CS 839: Cloud-Native Database Systems
Lecture 1: Introduction

Xiangyao Yu
09/06/2023
Who am I?

Name: Xiangyao Yu

Assistant professor in Computer Sciences, Database Group

Research interests: database systems

- Cloud-native database
- New hardware for database
- Transactions and HTAP
Basic Information

Course website: https://pages.cs.wisc.edu/~yxy/cs839-f23

Instructor: Xiangyao Yu

Office hour:
  – Monday 4:00pm–5:00pm CS 4361

Piazza for discussions and questions
  – You will be automatically enrolled in piazza once enrolled in the class
Agenda

Cloud database overview

Course logistics
Databases Moving to the Cloud

According to Gartner Report [1]

$39.2 billion, 49% of all DBMS revenue from cloud in 2021

Cloud vs. On-premises Revenue

- **On-prem database**
  - $40.8B in 2021

- **Cloud database**
  - $39.2B in 2021

According to Gartner Report [1]

$39.2 billion, 49% of all DBMS revenue from cloud in 2021

Databases Moving to the Cloud

**Transactional DB**
- Amazon Aurora
- POLARDB
- Orleans
- SQL Server
- GaussDB
- TiDB
- CockroachDB
- yugabyteDB
- Azure Cosmos DB

**Analytical DB**
- Spark
- SQL
- snowflake
- mongoDB
- HIVE
- VERTICA
- presto
- Amazon Athena
- REDSHIFT
- Google BigQuery
- trino
Cloud Computing

On-premises

- Function
- Application
- Runtime
- Operating System
- Virtualization
- Server
- Storage
- Networking

Self-manage Hardware

IaaS

Infrastructure as a Service

- Function
- Application
- Runtime
- Operating System
- Virtualization
- Server
- Storage
- Networking

Self-deploy database

Managed by customer

Managed by provider
Cloud Computing

**On-premises**
- Function
- Application
- Runtime
- Operating System
- Virtualization
- Server
- Storage
- Networking

**IaaS**
Infrastructure as a Service
- Function
- Application
- Runtime
- Operating System
- Virtualization
- Server
- Storage
- Networking

Managed by customer

**SaaS**
Software as a Service
- Function
- Application
- Runtime
- Operating System
- Virtualization
- Server
- Storage
- Networking

Managed by provider

Self-manage Hardware
Self-deploy database
DB as a Service (DBaaS)
Cloud Databases

Cloud DB 1.0
- On-prem DB architecture in cloud Virtual Machines (VMs)
Cloud Databases

Cloud DB 1.0
  – On-prem DB architecture in cloud Virtual Machines (VMs)

Cloud-native databases (Cloud DB 2.0)
  – Storage disaggregation architecture
  – Serverless
  – Autoscaling
Cloud Databases

Cloud DB 1.0
- On-prem DB architecture in cloud Virtual Machines (VMs)

Cloud-native databases (Cloud DB 2.0)
- Storage disaggregation architecture
- Serverless
- Autoscaling

Next-gen cloud database (Cloud DB 3.0)?
- New hardware
- Multi-cloud
- Auto-tuning
- HTAP
New Challenges in Cloud Databases

New Requirements

- Geo-distribution
- High availability
- Low cost
- Elasticity
- Autoscaling

Solution: Modularity in distributed system design
Modular Distributed System Design

**Conventional** distributed system architecture
Modular Distributed System Design

Conventional distributed system architecture

Data Center Network

Concurrency control

Logging

Storage and Paxos/Raft
Modular Distributed System Design

**Conventional** distributed system architecture

- Data Center Network
- Concurrency control
- Logging
- Storage and Paxos/Raft

**Disaggregated** distributed system architecture

- Data Center Network

Each service is deployed as a separate distributed cluster
Disaggregated Distributed System

Advantages
- **Scalability**: Services can scale independently
- **Performance and cost**: Services can be custom optimized (e.g., low cost storage service)
- **Separation of concerns**: Services can be independently developed

Disadvantage
- Network can throttle performance
Cloud DB: Storage-Disaggregation

- **Compute cluster**: Database logic in computer cluster
- **Data Center Network**: Database states (e.g., tables and log) in cloud storage service
- **Storage as a Service (SaaS)**

Manage computation and storage as separate services
Advantages of Storage-Disaggregation

**Advantage #1: Elasticity**
– Compute and storage resources can scale independently
Advantages of Storage-Disaggregation

Advantage #1: Elasticity
– Compute and storage resources can scale independently

Storage-intensive workload

Compute-intensive workload
Advantages of Storage-Disaggregation

Advantage #2: Low Cost
– Storage service can be much cheaper than compute servers

<table>
<thead>
<tr>
<th></th>
<th>S3 storage price</th>
<th>16 vCPU Virtual Machine</th>
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</thead>
<tbody>
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<td>$0.02 per GB per month</td>
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Advantages of Storage-Disaggregation

