Introduction to Enterprise and Cloud Computing

Dominic Duggan
Stevens Institute of Technology

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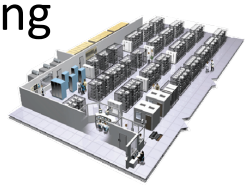
Characteristics of Enterprise Computing



- Large scale of operations
  - Scale has implications for:
    - Power
      - Cooling costs
      - "Green computing"
    - Management
      - Consistency of replicated data
    - Resource Allocation

2

Characteristics of Enterprise Computing

- Computing is data-intensive
  - Example: airline reservation systems
  - Example: bank networks
  - Enterprise computing tends to be "I/O bound"
    - Heavy access to databases and disk storage
    - On-line for transaction processing, analysis
    - Batch (overnight) processing for reconciliation, reports
    - I/O bandwidth and speed more important than CPU speed

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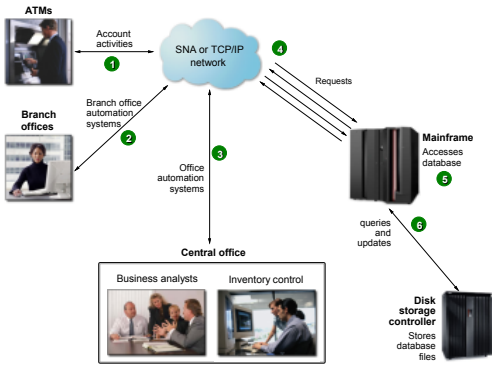
Characteristics of Enterprise Computing



- Computing is data-intensive
  - On-line processing
    - Customer transaction processing
    - Web site transactions
    - Branch office querying and updating of central databases
    - Central office analysis

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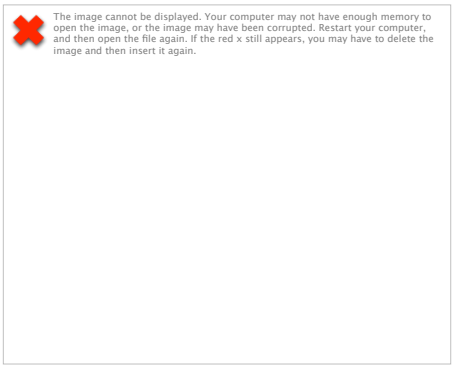
Characteristics of Enterprise Computing



- Computing is data-intensive
  - Batch processing
    - Regularly scheduled reports and analysis
    - Customer billing
    - Reconciling databases
      - E.g. inter-bank funds transfers
    - Backing up audit logs
      - Required by legislation

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Characteristics of Enterprise Computing: Reliability

- Cost of lost transactions
- Cost of lost reputation
- Two aspects of reliability:
  - Recoverability
  - Availability

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Characteristics of Enterprise Computing: Reliability

- Multiple overlapping redundant systems
  - CPU: Execute every instruction twice, compare
  - Disk: RAID (redundant arrays of independent disks)
  - Servers: Load balancers
  - Server centers: Backup data centers

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Characteristics of Enterprise Computing: Performance

- Poorly responding == failed
- Service Level Agreements (SLAs)
  - Examples:
    - 95% of ATM transactions are completed in less than one second.
    - 90% of daily reports are completed by 6 A.M.
    - System down for a total maximum of 30 seconds for the year.

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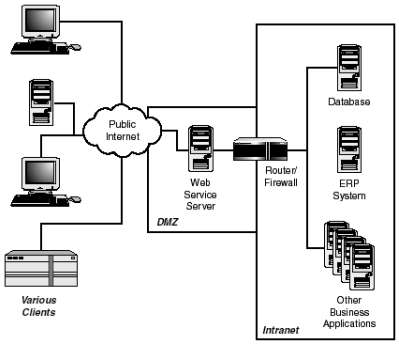
Characteristics of Enterprise Computing: Security

- Web and email provide gateways into internal network
- Firewalls control access to internal network:
  - Enclave
  - Demilitarized zone
- Authentication servers (e.g. RACF, Kerberos)
- Encrypt data storage and network traffic
- Key management (PKI)



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Characteristics of Enterprise Computing: Privacy

- Legislative requirements:
  - HPPA for healthcare
  - Sarbanes-Oxley for financial
- Accountability
  - Appropriate uses of the data
- Reporting requirements, evidence of compliance
  - Record management
  - Data protection and recovery
  - Audit logs, encrypted and backed up on tape
  - Terabytes of data per day
    - Physical storage is a real issue

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Characteristics of Enterprise Computing

- Large scale of operations
- Computing is data-intensive
- Reliability is essential
- Performance must be predictable
- Security is critical
- Privacy is also critical

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VIRTUALIZATION

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Virtualization

- Data centers as IT backbone
- Front-end applications direct client requests to back-end services
  - Front-end Web server
  - Service may be application server
  - Cluster of servers for a service
  - Load-balancers distribute client requests

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Cost of Distributed Servers

- Energy costs
  - Cooling costs
- Staffing costs
- Data silos and data synchronization

