Introduction to Data Management
CSE 344

Lecture 25: DBMS-as-a-service and NoSQL

Where We Are

• We learned quite a bit about data management... see course calendar

• Three topics left:
  – DBMS-as-a-service and NoSQL
  – Data integration
  – Data cleaning

• Strongly encouraged to take 444 to learn more!

References

• Amazon SimpleDB, RDS, Elastic MapReduce Websites
  – Part of Amazon Web services

• Google App Engine Datastore Website
  – Part of the Google App Engine

• Microsoft SQL Azure
  – Part of Windows Azure

• Very dynamic space! Need to check docs regularly!

Cloud Computing

• A definition
  – "Style of computing in which dynamically scalable and often virtualized resources are provided as a service over the Internet"

• Basic idea
  – Developer focuses on application logic
  – Infrastructure, software, and data hosted by someone else in their "cloud"
  – Hence all operations tasks handled by cloud service provider

Cloud Computing History

• “Computation may someday be organized as a public utility” (John McCarthy – 1960)
• Late 1990's: Infrastructure as a Service (i.e., rent machines)
• Late 1990s': Software as a service (e.g., Hotmail, Salesforce)
• Early 2000s: Web services
• 2006: Amazon Web Services
• And now it’s a craze!

Levels of Service

• Infrastructure as a Service (IaaS)
  – Example Amazon EC2

• Platform as a Service (PaaS)
  – Example Microsoft Azure, Google App Engine

• Software as a Service (SaaS)
  – Example Google Docs
How About Data Management as a Service?

- Running a DBMS is challenging
  - Need to hire a skilled database administrator (DBA)
  - Need to provision machines (hardware, software, configuration)
    - If business picks up, may need to scale quickly
    - Workload varies over time
- Solution: Use a DBMS service
  - All machines are hosted in service provider’s data centers
  - Data resides in those data centers
  - Pay-per-use policy
  - Elastic scalability
  - No administration!

Basic Features for Data Management as a Service

- Data storage and query capabilities
- Operations and administration tasks handled by provider
  - Include high availability, upgrades, etc.
  - Elastic scalability: Clients pay exactly for the resources they consume; consumption can grow/shrink dynamically
    - No capital expenditures and fast provisioning

Types of Data Management as a Service

Three different types exist at the moment

- Relational data management systems (e.g., SQL Azure)
- Simplified data mgmt systems (e.g., Amazon SimpleDB)
  - Also called “NoSQL” systems. We will see why in a few slides
- Analysis services such as Amazon Elastic MapReduce

Outline

- Overview of three systems
  - Amazon Web Services with SimpleDB RDS, and Elastic MapReduce
  - Google App Engine with the Google App Engine Datastore
  - Microsoft Azure platform with Azure SQL
- Discussion
  - Technical challenges behind databases as a service
  - Broader impacts of databases as a service

Amazon Web Services

- Since 2006
- “Infrastructure web services platform in the cloud”
- Amazon Elastic Compute Cloud (Amazon EC2™)
- Amazon Simple Storage Service (Amazon S3™)
- Amazon SimpleDB™
- Amazon Elastic MapReduce™
- And more…
- And growing…

Amazon EC2

- Amazon Elastic Compute Cloud (Amazon EC2™)
- Rent compute power on demand (“server instances”)
  - Select required capacity: small, large, or extra large instance
  - Share resources with other users (multitenant): Virtual machines
  - Variety of operating systems
- Includes: Amazon Elastic Block Store
  - Off-instance storage that persists independent from life of instance
  - Highly available and highly reliable
Amazon S3

• Amazon Simple Storage Service (Amazon S3™)
  – “Storage for the Internet”
  – “Web services interface that can be used to store and retrieve any amount of data, at any time, from anywhere on the web.”

• Some key features
  – Write, read, and delete uniquely identified objects containing from 1 byte to 5 TB of data each
  – Objects are stored in buckets. User chooses geographic area
  – A bucket can be accessed from anywhere
  – Authentication
  – Reliability

Amazon RDS

• Amazon Relational DB Service (Amazon RDS™)
  – Web service that facilitates set up, operations, and scaling of a relational database in the cloud
  – Full capabilities of a familiar MySQL or Oracle DBMS

• Some key features
  – Automated patches of DBMS
  – Automated backups for user-defined retention period
  – Elastic scalability but can only scale-up
  - Make your instance more powerful (CPU and memory)
  - Attach more storage to your instance
  – Can scale-out only by adding read replicas

NoSQL Motivation

• Scaling a relational DBMS is hard
• We saw how to scale queries with parallel DBMSs
  • Need to partition the database across multiple machines
  • If a transaction touches one machine, life is good
  • If a transaction touches multiple machines, ACID becomes extremely expensive! Need what is called two-phase commit

• Replication
  – Replication can also help to increase throughput
  – Create multiple copies of each database partition
  – Spread queries across these replicas
  – Easy for reads but writes, once again, become expensive!

