分布式事务一致性：协议设计与系统测试

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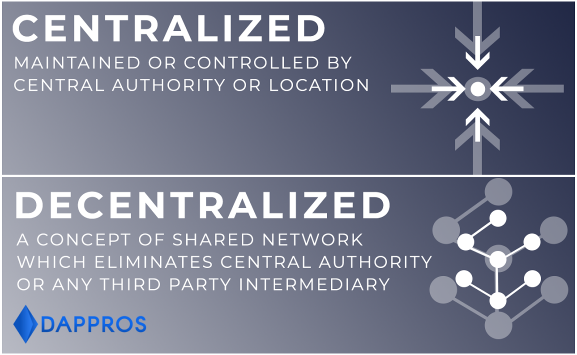
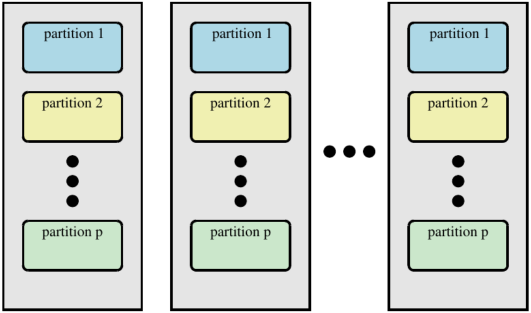
2022 年 11 月 04 日

集中式数据库 *vs.* 分布式数据库

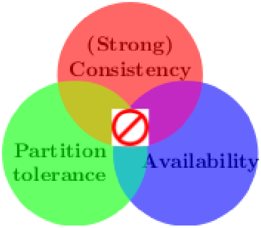


“数据分区 + 数据副本”系统架构

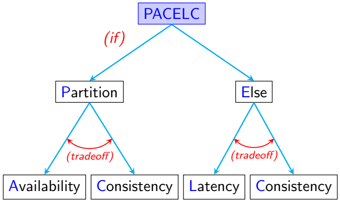


数据一致性问题

强一致性、高可用性、延迟、分区容忍性四者之间的权衡关系

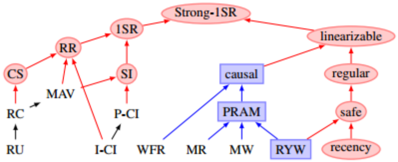


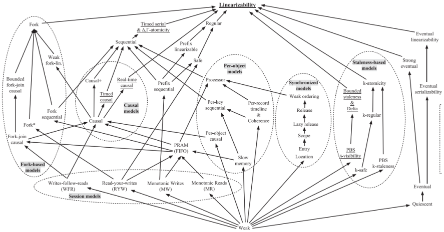
CAP Theorem



PACELC Tradeoff
[abadi:computer12]

使用强弱不同的数据一致性模型刻画不同的权衡





以数据一致性模型为核心的数据一致性理论

理论基础: 什么是不可能的? 下界是什么?

协议设计: 如何设计容错、高可扩展、高性能的协议?

系统测试: 复杂度是多少? 如何设计高效的测试算法?

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经典的分布式计算理论在技术发展的需求导向下与时俱进

研究工作第一阶段 ($\geq$ 2012)：读写寄存器 (Read/Write Register)

分布式 NoSQL Key-Value 数据库 (TODO: 重新画图)

TODO: +research outcomes

研究工作第二阶段 ($\geq$ 2017)：复制数据类型 (Replicated Data Types)

(a) Google Docs

(b) Apache Wave

TODO: Jupiter/Redis/Riak

(c) Wikipedia

Overleaf + ShareLaTeX

(d) LaTeX Editor

TODO: +research outcomes

研究工作第二阶段 ($\geq$ 2020)：分布式事务 (Distributed Transactions)
TODO: +research outcomes TODO: +logos

UniStore: A fault-tolerant marriage of causal and strong consistency

Manuel Bravo   Alexey Gotsman   Borja de Régil   Hengfeng Wei *
IMDEA Software Institute   *Nanjing University*

ATC'2021 (CCF A)

UniStore is the first fault-tolerant and scalable transactional data store that combines causal and strong consistency.

