# Ré-identification sans coordination dans les types de données répliquées sans conflits (CRDTs)

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COAST team

21 novembre 2022



# LogootSplit [1]

State of the art of *Sequence Conflict-free Replicated Data Types (CRDTs)*
Elements are ordered by their identifier, noted here with the following formalism : $position^{node\_id\ node\_seq}_{offset}$

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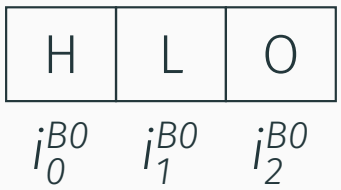


**Figure 1 –** State of a sequence which contains the elements ”HLO” and their corresponding identifiers

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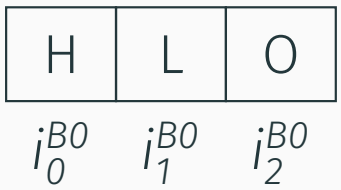


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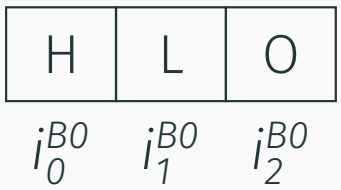


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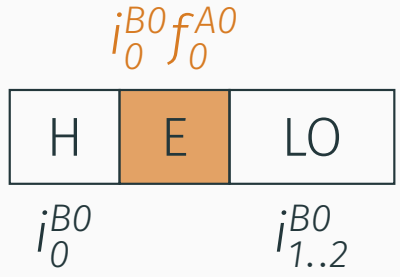


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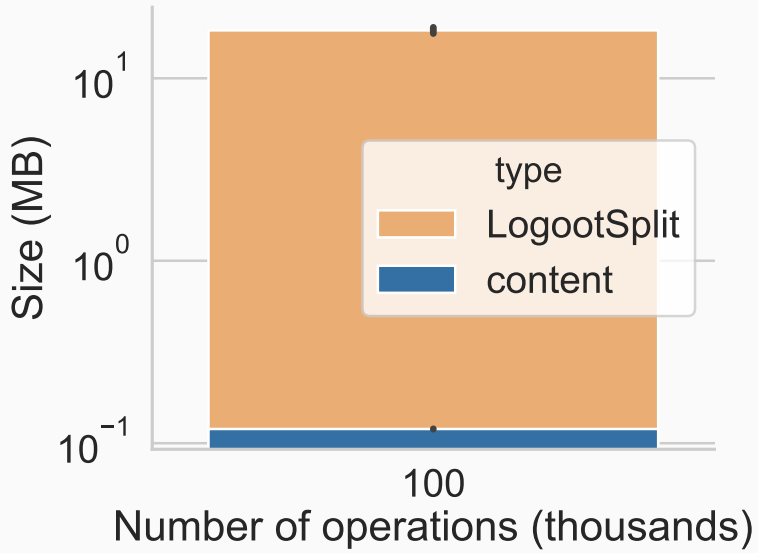
# Research issue

**Evergrowing overhead :** impacts memory, bandwidth and CPU




**Operation count :** 100k

**Size of content :** 100KB

**Size of data structure :** 20MB

**FIGURE 4 –** Memory footprint of the data structure

How to reduce the overhead introduced by the data structure ?

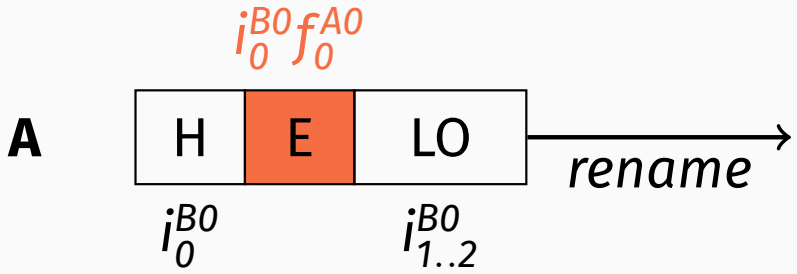
## Our approach

Reassign shorter identifiers and aggregate them into blocks in a fully distributed manner

# RenamableLogootSplit

Propose *RenamableLogootSplit*, *LogootSplit* with a *rename* operation

Can be performed without coordination

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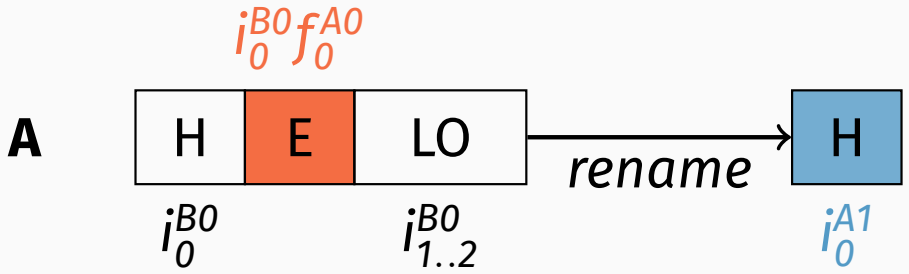


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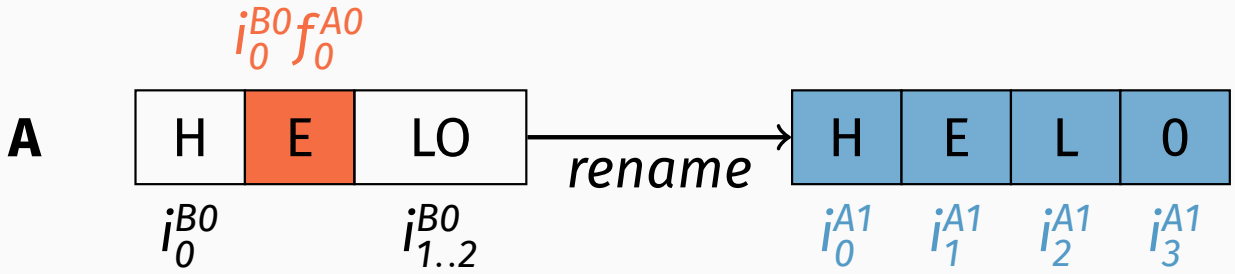


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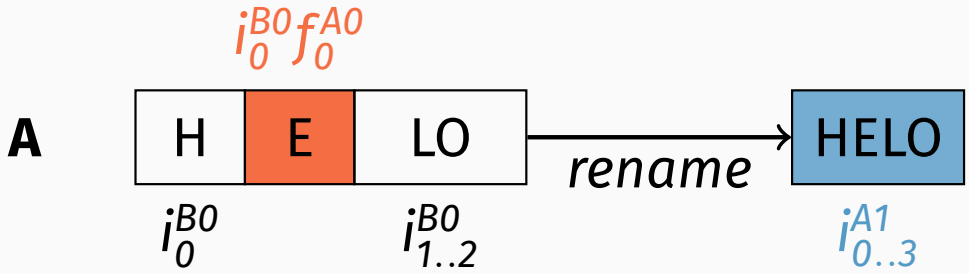


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# Handling concurrent operations

