Specification and Implementation of Replicated List

— The Jupiter Protocol Revisited

(Brief Announcement at PODC'2018)

Hengfeng Wei, Yu Huang, Jian Lu

Nanjing University

July 24, 2018

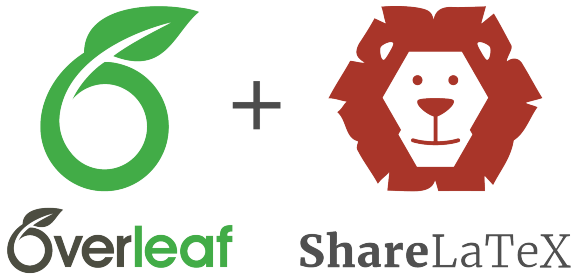
Background

Collaborative Text Editing Systems

(a) Google Docs

(b) Apache Wave

(c) Wikipedia



(d) LaTeX Editor

Replication (for availability)

Replication (for availability)

- Replicas respond to user operations immediately
  - Updates are propagated asynchronously

List

$\textsc{Ins}(a, p)$: Insert a at position p.

$\textsc{Del}(p)$: Delete an element at position p.

$\textsc{Read}$: Return the list.

List

$\textsc{Ins}(a, p)$: Insert a at position p.

$\textsc{Del}(p)$: Delete an element at position p.

$\textsc{Read}$: Return the list.

To implement a highly available replicated list object.

Definition (Eventual Convergence (EC) [])

The lists at all replicas are identical *at quiescence*.

Definition (Strong Eventual Consistency (SEC) [])

The lists at the replicas that *have executed the same set of user operations* are identical.

Definition (Eventual Convergence (EC) [])

The lists at all replicas are identical *at quiescence*.

Definition (Strong Eventual Consistency (SEC) [])

The lists at the replicas that *have executed the same set of user operations* are identical.

Specify little on *intermediate states* going through by replicas.

Specification and Complexity of Collaborative Text Editing

Hagit Attiya
Technion

Sebastian Burckhardt
Microsoft Research

Alexey Gotsman
IMDEA Software Institute

Adam Morrison
Technion

Hongseok Yang
University of Oxford

Marek Zawirski*
Inria & Sorbonne Universités,
UPMC Univ Paris 06, LIP6

Strong/Weak List Specification []

Specify global properties on all (intermediate) states at all replicas.

Specification and Complexity of Collaborative Text Editing

Hagit Attiya
Technion

Sebastian Burckhardt
Microsoft Research

Alexey Gotsman
IMDEA Software Institute

Adam Morrison
Technion

Hongseok Yang
University of Oxford

Marek Zawirski*
Inria & Sorbonne Universités,
UPMC Univ Paris 06, LIP6

Strong/Weak List Specification []

Specify global properties on all (intermediate) states at all replicas.

Proved: RGA [**?**] satisfies the strong list spec.

Conjecture: *Jupiter* [**?**] satisfies the weak list spec.

Does Jupiter satisfy the weak list specification?

Yes, it does.

Weak List Specification

Definition (Weak List Specification $\mathcal{A}_{\text{weak}}$ [?])

Informally, $\mathcal{A}_{\text{weak}}$ requires the ordering between elements that are not deleted to be consistent across the system.

Definition (Weak List Specification $\mathcal{A}_{\text{weak}}$ [?])

Informally, $\mathcal{A}_{\text{weak}}$ requires the ordering between elements that are not deleted to be consistent across the system.

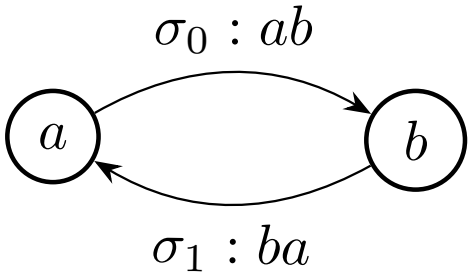
Pairwise state compatibility property:

$$\forall \sigma, \sigma' : a, b \in \sigma \cap \sigma' \implies (a \prec_\sigma b \iff a \prec_{\sigma'} b)$$

$(\sigma, \sigma' :$ list; $\quad a, b :$ element; $\quad \prec_\sigma :$ precedes$)$

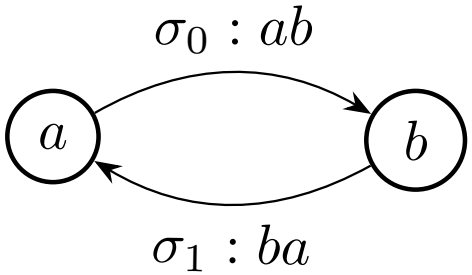
$$\forall \sigma, \sigma' : a, b \in \sigma \cap \sigma' \implies (a \prec_{\sigma} b \iff a \prec_{\sigma'} b)$$

$\boxed{\sigma_0 : ab}$ $\boxed{\sigma_1 : ba}$

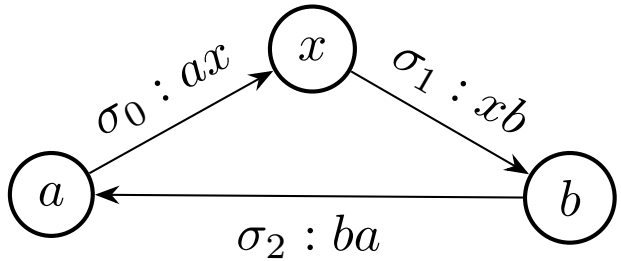


$$\forall \sigma, \sigma' : a, b \in \sigma \cap \sigma' \implies (a \prec_{\sigma} b \iff a \prec_{\sigma'} b)$$

