



TRƯỜNG ĐẠI HỌC BÁCH KHOA HÀ NỘI
HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

CAP theorem

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School of Information and Communication Technology

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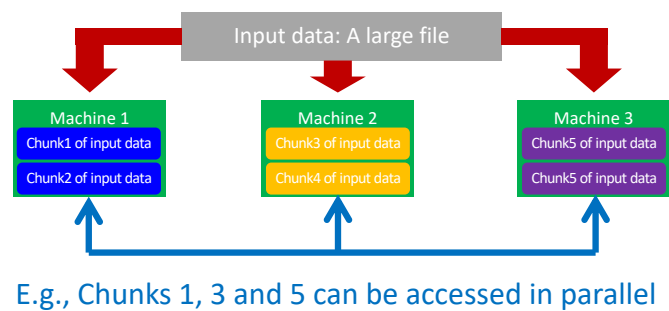
Scaling Traditional Databases

- Traditional RDBMSs can be either scaled:
 - Vertically (or Up)
 - Can be achieved by hardware upgrades (e.g., faster CPU, more memory, or larger disk)
 - Limited by the amount of CPU, RAM and disk that can be configured on a single machine
 - Horizontally (or Out)
 - Can be achieved by adding more machines
 - Requires database sharding and probably replication
 - Limited by the Read-to-Write ratio and communication overhead

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Data sharding

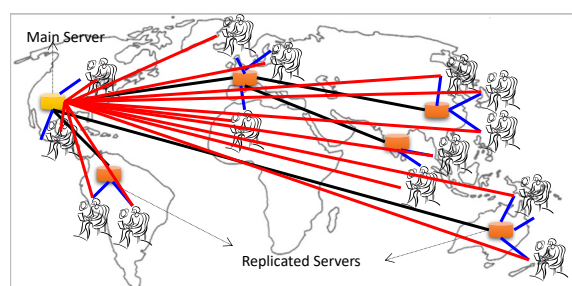
- Data is typically sharded (or striped) to allow for concurrent/parallel accesses
- Will it scale for complex query processing?



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Data replicating

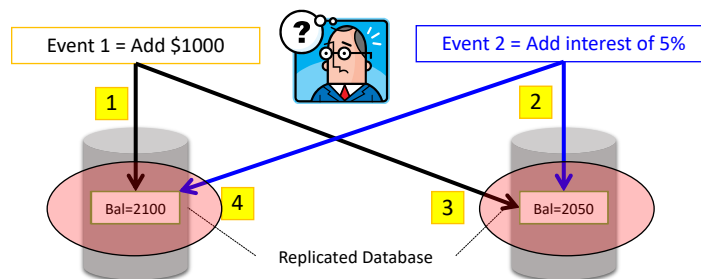
- Replicating data across servers helps in:
 - Avoiding performance bottlenecks
 - Avoiding single point of failures
 - And, hence, enhancing scalability and availability



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But, Consistency Becomes a Challenge

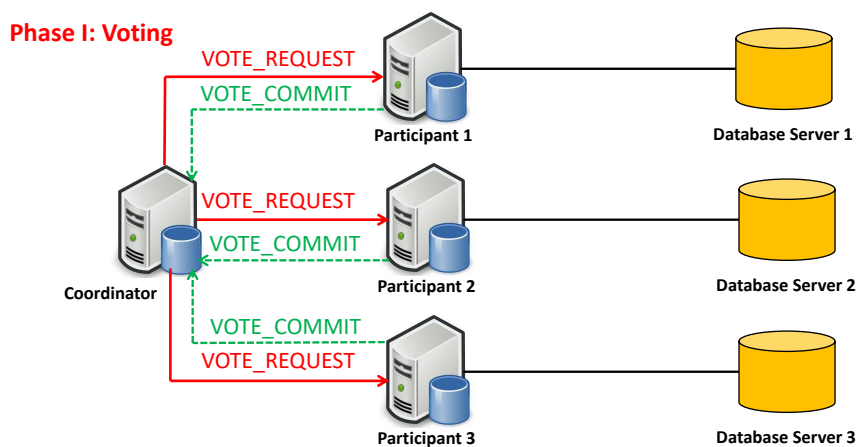
- An example:
 - In an e-commerce application, the bank database has been replicated across two servers
 - Maintaining consistency of replicated data is a challenge