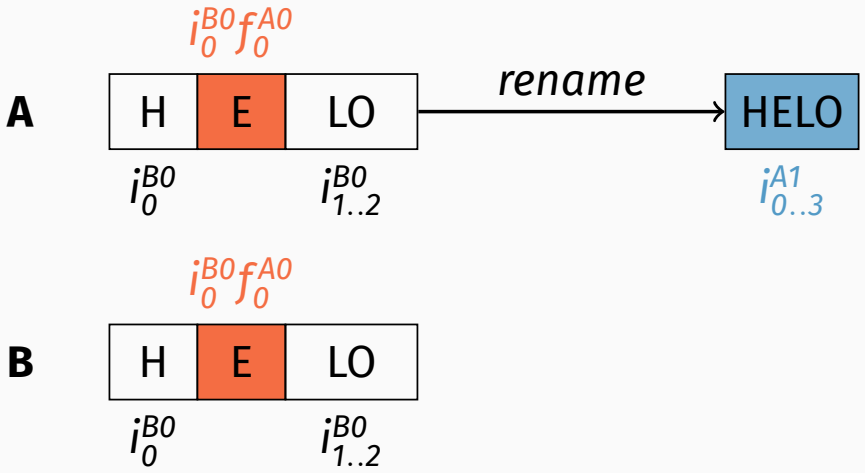


FIGURE 6 – Applying naively concurrent update

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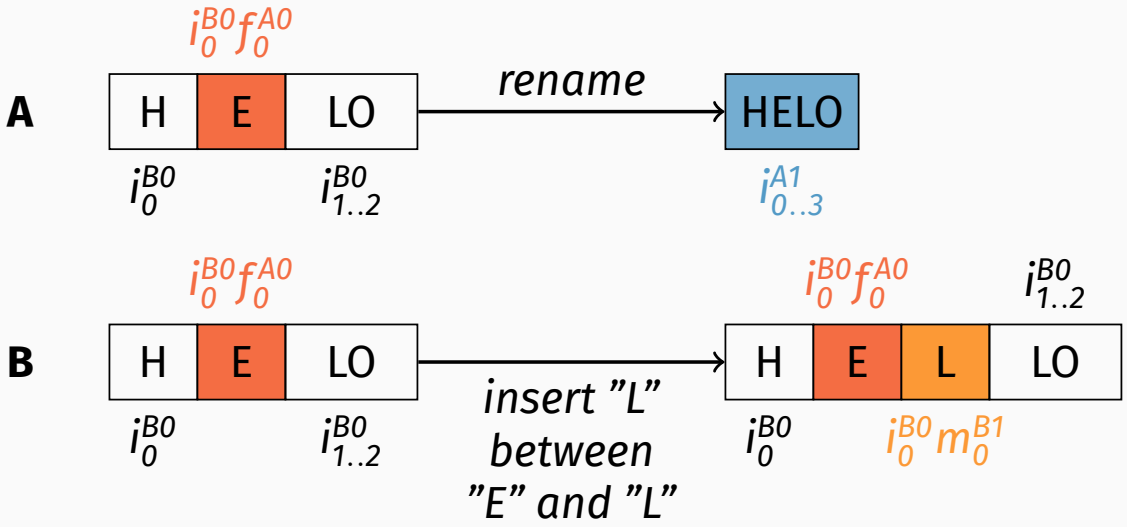


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Can issue operations concurrently to *rename*

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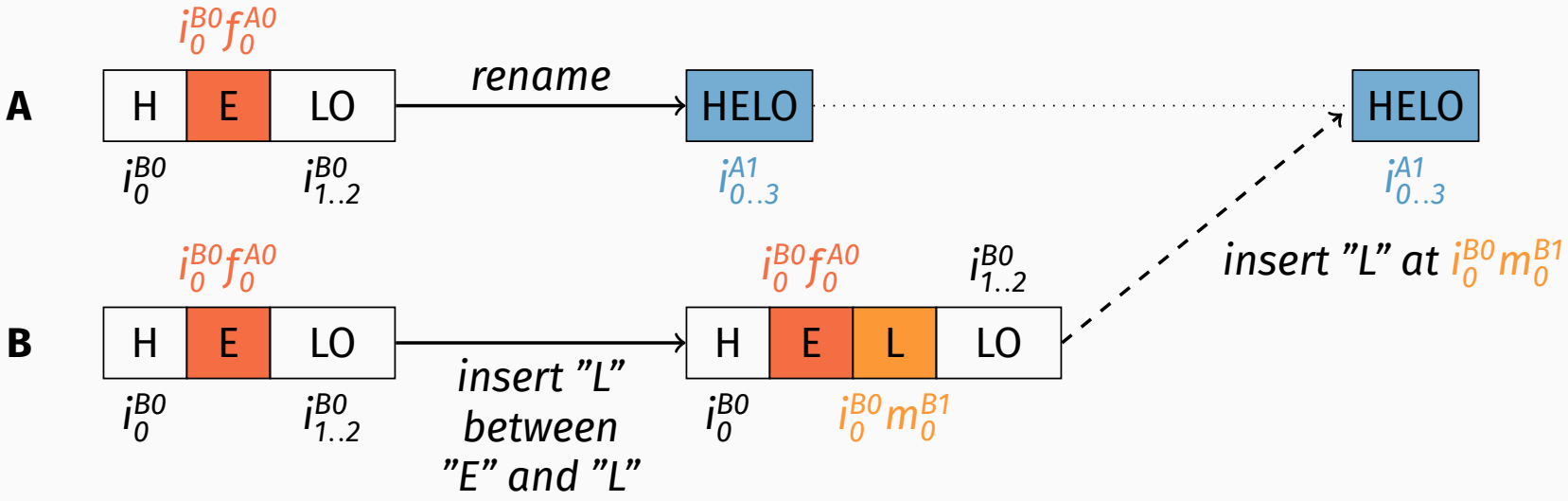


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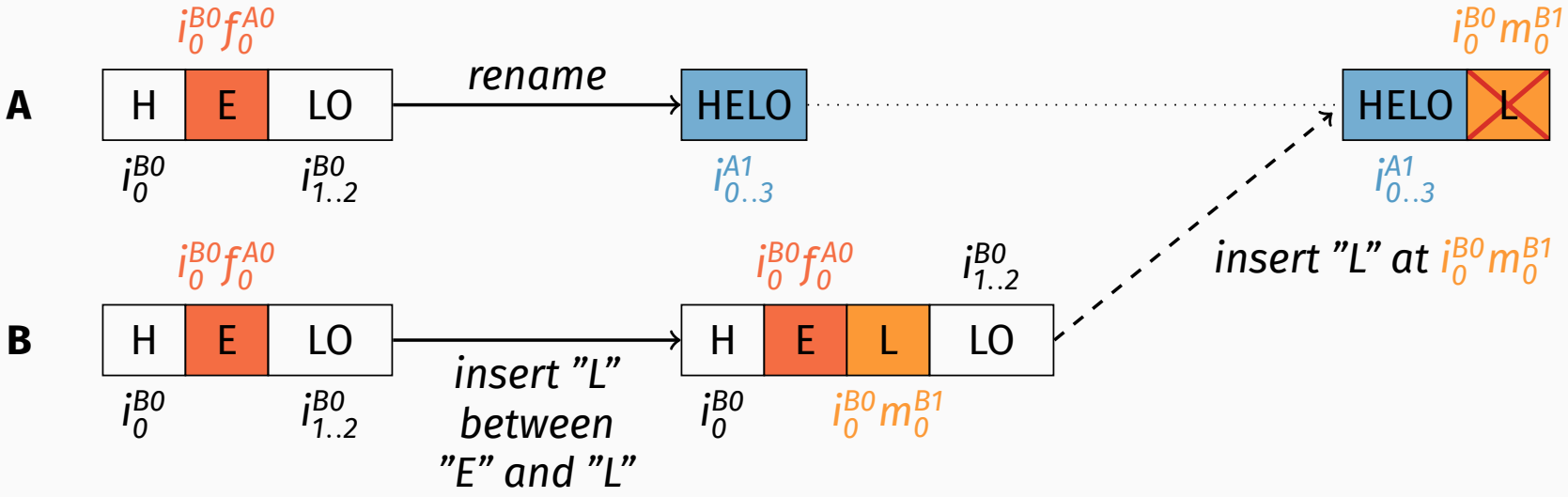


