CS236635
Network Functions Virtualization (NFV)

Class 4

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Last week

• Hypervisors in practice – the x86 challenge
• From Hypervisors to the cloud
  – cloud based services
  – entities in the Cloud:
    • **Amanda** - Cloud owner (e.g. Amazon)
    • **Dana** - Cloud customer (e.g. Netflix)
    • **Emma** - Dana’s customer (e.g. You!)
This week

Cloud Computing and Data Centers
Cloud computing is Internet-based computing, whereby shared resources, software, and information are provided to computers and other devices on demand, like the electricity grid. Cloud computing is a paradigm shift following the shift from mainframe to client–server in the early 1980s.
Cloud computing

Definition from NIST (National Institute of Standards and Technology)

Cloud computing is a model for enabling 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.

An emerging computing paradigm where data and services reside in massively scalable data centers and can be ubiquitously accessed from any connected devices over the internet.
Case study - **Animoto**

- **Animoto** – service that helps you create movies from pictures/videos/music
- Why not software? (SAS software as a service)
- Requires massive data storage and massive CPU
- Hard to support the (unknown, unexpected) demand by a small start up
- So use **the cloud (Amazon AWS)** to
  - ubiquitously provide scalable agile resources, in an elastic way (at a low cost to the customer)
Wording

• **Ubiquitously**
  - באופן שהוא יכול לכלול البيت בקמויות בו-זמנית

• **agility**
  - זְרִיזוּת, קְלִילוּת, קַלּוּת רַגְלַיִם

• **Elastic**
  - אֶלַסְטִי, גָמִישׁ, קְפִיצִי

• **Virtualization**
  - הדמיה של חומרה על-ידיشيוםemachine בחרכה

• **Scalability**
  - יכילו של מערכות טכנולוגיות התאימו עץמהまでのפיקס גדולים
Wording Google Trends
SOA: Service Oriented Architecture

• Service Oriented Architecture (SOA) is essentially a collection of services which communicate with each other and provide a loosely-integrated suite of services that can be used within multiple business domains.

• Important concepts:
  – QoS Quality of Service
  – User Experience
  – SLA – Service Level Agreement
Service Models

- **IaaS – Infrastructure as-a-Service**
  - renting virtualized infrastructure and building IT system using these resources (AWS)
    - Virtualized resources
- **PaaS – Platform as-a-Service**
  - directly use some existed IT system solutions to compose your solution (Azure)
    - Programming IDE
- **SaaS – Software as-a-Service**
  - Developing IT solution based on one Cloud platform (Google Docs)
    - Web services
Software as-a-Service

• End users use [Google apps](#) that access cloud-based data
  
  – No need for OS (windows)
  – Access from anywhere and any device
  – Sharing
  – Never get lost / deleted
  – No need to worry about storage / backups
Software as-a-Service \(^{(2)}\)

- End users use **Google apps** that access **cloud-based data**
  - Where is my data stored?
  - What do I do when I can't access my data?
  - What can't I do?
  - Is it safe?
  - Do I need to keep copies of my data at home?
  - Are my files too big? I
  - What happens if you go out of business?
  - What happens if I forget to pay for a month?
Enabling Technology

• **Virtualization**
  – an abstraction of logical resources away from underlying physical resources

• **Data Centers**
  – Dramatically reduce cost of resources
Characteristics of Cloud Computing

• **Virtual** – Physical location and underlying infrastructure details are transparent to users

• **Scalable** – Able to break complex workloads into pieces to be served across an incrementally expandable infrastructure

• **Efficient** – Services Oriented Architecture for dynamic provisioning of shared compute resources

• **Flexible** – Can serve a variety of workload types – both consumer and commercial

• **Available** – *reliable service - any time*

• **Accessible** – *can be accessed from any place*
Business motivation

• Cost of:
  – Computing
  – massive storage
  – networking

• Using massive data centers can
  – dramatically reduce the cost
  – amortize over many users
  – depends on the technical ability to have
    • elastic agile resources

Cost Efficient resource allocation is essential for the business
Virtualization over managed resources

• Much depends on the efficient use of resources
  – in data centers
  – across data centers
  – networking resources

customers

applications and services

virtual resources

physical resources

management
Cloud Computing

• Computation is done “in the cloud”:
  – end user – Google Apps
  – enterprise – replace part of the IT infrastructure

• Extends “software as a service”

• Needs:
  – end to end QoS
  – efficient resource utilization
The Complaint - Gmail

- **Gmail problems**

- **GMail outage pours rain on Cloud Computing parade**
Cloud Management: Challenges

- Guaranty the desired end to end QoS to the application (service)
- Utilize much of the available resources with as little as possible overhead

- Automated discovery and configuration in the heterogeneous environment
- Distributed, cost aware, system and resource management
What is SM (System management?)

System Management

Normal operation conditions

It is all a matter of design
The Cloud is everywhere

Data centers are scattered all over the Globe: Google’s Data centers
The Cloud is everywhere

Data centers are scattered all over the Globe: Data centers

Key feature: cost effectiveness ➜ resource management
The Cloud is everywhere

AWS Data centers are scattered all over the Globe 2017 AWS
The Cloud is everywhere

Azure Data centers are scattered all over the Globe

2017 MCR
The Cloud is everywhere

Google Data centers are scattered all over the Globe
Resource allocation in the Cloud

• Where to acquire resources (CPU, Storage)?
  – building the next data center (Google)
  – getting EC2 resources and how much (smaller users)

• Where to place the service and the data?
  – VM placement
  – service/data migration

• Which location should serve a specific request?
  – Load balancing
Rest of class Data Centers

– risk analysis
– benefit of the cloud for users
– migration
– networking in the cloud
– energy efficiency and green clouds
Data Centre Topology

**Goal:** Collapse function-specific network and compute elements into “virtual” sessions that are hosted on shared network and compute fabric.