对协议设计有理论参考与应用指导价值

Partial Order-Restrictions Consistency (PoR consistency)

介于(事务) 因果一致性与可串行化之间

关键挑战 (一): 在容错的情况下保证系统的活性 (liveness)

关键挑战 (二): 严格的协议正确性证明

UniStore: A fault-tolerant marriage of causal and strong consistency

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负责严格的正确性证明工作
(完成 arXiv 完整版本中的 20 页证明)

在证明过程中发现协议中一处较为严重的错误
(同样存在于经典协议中)

弱一致性 (事务因果一致性): 低延迟、高可用

强一致性 (可串行化): 易理解, 易编程, 易于满足应用不变式

DEPOSIT WITHDRAW QUERY INTEREST

应用不变式: balance ≥ 0

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TODO: 事务因果一致性允许并发的 WITHDRAW 执行，提升性能

DEPOSIT　WITHDRAW　QUERY　INTEREST

应用不变式: balance ≥ 0

TODO: 事务因果一致性允许并发的 WITHDRAW 执行，提升性能

只有 WITHDRAW 需要使用强一致性, 按某种顺序执行

UniStore implements a transactional variant of Partial Order-Restrictions (PoR) consistency [Li@ACT'2018]

(I) 默认情况下, 使用事务因果一致性

(II) 允许用户定义事务之间的冲突关系; 冲突事务按顺序执行

Definition (Session Order)

A transaction t_1 precedes a transaction t_2 in the session order, denoted $t_1 \xrightarrow{so} t_2$, if they are executed by the same client and t_1 is executed before t_2.

Definition (Conflict Relation)

The conflict relation, denoted $\bowtie$, between transactions is a symmetric relation.

$$t_1 \bowtie t_2 \iff t_2 \bowtie t_1.$$

Consistency Model of UniStore

Definition (PoR)

A set of transactions $T \triangleq T_{causal} \uplus T_{strong}$ committed by UniStore satisfies PoR if there exists a causal order $\prec$ on T such that

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Causality: '$\prec$' is a partial order and $so \subseteq \prec$.

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- **Causality:** '$\prec$' is a partial order and $so \subseteq \prec$.
- **ConflictOrdering:** $\forall t_1, t_2 \in T_{strong}.\ t_1 \bowtie t_2 \implies t_1 \prec t_2 \lor t_2 \prec t_1$.
- **EventualVisibility:** A transaction $t \in T$ that is either strong or originates at a correct data center eventually become visible at all correct data centers: from some point on, t precedes in $\prec$ all transactions issued at correct data centers.

Consistency Model of UNISTORE

Definition (POR)

A set of transactions $T \triangleq T_{causal} \uplus T_{strong}$ committed by UNISTORE satisfies POR if there exists a causal order $\prec$ on T such that

CAUSALITY: '$\prec$' is a partial order and $so \subseteq \prec$.

CONFLICTORDERING: $\forall t_1, t_2 \in T_{strong}.\ t_1 \bowtie t_2 \implies t_1 \prec t_2 \lor t_2 \prec t_1$.

EVENTUALVISIBILITY: A transaction $t \in T$ that is either strong or originates at a correct data center eventually become visible at all correct data centers: from some point on, t precedes in $\prec$ all transactions issued at correct data centers.

RETVAL: INTRETVAL $\land$ EXTRETVAL

Consistency Model of UniStore

Consider a read r from key k in a transaction t.

IntRetVal : read from the latest update on k preceding r in t

$$\textsc{RetVal} = \textsc{IntRetVal} \land \textsc{ExtRetVal}$$

ExtRetVal : read from the last update on k
of the latest transaction (in an order consistent with $\prec$) preceding t

DEPOSIT WITHDRAW QUERY INTEREST

Invariant: balance ≥ 0

Declaring that strong transactions including WITHDRAW on the same account conflict.

Design Challenge of UniStore

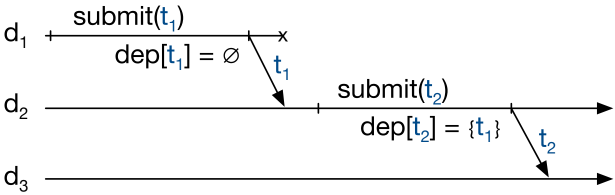
To satisfy liveness (EventualVisibility) despite failures

A transaction $t \in T$ that is either strong or originates at a correct data center eventually become visible at all correct data centers.

Design Challenge of UniStore (I)

d_1 本地提交了事务 t_1，

但在将 t_1 复制到 d_3 之前，d_1 出现故障



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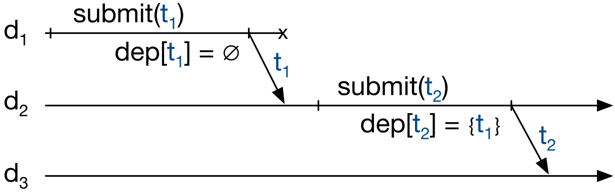

事务 t_2 依赖于 t_1,

因此, 在 d_3 上, t_2 可能永远不可见, 违反"活性"要求

Fault-tolerance of UniStore (I)