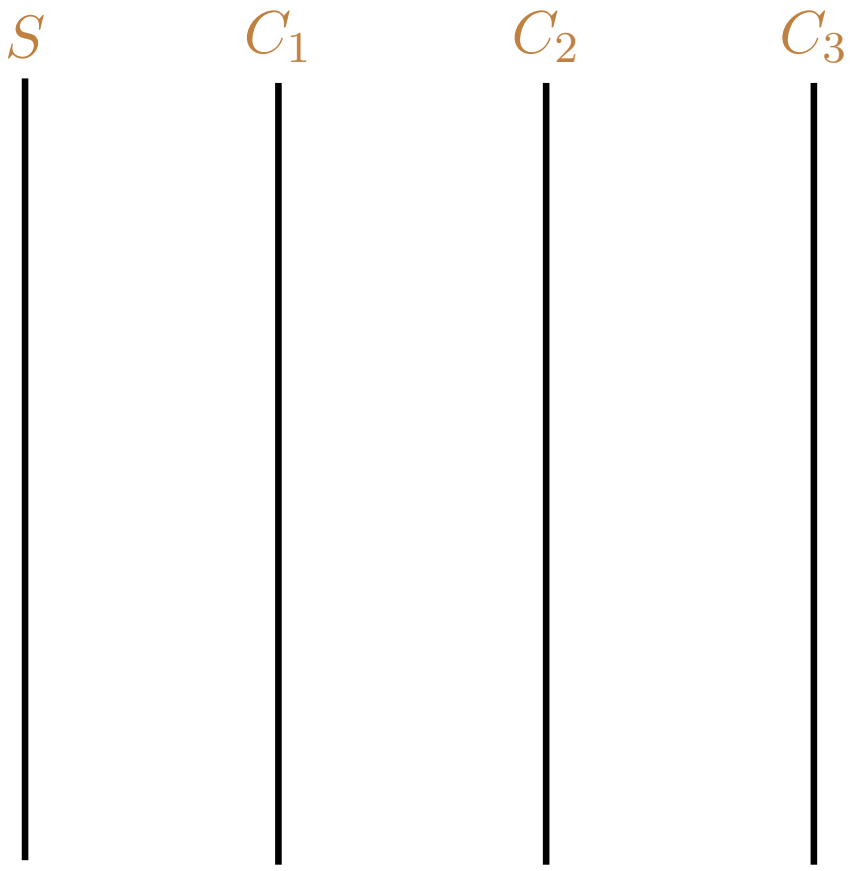
$\boxed{\sigma_0 : ab}$ $\boxed{\sigma_1 : ba}$