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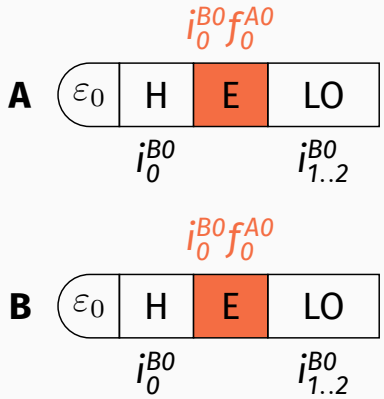
Can issue operations concurrently to *rename*

Produce inconsistencies if applied naively

# Fixing handling concurrent operations

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Use *epoch-based* system to track concurrent operations

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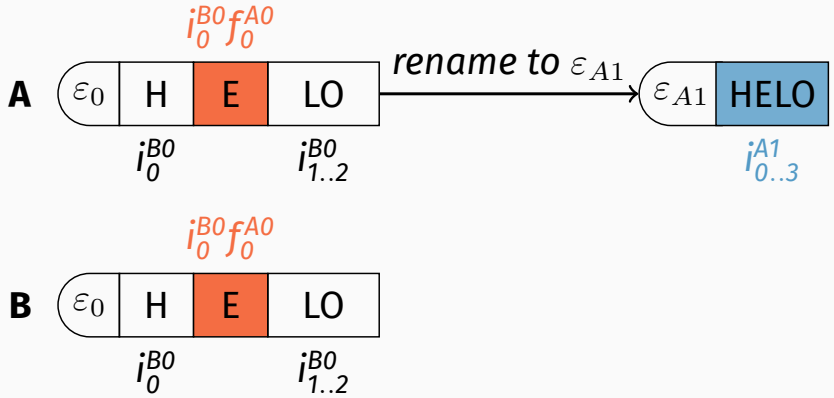


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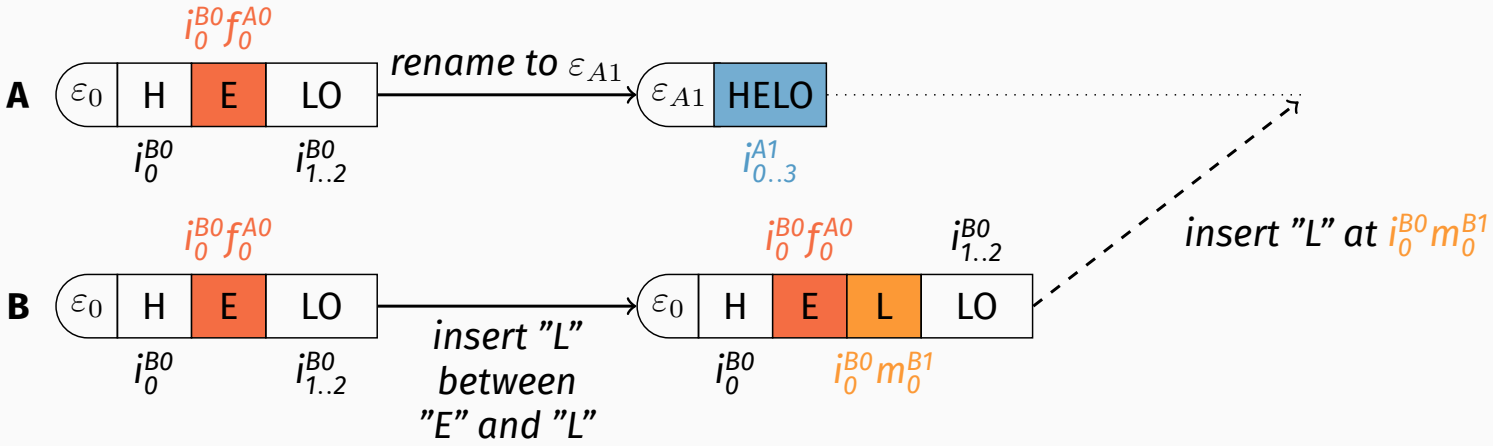


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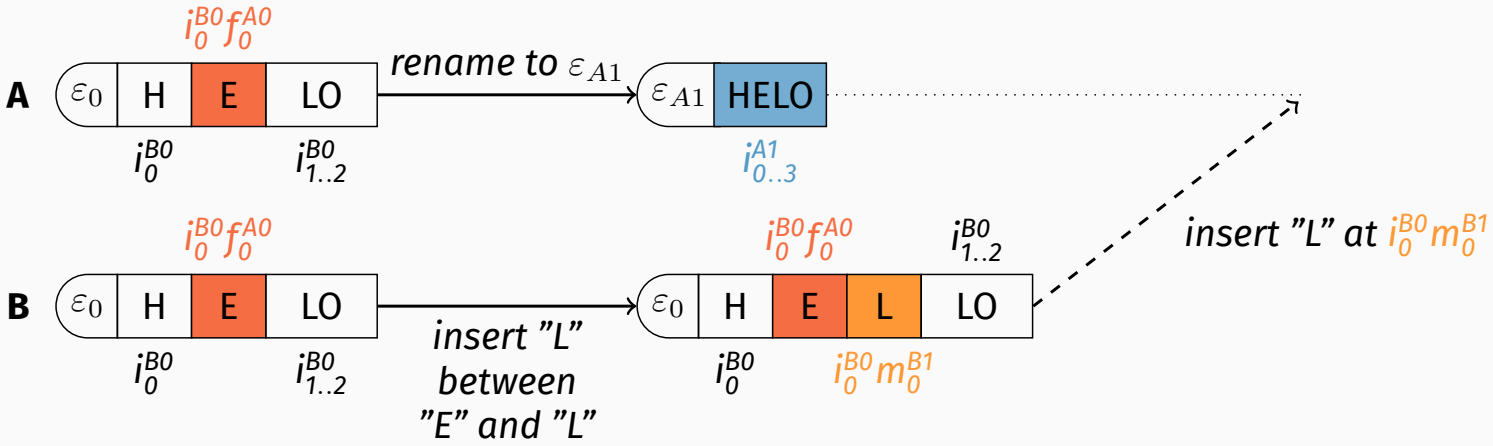


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Transform operations against *rename* ones (*OT*)

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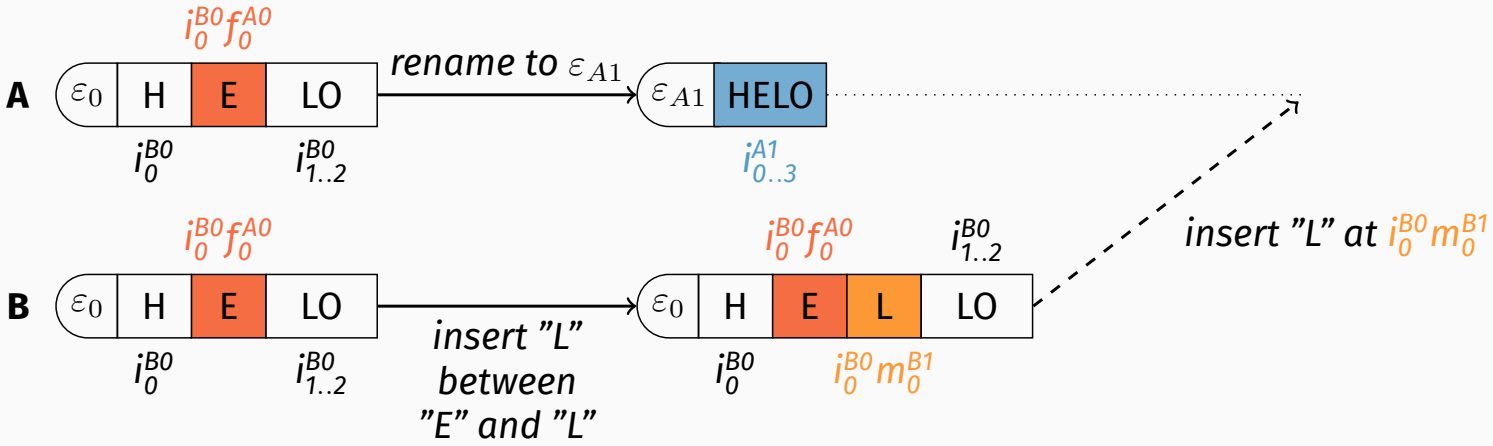