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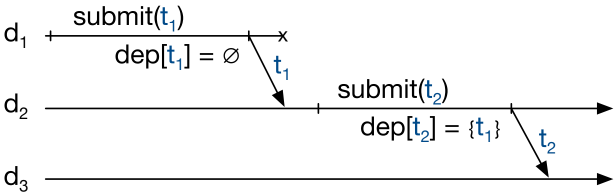

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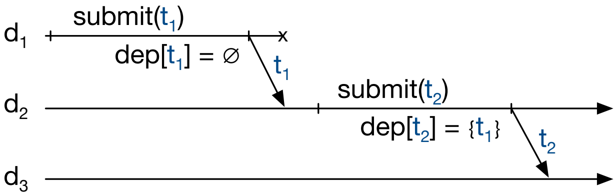
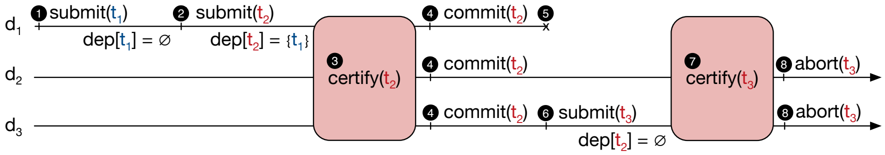


事务 t_2 依赖于 t_1，d_2 需要向 d_3 **转发** t_1

Data center d_1 crashes

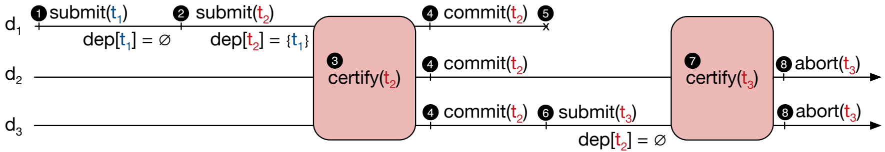
before t_1 is replicated to correct data center d_3.



Design Challenge of UNISTORE (II)

Data center d_1 crashes

before t_1 is replicated to correct data center d_3.

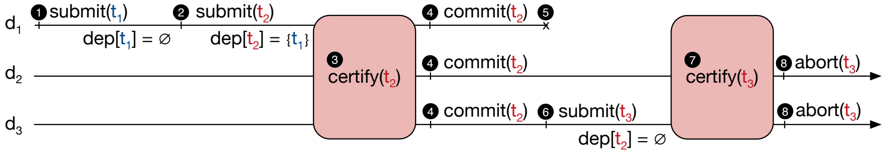


Transaction t_2 will never be visible at d_3.

No transaction t_3 conflicting with t_2 can commit (by CONFLICTORDERING).

Fault-tolerance of UniStore (II)

UniStore ensures that before a strong transaction commits, all its causal dependencies are uniform, i.e., will eventually become visible at all correct data centers.



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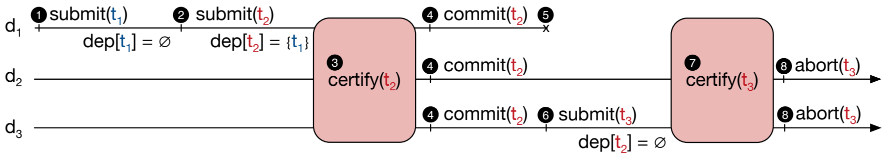


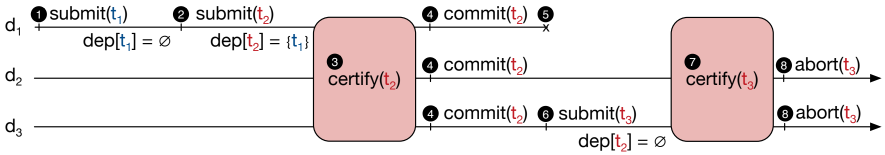
Transaction t_1 will eventually be visible at d_3.

Transaction t_2 will eventually be visible at d_3.

Transaction t_3 may be committed at d_3.

Performance of UniStore

Causal transactions remain highly-available, i.e., committed locally.



A strong transaction may have to wait for some of its dependencies to become uniform before committing.

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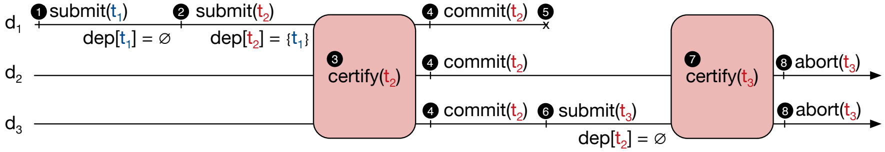


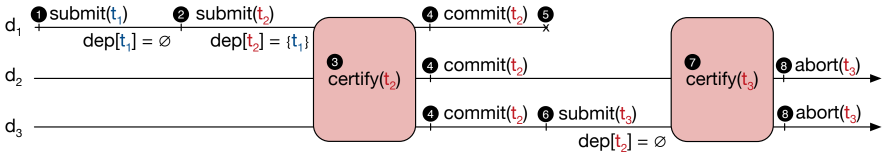
A strong transaction may have to wait for some of its dependencies to become uniform before committing.