$\boxed{\sigma_0 : ax}$ $\boxed{\sigma_1 : xb}$ $\boxed{\sigma_2 : ba}$

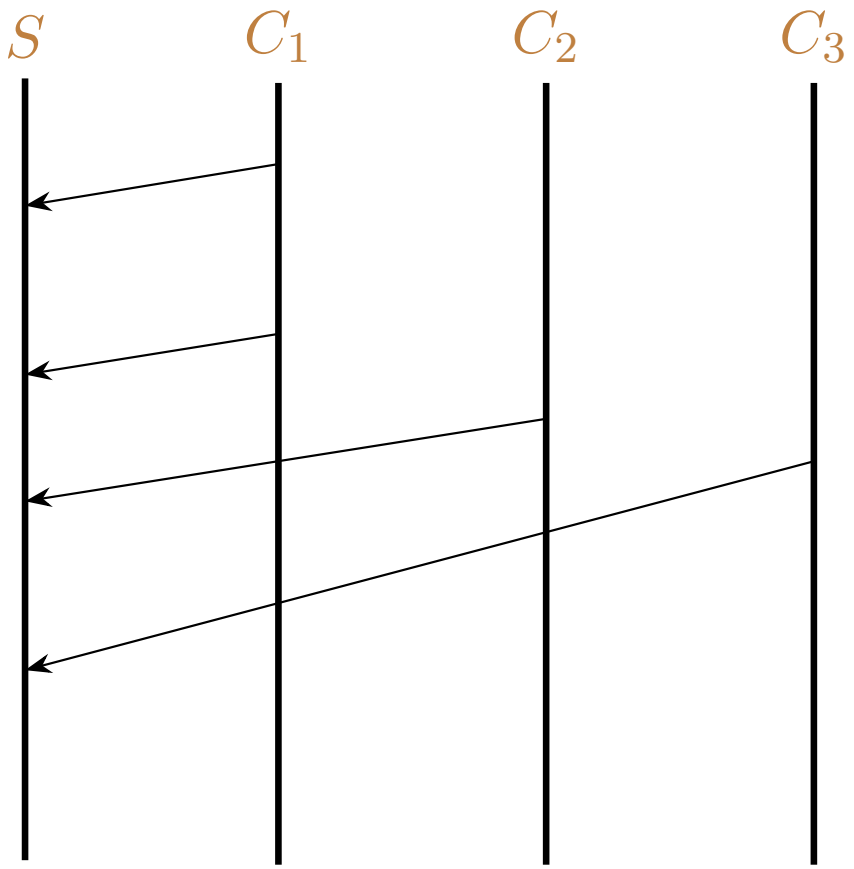


Jupiter



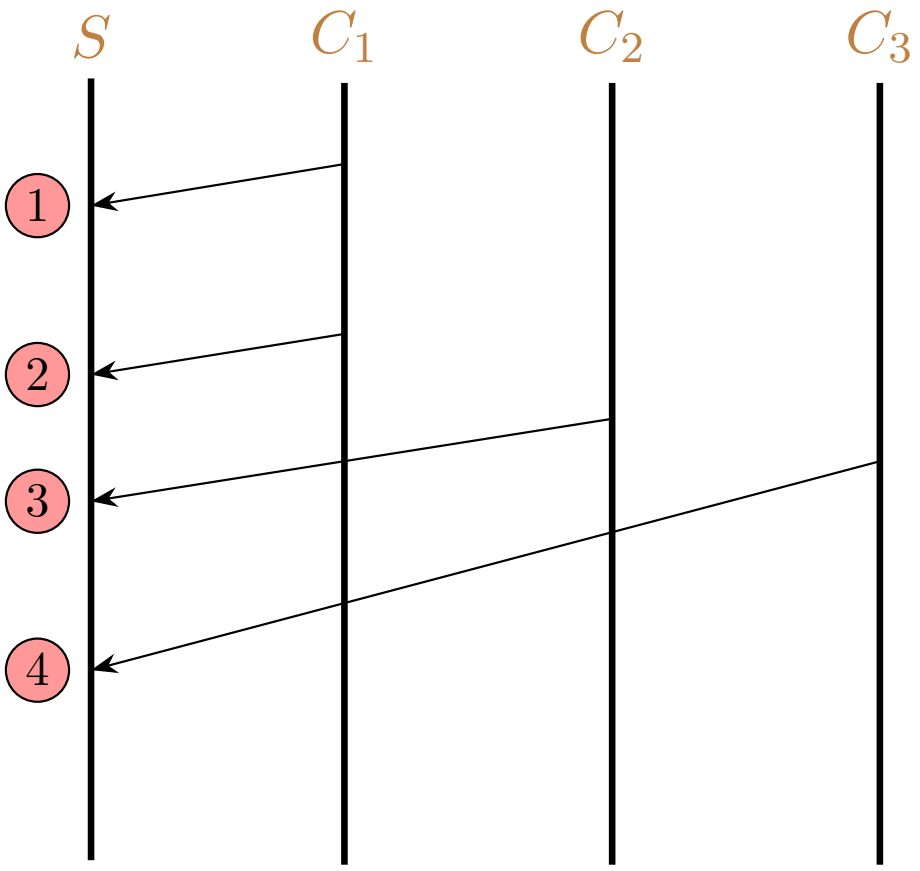
System model of Jupiter:

- client-server architecture



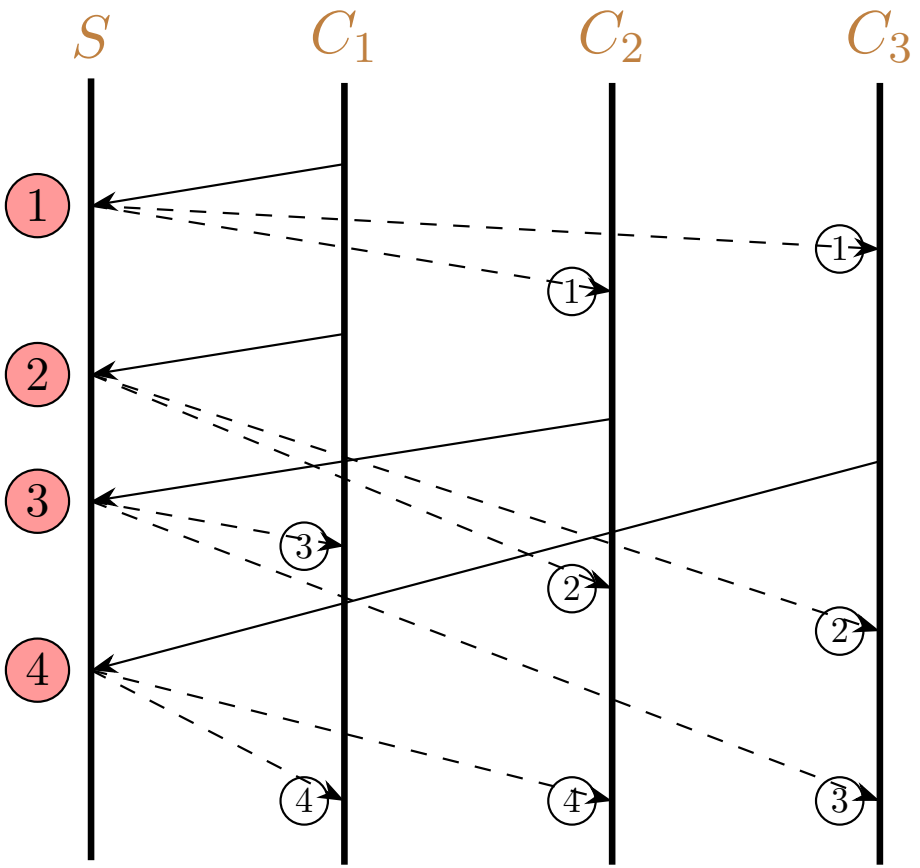
System model of Jupiter:

- client-server architecture
- client $\xrightarrow{\text{FIFO}}$ server



System model of Jupiter:

- client-server architecture
- client $\xrightarrow{\text{FIFO}}$ server
- totally ordered at the server

