Data Centers and Cloud Computing
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

• Used for
  • Data processing
  • Web sites
  • Business apps
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
Inside a Data Center

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

• Cooling infrastructure
• Power converters
• Backup generators
Modular Data Center

- ...or use shipping containers
- Each container filled with thousands of servers
- Can easily add new containers
  - “Plug and play”
  - Just add electricity
- Allows data center to be easily expanded
- Pre-assembled, cheaper
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

Virtualization Layer

VM 1
Windows

VM 2
Linux

Parallels

KVM

Xen

VirtualBox

vmware
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
Data Center Challenges

• Resource management
  • How to efficiently use server and storage resources?
  • Many apps have variable, unpredictable workloads
  • Want high performance and low cost
  • Automated resource management
  • Performance profiling and prediction

• Energy Efficiency
  • Servers consume huge amounts of energy
  • Want to be “green”
  • Want to save money
Reliability Challenges

• Typical failures in first year of a google data center:
  • 0.5% overheat (power down most machines in under five minutes, expect 1-2 days to recover)
  • 1 PDU (Power Distribution Unit) failure (about 500-1000 machines suddenly disappear; budget 6 hours to come back)
  • 1 rack-move (You have plenty of warning: 500-1000 machines powered down, about 6 hours)
  • 1 network rewiring (rolling 5% of machines down over 2-day span)
  • 20 rack failures (40-80 machines instantly disappear, 1-6 hours to get back) 5 racks go wonky (40-80 machines see 50% packet loss)
  • 8 network maintenances (4 might cause ~30-minute random connectivity losses)
  • 12 router reloads (takes out DNS and external virtual IP address (VIPS) for a couple minutes)
  • 3 router failures (have to immediately pull traffic for an hour)
  • dozens of minor 30-second blips for DNS
  • 1000 individual machine failures
  • thousands of hard drive failures

Data Center Costs

- Running a data center is expensive

Economy of Scale

• Larger data centers can be cheaper to buy and run than smaller ones
  • Lower prices for buying equipment in bulk
  • Cheaper energy rates

• Automation allows small number of sys admins to manage thousands of servers

• General trend is towards larger mega data centers
  • 100,000s of servers

• Has helped grow the popularity of cloud computing
What is the cloud?

- Remotely available
- Pay-as-you-go
- High scalability
- Shared infrastructure
The Cloud Stack

Software as a Service
Hosted applications
Managed by provider

Office apps, CRM

Platform as a Service
Platform to let you run your own apps
Provider handles scalability

Azure

Infrastructure as a Service
Raw infrastructure
Can do whatever you want with it

Servers & storage
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

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PaaS: Google App Engine

• Provides highly scalable execution platform
  • Must write application to meet App Engine API
  • App Engine will autoscale your application
  • Strict requirements on application state
    • “Stateless” applications much easier to scale

• Not based on virtualization
  • Multiple users’ threads running in same OS
  • Allows google to quickly increase number of “worker threads” running each client’s application

• Simple scalability, but limited control
  • Only supports Java and Python
Public or Private

• 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 Model
  • Move resources between private and public depending on load
  • Cloud Bursting
Programming Models

• **Client/Server**
  • Web servers, databases, CDNs, etc

• **Batch processing**
  • Business processing apps, payroll, etc

• **Map Reduce**
  • Data intensive computing
  • Scalability concepts built into programming model
Cloud Challenges

- Privacy / Security
  - How to guarantee isolation between client resources?

- Extreme Scalability
  - How to efficiently manage 1,000,000 servers?

- Programming models
  - How to effectively use 1,000,000 servers?
**Further Resources**

- “Above the Clouds” - cloud computing survey paper from Berkeley

- **Workshops & Conferences**
  - Hot Topics in Cloud Computing (HotCloud)
  - Symposium on Cloud Computing (SOCC)
  - lots of other small workshops
  - most recent systems conferences (NSDI, USENIX ATC, OSDI, SOSP)

- **Other**
  - Google App Engine / Amazon EC2 blogs