**

Microservices

51



Serverless Computing

52

- Any service that lets the user consume functionality (compute, network, storage), without managing the underlying infrastructure and with a "pay only for what you use" model can be considered *serverless*
- Application drives the allocation and/or removal of resources
  - No manual definition of the underlying infrastructure. None of the following questions need to be answered *apriori*:
    - What VM should I run the application on?
    - Where should I deploy the container that has my application code?
    - What storage device (or claim) should I attach to my application's VM (or container)?
    - What network should the application's VM (or container) live on?
- For clarity: Your application will execute on a VM or on a container and use resources (compute, network, storage) BUT YOU DON'T HAVE TO EXPLICITLY MANAGE THEM !!

Serverless computing (2)

53

- Specializations:
  - CAAS (Container as a Service): Deploy containerized applications without needing to know the details of underlying infrastructure (i.e. cluster, worker node, pod, etc.)
  - FAAS (Function as a Service):
    - Uses functions as a unit of work
      - Well defined start and finish of a specific task/function.
        - It only does *one thing*
    - Functions are triggered by events (from other services or functions)
    - Examples:
      - AWS Lambda, Azure Functions, Google Cloud Functions

Readings and other material (1)

54

Optional

- Background material on networking technology concepts
  - Go to : https://linkedinlearning.syr.edu/
  - Search for: The Internet
  - You will get a list of courses and materials related to how the internet works, chose the Course named "Computer Science Principles: The Internet". It will likely be the top item in your search results. You just need to cover the first 3 chapters of the course.

Additional Cloud Technology training resources

55

- I want to make you aware of a new resource available for free to SU students that will give you access to many books and training course in the areas of Cloud and Data Science (and more). It even has courses to prepare you for certifications in these areas, the following link will take you to a video that explains how to access it and use it.
- https://video.syr.edu/media/t/1_i1phumhm

Homework #1

56

- Due September 10 @5 p.m.
- Go to https://linkedinlearning.syr.edu/
  - Search for: Learning Linux Command Line
    - Select the first course listed (By: Scott Simpson)
  - Go through the course and complete the exam at the end of the course
    - You do not need to follow all the steps/options mentioned in Section 1: *Setting Up Your Environment*. Instead, to have your our Linux environment for testing, follow the instructions for one of the 3 setup options mentioned in the homework description.
    - Complete the Quizzes inside the course to verify that you are understanding the material.
  - Submit a screenshot of the course completion certificate with your score
    - Course score MUST be above 80%
  - Submit a screenshot of the results of three commands that you executed in the Ubuntu playground