Distributed Computer Systems Engineering

CIS 508: Lecture 6
Cloud Computing

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What is Cloud Computing

- Cloud computing is a collection of *both old and new ideas*
  - *Basic idea: delivering computing as a service rather than a product*
  - Shared resources, software, and information are provided to computers as a metered service over a network
  - Not requiring users to know the physical locations and hardware details of the computing infrastructure (no maintenance concern)
    - Buy computing power by hour
    - Buy bandwidth by usage (GB)
    - Buy storage by (GB/month)
- Synonymous names in the past
  - Grid computing, utility computing, elastic computing

Cloud Apps: Some Examples

- Data backup
  - Microsoft Skydrive, Dropbox, iCloud
- Office applications
  - Google Docs, Microsoft Office 360
- Image/Video Editing
  - Instagram, Youtube video editor, Vimeo editor
- Antivrius
  - Panda Cloud antivirus
- Maps
  - Google Maps, Mapquest
- Social Networks
  - Facebook, LinkedIn
- Streaming
  - Spotify, Netflix

Replacing traditional desktop applications

Classes of Cloud Platforms

- Applications-As-A-Service (AaaS) /Software-As-A-Service (SaaS)
  - Google App, SAP, IBM, HP

- Platform-As-A-Service (PaaS)
  - Microsoft Azure

- Infrastructure-As-A-Service (IaaS)
  - Amazon web services

Applications-As-A-Service

- Applications-As-A-Service (AaaS) /Software-As-A-Service (SaaS)

  - Applications supplied by the service provider in a cloud infrastructure

  - Applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email)

    - Users do not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities

    - Limited user-specific application configuration settings

Platform-As-A-Service

- Enable executions of consumer-created applications using programming languages and tools supported by the provider

- Customer do not manage or control the underlying cloud infrastructure including network, servers, OSes, storage

- Customers have control over the deployed applications and hosting environment configurations

- Rely on proprietary programming languages, when the underlying hardware and software need to be customized to improve the performance of the application

- For there is a need to automate the deployment and testing services

Infrastructure-As-A-Service

- Provisioning computing processing, storage, networks, and other fundamental computing resources

- Consumers are able to deploy and run arbitrary software, which can include operating systems and applications

- Customers do not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications

- Limited control of select networking components (e.g., host firewalls)

- Services offered by this paradigm include:

    - Server hosting, web servers, storage, computing hardware, operating systems, virtual instances, load balancing, Internet access, and bandwidth provisioning

Advantages

- Outsourcing the management and maintenance of hardware and network infrastructure

- Rapidly scale up/ scale down/automatic scaling based on real-time demand

- No upfront cost and purchase cost

- Minimal upgrade cost

- Minimal operational cost (e.g. electricity, cooling)

- 24 hour technical support
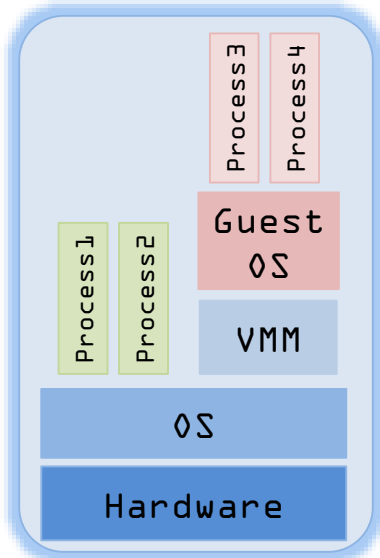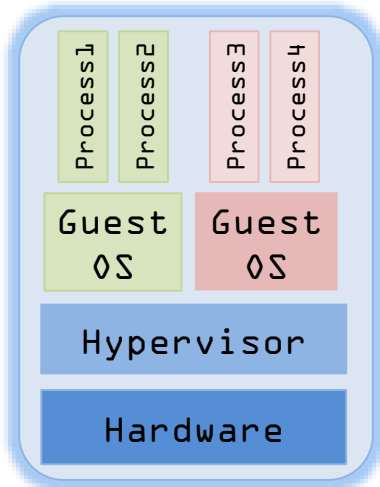
- Geographical diverse facilities

Disadvantages

- Control is relinquished to third party services

- Data is stored on multiple sites administered by several external organizations

- Multiple services interoperate across the network

- Lock-in

- Durability (e.g., Megaupload incident)

- Cheap?

- Small sized projects?

