Cloud Computing

- Part 1: Data centers
- Part 2: Cloud Computing
- Part 3: Kubernetes and Orchestration

Part 1: Data Centers

- Large server and storage farms
  - 1000s of servers
  - Many TBs or PBs of data
- Used by
  - Enterprises for server applications
  - Internet companies
    - Some of the biggest DCs are owned by Google, Facebook, etc
  - Cloud Computing Platforms
- Used for
  - Data processing
  - Web sites
  - Business apps

Inside a Data Center

- Giant warehouse filled with:
- Racks of servers
- Storage arrays

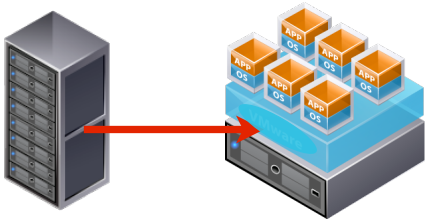
- Cooling infrastructure
- Power converters
- Backup generators

Traditional vs "Modern"

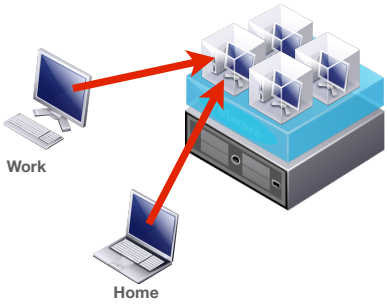
- Data Center architecture and uses have been changing
- Traditional - static
  - Applications run on physical servers
  - System administrators monitor and manually manage servers
  - Use Storage Array Networks (SAN) or Network Attached Storage (NAS) to hold data
- Modern - dynamic, larger scale
  - Run applications inside virtual machines
  - Flexible mapping from virtual to physical resources
  - Increased automation allows larger scale

Virtualization in Data Centers

- Virtual Servers
  - Consolidate servers
  - Faster deployment
  - Easier maintenance

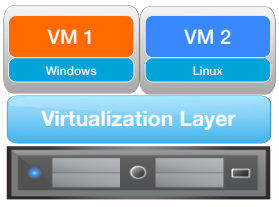


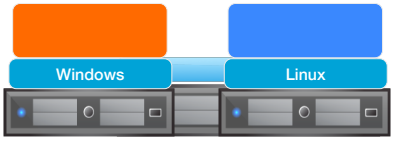
- Virtual Desktops
  - Host employee desktops in VMs
  - Remote access with thin clients
  - Desktop is available anywhere
  - Easier to manage and maintain



Server Virtualization

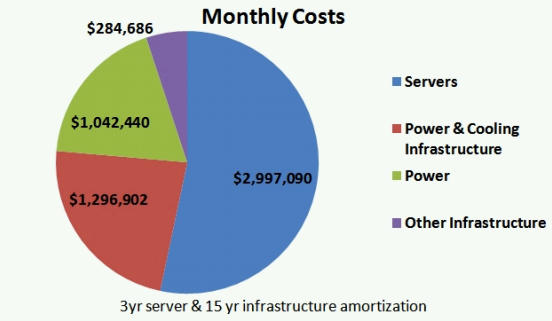
- Allows a server to be “sliced” into Virtual Machines
- VM has own OS/applications
- Rapidly adjust resource allocations
- VM migration within a LAN





Data Center Costs

- Running a data center is expensive
- Efficiency captured as PUE (Power Usage Effectiveness)
  - Ratio of Total Power / IT Power (typical: 1.7, Google PUE ~ 1.1)



http://perspectives.mvdirona.com/2008/11/28/CostOfPowerInLargeScaleDataCenters.aspx

Part 2: Cloud Computing

- Cloud computing: use of remote servers to run distributed applications

- Cloud computing platform
  - Data center where remote resources can be leased by any user or company
    - No need to create and deploy own data center and IT infrastructure
- Benefits:
  - Remotely available from the Internet
  - Pay as you go
  - Highly scalable: obtain resources on-demand
  - Shared infrastructure and economy of scale