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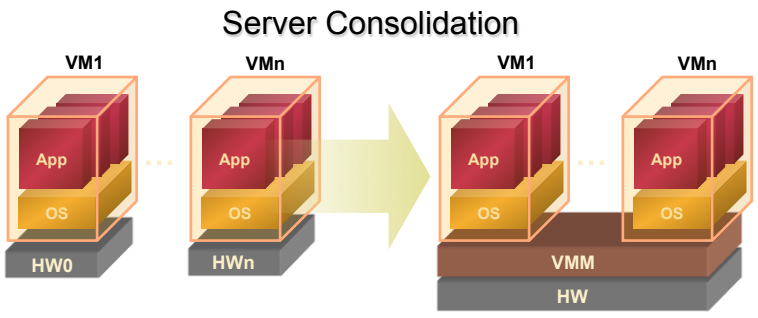
Server Consolidation via Virtualization



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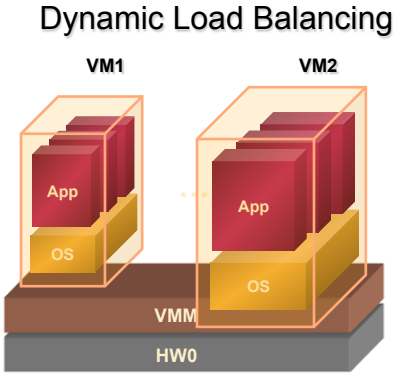
Load Balancing via Virtualization



Load balancers in distributed systems cannot take resources from idle servers.

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The Hypervisor

- Thin layer of software running on the hardware

Hypervisor

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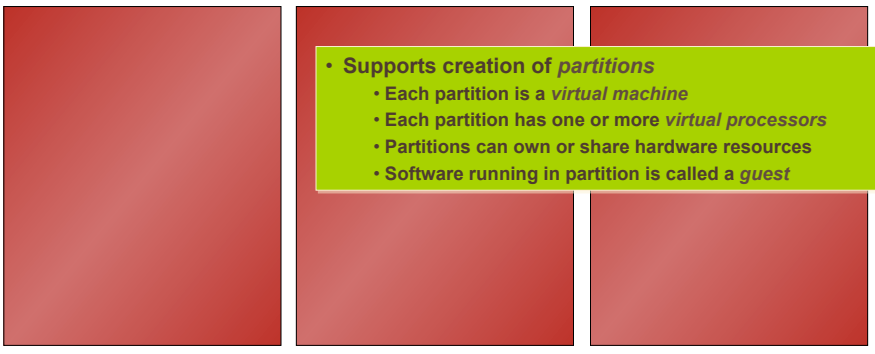
The Hypervisor



- Supports creation of *partitions*
  - Each partition is a *virtual machine*
  - Each partition has one or more *virtual processors*
  - Partitions can own or share hardware resources
  - Software running in partition is called a *guest*

Hypervisor

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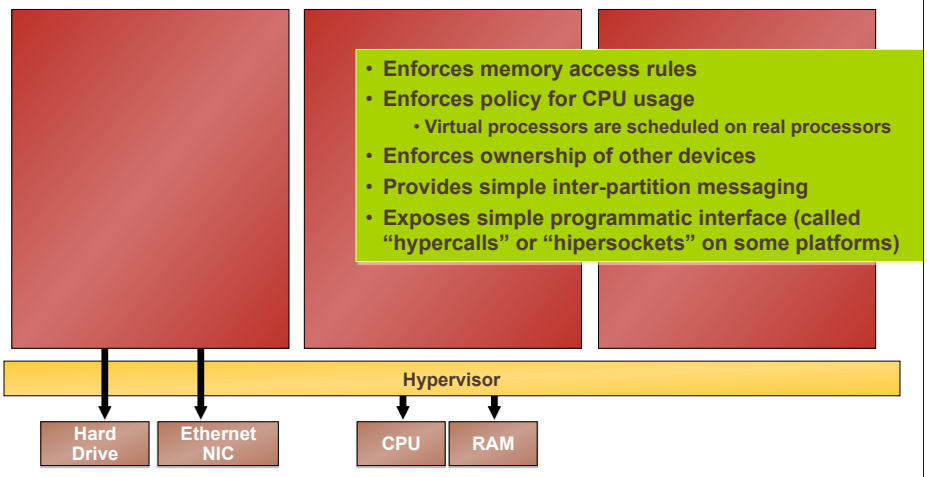
The Hypervisor



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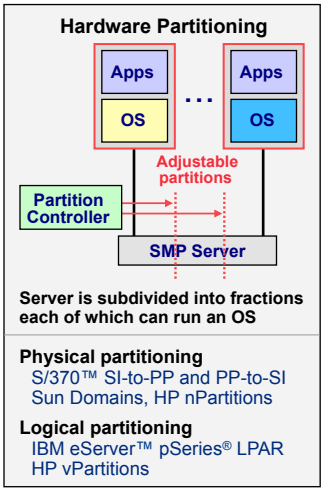
Implementing Separation: Hardware Partitioning