Virtualization: Recap

- Virtualization broadly refers to abstraction of resources in many aspects of computing

- One physical machine to support multiple operating systems that run in parallel
  - Hypervisor: Isolate multiple guest OSes
  - Hardware virtualization (IBM pSeries Servers)
  - Software virtualization (VMware Server, Xen)

- Virtualization is key technology to facilitate cloud computing

- Processes can be deployed dynamically

- Without relying on fixed hardware resources

Amazon Web Services

- One of biggest cloud computing service providers

- Leverage on its massive number of server ranks for web stores

- Amazon Web Services (AWS)

    - EC2 (Elastic Compute Cloud):

        - Virtualization powered by Xen

    - S3 (Simple Storage Service): Web based storage

    - CloudFront (Content distribution network)

    - Elastic MapReduce

    - RDS (Relational Database Service)

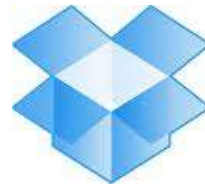   - and many other services …

Some Customers of AWS

Where does Dropbox store everyone's data?

« Back to Help Center

Once a file is added to your Dropbox, the file is then synced to Dropbox's secure online servers. All files stored online by Dropbox are encrypted and kept securely on Amazon's Simple Storage Service (S3) in multiple data centers located across the United States.

You can find more information about Amazon S3 or learn about Amazon S3's security measures on the Amazon website.

Was this article helpful?   ☺ Yes   ☹ No

Amazon S3

- Amazon S3 provides reliable storage through web services interfaces (HTTP, SOAP, and BitTorrent)

    - Minimal set of functions: write, read, and delete

    - Allow an application to handle an unlimited number of objects ranging in size from 1 byte to 5 TB

    - An object is stored in a bucket and retrieved via a unique, developer-assigned key; a bucket can be stored in a Region selected by the user

- S3 maintains for each object: the name, modification time, an access control list; the object names are global

- Authentication mechanisms ensure secure data access; objects can be made public, and rights can be granted to other users

Pricing for Amazon S3

	Standard Storage	Reduced Redundancy Storage
First 1 TB / month	$0.125 per GB	$0.093 per GB
Next 49 TB / month	$0.110 per GB	$0.083 per GB
Next 450 TB / month	$0.095 per GB	$0.073 per GB
Next 500 TB / month	$0.090 per GB	$0.063 per GB
Next 4000 TB / month	$0.080 per GB	$0.053 per GB
Over 5000 TB / month	$0.055 per GB	$0.037 per GB

Pricing	
PUT, COPY, POST, or LIST Requests	$0.01 per 1,000 requests
GET and all other Requests	$0.01 per 10,000 requests

Amazon Elastic Block Store

- Provide raw block devices, can be attached to Amazon EC2 instances

- Support formatting the device with a filesystem and mounting

- Support a number of advanced storage features, including snapshotting and cloning

- Not as reliable as S3 (which replicates data into multiple availability zones)

us-east-1a

EC2 Instance

EBS Volume   EBS Volume

Attach multiple volumes to the same EC2 instance.

EBS Volumes

- 1GB - 1TB
- $0.10/GB per month
- Attach an EBS Volume(s) to any EC2 instance in the same Availability Zone
- Create an EBS Snapshot of an EBS Volume at any point in time
- Create an EBS Volume(s) from any EBS Snapshot

Amazon EC2

- Virtual machine platform allows launching instances of application under several OSes (e.g. Linux distributions, Microsoft Windows Server 2003/2008, OpenSolaris, FreeBSD, and NetBSD)

- Allows users to

  - Load instances of an application with a custom application environment

  - Manage networks access permissions

  - Run the images using as many or as few systems as desired

- EC2 instances boot from an AMI (Amazon Machine Image) digitally signed and stored in S3

- One could use the images provided by Amazon or customize an image and store it in S3

