07 SQL

- DBMS **和 KV 数据库**比较：In a key-value store, all the relationships and operations are managed **by the programmer** (**p29**左右)

关系模型（p32起）

关系relation, 元组tuple

怎么定位一个tuple？Table name + primary key

Short summary of relational model

Goal: hide the implementation detail of data behind a clean interface
– Yet, the interface is expressive enough
– The interface is also pr

Relational model
– Data model is based on set
– Data query language is based on set algebra

The query language (e.g., SQL) is **declarative**
– The developers only specify what they want

DML （Data Manipulation Languages）

- **procedural 过程式、declarative 声明式**

关系代数（p40-50）

复杂数据关系的表示（p59起）

- Duplication and normalizing 重复和规范化（p65）
- representing one-to-many 表示一对多关系（p66）

1. 解决方案1：**添加新表和外键**
2. 解决方案2：**document model 文档模型** （一对多关系）

Document model 文档模型（e.g. JSON）

- schema flexibility：任意修改schema
    - 关系数据库中的schema更改**很慢**

关系模型和文档模型对比

Summary: relational model vs. document model

Document model is a representative model in NoSQL databases

Benefits of **document model**
- Better locality
- Schema flexibility

Benefits of **relational model**
- Join supports
- Better modeling many-to-one & many-to-many relationships

OldSQL → NoSQL → NewSQL → HTAP

OldSQL（p81）

- **OldSQL = Relational Model + SQL + ACID**
- OLTP transaction
    - 生命周期短
    - 需要的数据量小

OldSQL = Relational Model + SQL + ACID

The architectural or historical baggage of SQL

Abstraction
- Relational + Transaction

Semantic
- ACID

Architecture
- Mostly focus on Single-node & On-disk

NoSQL（p91）

Scale Horizontally with Middleware 使用中间件横向扩展

- **[√]** Read/Write single Record
- **[×]** No Distributed Transaction & Join
    - Unavailable when: Changing schema - Server failover
    - Data Scaling & Re-sharding

tradeoff（p95-99）

- 简化数据模型 => 降低复杂度
- 弱化transaction，异步复制 => 牺牲一致性，换取scalability和availability

NoSQL - Build from scratch

How does NoSQL make trade off?
- Specific (simplified) data model
- Weaken Transaction
- Async Replication

Reducing the complexity of Relational Model (Mainly due to Join)

Sacrifice consistency for scalability & availability

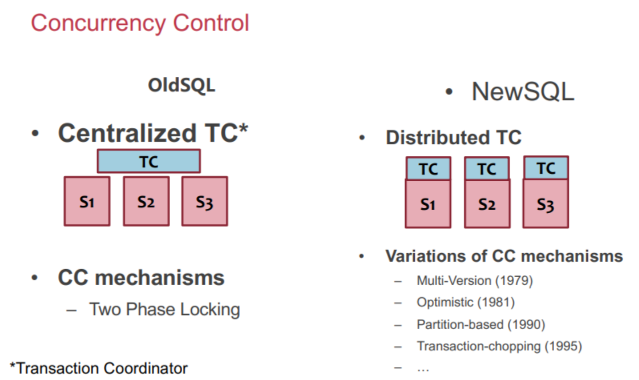
NewSQL（p105）

定义：A class of modern RDBMS, which provides:

- NoSQL’s Scalability
- SQL’s ACID Transaction & Relational Model

怎么扩展scale?

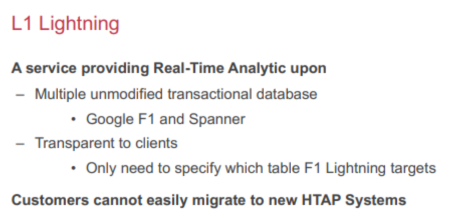
- **Shared-nothing Partitioning**

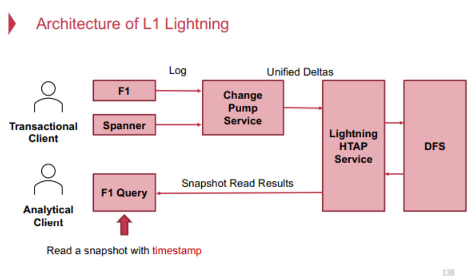


HTAP(Hybrid Transactional/Analytical Processing)（p131）

- **real-time analytics on fresh data**
- OLAP (ML)

L1 Lightning（p137-140）





08 Transactions

- **Atomicity**: TX is either performed entirety or not performed at all. **(rollback回滚)**
- **Cosistency**: Transaction must change the data from a consistent state to another
- **Isolation**: Two concurrently executed transactions are isolated from each other
- **Durability**: Once a transaction is committed, its changes must durably stored to a persistent storage