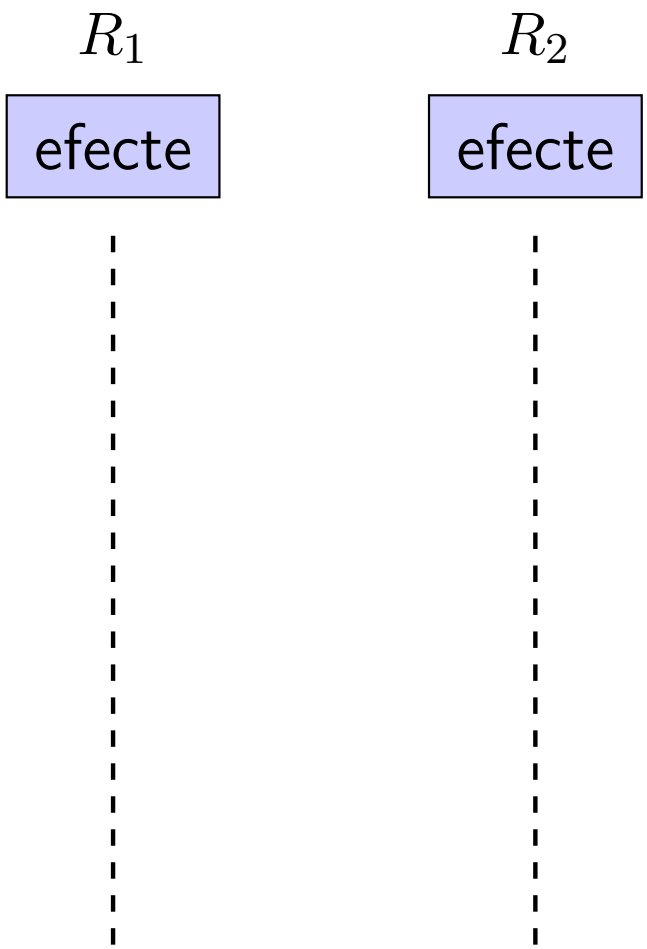


System model of Jupiter:

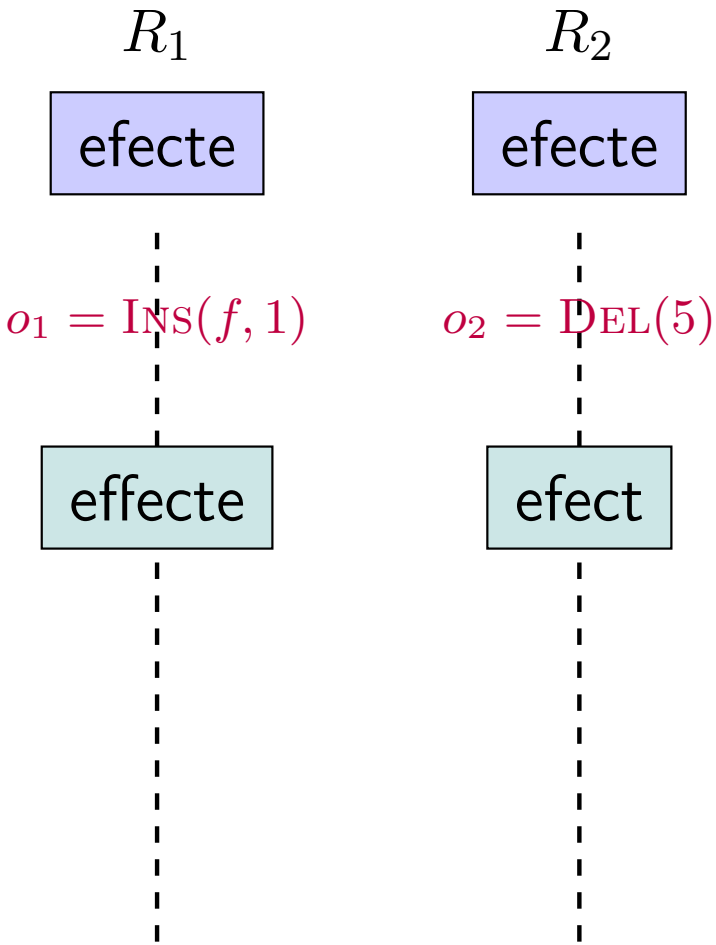
- client-server architecture
- client $\xrightarrow{\text{FIFO}}$ server
- totally ordered at the server
- server $\xrightarrow{\text{FIFO}}$ client

OT (Operational Transformation) []

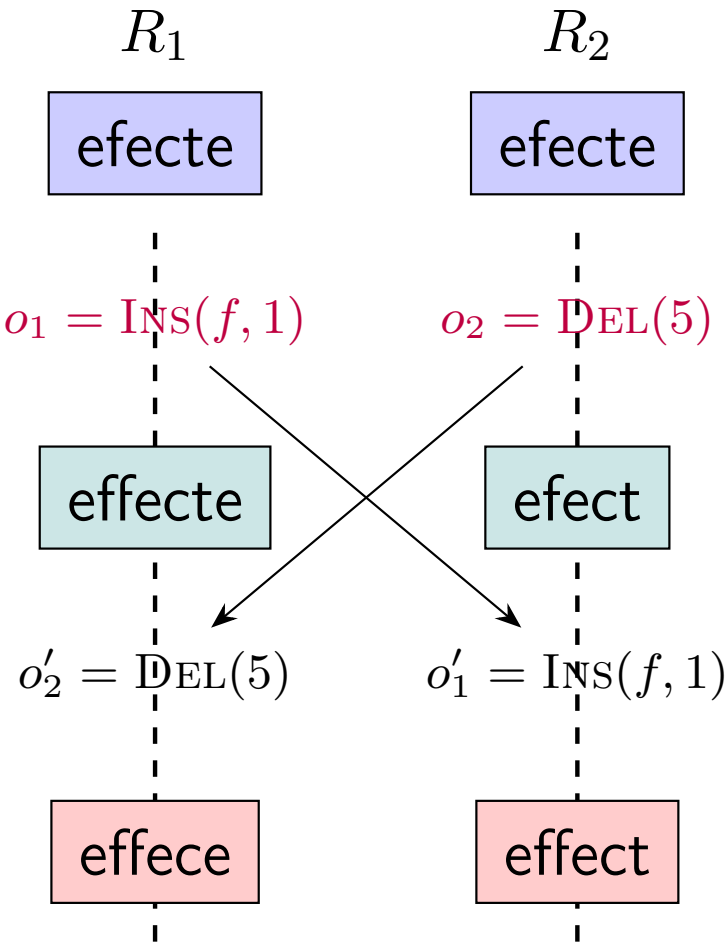
OT (Operational Transformation) []