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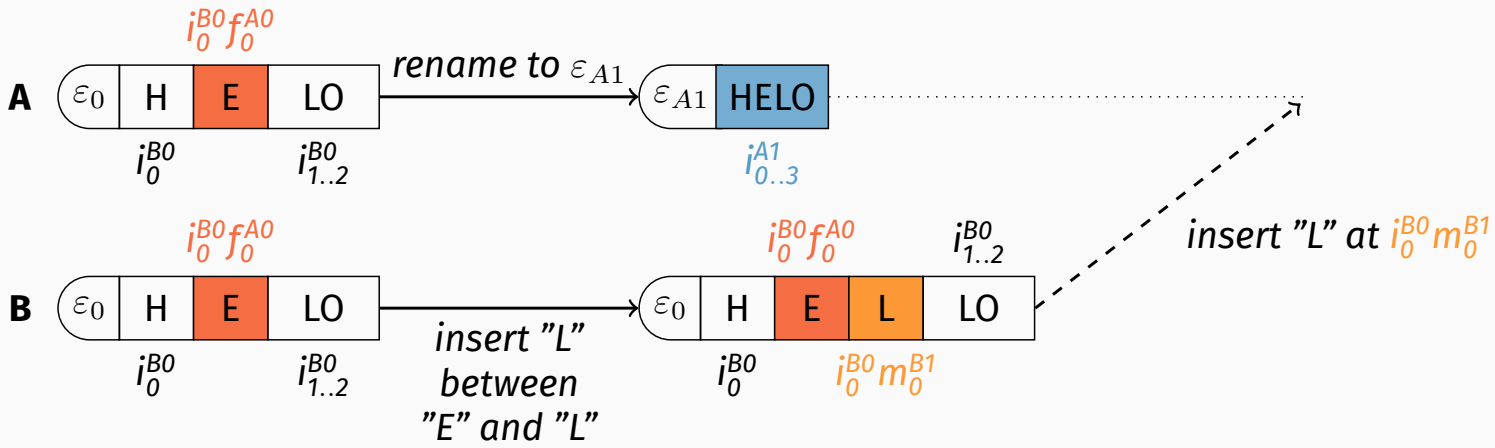


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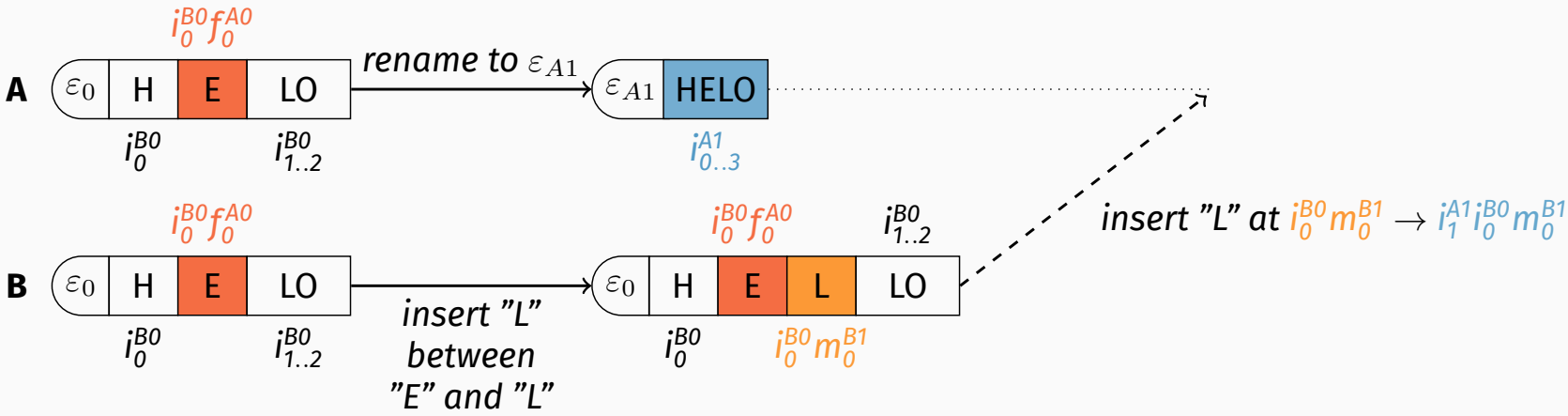


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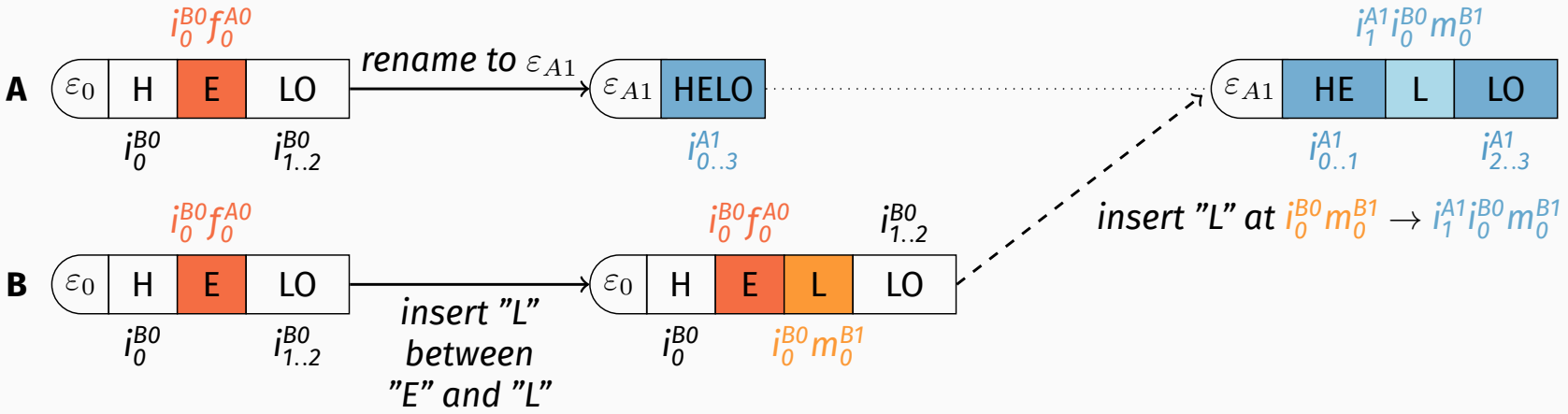