Amazon Machine Image
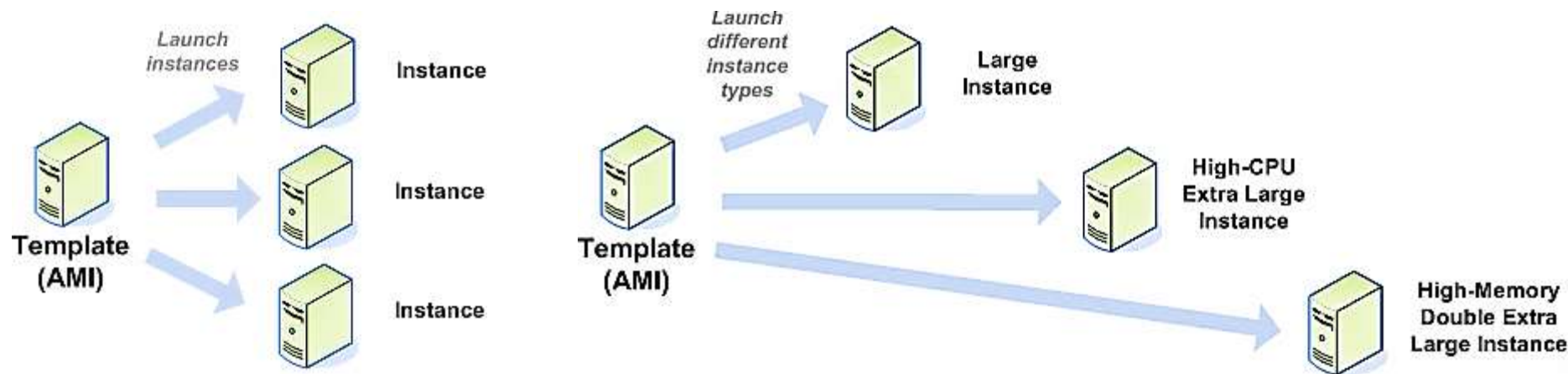
- Users can use a pre-configured Amazon Machine Image (AMI)
  - Pre-configured operating system and application software
- Or create their own AMIs
- Users can then choose between different instance types with different virtual CPU cores and amount of memory
  - High-CPU/ Memory/ I/O Instances, Cluster Compute Instances (for HPC and network-bound applications), Cluster GPU Instances

Amazon Machine Image
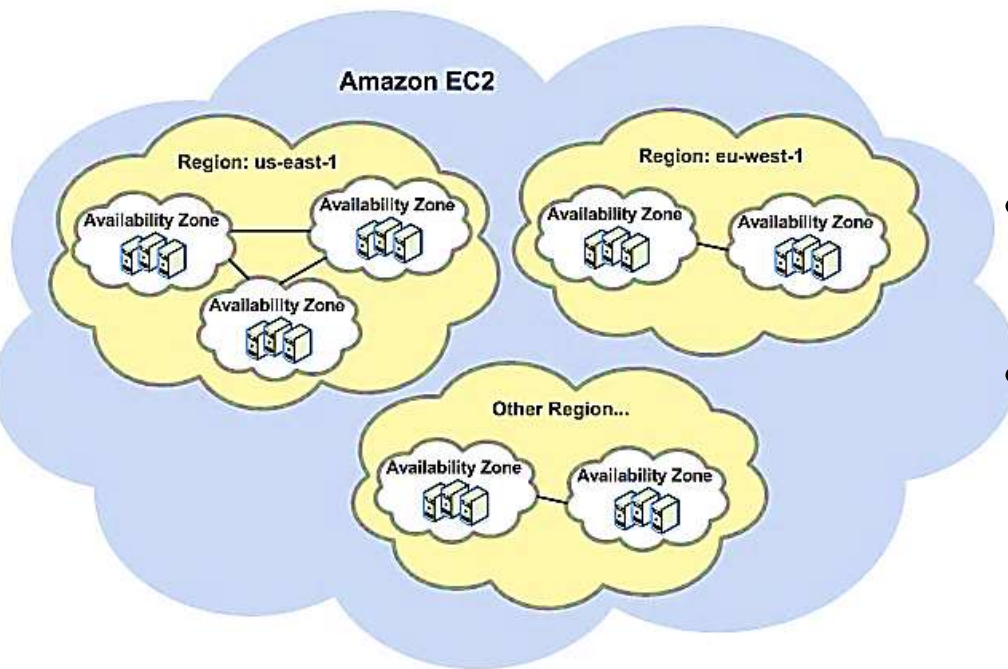
- EC2 instances can be launched in multiple locations (Regions and Availability Zones)

- Failures are insulated among different Availability Zones

- *Elastic IP Addresses*
  - Static IP addresses
  - Can be used to remap public IP addresses to any instance in an account in case of instance or Availability Zone failures

Amazon EC2

- EC2 system offers several instance types:
  - Standard instances:
    - Micro (StdM), small (StdS), large (StdL), extra large (StdXL); small is the default
  - High memory instances:
    - High-memory extra large (HmXL), high-memory double extra large (Hm2XL), and high-memory quadruple extra large (Hm4XL)
  - High CPU instances:
    - High-CPU extra large (HcpuXL)
  - Cluster computing:
    - Cluster computing quadruple extra large (Cl4XL)
- EC2 provides computation on-demand, not permanent storage
  - S3 provides permanent storage