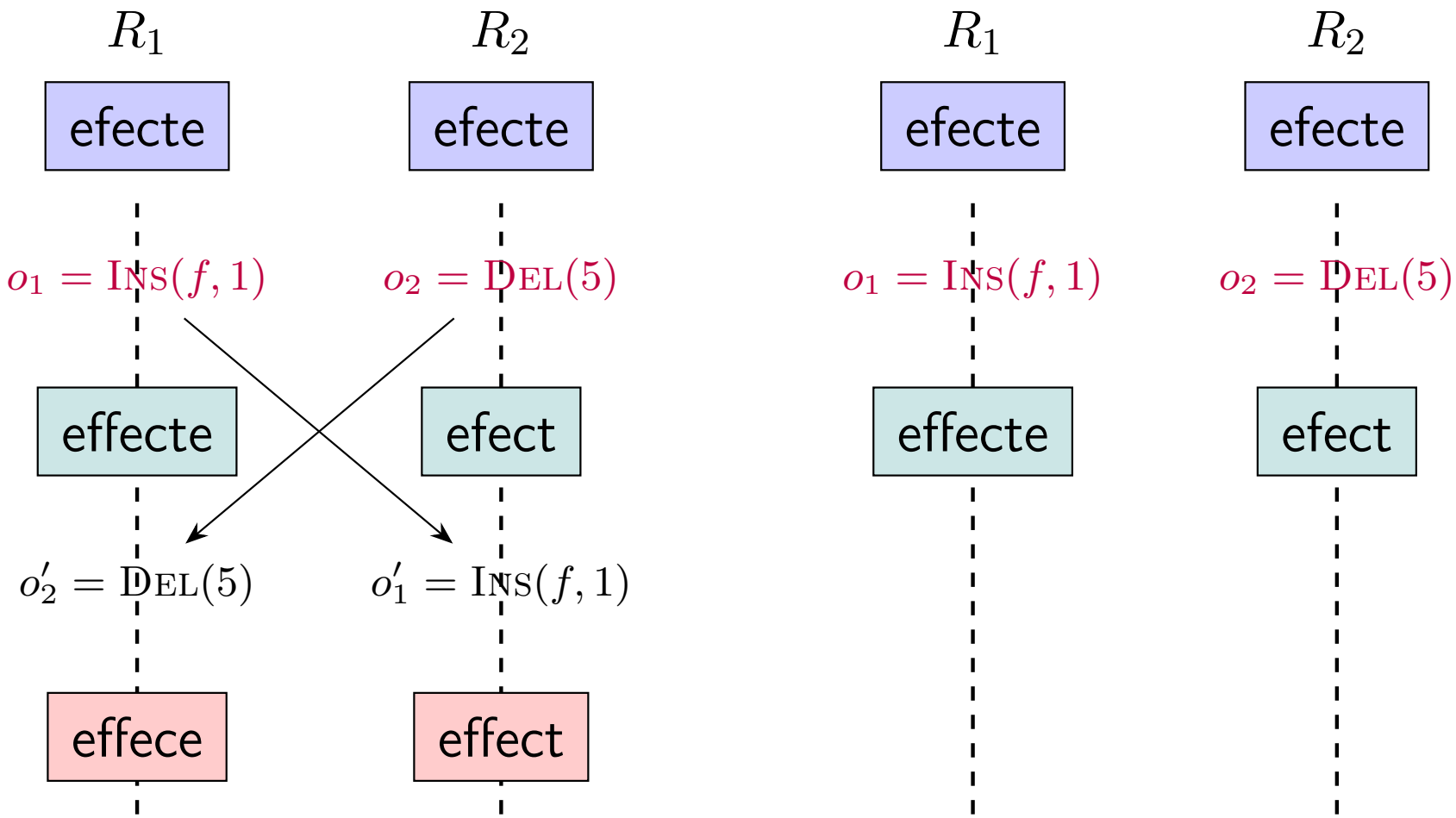
OT (Operational Transformation) []