- Group hardware into separate units
  - Disks
  - Network interfaces
  - CPU/memory boards
- *Physical partitioning*
  - Electrical isolation
  - E.g. Oracle domains
- *Logical*
  - Isolation in firmware
  - E.g. IBM LPARs



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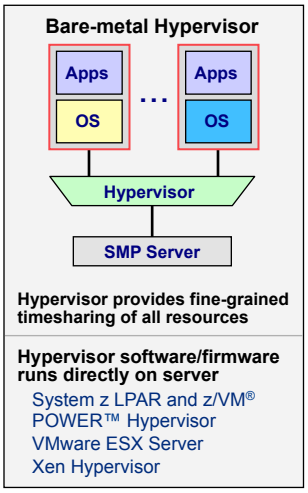
Implementing Separation: Bare Metal Hypervisor (Type 1)

- Mediated access to shared resources
- Hardware support (e.g. *interpretive execution*)
- And/or modification of guest OS (*paravirtualization*)
- Examples: Xen, HyperV, VMWare ESX, IBM z/VM



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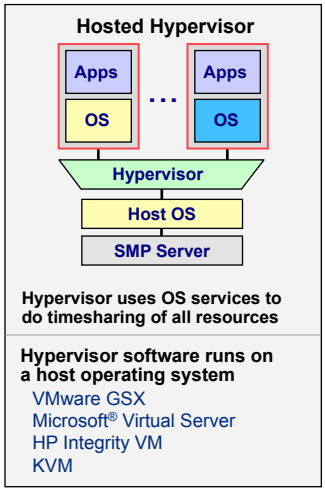
Implementing Separation: Hosted Hypervisor (Type 2)

- Useful for clients where host OS integration is important
- Examples: VMWare GSX, Parallels
- KVM approach (Linux hypervisor)



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Total Cost of Ownership (TCO)

- Cost analysis technique for evaluating the economic value of an IT investment
- Example: TCO of purchasing an automobile
  - Purchase cost
  - Insurance
  - Fuel costs
  - Maintenance costs
  - Resale value

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Total Cost of Ownership (TCO)

- TCO of a data center, affected by virtualization
  - -Equipment purchase cost
    - Virtualization requires hardware and OS support
    - A key part of IBM mainframe architectures
    - Now available on x86 platforms
  - +Personnel
    - Fewer physical machines simplify administration
  - +Supporting infrastructure (e.g. air conditioning)
    - Less physical machines reduces cooling load
  - +Software cost
    - Depends on licensing model
    - Example: IBM z Series, software license costs are based on number of physical processors, which can be shared by VMs
  - +Energy, space usage cost

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SOFTWARE AS A SERVICE AND UTILITY COMPUTING

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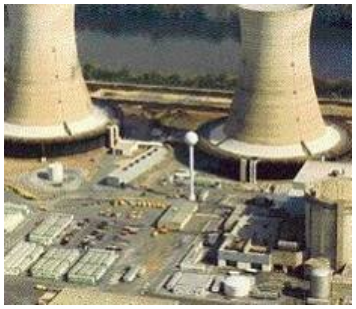
Software as a Service (SaaS)

Ex: SalesForce.com

Traditional Software



Build Your Own

On-Demand Utility

Plug In, Subscribe
Pay-per-Use

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Software as a Service (SaaS)

- Application used as on demand service
  - Often provided via the Internet
- Example: Google Apps

- Benefits to users
  - Reduce expenses: multiple computers, multiple users
  - Ease of usage: easy installation, access everywhere
- Benefits to providers
  - Easier to maintain
  - Control usage (no illegal copies)

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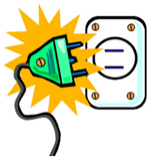
Utility Computing (UC)



- Computing resources (cpu hours, memory, network) and platform to run software are provided as on demand service
  - *Hardware as a service (HaaS)*
  - *Infrastructure as a service (IaaS)*
  - *Platform as a Service (PaaS)*
- Examples of UC providers:
  - PaaS: MS Azure …
  - IaaS: Amazon EC2 …
- Who will use UC?

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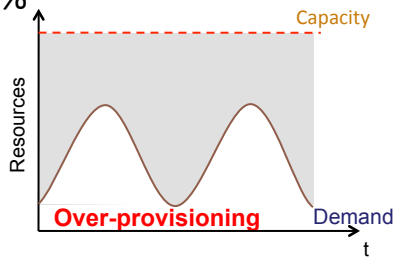
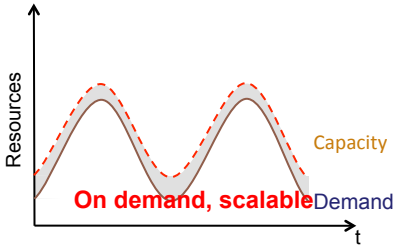
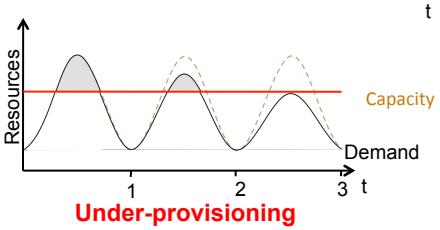
Utility Computing: Mitigate Risks