NoSQL Systems

• Goal: elastic and highly scalable data management
  • Basic data storage, basic querying, and atomic updates
  • More flexible than a relational DBMS: no fixed schema!
  • Highly scalable!
  • But to scale-out, give up on complex queries
  • No joins (or limited joins)
  • Gives up on ACID: instead eventually consistent
  • No transactions! Or limited transactions
  • Caveat: Hard to build apps without ACID guarantees
  • Today: Many NoSQL systems provide choice between strong consistency and eventual consistency

Amazon SimpleDB

• An example of a NoSQL data management system

• Partitioning
  – Data partitioned into domains: queries run within domain
  – Domains seem to be unit of replication. Limit 10GB
  – Can use domains to manually create parallelism

• Schema
  – No fixed schema
  – Objects are defined with attribute-value pairs

Amazon SimpleDB (2/3)

• Indexing
  – Automatically indexes all attributes

• Support for writing
  – PUT and DELETE items in a domain

• Support for querying
  – select output_list from domain_name where expression [sort_instructions] [limit limit]
  – GET by key
  – Selection + sort
  – A simple form of aggregation: count
  – Query is limited to 5s and 1MB output (but can continue)
Amazon SimpleDB (3/3)

- **Availability and consistency**
  - "Fully indexed data is stored redundantly across multiple servers and data centers.”
  - "Takes time for the update to propagate to all storage locations. The data will eventually be consistent, but an immediate read might not show the change.”
  - Today, can choose between consistent or eventually consistent read

- **Integration with other services**
  - "Developers can run their applications in Amazon EC2 and store their data objects in Amazon S3.”
  - "Amazon SimpleDB can then be used to query the object metadata from within the application in Amazon EC2 and return pointers to the objects stored in Amazon S3.”

Amazon Elastic MapReduce

- "Web service that enables businesses, researchers, data analysts, and developers to easily and cost-effectively process vast amounts of data”
- Hosted Hadoop framework on top of EC2 and S3
- Support for Hive and Pig
- User specifies
  - Data location in S3
  - Query
  - Number of machines
- System sets-up the cluster, runs query, and shuts down

Google App Engine

- “Run your web applications on Google's infrastructure”
- Limitation: app must be written in Python or Java
- Key features (examples for Java)
  - A complete development stack that uses familiar technologies to build and host web applications
  - Includes: Java 6 JVM, a Java Servlets interface, and support for standard interfaces to the App Engine scalable datastore and services, such as JDO, JPA, JavaMail, and Jcache
  - JVM runs in a secured "sandbox" environment to isolate your application for service and security (some ops not allowed)

Google App Engine Datastore (1/3)

- "Distributed data storage service that features a query engine and transactions”
- **Partitioning**
  - Data partitioned into "entity groups”
  - Entities of the same group are stored together for efficient execution of transactions
- **Schema**
  - Each entity has a key and properties that can be either
    - Named values of one of several supported data types (includes list)
    - References to other entities
  - Flexible schema: different entities can have different properties

Google App Engine Datastore (2/3)

- **Indexing**
  - Applications define indexes: must have one index per query type
- **Support for writing**
  - PUT and DELETE entities (for Java, hidden behind JDO)
- **Support for querying**
  - GET an entity using its key
  - Execute a query: selection + sort
  - Language bindings: invoke methods or write SQL-like queries
  - Lazy query evaluation: query executes when user accesses results

Google App Engine Datastore (3/3)

- **Availability and consistency**
  - Every datastore write operation (put/delete) is atomic
  - Outside of transactions, get READ_COMMITTED isolation
  - Support transactions (many ops on many objects)
    - Single-group transactions
    - Cross-group transactions with up to 5 groups
    - Transactions use snapshot isolation
  - Interesting details on transaction implementation: see 444
Microsoft Azure Platform

- “Internet-scale cloud computing and services platform”
- “Provides an operating system and a set of developer services that can be used individually or together”

SQL Azure

- “Cloud-based relational database service built on SQL Server® technologies”
- Key features
  - Highly available, scalable, multitenant database service
  - Includes authentication and authorization
  - No administration
  - Full-featured DBMS
- Key limitation
  - Only 50 GB at the moment

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Challenges of DBMS as a Service

- Scalability requirements
  - Large data volumes and large numbers of clients
  - Variable and heavy workloads
- High performance requirements: interactive web services
- Consistency and high availability guarantees
- Service Level Agreements
- Security

Broader Impacts

- Cost-effective solution for building web services
- Content providers focus only on their application logic
  - Service providers take care of administration
  - Service providers take care of operations
- Security/privacy concerns: all data stored in data centers