**Advantage #2: Low Cost**

- Storage service can be much cheaper than compute servers

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![Diagram showing load and time]
Advantages of Storage-Disaggregation

Data Center Network

Compute cluster

Storage as a Service (SaaS)

Advantage #2: Low Cost

- Storage service can be much cheaper than compute servers

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Load

Cost of provisioning for peak

Time
Advantages of Storage-Disaggregation

Advantage #2: Low Cost

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![Diagram showing load and cost of previsioning for peak and elastic previsioning.](Image)
Advantages of Storage-Disaggregation

**Compute cluster**

**Data Center Network**

**Storage as a Service (SaaS)**

**Advantage #2: Low Cost**

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Cost of previsioning for peak

Cost of elastic previsioning

No compute cost at zero load

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Load

Cloud

Redis

TiKV

Azure Storage

RocksDB

Bigtable

25
Advantages of Storage-Disaggregation

**Advantage #3: Availability**
- Storage service provides high availability through geo-replication
- Leverage high availability in storage to simplify fault tolerance in database

Separation of concerns between database logic and replication protocols
Advantages of Storage-Disaggregation

Advantage #1: Elasticity
Advantage #2: Low Cost
Advantage #3: Availability

Storage-disaggregation architecture widely deployed in cloud databases

Redesign databases in storage-disaggregation architecture
Course Content

Storage disaggregation for analytics
Storage disaggregation for transactions
Course Content

Storage disaggregation for analytics
Storage disaggregation for transactions
Serverless
DBOS
Auto-scaling
Auto-tuning
Multi-cloud
Course Content

Storage disaggregation for analytics
Storage disaggregation for transactions
Serverless
DBOS
Auto-scaling
Auto-tuning
Multi-cloud
HTAP
New hardware
  - Memory disaggregation
  - GPU
  - RDMA
  - SmartNIC
Agenda

Cloud database overview

Course logistics
Course Information


Canvas page: [https://canvas.wisc.edu/courses/375821](https://canvas.wisc.edu/courses/375821)

Piazza: [https://piazza.com/class/lm5r0a40r6s1bd](https://piazza.com/class/lm5r0a40r6s1bd)
  – Can be accessed directly through canvas

Prerequisite: CS 564 or equivalent
Lecture Structure

Submit paper review before lecture
  – If multiple papers are provided, pick your favorite one

Mixture of presentations from instructor and students
  – 2-3 student presentations for most lectures
  – A presentation signup sheet will be provided before next lecture

Q/A and in-class group discussion

Summarize group discussion and submit to hotcrp
  – Each student needs to write 3-5 summaries during the entire semester.
Grading

Paper review: 25%

Class participation: 25%

Project proposal: 10%

Project presentation: 10%

Project final report: 30%
Paper Review (25%)

**Paper reading**: pick one paper to read per lecture

– username: cs839  password: dbguru
Paper Review (25%)

**Paper reading**: pick one paper to read per lecture
- username: cs839  password: dbguru

**Upload review**: [https://tbd.hotcrp.com](https://tbd.hotcrp.com) (must submit before the lecture starts in order to be graded)
- Overall merit
  - Accept or reject?
- Paper summary
  - What main research problem/challenge did the paper address?
  - What is the key contribution of the paper?
- **Comments and questions**
  - Aspects you like or dislike about the paper
  - Questions about that paper that you wish to be discussed in lecture
Paper Review (25%)

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**Grading:** You can skip up to 2 reviews without losing points; otherwise 1% of total grade (up to 25%) is deducted for each missing review
Class Participation

2-3 student presentations in most classes

Summary of group discussion
Course Project (50%)

In **groups of 2–4** students

Example project ideas will be provided but you are encouraged to propose your own ideas

- Project ideas for CS 764 2020–2022 are available on the course website
- Example CS 764 projects available on the course website (two papers based on course projects have been accepted to SIGMOD 2022 and SIGMOD 2023)
Course Project (50%)

In groups of 2–4 students

Example project ideas will be provided but you are encouraged to propose your own ideas

- Project ideas for CS 764 2020–2022 are available on the course website
- Example CS 764 projects available on the course website (two papers based on course projects have been accepted to SIGMOD 2022 and SIGMOD 2023)

Important dates

- Discuss project ideas with instructor: Oct. 9
- Create teams and submit proposal: Oct. 16
- Project meetings with instructor: TBD
- Presentation: Dec. 11 & 13
- Paper submission: Dec. 18
Computation Resources

CloudLab


Chameleon

https://www.chameleoncloud.org (project name: ngdb)
Waitlist

If you are enrolled but don’t want to take the class, please drop ASAP so that students on the waitlist can be enrolled

We manage the waitlist first-come-first-serve
Before next lecture

Read the following paper and **submit review**

- The review website will be ready (hopefully) in a few days