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The Two-Phase Commit Protocol

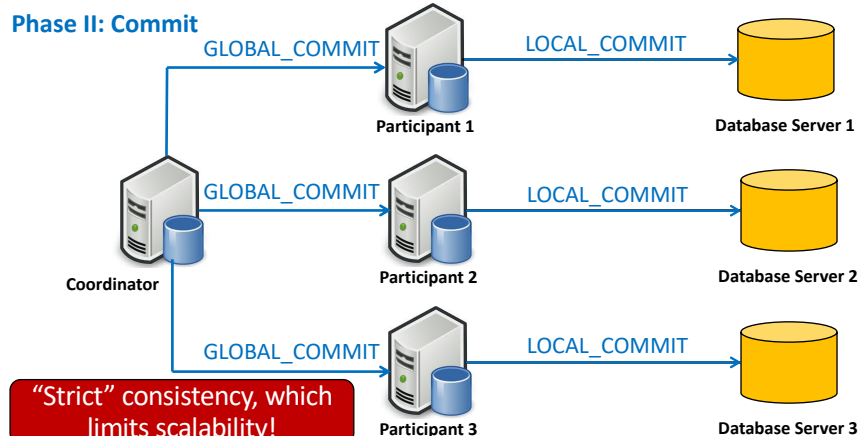
- The two-phase commit protocol (2PC) can be used to ensure atomicity and consistency



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The Two-Phase Commit Protocol

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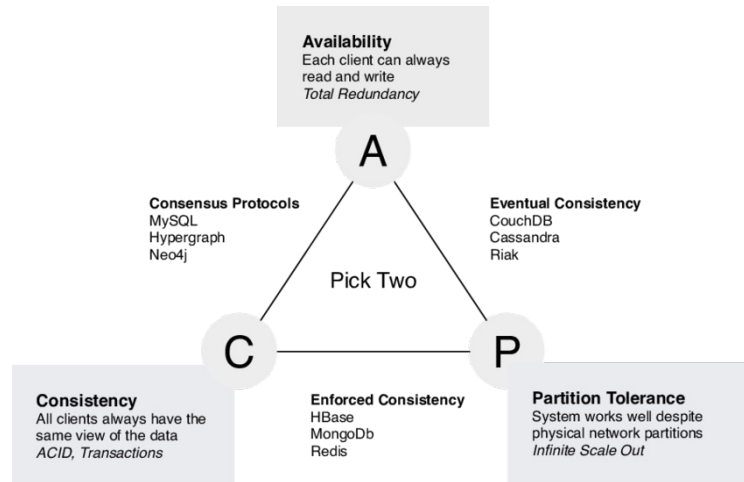
The CAP Theorem

- The limitations of distributed databases can be described in the so called the CAP theorem
 - Consistency: every node always sees the same data at any given instance (i.e., strict consistency)
 - Availability: the system continues to operate, even if nodes in a cluster crash, or some hardware or software parts are down due to upgrades
 - Partition Tolerance: the system continues to operate in the presence of network partitions

CAP theorem: any distributed database with shared data, can have at most two of the three desirable properties, C, A or P. These are trade-offs involved in distributed system by Eric Brewer in PODC 2000.