- Real world utilization 5%-20%
- Animoto demand surge: from 50 servers to 3500 servers in 3 days
- Black Friday sales







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Utility Computing – Amazon EC2

- **Elastic Compute Cloud**
- Rent VM instances to run your software
- Full root-level access to VM

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Amazon EC2

- Create an Amazon Machine Image (AMI)
- Upload AMI to Amazon S3 (simple storage service)
- Use Amazon EC2 web service to configure
- Choose OS, start AMI instances

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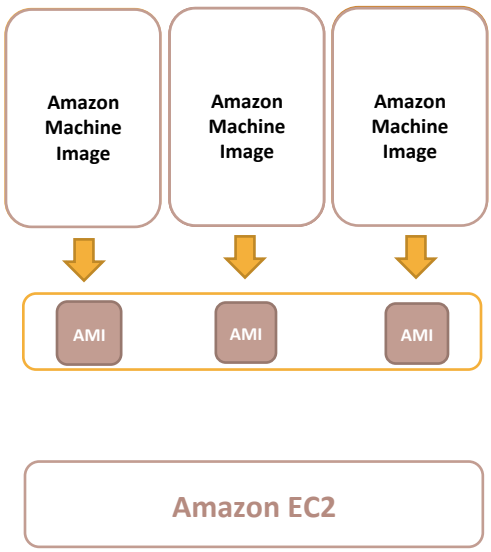

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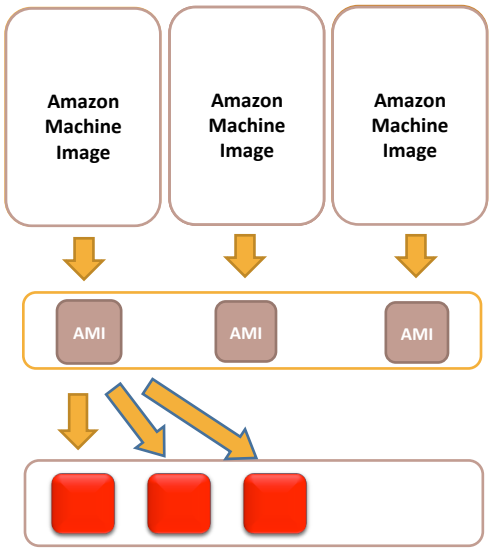

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Utility Computing – MS Azure

- Write your web program and submit to Azure
- How to use
  - Download MS SDK, Azure tools
  - Develop your program locally
  - Register for an application id
  - Submit your application to Azure

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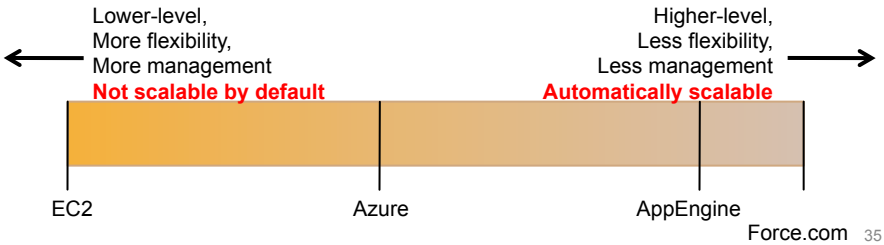
Spectrum Of Abstractions

- Different levels of abstraction
  - Instruction Set VM: Amazon EC2
  - Framework VM: MS Azure
- Similar to languages
  - Higher level abstractions can be built on top of lower ones