EC2: Spec/On-demand Price

Instance Name	API Name	Platform	Memory(GB)	Max EC2	I-memory	I/O
StdM		32 bit	0. 633	1 VC; 2 CUs		
StdS	m1.small	32 bit	1.7	1 VC; 1 CU	160	M
StdL	m1.large	64 bit	7.5	2 VCs; 2 x 2 CUs	85	H
StdXL	m1.xlarge	64 bit	15	4 VCs; 4 x 2 CUs	1,690	H
HmXL	m2.xlarge	64 bit	17.1	2 VCs; 2 x 3:25 CUs	420	M
Hm2XL	m2.2xlarge	64 bit	34.2	4 VCs; 4 x 3:25 Cus	850	H
Hm4XL	m2.4xlarge	64 bit	68.4	8 VCs; 8 x 3:25 Cus	1,690	H
HcpuXL	c1.xlarge	64 bit	7	8 VCs; 8 x 2:5 Cus	1,690	H
Cl4XL	cc1.4xlarge	64 bit	18	33.5 CUs	1,690	Hs

| Instance	Linux/Unix	Windows
StdM	0.007	0.013
StdS	0.03	0.048
StdL	0.124	0.208
StdXL	0.249	0.381
HmXL	0.175	0.231
Hm2XL	0.4	0.575
Hm4XL	0.799	1.1
HcpuXL	0.246	0.516
Cl4XL	0.544	

EC2 Spot Market

- Apart from launching instances on demand, users can also reserve certain instances or bid on unused EC2 capacity to run Spot Instances

- For flexible running schedule

    - E.g. Run 15 mins during the next 5 hours

- Not guaranteed, not on-demand

- Bid at spot market, cheaper than on-demand prices

- Spot Instances, and lower your costs significantly

- Set by Amazon EC2, the Spot Price for these instances fluctuates periodically depending on the supply of and demand for Spot Instance capacity

EC2 Spot Market

How does it work?

- Place a Spot Instance request (your bid) specifying the maximum price you are willing to pay per hour per instance

- If the maximum price of your bid is greater than the current Spot Price, your request is fulfilled and your instances run until you terminate them or the Spot Price increases above your maximum price (whichever comes first).

- The Spot Price is adjusted periodically as requests come in and the available supply of instances changes

- Everyone pays that same Spot Price for that period regardless of whether their maximum bid price was higher, and you will never pay more than your hourly maximum bid price

Spot Price
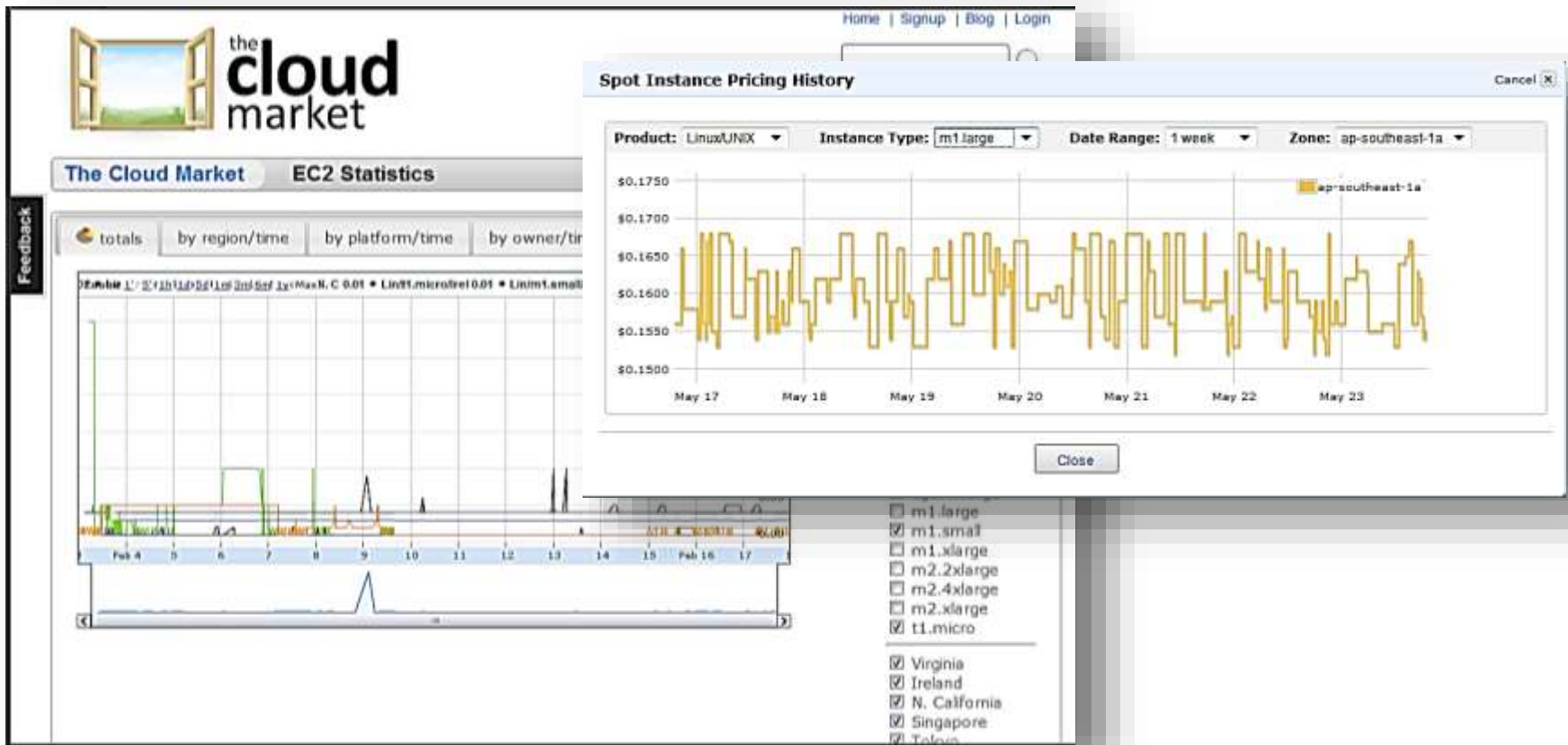
http://thecloudmarket.com/stats#/spot_prices