The Cloud Stack

Hosted applications
Managed by provider

Platform to let you run your own apps
Provider handles scalability

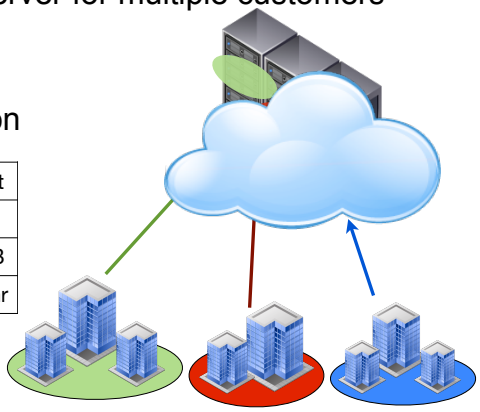
Raw infrastructure
Can do whatever you want with it

IaaS: Amazon EC2

- Rents servers and storage to customers
  - Uses virtualization to share each server for multiple customers
  - Economy of scale lowers prices
  - Can create VM with push of a button

	Smallest	Medium	Largest
VCPUs	1	5	33.5
RAM	613MB	1.7GB	68.4GB
Price	$0.02/hr	$0.17/hr	$2.10/hr

Storage	$0.10/GB per
Bandwidt	$0.10 per GB



Types of IaaS Instances

- **On-demand** instances
  - Provision on-the-fly
  - Pay by the minute
  - Keep until terminated
- **Reserved** instances
  - Long-term commitment for on-demand server: 1 year, 3 year
  - Discount over on-demand pricing
- **Spot** instances
  - Excess capacity sold by cloud platform at high discount
  - Can be revoked by cloud provided with a warning time
    - Take back server if regular customers need it
    - Cheap method to run large computations in off-peak periods

PaaS Cloud

- Cloud resources offered as highly scalable run-time platform
  - Application developers provide code
  - Platform deploys code, provisions resources,
  - Platform can also autoscale the application
  - Language supported: Python, Java, Node, .NET
  - Users do not need to provision or manage servers resources
  - Billing based on workloads or usage
  - Serverless computing has similarities to PaaS

Serverless Computing

- Developer: deploy code on a platform (eliminate need to provision servers)
- Cloud: platform can each application up or down automatically (elastic scaling)
  - Scale down to zero possible when idle

- One popular form: function-as-a-Service (FaaS)
  - Write code as a set of “functions” and deploy each function
    - functions can be chained together
    - Functions are often stateless
    - More fine-grained than micro-services
    - AWS Lambda: FaaS in the cloud

Public, Private, Hybrid Cloud

- Not all enterprises are comfortable with using **public cloud** services
  - Don’t want to share CPU cycles or disks with competitors
  - Privacy and regulatory concerns
- **Private** Cloud
  - Use cloud computing concepts in a private data center
    - Automate VM management and deployment
    - Provides same convenience as public cloud
    - May have higher cost
- **Hybrid** Cloud
  - Move resources between private and public depending on load
  - Cloud Bursting

Cloud Workloads

- Client/Server
  - Web servers, databases, CDNs, etc
- Batch processing
  - Business processing apps, payroll, etc
- Data processing and analytics
  - Data intensive computing: map reduce, spark
  - Scalability concepts built into programming model
- AI workloads: ML training
  - Use servers with GPUs
- High performance computing: specialized instances

Cloud Storage

- Lease storage from cloud platforms
- Object storage: blobs of storage that use get() and put()
- Block storage / server disk — local storage for IaaS servers
- File Storage: network file system storage
  - Can be shared across machines, not tied to a machine
- Archival storage — used for backups
- Other models
  - Dropbox: cloud storage for end-user machines; automatic sync
  - Google Drive, OneDrive, Box,
  - Cloud backups, Cloud media storage

Cloud Orchestration

- Cloud controller: similar to K8s controller
  - Customer requests one or more instances
  - Create virtual machines on cloud servers
  - Configure networking and storage
  - Boot VM using specified images

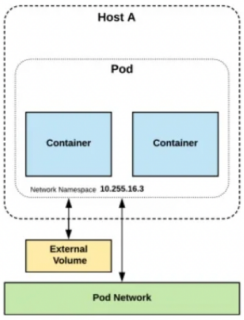
- IaaS platforms now support containers and VMs
  - Container orchestration similar to k8s but for third party users