However, this may cost too much.

Performance of UniStore

UniStore makes a remote causal transaction visible to clients only after it is uniform.

Causal transactions are executed on an (almost) uniform snapshot that may be slightly in the past.



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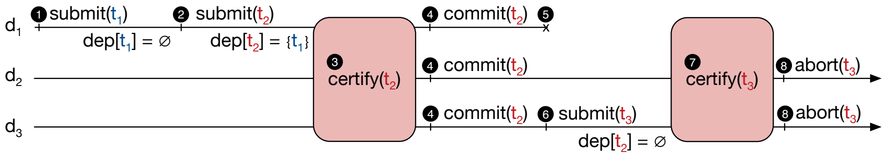


A strong transaction only needs to wait for causal transactions originating at the local data center to become uniform.

Scalability of UniStore

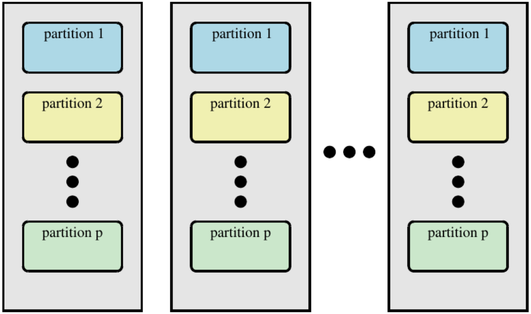
UniStore scales horizontally,

i.e., with the number of machines (partitions) in each data center.

System Model

$$\mathcal{D} = \{1, \ldots, D\} : \text{the set of data centers}$$

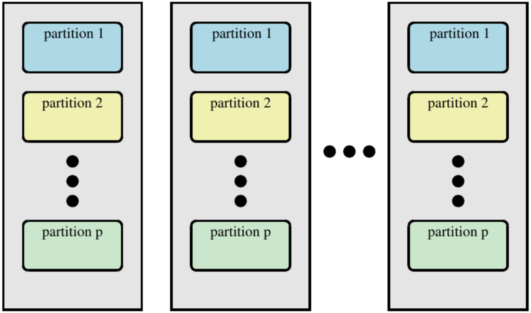
$$\mathcal{P} = \{1, \ldots, N\} : \text{the set of (logical) partitions}$$



p_d^m : the replica of partition m at data center d

System Model

$D = 2f + 1$ and $\leq f$ data centers may fail



Any two replicas are connected by a reliable FIFO channel.

Messages between correct data centers will eventually be delivered.

System Model

Replicas have loosely synchronized physical clocks.

The correctness of UNISTORE does not depend on the precision of clock synchronization.

Fault-tolerant Causal Consistency Protocol

Requirement: Tracking Uniformity

UNISTORE makes a remote causal transaction visible to clients only after it is uniform.

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Definition (Uniform)

A transaction is uniform if both the transaction and its causal dependencies are guaranteed to be eventually replicated at all correct data centers.

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Definition (Uniform)

A transaction is uniform if both the transaction and its causal dependencies are guaranteed to be eventually replicated at all correct data centers.

A transaction is considered uniform once it is visible at $f + 1$ data centers.

Metadata for Causal Transactions

Each transaction is tagged with a commit vector $commitVec$.

$$commitVec \in [\mathcal{D} \to \mathbb{N}]$$

For a transaction originating at data center d,
we call $commitVec[d]$ its local timestamp.

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Commit vectors are sent to sibling replicas
via replication and forwarding.

Metadata for Causal Transactions

Each replica p_d^m maintains the following three vectors:

$$\mathsf{knownVec} \in [\mathcal{D} \to \mathbb{N}]$$

$$\mathsf{stableVec} \in [\mathcal{D} \to \mathbb{N}]$$

$$\mathsf{uniformVec} \in [\mathcal{D} \to \mathbb{N}]$$

Metadata for Causal Transactions

$$\textsf{knownVec} \in [\mathcal{D} \to \mathbb{N}]$$

Property (Property of $\textsf{knownVec}$)

For each data center i,
the replica p_d^m stores the updates to partition m
by transactions originating at i with local timestamps $\leq \textsf{knownVec}[i]$.

Metadata for Causal Transactions

$$\mathsf{stableVec} \in [\mathcal{D} \to \mathbb{N}]$$

Property (Property of $\mathsf{stableVec}$)

For each data center i,

the data center d stores the updates

by transactions originating at i with local timestamps $\leq \mathsf{stableVec}[i]$.