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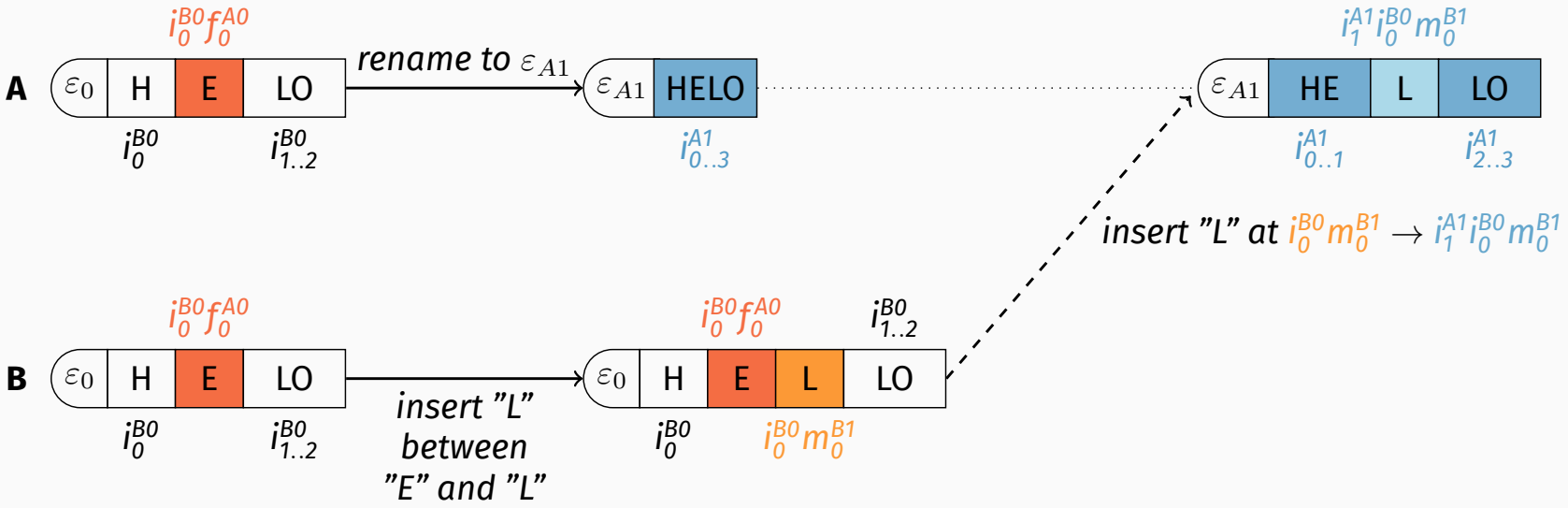


FIGURE 8 – Concurrent *rename* operations leading to divergent states

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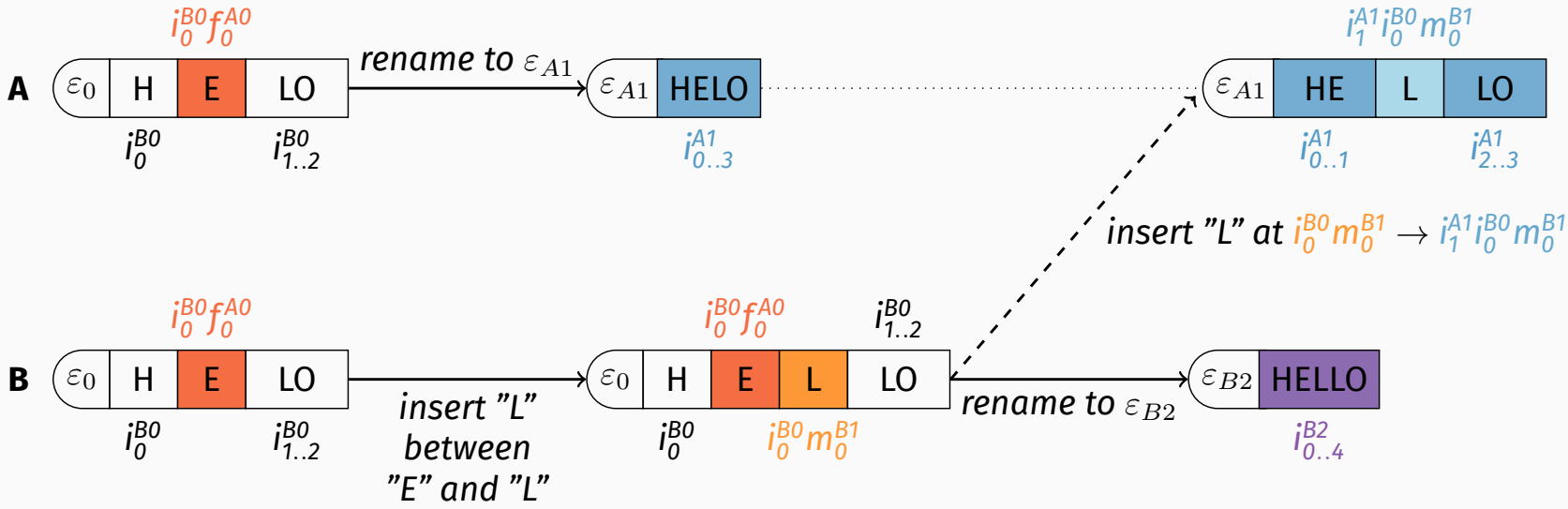


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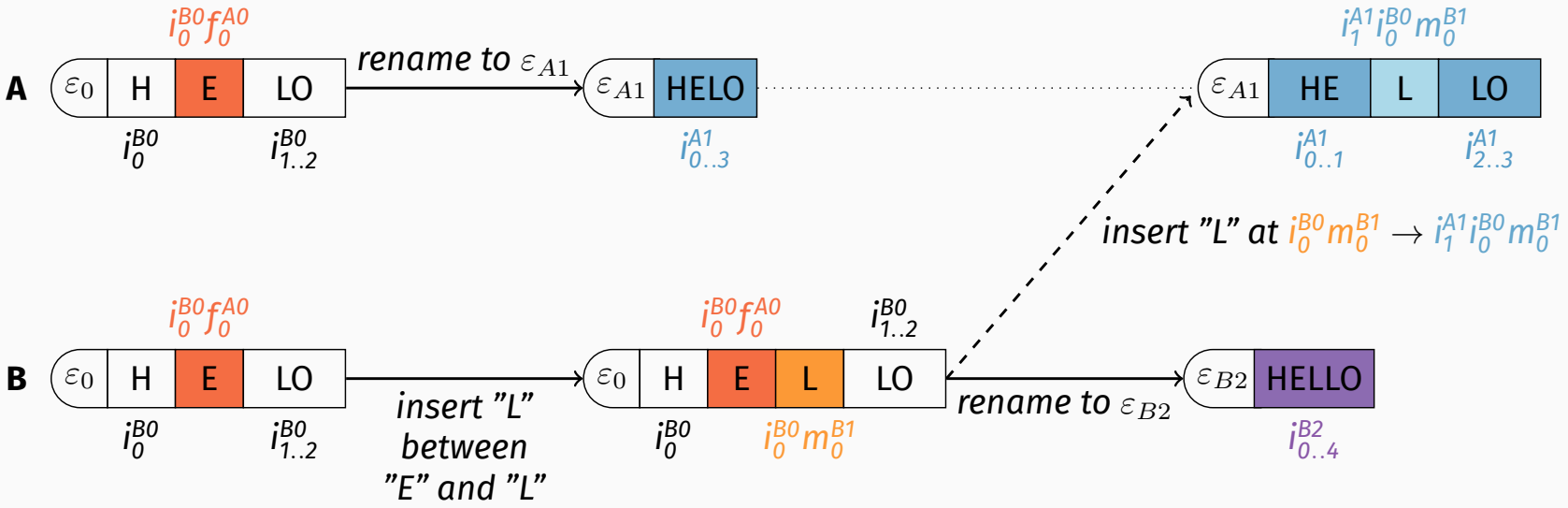


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*Rename* operations are system operations