**Legacy Topology**

**Future Topology**

- **Network + Compute Fabric**
  - Blade form-factor with network and compute elements housed in common chassis

*From: HP®*
The Datacenter as a Computer: An Introduction to the Design of Warehouse-Scale Machines
Luiz Ande Barroso and Urs Holzle
Storage

• A Network Attached Storage (NAS)
  – storage is accessed via SAN
  – all servers have access to external Disks
  – easy to build and maintain
  – considerable cost

• Using build in disks
  – require a special fault-tolerant file system (GFS)
  – high write overhead
  – more utilization of communication between servers
  – may better tolerate server lost
  – low cost

depends on work-load
Networking

• speed, scale, cost
• 1 Gbps per rack is a commodity
  – for 30$ per Gbps per port
• For bigger switches (more than 48 ports)
  – cost become much higher
    • for 400 ports: 300$ per port per Gbps
• Thus:
  – hierarchical structure
    • Connectivity is not the same across racks
  – Infiniband can cost > 500$ per port
  – new solutions

networking / computing trade-off
Performance of large DC (WSC)

- A system with 2,000 servers,
  - each with 8 GB of DRAM
  - four 1-TB disk drives
- Rack of 40 with 1-Gbps switch
- Each switch has an additional eight 1-Gbps ports used for connecting the rack to the cluster-level switch
- Network latency numbers assume:
  - a socket-based TCP-IP transport
- Disks
  - typical commodity disk drive (SATA) latencies and transfer rates
An example of daily traffic fluctuation
DataCenters construction

• Need:
  – power
    • +UPS
  – remove heat
    • cooling system

• What level of redundancy (Tier I-IV)

• CRAC - *computer room air conditioning*
  – *being green*

• Container-based datacenters
Energy efficiency

- PUE - power usage effectiveness - the ratio of the total power and the power used for the IT (computing)
- In many cases 3 or more!!
- Improve cooling (~half of power) - work in 27 degrees not 20 degrees - better design of cooling systems
- Improve UPS (~20% of power)
- Load design issues
Failures

• MTBF – Mean Time between failures
  – lets assume (an unbelievable) 30Y=10K days
  – a datacenters with 10,000 servers will see a failure a day

• Must deal with failures

• For the entire DC – MTBF is 2-5hours
  – may include software failures as well

• Software must be fault-tolerant
Failures – reason for service disruption

from Google’s Robert Stroud
The data is based on a 6-month observation of all machine restart events regardless of cause:
- include machines that are in the repairs pipeline
- planned downtime for upgrades
- all kinds of machine crashes.
- More than half of the servers are up throughout the observation interval
- More than 95% of machines restart less often than once a month
- The tail, however, is relatively long (the figure truncates the data at 11 or more restarts):
  - approximately 1% of all machines restart more often than once a week

from Google’s Andrew Morgan
• Approximately 55% of all restart events last less than 6 minutes
  • 25% of them last between 6 and 30 minutes
  • most of the remaining restarts finishing in about a day
• Approximately 1% of all restart events last more than a day
  • likely corresponds to systems going into repairs
• Average downtime is just more than 3 hours
  • this is heavily affected by the group of restart events that last between 30 and 2,000 minutes (~33 hours)
• The resulting average machine availability is 99.84%, or nearly “three nines.”

from Google’s Andrew Morgan
Failures - real machine crashes

- Crash rate of mature servers (i.e., those that survived infant mortality) ranges between 1.2 and 2 crashes per year.
- This means that a service that uses 2,000 servers should plan to tolerating a machine crash approximately every 2.5 hours.
- Approximately 10 machines per day.
- Given that the expected machine downtime for 99% of all restart cases is less than 2 days.
- One would need 20 spare machines to safely keep the service fully provisioned.
- A larger margin might be desirable if there is a large amount of state that must be loaded for a machine to be ready for service.
Risk analysis

- Let's say we want “five nines” availability of the service.
- How many spare machines do we need?
- We define time slots (1 hour, 6 hours, 24 hours) and the probability that we will lose a server to be (p = 0.002%, 0.012%, 0.05%).
- Assume P is independent probability per each server.
- If we need n servers and we have k spare servers, what is the probability that we will go below the needed number?

1 - \[\sum_{i=0}^{k} \text{probability [i servers are down]} = 1 - \sum_{i=0}^{k} \binom{k+n}{i} p^i (1-p)^{n+k-i}\]
Risk analysis (2)

- For n=5000
  - Five nines
    - P = 0.002% - 5
    - P = 0.012% - 6
    - P = 0.048% - 12
To cloud compute or NOT to cloud compute?

- What is better for a user = {enterprise, start-up, home-user} to work locally or use the cloud?
  - cost
    - what is local cost
    - what is the cloud cost scheme (pay per use?)
  - performance
    - can we get the needed QoS from the cloud?
  - security
    - can we trust the cloud?
    - can we identify transactions with sensitive data?
Migration

• When should we migrate services?
  • from server to server in the same DC
  • across DCs

• How to migrate?
  • cold migration
  • live migration

• Cost of migration
  • inbound
  • out of band
To cloud compute or NOT to cloud compute?

• Hybrid approach (cost optimization)
  • have a local DC
  • shift overload to the cloud
  • when/what to redirect
  • data consistency

• Game theoretic approach
  • cloud is shared
  • online decisions regarding the next request
So what did we do today?

- Cloud Computing
- Data Centers
- Tirgul – AWS
- Next week – networking → SDN
Questions?