Metadata for Causal Transactions

function $\textsc{broadcast\_vecs}()$

  send $\boxed{\textsc{knownvec\_local}}(m, \mathsf{knownVec})$ **to** p_d^l, $l \in \mathscr{P}$

  send $\textsc{stablevec}(d, \mathsf{stableVec})$ **to** p_i^m, $i \in \mathscr{D}$

  send $\textsc{knownvec\_global}(d, \mathsf{knownVec})$ **to** p_i^m, $i \in \mathscr{D}$

$$\mathsf{stableVec} \in [\mathcal{D} \to \mathbb{N}]$$

when received $\textsc{knownvec\_local}(l, knownVec)$

  $\mathsf{localMatrix}[l] \leftarrow knownVec$

  for $i \in \mathscr{D}$ **do**

    $\boxed{\mathsf{stableVec}[i] \leftarrow \min\{\mathsf{localMatrix}[n][i] \mid n \in \mathscr{P}\}}$

  $\mathsf{stableVec}[strong] \leftarrow \min\{\mathsf{localMatrix}[n][strong] \mid n \in \mathscr{P}\}$

Metadata for Causal Transactions

$$\mathsf{uniformVec} \in [\mathcal{D} \to \mathbb{N}]$$

Property (Property of $\mathsf{uniformVec}$)

All update transactions originating at i

with local timestamps $\le \mathsf{uniformVec}[i]$

are replicated at $f+1$ data centers including d.

Metadata for Causal Transactions

function BROADCAST_VECS()
  send KNOWNVEC_LOCAL(m, knownVec) **to** p_d^l, $l \in \mathscr{P}$
  send $\boxed{\text{STABLEVEC}}$(d, stableVec) **to** p_i^m, $i \in \mathscr{D}$
  send KNOWNVEC_GLOBAL(d, knownVec) **to** p_i^m, $i \in \mathscr{D}$

$$\text{uniformVec} \in [\mathcal{D} \to \mathbb{N}]$$

when received STABLEVEC(i, $stableVec$)
  stableMatrix[i] $\leftarrow$ $stableVec$
  $G \leftarrow$ all groups with $\boxed{f+1}$ replicas that include p_d^m
  for $j \in \mathscr{D}$ **do**
    var $ts \leftarrow \max\{\boxed{\min\{\text{stableMatrix}[h][j] \mid h \in g\}} \mid g \in G\}$
    uniformVec[j] $\leftarrow \max\{\text{uniformVec}[j], ts\}$

Metadata for Causal Transactions

$$\mathsf{uniformVec} \in [\mathcal{D} \to \mathbb{N}]$$

Lemma

All update transactions

with commit vectors $\leq \mathsf{uniformVec}$ *are uniform.*

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Lemma

All update transactions
with commit vectors $\leq \mathsf{uniformVec}$ *are uniform.*

UniStore makes a remote causal transaction visible to clients only after it is uniform.

Causal Consistency Protocol: Start

pastVec : causal past of client

1: **function** $\boxed{\text{START}()}$
2: p $\leftarrow$ a random partition in data center d
3: $\langle$tid, $snapVec\rangle \leftarrow$ **send** START_TX(pastVec) **to** p
4: pastVec $\leftarrow$ $snapVec$
5: **return** tid

$\forall i \in \mathcal{D} \setminus \{d\}$, all transactions originating at i with local timestamps $\leq \mathsf{pastVec}[i]$ are already uniform.

Causal Consistency Protocol: Start

Causal transactions are executed on an (almost) uniform snapshot.

```
function START_TX(V)
    for i ∈ 𝒟 \ {d} do
        uniformVec[i] ← max{V[i], uniformVec[i]}
    var tid ← generate_tid()
    snapVec[tid] ← uniformVec
    snapVec[tid][d] ← max{V[d], uniformVec[d]}
    snapVec[tid][strong] ← max{V[strong], stableVec[strong]}
    return ⟨tid, snapVec[tid]⟩
```

snapVec[tid][d] ensures “read-your-writes”.