Google Cloud Platforms

- Software-as-a-Service

  - Gmail, Google docs, Google calendar, Picassa and Google Groups are Google services free of charge

- Platform-as-a-Service

  - AppEngine is a developer platform hosted on the cloud (Platform-as-a-Service)

  - Initially it supported only Python and support for Java was added later

  - The database for code development can be accessed with GQL (Google Query Language) with an SQL-like syntax

Google Cloud Platforms

- Infrastructure-as-a-Service

  - *Google Compute Engine*

  - Offers flexible VMs hosted on Google

  - Just launched

  - Only supports Linux based virtual machines running on KVM hypervisor right now

  - Users can choose the specific location (called zone) to launch instances

  - A zone is defined by (region, availability group) tuple which is similar to (region, availability zone) in AWS

Microsoft Azure

- Azure and Online Services are PaaS and SaaS cloud platforms

- Windows Azure is an operating system

- SQL Azure is a cloud-based version of the SQL Server

- Azure AppFabric (formerly .NET Services) is a collection of services for cloud applications

  - Fabric Controller which deploys, manages, and monitors applications; it interconnects nodes consisting of servers, high-speed connections, and switches

Data Deluge

- Data is getting ever BIGGER

- Google processing 20 PB data a day

- eBay's processing 6.5 PB of user data spanning 170 trillion records and growing by 150 billion new records per day