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CLOUD COMPUTING

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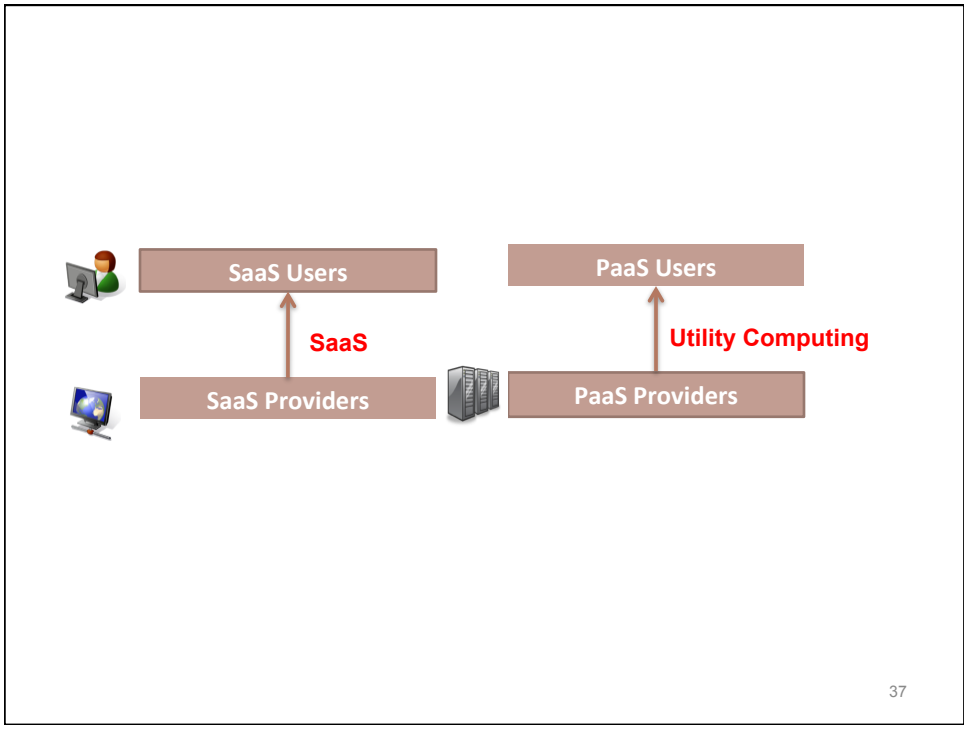
SaaS Users
SaaS
SaaS Providers
PaaS Users
Utility Computing
PaaS Providers
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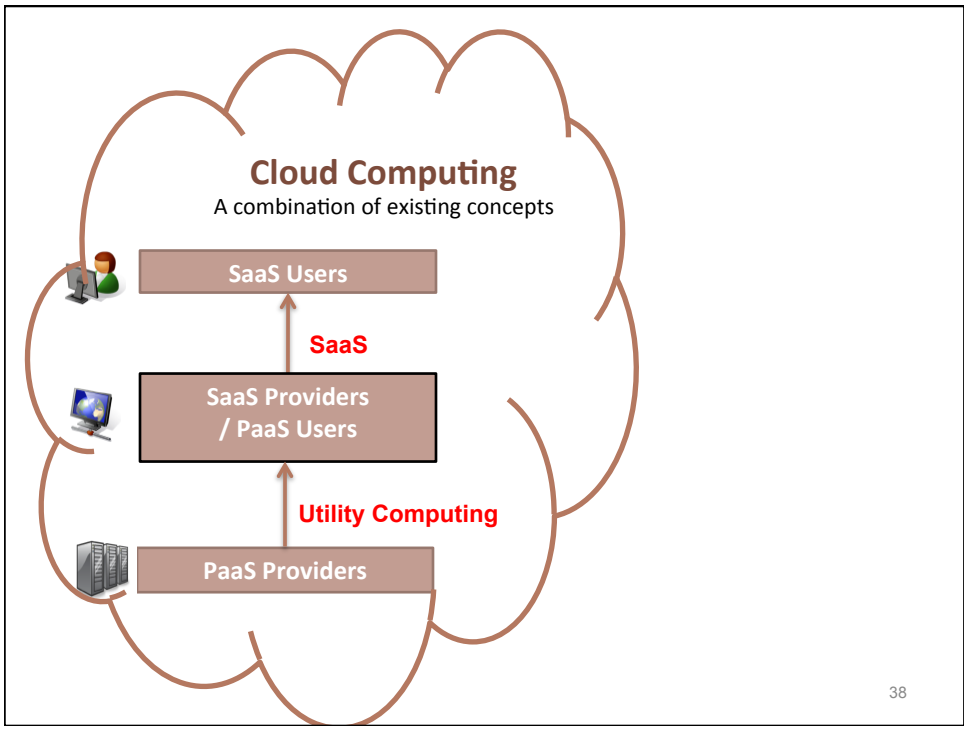
Cloud Computing
A combination of existing concepts
SaaS Users
SaaS
SaaS Providers
/ PaaS Users
Utility Computing
PaaS Providers
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Cloud Computing

Cloud Computing = SaaS + PaaS (utility computing)

Cloud TV
(Cloud Computing)

Video On Demand
(SaaS)

Electricity On Demand
(PaaS)

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Significance of Cloud Computing

- The illusion of infinite computing resources
- The elimination of an up-front commitment by users
- The ability to use and pay on demand

- Cloud Computing vs P2P?
  - Both take advantage of remote resources
  - P2P: does not use clouds (datacenters), peers do not get paid, lower reliability
- Cloud Computing vs Grid Computing?
  - Both use clouds
  - Grid Computing requires commitment, share based on common interests. Not public cloud

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Cloud Killer Apps

- Mobile and web applications
  - Mobile devices: low memory & computation power
- Extensions of desktop software
  - Matlab, Mathematica
- Batch processing / MapReduce
  - Peter Harkins at The Washington Post: 200 EC2 instances (1,407 server hours), convert 17,481 pages of Hillary Clinton's travel documents within 9 hours
  - The New York Times used 100 Amazon EC2 instances + Hadoop application to recognize 4TB of raw TIFF image into 1.1 million PDFs in 24 hours ($240)

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ECONOMICS OF THE CLOUD

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Should I Move Into A Cloud?