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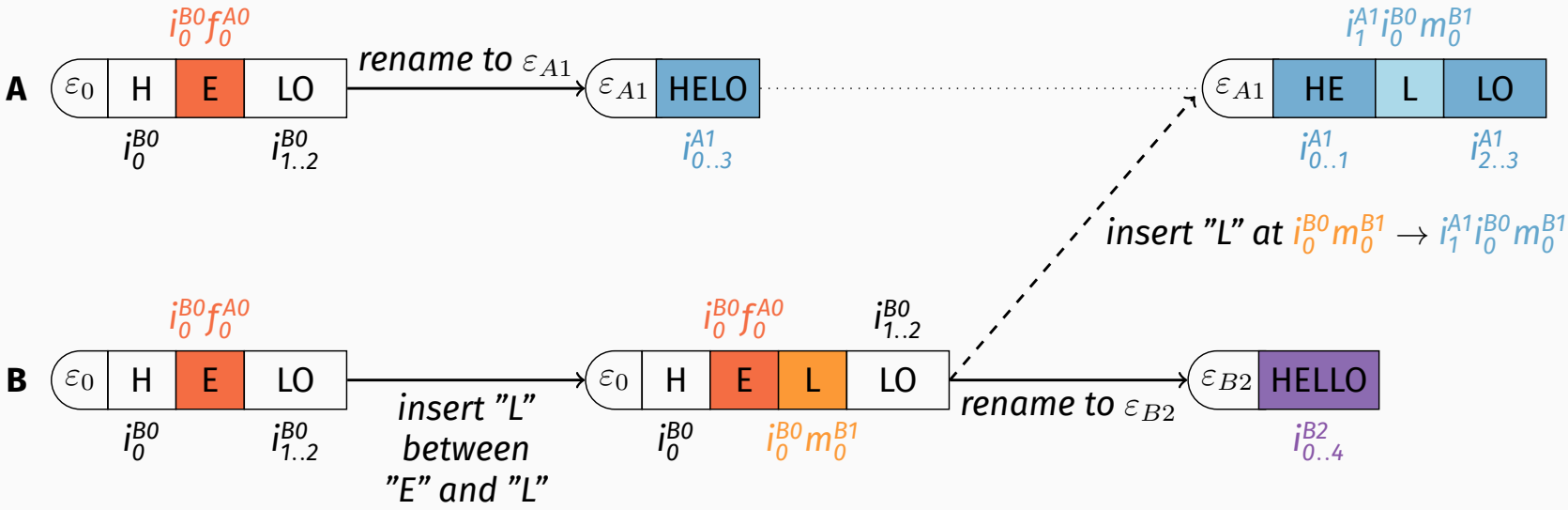


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*Rename* operations are system operations

Can resolve conflict by only applying one of them

# How to do so ?

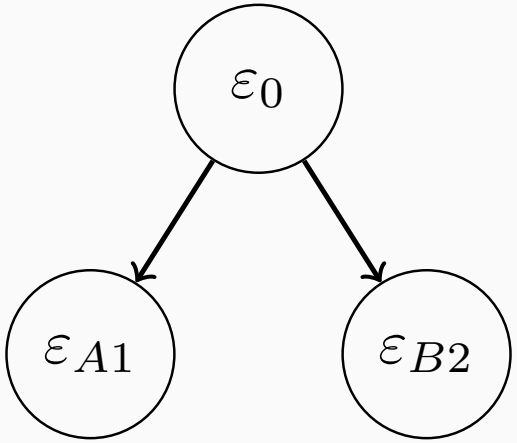


FIGURE 9 – *Epoch tree* corresponding to previous scenario

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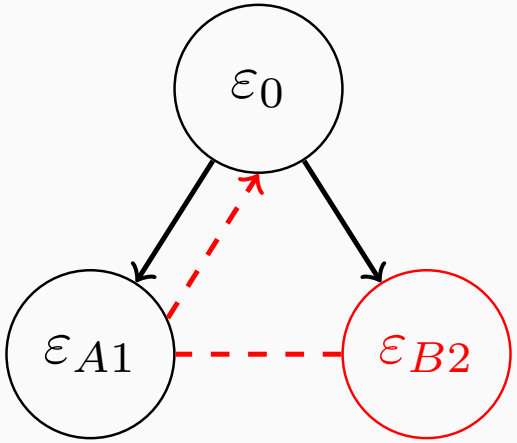


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Define total order on epochs

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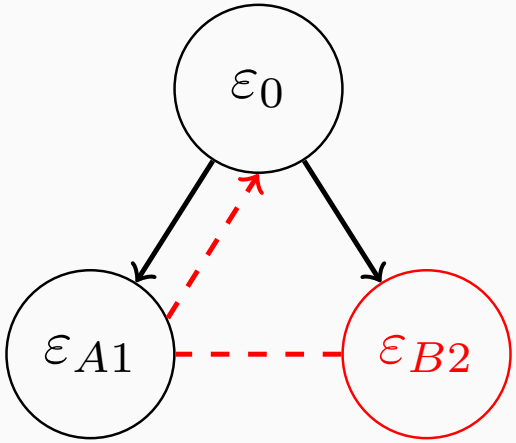


FIGURE 9 – *Epoch tree* corresponding to previous scenario

Have to pick an epoch as the target one

- Define total order on epochs

Have to move through the tree

- Design transformation function to revert *rename* operation

# Applying concurrent *rename* operations

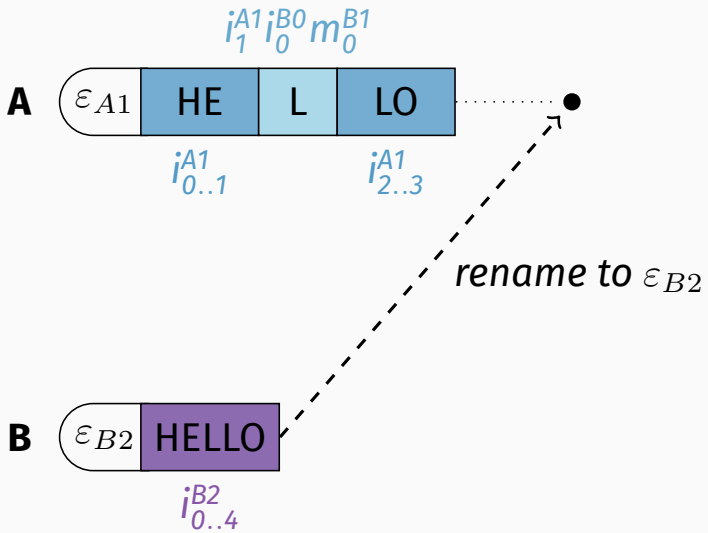


FIGURE 10 – Applying a concurrent *rename* operation

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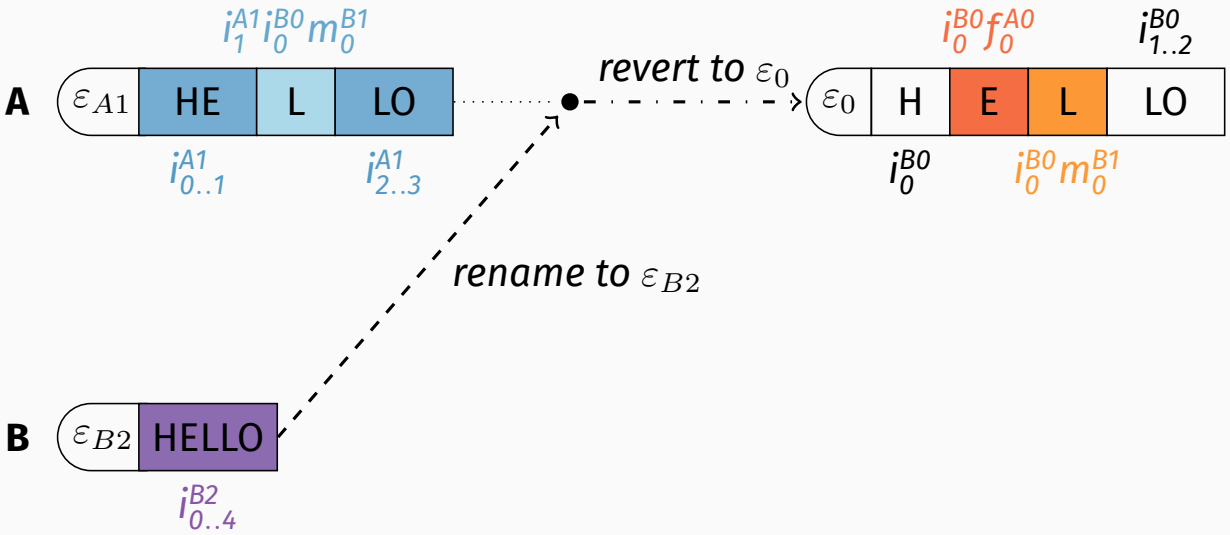