- Facebook processing 2.5 petabytes of user data, growing at about 15 terabytes per day
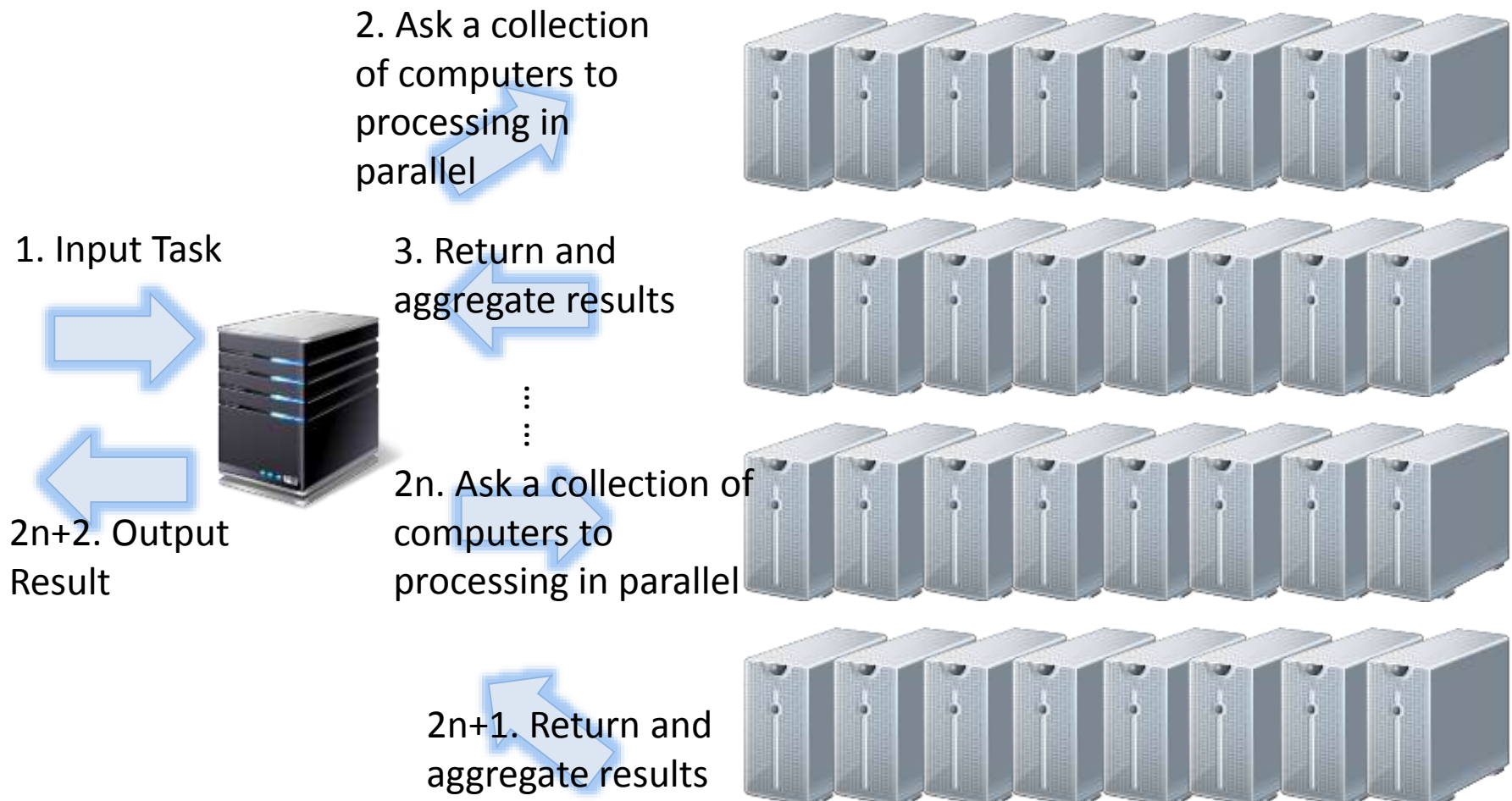

The data deluge
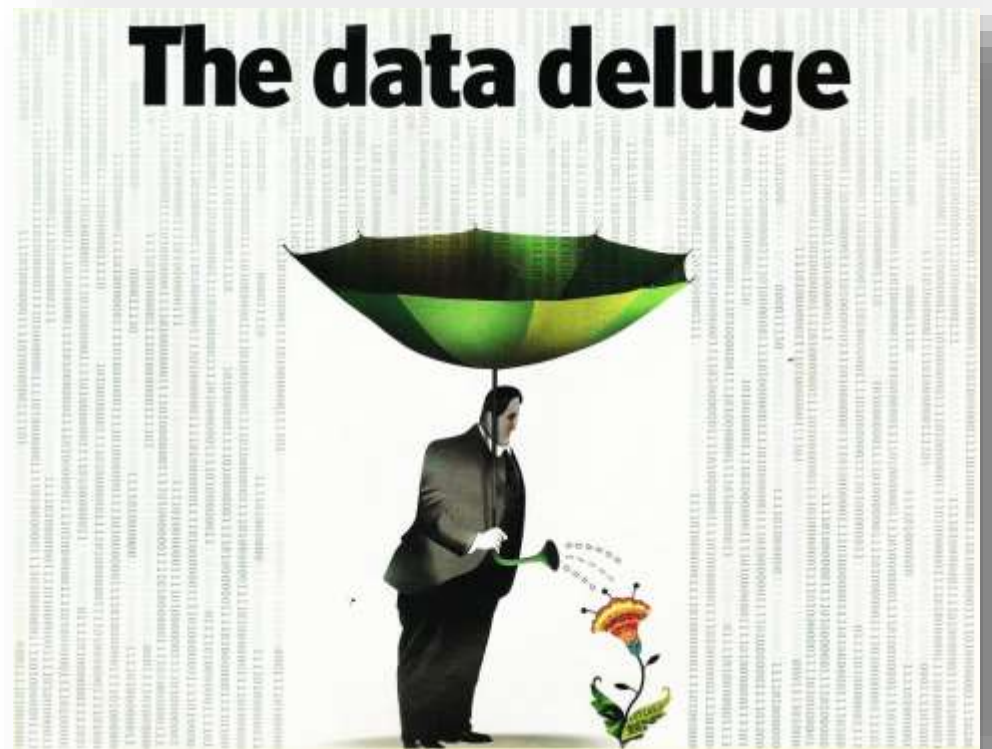
The Google Approach

- Indexing the WWW

- 20+ billion web pages x 20KB=400+ TB

- One computer: read 30-35MB/sec from disk

  - Four months to read the web

  - 1000 hard drives to store the web

- Good news:

  - With 1000 machines, need < 3 hrs

- Bad news:

  - Programming work, and repeated for every problem

The Google Approach

2. Ask a collection of computers to processing in parallel

1. Input Task

3. Return and aggregate results

2n+2. Output Result

2n. Ask a collection of computers to processing in parallel

2n+1. Return and aggregate results

Machine Specification

- Typical machine runs Google File System (GFS)

- 2 CPUs (Dual-core)

- 1-6 locally attached disks

    - 200GB – 2 TB of disk

- 4 GB – 16 GB of RAM

- Racks of machines connected by commodity Ethernet switches

- No GPUs

- No Shared Memory

Bigtable

- Distributed storage

  - Built off of GFS (Google File Systems)

- Not a database: cells indexed by row/column/time

  - e.g. can recover n most recent values

- Multiple layers of caching:

  - Machine and network level

  - Transaction processing is optional

The Google Approach

- Distributed grep (text-search)

- Distributed sort

- Web access log statistics

- Web link-graph reversal

- Term-vector per host

- Inverted index construction

- Document clustering

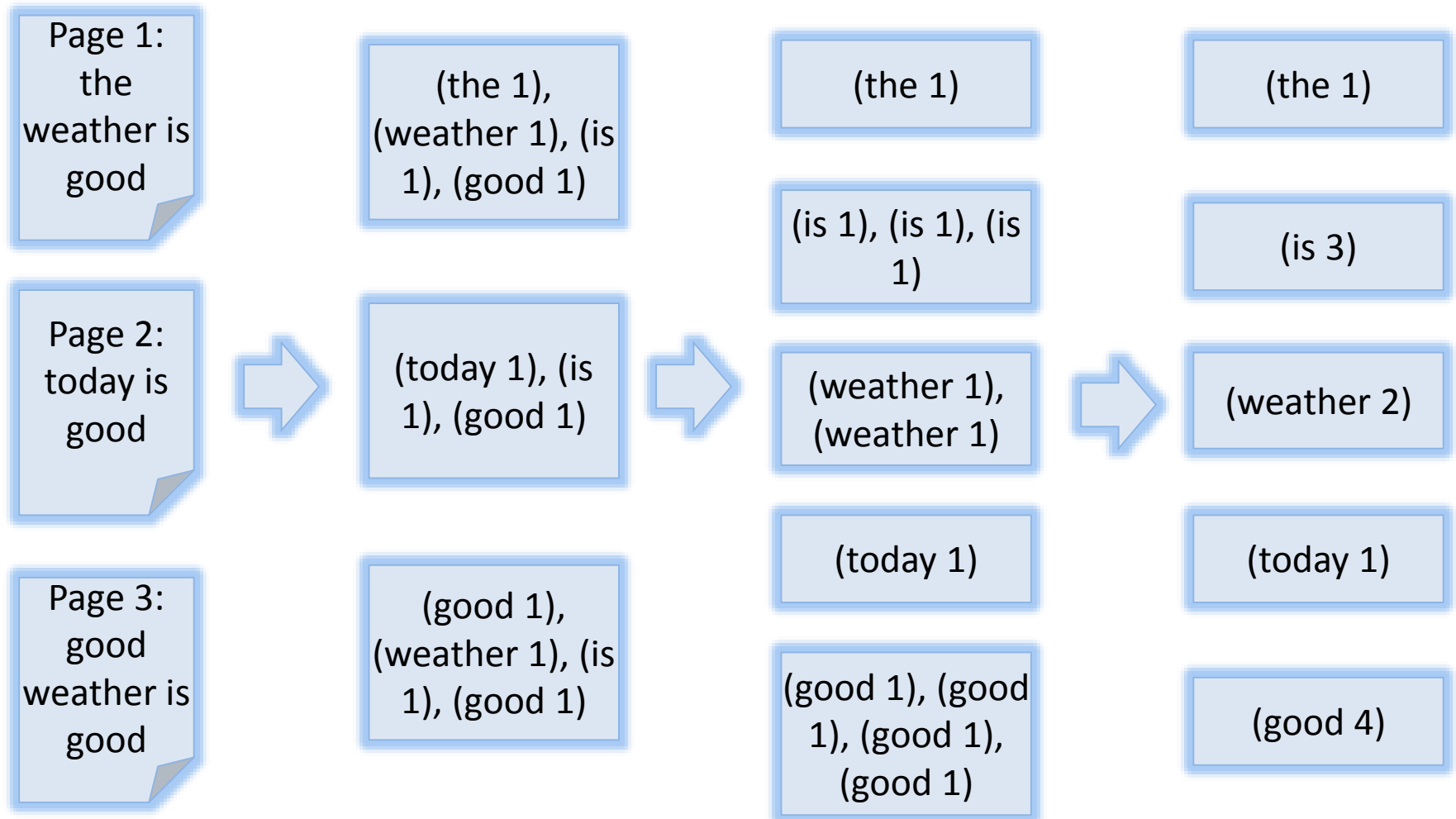- Statistical machine translation

- Machine learning

Common programming interface and supporting libraries

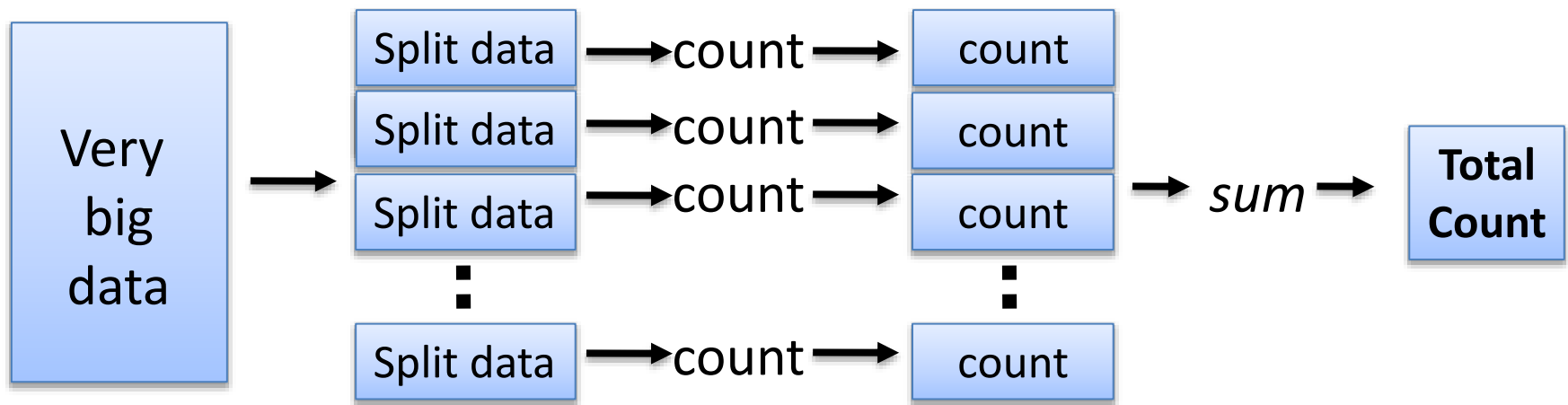# What is MapReduce?

- A programming model (& its associated implementation)

- For processing large data set

- Exploits large set of commodity computers

- Executes process in distributed manner

- Offers high degree of transparencies

- In other words

  - Simple and suitable for many information processing tasks

- MapReduce is the most successful abstraction over large-scale computational resources