- Does it really save money?

$$\text{UserHours}_{\text{cloud}} \times (\text{revenue} - \text{Cost}_{\text{cloud}}) \geq \text{UserHours}_{\text{datacenter}} \times (\text{revenue} - \frac{\text{Cost}_{\text{datacenter}}}{\text{Utilization}})$$

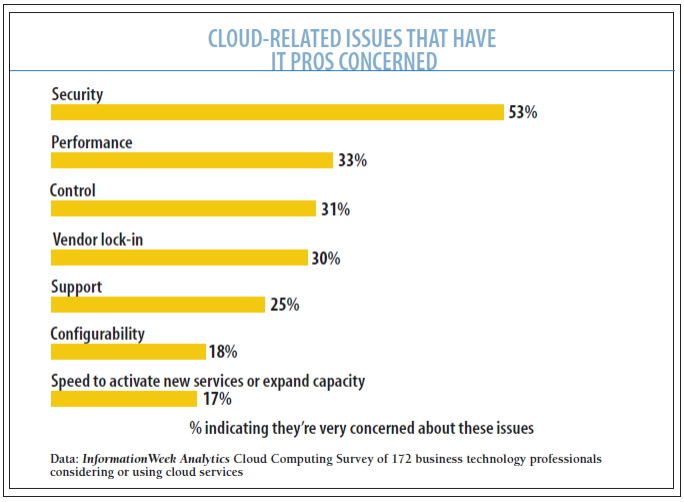
  - $Cost_{cloud} > Cost_{datacenter}$, balance by *Utilization*
  - $UserHours_{cloud} > UserHours_{datacenter}$ (under-provisioning)
- Other factors
  - Re-implement programs
  - Move data into cloud
  - What else?
- Example:
  - Upload rate 20Mbits / s. 500GB takes 55 hours
  - If can process locally in less than 55 hours → moving into a cloud would not save time

Adoption Challenges

Challenge	Opportunity
Availability	Multiple providers
Data lock-in	Standardization
Data Confidentiality and Auditability	Encryption, VLANs, Firewalls

- Coghead, a cloud vendor closed its business in February 2009
  - Customers need to rewrite their applications
  - Another company will automatically convert customer data to their proprietary formats…
- Online storage service The Linkup closed July 10, 2008
  - 20,000 paying subscribers lost their data

Adoption Challenges



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Cloud Control, InformationWeek Reports, 2009

Growth Challenges

Challenge	Opportunity
Data transfer bottlenecks	FedEx-ing disks, reuse data multiple times
Performance unpredictability	Improved VM support, flash memory
Scalable storage	Invent scalable storage
Bugs in large distributed systems	Invent Debugger using Distributed VMs
Scaling quickly	Invent Auto-Scaler

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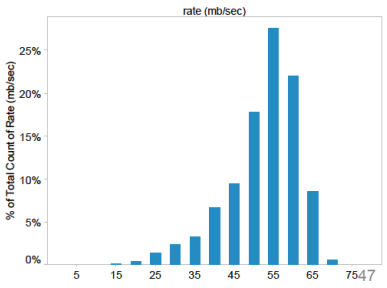
Growth Challenges

- Data transfer bottle neck
  - WAN cost reduces slowest: 2003 → 2008: WAN 2.7x, CPU 16x, storage 10x
  - Fastest way to transfer large data: send the disks
- Performance unpredictability
  - Large variation in I/O operations
  - Inefficiency in I/O virtualization



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Policy And Business Challenge

Challenge	Opportunity
Reputation Fate Sharing	Offer reputation-guarding services like those for email
Software Licensing	Pay-for-use licenses; Bulk use sales

- Reputation: Many blacklists use IP addresses and IP ranges
- Software licensing:
  - Open source software readily applicable
  - Windows, IBM software offered per hour for EC2

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THIS COURSE

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Graduate Certificate / MS in Enterprise and Cloud Computing

- CS522 Mobile Systems and Apps
- **CS526 Enterprise and Cloud Computing**
- CS548 Enterprise Software Architecture
- CS549 Distributed Systems and Cloud Computing
- CS594 Enterprise and Cloud Security

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MS/ECC Program Outcomes

	CS522	CS526	CS548	CS549	CS594
Infrastructure		X Virtualization		X Availability	
Data Modeling			X		
Design			X		
Applications	X	X	X	X	
Security & Privacy		X Secure Virt			X

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CS526 Enterprise and Cloud Computing

- Tools (C#)
  - Web apps: ASP.NET
  - Web services: Windows Comm Foundation (WCF)
  - Cloud platform: Azure
- Tools (Java)
  - MapReduce (Hadoop)
  - NoSQL: BigTable & Cassandra
- Conceptual
  - Virtualization

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Web Apps & Web Services

	Azure	Java
Client-Side B2C	AJAX Silverlight	AJAX Android
Server-Side B2C	**ASP.NET**	Java Faces
Server-Side B2B	**Windows Communication Foundation (WCF)**	Java EE • EJB • JAX-WS (SOAP) • JAX-RS (REST)
Database	**Entity Framework** **LINQ**	Java Persistence Architecture (JPA)

CS549 Distributed Systems and Cloud Computing

- Tools (Java)
  - Web services: Jersey, Atmosphere, Glassfish
  - Cloud platform: Amazon EC2
  - MapReduce (Hadoop)
  - NoSQL: MongoDB & CouchDB
- Conceptual
  - Highly available distributed systems

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CS548 Enterprise Software Architecture and Design