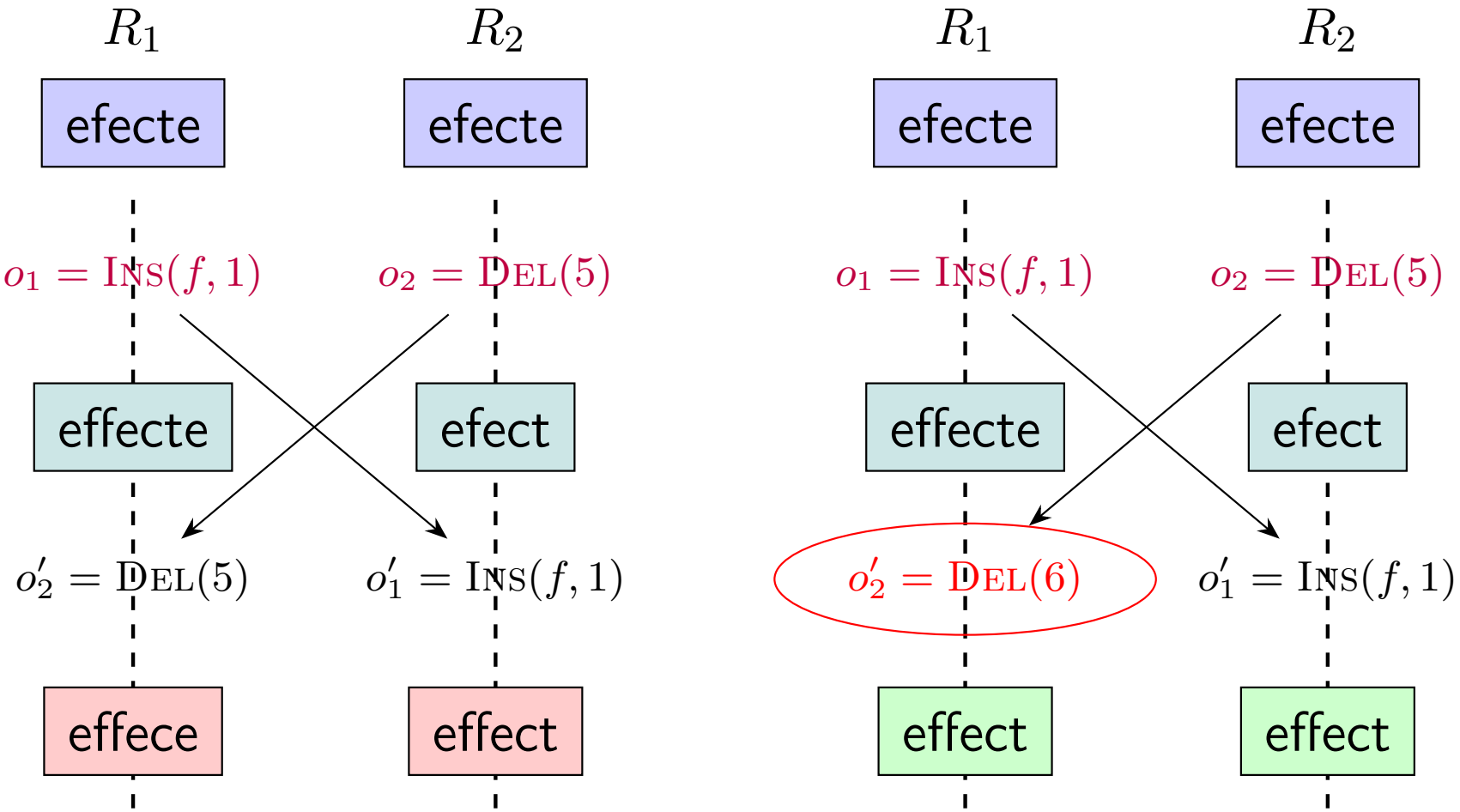
OT (Operational Transformation) []

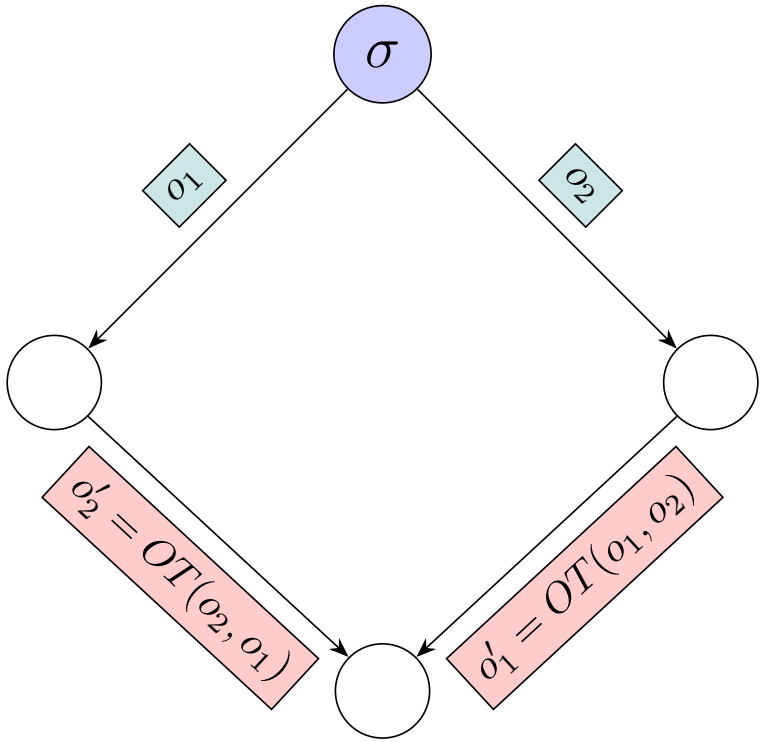


OT (Operational Transformation) []



OT (Operational Transformation) []