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CAP Theorem

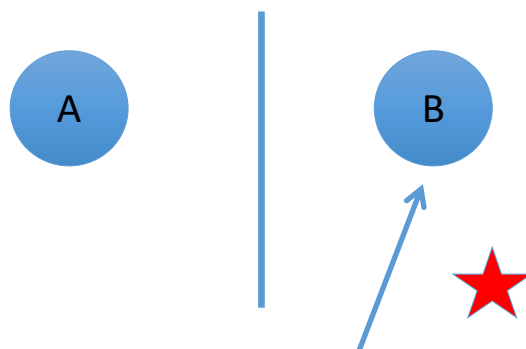


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CAP Theorem: Proof

- A simple proof using two nodes:

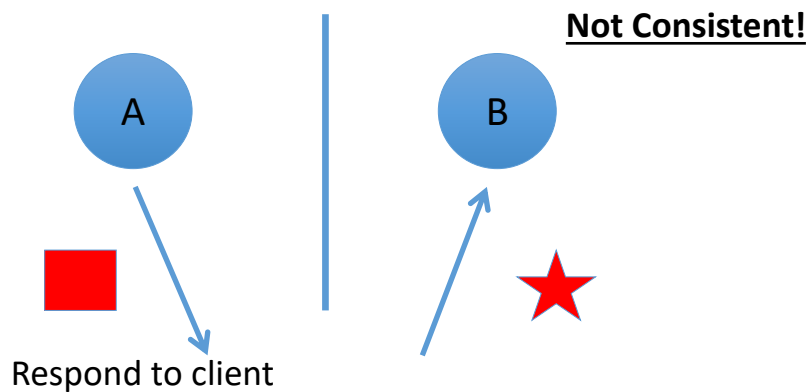


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CAP Theorem: Proof

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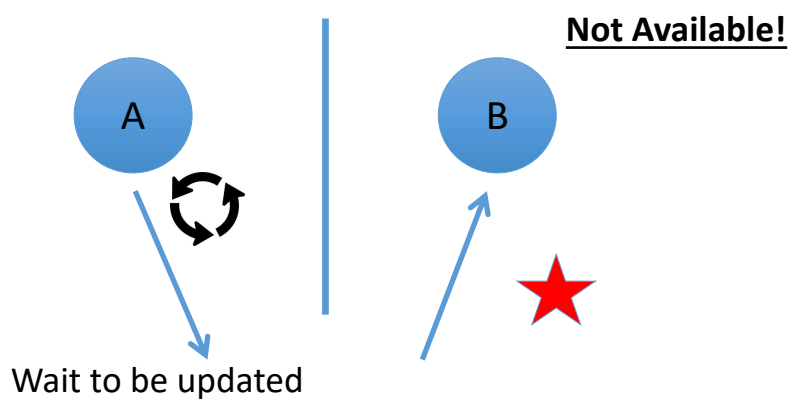


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CAP Theorem: Proof

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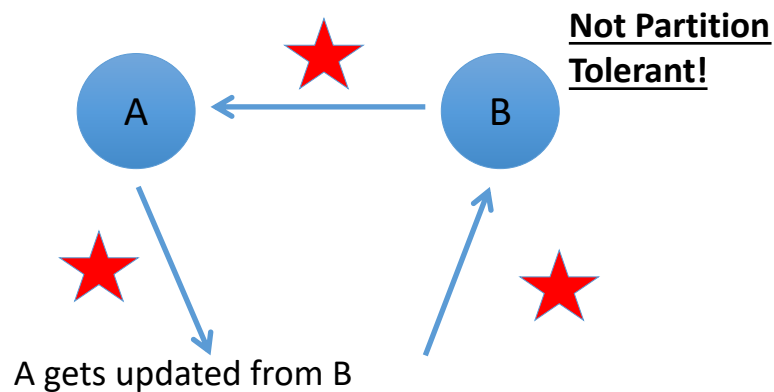


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CAP Theorem: Proof

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Scalability of relational databases

- The Relational Database is built on the principle of **ACID** (Atomicity, Consistency, Isolation, Durability)
- It implies that a truly distributed relational database should have **availability, consistency and partition tolerance**.
- Which unfortunately is **impossible** ...