Causal Consistency Protocol: Update

```
function UPDATE(k, v)
    _ ← send DO_UPDATE(tid, k, v) to p
    return ok
```

```
function DO_UPDATE(tid, k, v)
    var l ← partition(k)
    wbuff[tid][l][k] ← v
    rset[tid][l] ← rset[tid][l] ∪ {k}
    return ok
```

wbuff$[tid][l]$: buffer for the latest local update on each key

Causal Consistency Protocol: Read

function $\text{READ}(k)$
  $\langle v, c\rangle \leftarrow$ **send** $\text{DO\_READ}(\mathsf{tid}, k, \mathsf{lc})$ **to** p
  if $c \neq \perp$ **then**
    $\mathsf{lc} \leftarrow \mathsf{max}\{\mathsf{lc}, c\}$
  return v

function $\text{DO\_READ}(tid, k, c)$
  $\mathsf{lc} \leftarrow \mathsf{max}\{\mathsf{lc}, c\}$
  var $l \leftarrow \mathsf{partition}(k)$
  if $\mathsf{wbuff}[tid][l][k] \neq \perp$ **then**
    return $\langle \mathsf{wbuff}[tid][l][k], \perp\rangle$
  $\langle v, c\rangle \leftarrow$ **send** $\text{READ\_KEY}(\mathsf{snapVec}[tid], k)$ **to** p_d^l
  $\mathsf{rset}[tid][l] \leftarrow \mathsf{rset}[tid][l] \cup \{k\}$
  return $\langle v, c\rangle$

Causal Consistency Protocol: Read

Causal transactions are executed on an (almost) uniform snapshot.

when received $\boxed{\text{READ\_KEY}(snapVec, k)}$ **from** p
  for $i \in \mathscr{D} \setminus \{d\}$ **do**
    $\boxed{\mathsf{uniformVec}[i] \leftarrow \max\{snapVec[i], \mathsf{uniformVec}[i]\}}$
  wait until $\boxed{\mathsf{knownVec}[d] \geq snapVec[d]} \land \mathsf{knownVec}[strong] \geq snapVec[strong]$
  $\langle v, commitVec, c\rangle \leftarrow \boxed{\mathsf{snapshot}}(\mathsf{opLog}[k], snapVec)$ ▷ returns the latest $commitVec$ (in terms of Lamport clock order in Definition $\boxed{50}$) such that $commitVec \leq snapVec$
  send $\langle v, c\rangle$ **to** p

wait : ensure that it is as up-to-date as required by the snapshot

Causal Consistency Protocol: Commit

function $\boxed{\text{COMMIT\_CAUSAL\_TX()}}$

  $\langle vc, c \rangle \leftarrow$ **send** COMMIT_CAUSAL(tid, lc) **to** p

  pastVec $\leftarrow vc$

  lc $\leftarrow c$

  return ok

Causal Consistency Protocol: Commit

Read-only transactions returns immediately.

function $\boxed{\text{COMMIT\_CAUSAL}(tid, c)}$
  $\mathsf{lc} \leftarrow \max\{\mathsf{lc}, c\} + 1$
  if $\forall l \in \mathscr{P}.\ \mathsf{wbuff}[tid][l] = \emptyset$ **then**
    return $\langle \mathsf{snapVec}[tid], \mathsf{lc} \rangle$
  var $commitVec \leftarrow \mathsf{snapVec}[tid]$
  send $\boxed{\text{PREPARE}}(tid, \mathsf{wbuff}[tid][l], \mathsf{snapVec}[tid])$ **to** p_d^l, $l \in \mathscr{P}$
  for all $l \in \mathscr{P}$ **do**
    $\boxed{\textbf{wait receive } \text{PREPARE\_ACK}}(tid, ts)$ **from** p_d^l
    $commitVec[d] \leftarrow \max\{commitVec[d], ts\}$
  send $\boxed{\text{COMMIT}}(tid, commitVec, \mathsf{lc})$ **to** p_d^l, $l \in \mathscr{P}$
  return $\langle commitVec, \mathsf{lc} \rangle$

2PC protocol for update transactions

Causal Consistency Protocol: Commit

ts : prepare timestamp from its local clock

when received PREPARE$(tid, wbuff, snapVec)$ **from** p
  for $i \in \mathscr{D} \setminus \{d\}$ **do**
    $\mathsf{uniformVec}[i] \leftarrow \max\{snapVec[i], \mathsf{uniformVec}[i]\}$
  var $\boxed{ts \leftarrow \mathsf{clock}}$
  $\mathsf{preparedCausal} \leftarrow \mathsf{preparedCausal} \cup \{\langle tid, wbuff, ts\rangle\}$
  send PREPARE_ACK(tid, ts) **to** p

Causal Consistency Protocol: Commit

wait : ensure that its local clock is up-to-date

when received COMMIT$(tid, commitVec, c)$
  $\boxed{\textbf{wait until } \mathsf{clock} \geq commitVec[d]}$
  $\langle tid, wbuff, \_\rangle \leftarrow \mathsf{find}(tid, \mathsf{preparedCausal})$
  $\boxed{\mathsf{preparedCausal}} \leftarrow \mathsf{preparedCausal} \setminus \{\langle tid, \_, \_\rangle\}$
  for all $\langle k, v\rangle \in wbuff$ **do**
    $\mathsf{opLog}[k] \leftarrow \mathsf{opLog}[k] \cdot \langle v, commitVec, c\rangle$
  $\boxed{\mathsf{committedCausal}[d]} \leftarrow \mathsf{committedCausal}[d] \cup \{\langle tid, wbuff, commitVec, c\rangle\}$