Example: Word Count

Page 1: the weather is good

Page 2: today is good

Page 3: good weather is good

(the 1), (weather 1), (is 1), (good 1)

(today 1), (is 1), (good 1)

(good 1), (weather 1), (is 1), (good 1)

(the 1)

(is 1), (is 1), (is 1)

(weather 1), (weather 1)

(today 1)

(good 1), (good 1), (good 1), (good 1)

(the 1)

(is 3)

(weather 2)

(today 1)

(good 4)

Distributed Word Count

Very big data → Split data → count → count

Split data → count → count

Split data → count → count

⋮

Split data → count → count

⋮

→ *sum* → **Total Count**

MapReduce Applicability

Suitable for your task if:

- Have a cluster

- Working with large dataset

- Working with independent data (or assumed)

- Can be cast into *map* and *reduce*

Google Distributed File System handle:

- Parallelization

- Fault-tolerance

- Locality optimization

- Load balancing

Hadoop: MapReduce outside Google

- Software framework supports data-intensive distributed apps

- Enables applications to work with thousands of nodes and petabytes of data

- Hadoop was inspired by Google's MapReduce and Google File System (GFS)

- A top-level Apache project being built and used by a global community of contributors, using the Java programming language

- Yahoo! has been the largest contributor to the project, and uses Hadoop extensively across its businesses

References

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- **Amazon Web Services Documentation**

  - http://docs.amazonwebservices.com/AWSEC2/latest/UserGuide/Welcome.html

- **Statistics of Amazon Cloud**

  - http://thecloudmarket.com/stats

- **MapReduce**

  - http://research.google.com/archive/mapreduce.html