如何保证？ **(p28)**

- **I：一致性控制方法**

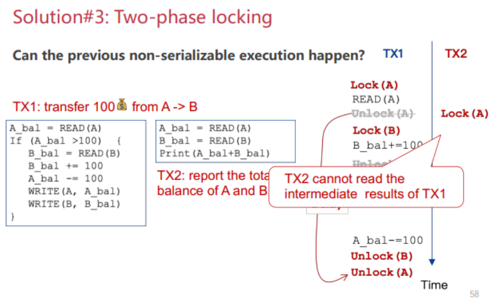
Serializability（p31）

- 是理想化的：**并发事务T1,T2,...,TN好像是按顺序执行的一样**
- 如何检查是不是serializability？replay the concurrent execution to a serial of reads/writes（**例子p35-42**）

Serializability的实现（p45）

使用锁lock

- 全局锁global lock：一次只能一个TX， 不并发（性能差）
- 简单细粒度锁simple fine-grained lock：每个record有一个锁（锁容易放太早，不正确）
- **Two-phase locking** 2PL：TX commit之后再放所有的锁 -> **保证Serializability**



2PL的问题——deadlock（p61）

解决方法：

Resolving deadlock

1. Acquire locks in a pre-defined order
- Not support general TX: TX must know the read/write sets before execution

2. Detect deadlock by calculating the conflict graph
- If there is a cycle, then there must be a deadlock
- Abort one TX to break the cycle
- High cost for detection

3. Using heuristics (e.g., timestamp) to pre-abort the TXs
- May have false positive, or live locks

Optimistic concurrency control -- OCC（p67）

- Executing TXs **optimistically** w/o acquiring the lock
- Checks the **results of TX** before it commits
  - If violate serializability, then **aborts & retries**

OCC Executes a Transaction in 3 Phases

Phase 1: Concurrent local processing
- Reads data into a read set
- Buffers writes into a write set

Phase 2: Validation in critical section
- Validates whether serializability is guaranteed:
- Has any data in the read set been modified?

Phase 3: Commit the results in critical section or abort
- Aborts: aborts the transaction if validation fails
- Commits: installs the write set and commits the transaction

具体例子（p69-80）

好处：

- phase1: Operates in **private** workspace; **rare inter-thread** synchronization (optimistic)
- phase2, 3: Needs synchronization, but usually very **short at low contention**

问题：

- False Aborts 错误的abort
- livelock：high contention情况下，一直abort，没有progress

Summary of realizing serializability

Pessimistic methods
- Presume that interference is likely
- Prevent any possibility of conflict actively
- E.g., global lock, 2-phase locking

Optimistic methods
- Allow write in any order and at any time
- If detect conflict, then "sorry, conflict write, please abort, clear the history and then retry"
- E.g., OCC

Modern Transaction Systems（p89）

HTM（p92）

intel RTM（p96）

Fun facts about RTM

How does Intel implement RTM?
- Basically, OCC!
- Use CPU cache to track TX’ s read/write sets

Why efficient?
- Cache is a perfect place for tracking TX’ s temporal updates
- Leverage existing cache coherence protocol to detect conflicts: reuse existing multi-core hardware to implement transactional memory!

Hardware support for transactional memory总结

- Easy programming model for the programmer
- Good performance if using properly
- However, the programmer should handle its pitfalls

DBX（p111）

a TX system to use **RTM for acceleration**, but **avoids its pitfalls** for TXs

Conclusion of DBX

RTM is a promising feature provided by Intel CPU

RTM alone is not sufficient for TXs

DBX provides a study of how to use RTM to accelerate in-memory databases

RTM can simplify the system building and get comparable performance
- Limitations of RTM force us to craft the transaction region and memory access pattern carefully

ROCOCO（p135）

回顾：优化TX的方向？Improve the TX algorithms properties

- E.g., better deadlock detection algorithms in 2PL
- E.g., reduce aborts in OCC

Overview of ROCOCO

1. Two-phase protocol

– Most pieces are executed at the second phase

2. Decentralized dependency tracking

– Servers track pieces' arrival order

– Identify non-serializable orders

– Deterministically reorder pieces

3. Offline workload checking

– Identifies safe workloads (common)

– Identifies small parts that need traditional approaches (rare)

Conclusion of ROCOCO

Traditional protocols perform poorly w/ contention

– OCC aborts & 2PL blocks

Rococo defers execution to enable reordering

– Strict serializability w/o aborting or blocking for common workloads

Rococo outperforms 2PL & OCC

– With growing contention

– Scales out