$\mathsf{committedCausal}[d]$: for replication

Causal Consistency Protocol: Replication

Property (Property of knownVec)

For each data center i,

the replica p_d^m stores the updates to partition m

by transactions originating at i with local timestamps $\leq \mathsf{knownVec}[i]$.

function PROPAGATE_LOCAL_TXS()
    if $\mathsf{preparedCausal} = \emptyset$ **then**
        $\boxed{\mathsf{knownVec}[d] \leftarrow \mathsf{clock}}$
    else
        $\boxed{\mathsf{knownVec}[d] \leftarrow \min\{ts \mid \langle \_, \_, ts \rangle \in \mathsf{preparedCausal}\} - 1}$
    var $txs \leftarrow \{\langle \_, \_, commitVec, c \rangle \in \mathsf{committedCausal}[d] \mid commitVec[d] \leq \mathsf{knownVec}[d]\}$
    if $txs \neq \emptyset$ **then**
        send $\boxed{\text{REPLICATE}(d, txs)}$ **to** $p_i^m, i \in \mathcal{D} \setminus \{d\}$
        $\mathsf{committedCausal}[d] \leftarrow \mathsf{committedCausal}[d] \setminus txs$
    else
        send $\boxed{\text{HEARTBEAT}(d, \mathsf{knownVec}[d])}$ **to** $p_i^m, i \in \mathcal{D} \setminus \{d\}$

HEARTBEAT : for liveness

Adding Strong Transactions

Requirement: ConflictOrdering

$$\forall t_1, t_2 \in T_{strong}.\ t_1 \bowtie t_2 \implies t_1 \prec t_2 \lor t_2 \prec t_1.$$

Each strong transaction is assigned a scalar strong timestamp.

$$commitVec \in [\mathcal{D} \cup \{strong\} \to \mathbb{N}]$$

Metadata for Strong Transactions

$$\mathsf{knownVec} \in [\mathcal{D} \cup \{strong\} \to \mathbb{N}]$$

Property (Property of $\mathsf{knownVec}[strong]$)

Replica p_d^m stores the updates to m by all strong transactions with $commitVec[strong] \le \mathsf{knownVec}[strong]$.

Metadata for Strong Transactions

$$\mathsf{stableVec} \in [\mathcal{D} \cup \{strong\} \to \mathbb{N}]$$

when received KNOWNVEC_LOCAL$(l, knownVec)$
  $\mathsf{localMatrix}[l] \leftarrow knownVec$
  for $i \in \mathscr{D}$ **do**
    $\mathsf{stableVec}[i] \leftarrow \min\{\mathsf{localMatrix}[n][i] \mid n \in \mathscr{P}\}$
  $\mathsf{stableVec}[strong] \leftarrow \min\{\mathsf{localMatrix}[n][strong] \mid n \in \mathscr{P}\}$

Property (Property of $\mathsf{stableVec}[strong]$)

Data center d stores the updates by all strong transactions with $commitVec[strong] \le \mathsf{knownVec}[strong]$.

Metadata for Strong Transactions

$$\mathsf{uniformVec} \in [\mathcal{D} \to \mathbb{N}]$$

when received $\textsc{StableVec}(i, \mathit{stableVec})$
$\quad \mathsf{stableMatrix}[i] \leftarrow \mathit{stableVec}$
$\quad G \leftarrow$ all groups with $f+1$ replicas that include p_d^m
$\quad$ **for** $j \in \mathscr{D}$ **do**
$\quad\quad$ **var** $ts \leftarrow \max\{\min\{\mathsf{stableMatrix}[h][j] \mid h \in g\} \mid g \in G\}$
$\quad\quad \mathsf{uniformVec}[j] \leftarrow \max\{\mathsf{uniformVec}[j], ts\}$

The commit protocol for strong transactions guarantees their uniformity.