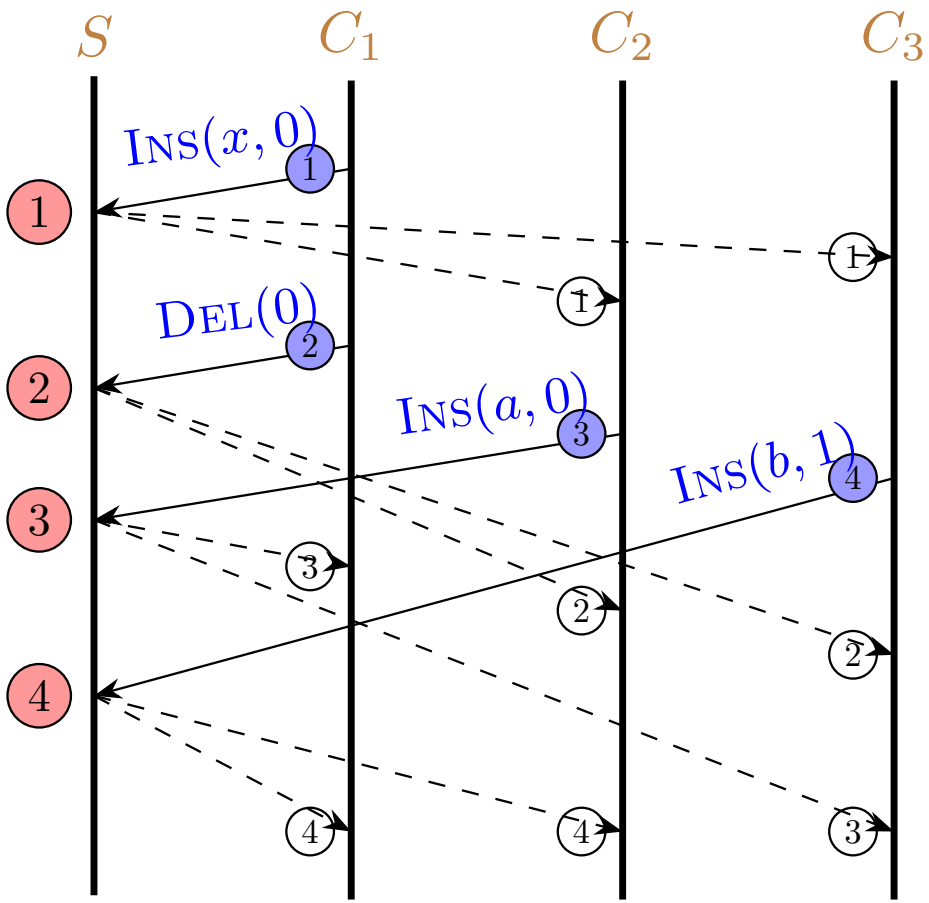


$$\sigma; o_1; o_2' \equiv \sigma; o_2; o_1' \ []$$

Jupiter uses $2D$ state spaces []
to manage how and when to perform OTs.

fig here

Consider a replicated system with n clients.



Each client maintains a $2D$ state space.

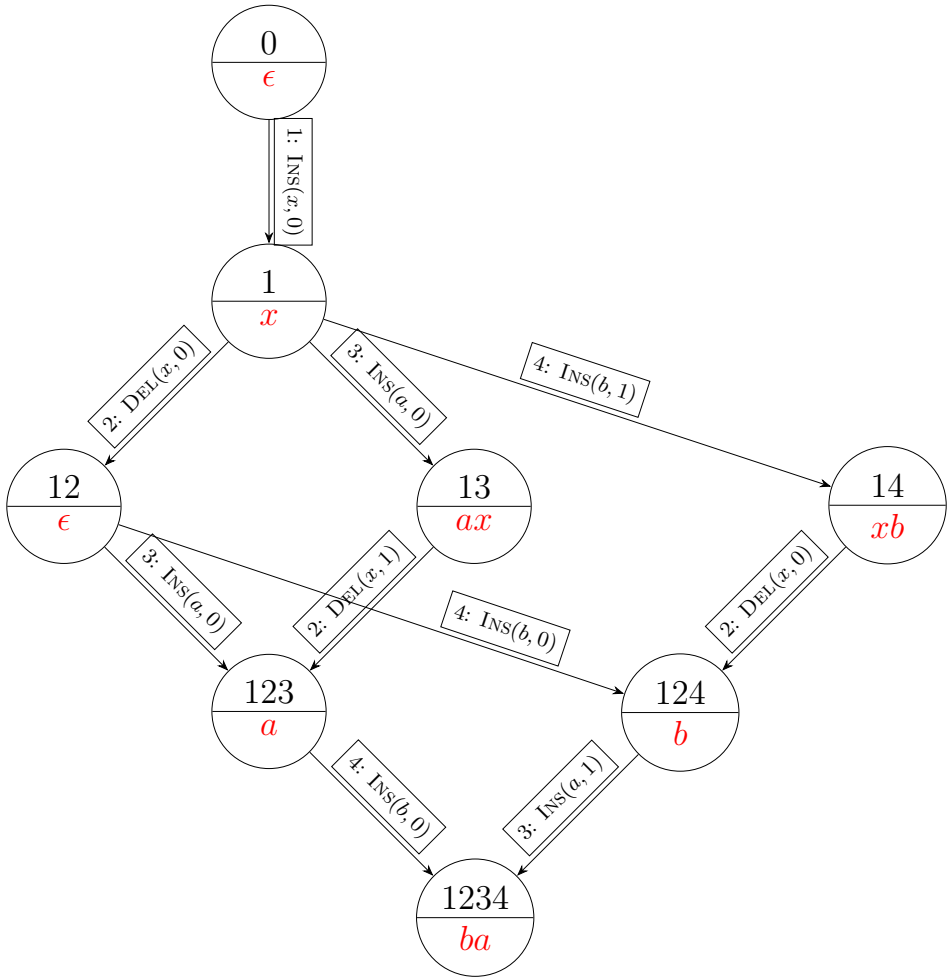
The server maintains n $2D$ state spaces, one for each client.