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Revert state to equivalent one at LCA epoch

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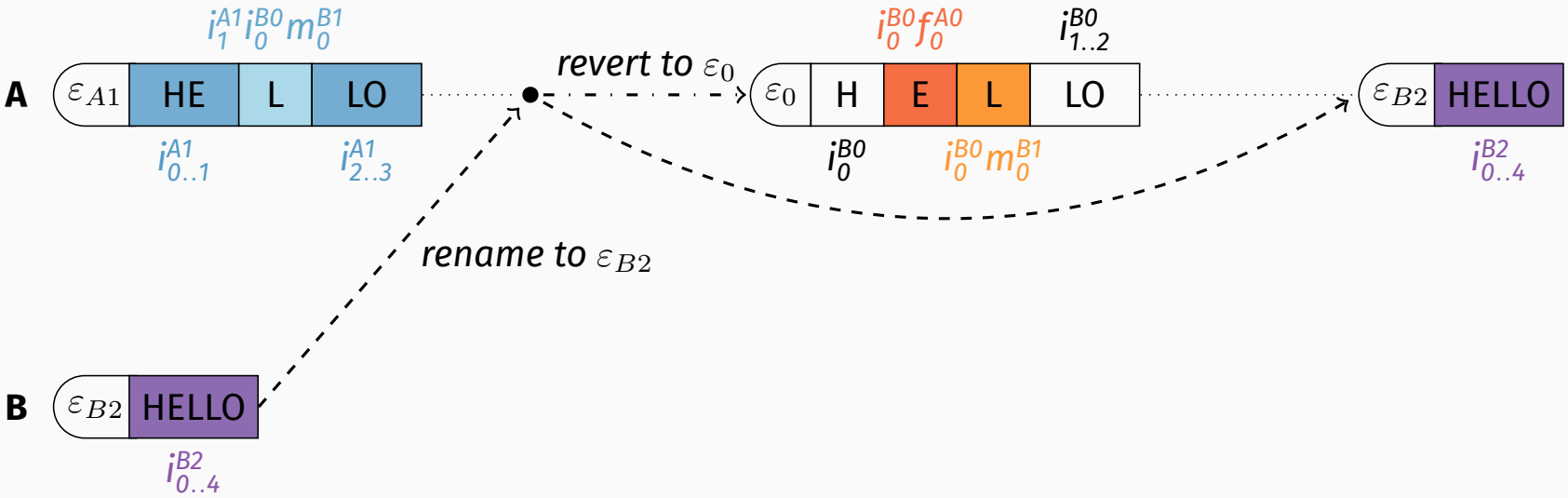


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Revert state to equivalent one at LCA epoch

Apply then *rename* operations leading to target epoch

# Downsides

**Need to store former state until no more concurrent operations**

- Can garbage collect it once the *rename* operation is causally stable [2]
- Can offload it to the disk meanwhile

**Need to propagate former state to other nodes**

- Can compress the operation to minimise bandwidth consumption
- Can trigger *rename* operations at a given number of blocks

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2. Carlos Baquero et al. Making operation-based crdts operation-based. In Kostas Magoutis et al., éditeurs, *Distributed Applications and Interoperable Systems*, pages 126–140, Berlin, Heidelberg. Springer Berlin Heidelberg, 2014 .

## Evaluation

Ran simulations to compare performance of RenamableLogootSplit to LogootSplit one

# Scenario

Simulate collaborative editing sessions using either LogootSplit or RenamableLogootSplit

**Phase 1 (content generation) :** 80/20% of *insert*/*remove*

**Phase 2 (editing) :** 50/50% of *insert*/*remove*

Nodes switch to phase 2 when document reaches critical size (15 pages - 60k elements)

# Results - Convergence

Compared final content of nodes per sessions

Did not observe any divergence

Empirical result, not a proof...

... but represents first step towards the validation

# Results - Memory footprint

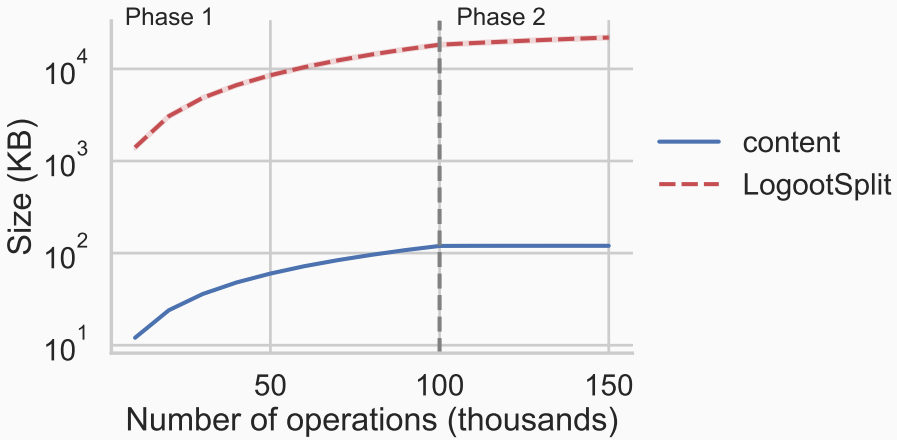


**Figure 11 –** Evolution of the size of the document

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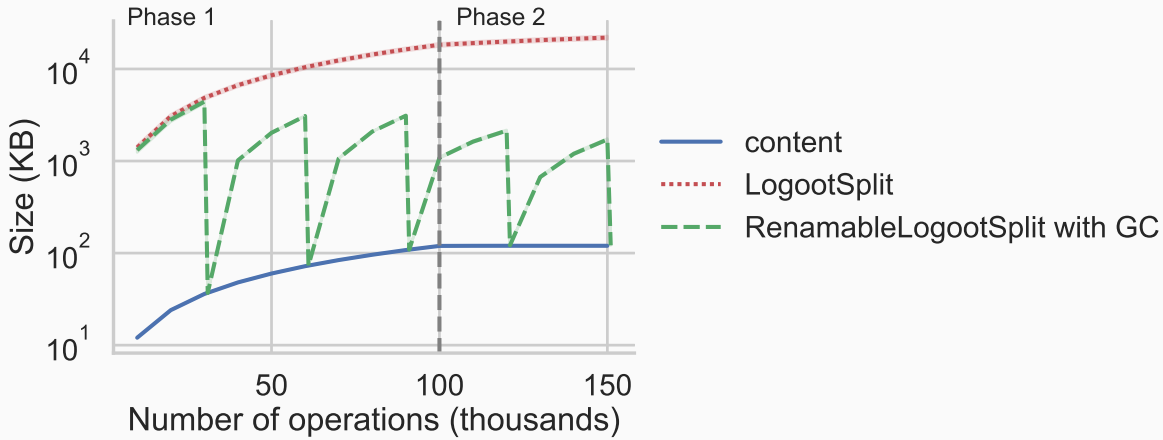