Part 3: Kubernetes (k8s)

- Cluster management using containers
- Container-based **Orchestration System**
  - Based on Google's Borg /Omega cluster managers
- Applications are containerized
- K8s will deploy them onto machines of the cluster
  - **Replicate** app on multiple machines if requested
  - **load balance** across replicas
  - Can **scale up** or down dynamically (vary replica pool size, a concept similar top dynamic thread/process pools)
  - Provide automated **restart** upon detecting failure (self-healing)

K8s Pods

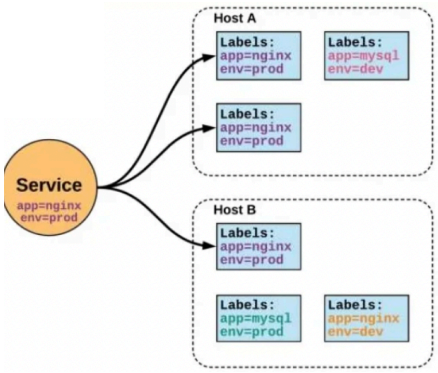
- Pod: contains one or more containers that share volumes and name space
  - Pods: smallest granularity of allocation in k8s.
- Distributed application: multiple components,
  - each component inside a container
  - Each pod consists of one or more components / containers
  - Pod can contain all containers of an application but:
    - If a component needs to be scaled, put each such component in a separate pod
  - Application consists of a set of pods, each independently scalable
    - Pods of an application can span multiple cluster machines



All k8s figures courtesy of https://www.slideshare.net/rishabhindoria52/introduction-to-kubernetes-139878615

k8s Services

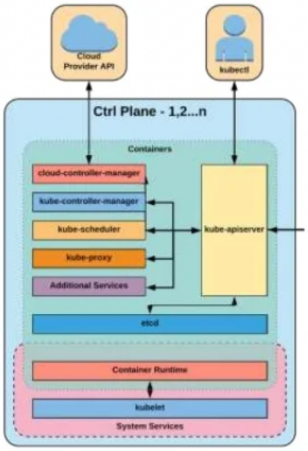
- service: method to access a pods's exposed interfaces
  - static cluster IP address
  - static DNS name
  - Services are not ephemeral
  - collection of pods
- Pods are ephemeral
  - each has its own IP
  - can be migrated to another machine
  - Pods can communicate with one another using this IP



All k8s figures courtesy of https://www.slideshare.net/rishabhindoria52/introduction-to-kubernetes-139878615

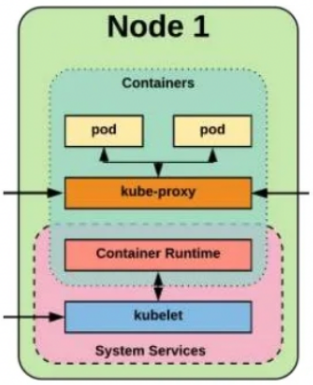
Control Plane

- **apiserver**: REST interfaces for clients to access management interface
- **etcd**: cluster key-value datastore
  - strongly consistent, highly durable (uses RAFT consensus)
- **controller-manager:** replicate pods, monitor for node failures and restart
- **scheduler:** assigns newly created pods to servers based on resource constraints
- **cloud-controller-manager**: interact with cloud platforms



K8s Node

- kubelet: agent on each node
  - ensure containers are running and healthy
- kubelet proxy
  - Manage network rules
  - Load balancing for cluster services
- container runtime
  - runtime for container execution
  - containerd/docker, cri-o, rkt



containerd

- Container orchestration runtime that is basis for docker, k8s and many other systems: for “lifecycle management”
  - Designed to be used as part of a larger system
  - Used by google, amazon, azure, IBM, docker, …

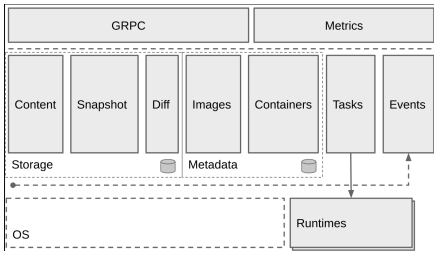


Fig courtesy https://github.com/containerd/containerd