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Large-Scale Databases

- When companies such as Google and Amazon were designing large-scale databases, 24/7 Availability was a key
 - A few minutes of downtime means lost revenue
- When horizontally scaling databases to 1000s of machines, the likelihood of a node or a network failure increases tremendously
- Therefore, in order to have strong guarantees on Availability and Partition Tolerance, they had to sacrifice “strict” Consistency (implied by the CAP theorem)

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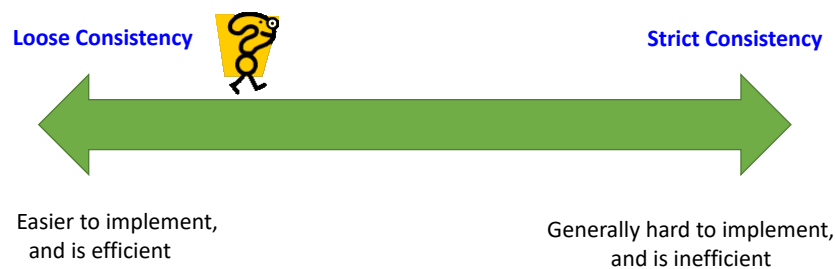
Trading-Off Consistency

- Maintaining consistency should balance between the strictness of consistency versus availability/scalability
 - Good-enough consistency depends on your application

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The BASE Properties

- The CAP theorem proves that it is impossible to guarantee strict Consistency and Availability while being able to tolerate network partitions
- This resulted in databases with relaxed ACID guarantees
- In particular, such databases apply the BASE properties:
 - Basically Available: the system guarantees Availability
 - Soft-State: the state of the system may change over time
 - Eventual Consistency: the system will eventually become consistent

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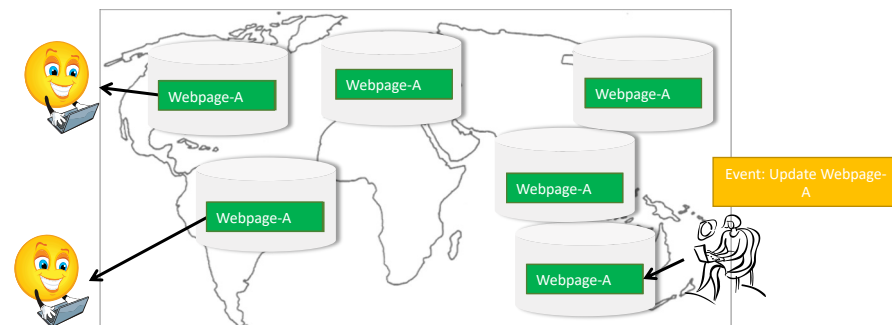
Eventual Consistency

- A database is termed as Eventually Consistent if:
 - All replicas will gradually become consistent in the absence of new updates

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Eventual Consistency

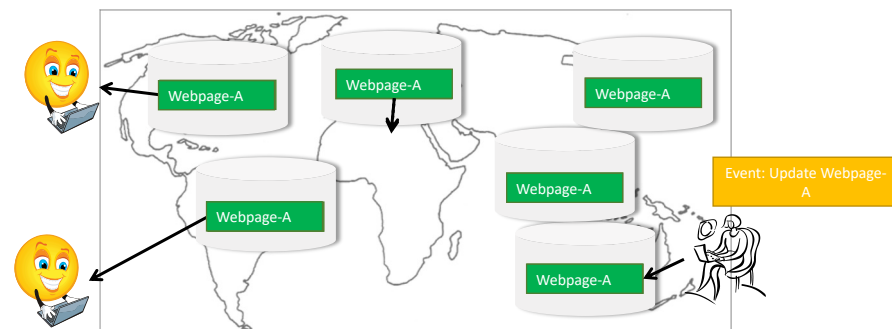
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Read-after-write consistency (eg. Amazon S3)

- But, what if the client accesses the data from different replicas?



Protocols like Read Your Own Writes (RYOW) can be applied!

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Thank you for your attention!
Q&A

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