Global property on all replica states
specified by the weak list specification

Local view each replica maintains in Jupiter

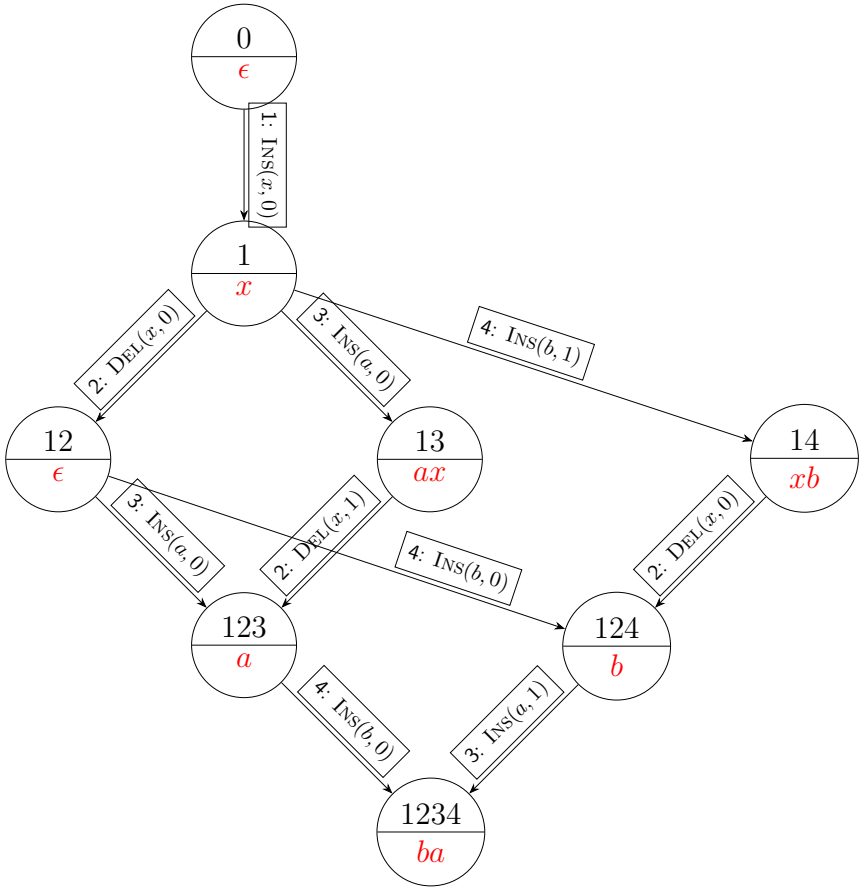
CJupiter (Compact Jupiter)

CJupiter maintains an n-ary ordered state space for each replica.



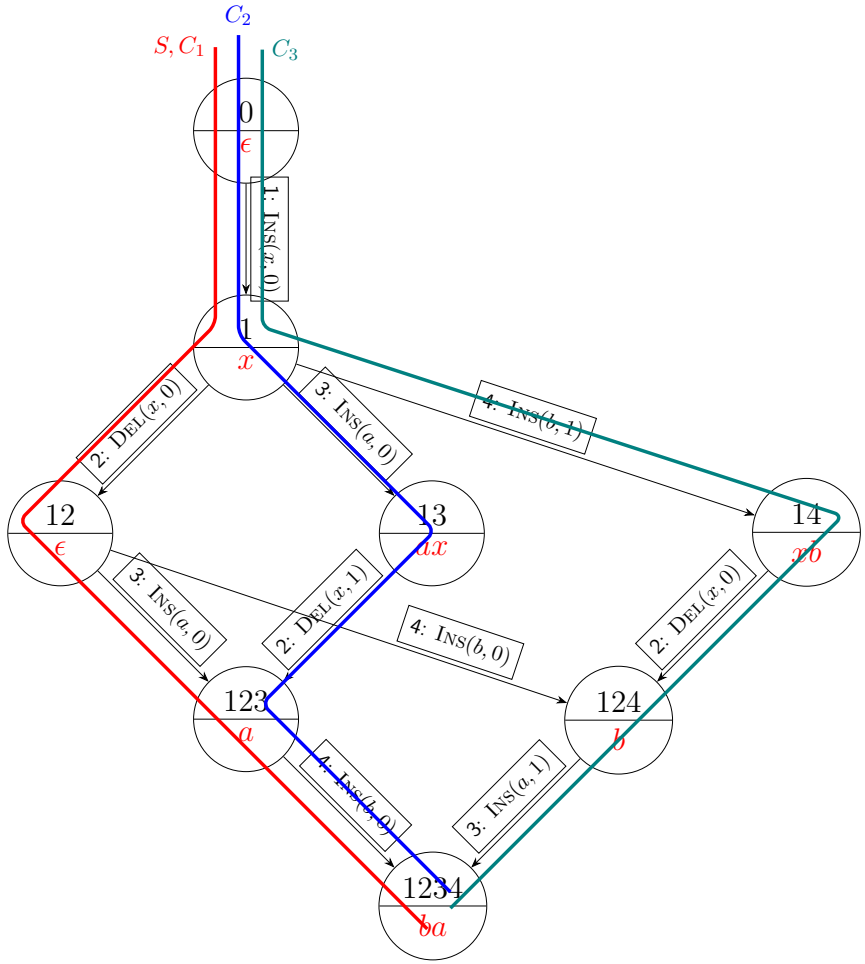
Proposition

At a high level, CJupiter maintains only one n-ary ordered state space.



Proposition

At a high level, CJupiter maintains only one n-ary ordered state space.

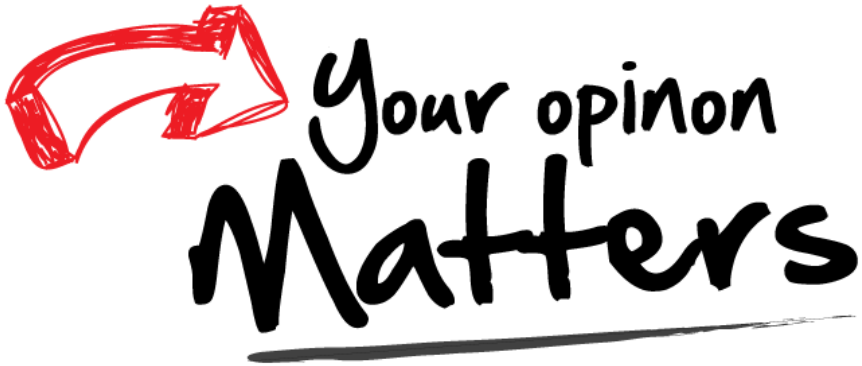


Each replica behavior corresponds to a path going through this state space.

Theorem (Equivalence)

equiv


Thank
You!



Office 302

Mailbox: H016

hfwei@nju.edu.cn