Strong Consistency Protocol: Commit

```
function COMMIT_STRONG(tid, c)
    UNIFORM_BARRIER(snapVec[tid])
    ⟨d, vc, c⟩ ← CERTIFY(tid, wbuff[tid], rset[tid], snapVec[tid], c)
    lc ← max{lc, c} + 1
    return ⟨d, vc, lc⟩
```

A strong transaction only needs to wait for causal transactions originating at the local data center to become uniform.

```
function UNIFORM_BARRIER(V, c)
    lc ← max{lc, c} + 1
    wait until uniformVec[d] ≥ V[d]
    return lc
```

Strong Consistency Protocol: Commit

function $\textsc{commit\_strong}(tid, c)$

$\quad \boxed{\textsc{uniform\_barrier}(\mathsf{snapVec}[tid])}$

$\quad \langle d, vc, c \rangle \leftarrow \boxed{\textsc{certify}}(tid, \mathsf{wbuff}[tid], \mathsf{rset}[tid], \mathsf{snapVec}[tid], c)$

$\quad \mathsf{lc} \leftarrow \max\{\mathsf{lc}, c\} + 1$

$\quad$ **return** $\langle d, vc, \mathsf{lc} \rangle$

$$\langle d \in \{\textsc{commit}, \textsc{abort}\}, vc \rangle \leftarrow \textsc{certify}(t)$$

Strong Consistency Protocol: Commit

function COMMIT_STRONG(tid, c)
$\boxed{\text{UNIFORM\_BARRIER}(\mathsf{snapVec}[tid])}$
$\langle d, vc, c\rangle \leftarrow \boxed{\text{CERTIFY}}(tid, \mathsf{wbuff}[tid], \mathsf{rset}[tid], \mathsf{snapVec}[tid], c)$
$\mathsf{lc} \leftarrow \max\{\mathsf{lc}, c\} + 1$
return $\langle d, vc, \mathsf{lc}\rangle$

$$\langle d \in \{\text{COMMIT}, \text{ABORT}\}, vc\rangle \leftarrow \text{CERTIFY}(t)$$

Multi-Shot Distributed Transaction Commit

Gregory Chockler
Royal Holloway, University of London, UK

Alexey Gotsman[1]
IMDEA Software Institute, Madrid, Spain

White-Box Atomic Multicast

Alexey Gotsman
IMDEA Software Institute

Anatole Lefort
Télécom SudParis

Gregory Chockler
Royal Holloway, University of London

2PC across partitions + Paxos among replicas of each partition

uses white-box optimizations that minimize the commit latency

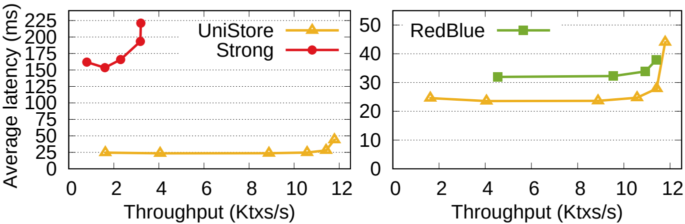
Strong Consistency Protocol: Deliver

upon DELIVER_UPDATES(W)
  for $\langle k, v, commitVec, c \rangle \in W$ in $\boxed{commitVec[strong] \text{ order}}$ **do**
    $\mathsf{opLog}[k] \leftarrow \mathsf{opLog}[k] \cdot \langle v, commitVec, c \rangle$
    $\mathsf{knownVec}[strong] \leftarrow commitVec[strong]$

Evaluation

Performance of UniStore

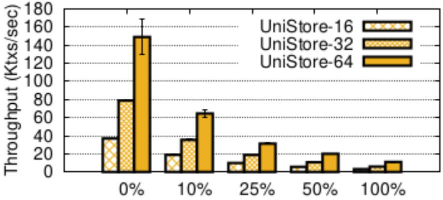
Throughput: 5% and 259% higher than RedBlue and Strong



RUBiS benchmark: throughput vs. average latency.

Latency: 24ms vs. 32ms of RedBlue and 162ms of Strong

Scalability of UniStore



Scalability when varying the ratio of strong transactions.

UniStore is able to scales almost linearly.

Evaluation

For more evaluations, please refer to the paper.

Conclusion

UNISTORE is a fast, scalable, and fault-tolerant

transactional distributed key-value store

that supports a combination of weak and strong consistency.

Conclusion

UniStore is a fast, scalable, and fault-tolerant

transactional distributed key-value store

that supports a combination of weak and strong consistency.

"We expect the key ideas in UniStore to pave the way for practical systems that combine causal and strong consistency."

总结

魏恒峰 (hfwei@nju.edu.cn)

聘期合同要求	工作情况
教学: 承担一门课程	问题求解课程 五个学期; 共 164 学时 (2019 级本科生 “我心目中的好课程”)
科研: 4-6 篇高水平论文	发表 3 篇 (含 1 篇短文) 在审 4 篇 (2017 年 CCF 优秀博士学位论文奖)
人才培养	负责或协助指导学生 9 人次 (学术积累: 组织 TLA^+ 与 Coq 讨论班)
主持/参与 多个基金项目	主持 1 项; 参与 1 项 个人可支配总经费 75 万元

Hengfeng Wei (hfwei@nju.edu.cn)