- Tools (Java)
  - Middleware: Java EE (JAX/RS, JPA, JMS)
  - Cloud platform: Amazon EC2
- Conceptual
  - Architecture: domain-driven, SOA, REST
  - NoSQL: Data modeling

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OVERVIEW OF THE AZURE CLOUD

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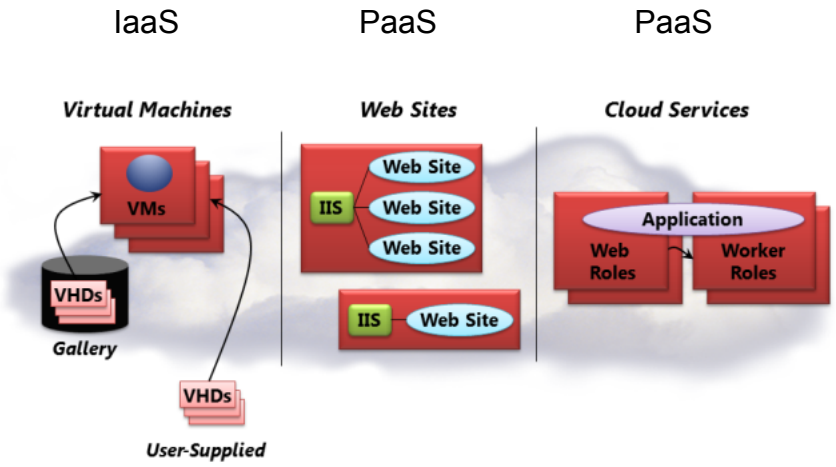
Azure Execution Models



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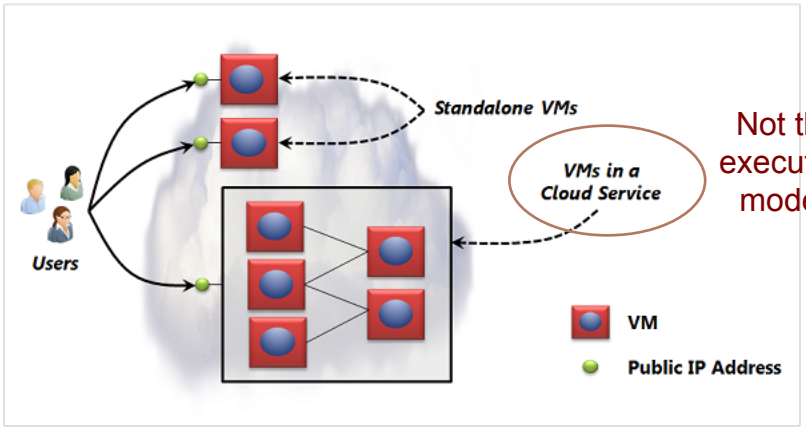
Virtual Machines



Not the execution model!

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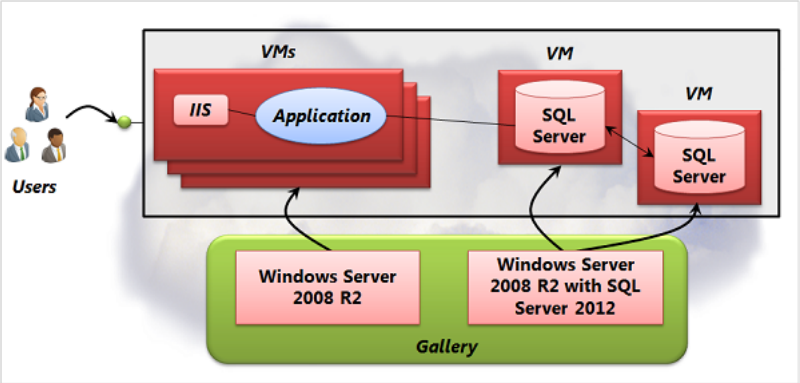
Virtual Machines Example



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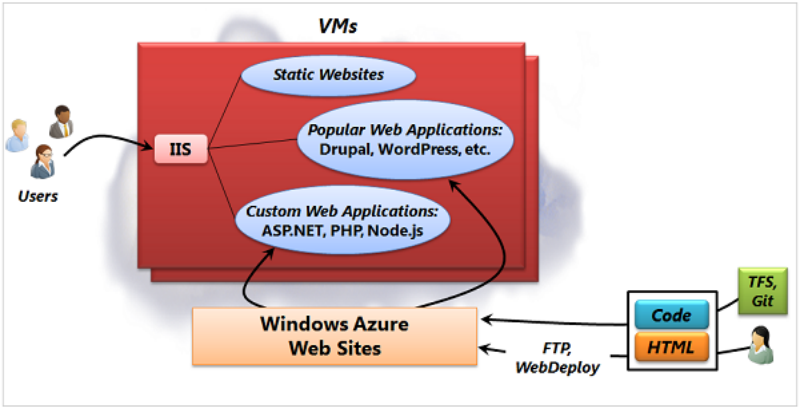
Web Sites



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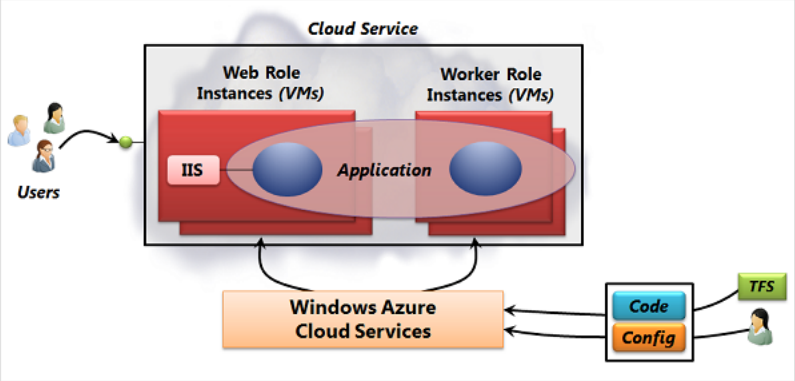
Cloud Service



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Cloud Service

- Roles for pre-configured VM instances
  - Web Role
  - Worker Role
- Deployment
  - Upload to staging area
  - Switch to production status
- Fault tolerance
  - Failure detection
  - Disk writes not persistent

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Cloud Service vs Web Site

- Admin access to VM
- Multi-tier apps
- Virtual networking
- Remote desktop

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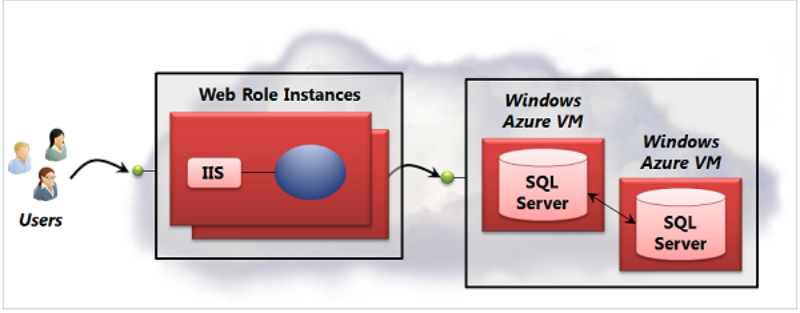
Combining Execution Models



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Azure Storage Models

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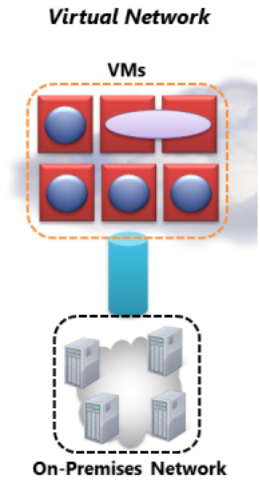
Azure Networking



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Business Analytics

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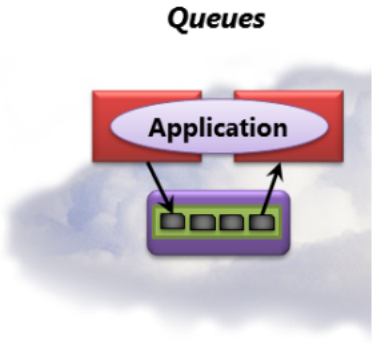
Messaging



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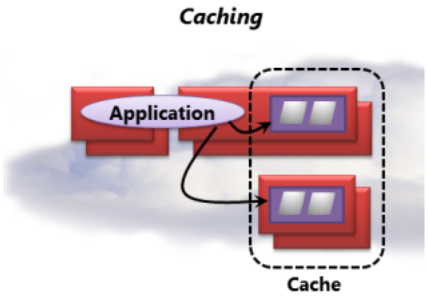
Caching



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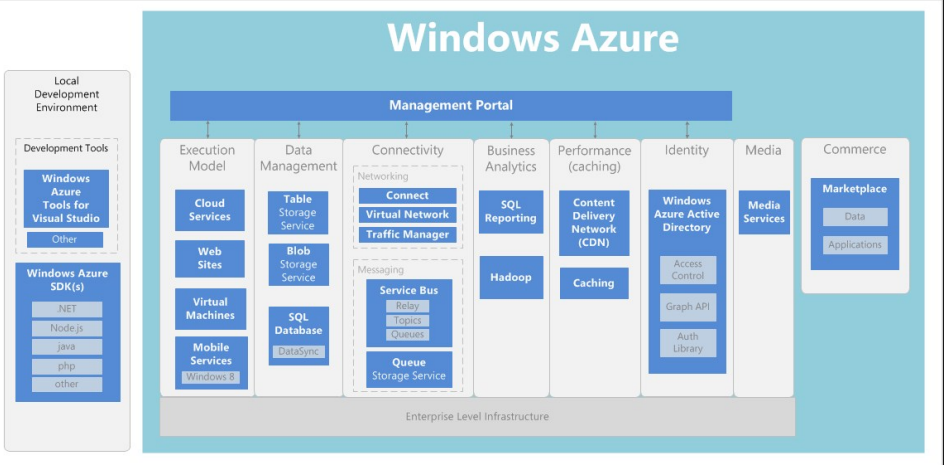
Azure Summary



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