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*Rename* resets the overhead of the CRDT, if can garbage collect

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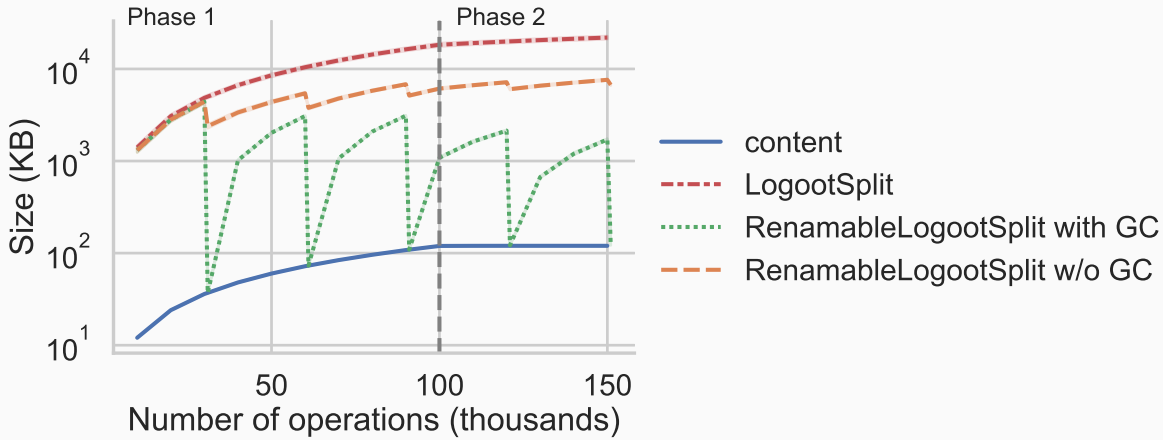
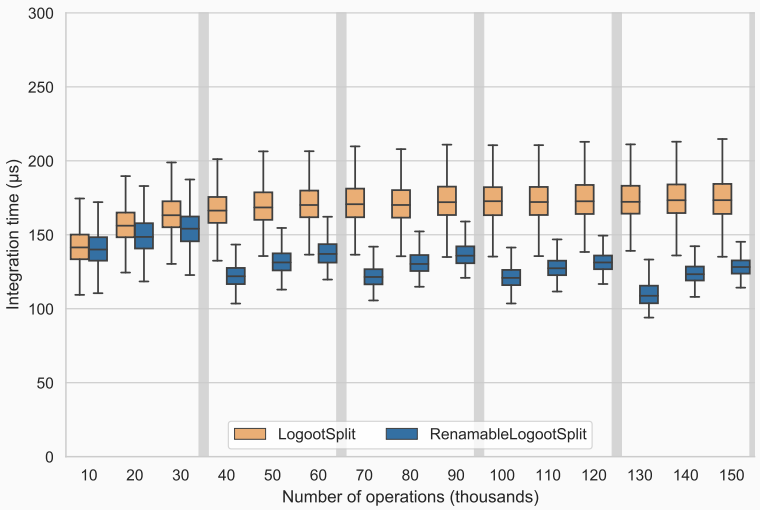



**Figure 11 –** Evolution of the size of the document

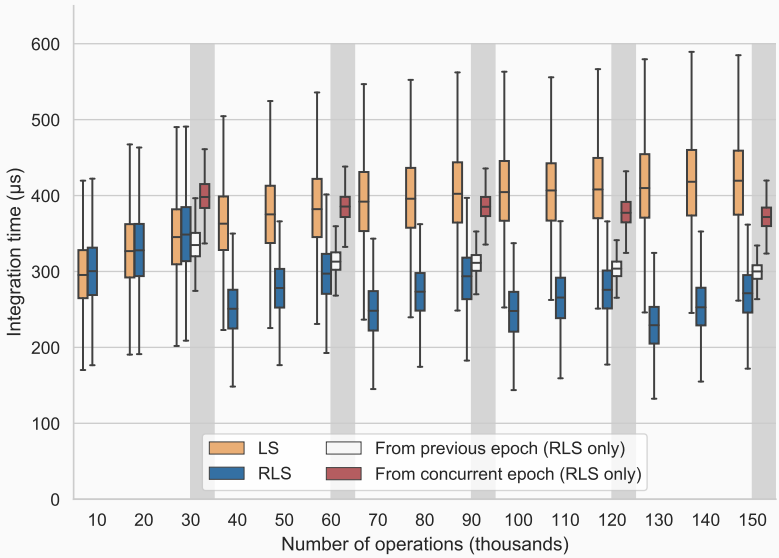
*Rename* resets the overhead of the CRDT, if can garbage collect

*Rename* still reduces by 66% the size otherwise

# Results - Integration time of *insert* operations




(a) Local operations




(b) Remote operations

**FIGURE 12 –** Evolution of the integration time of *insert* operations

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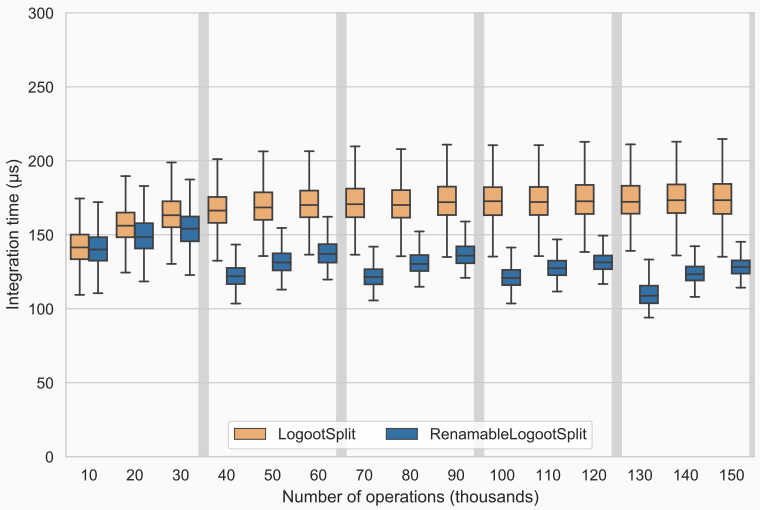


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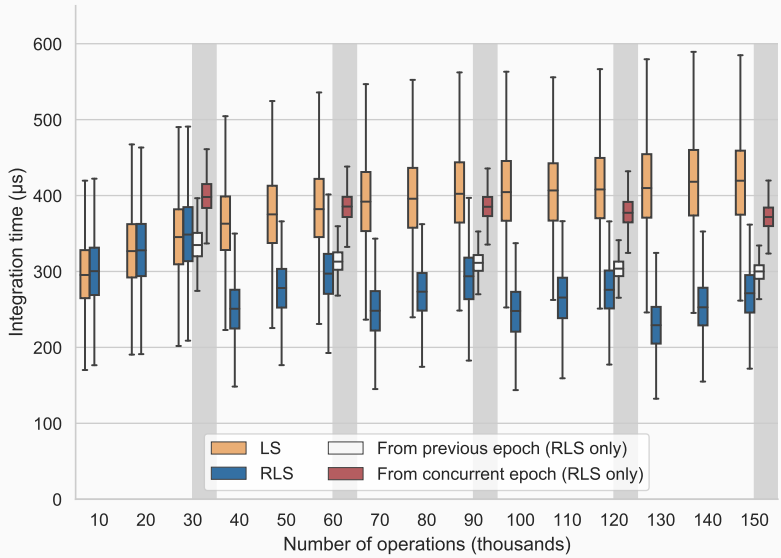


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**FIGURE 12 –** Evolution of the integration time of *insert* operations

*Rename* reduces integration times of future operations

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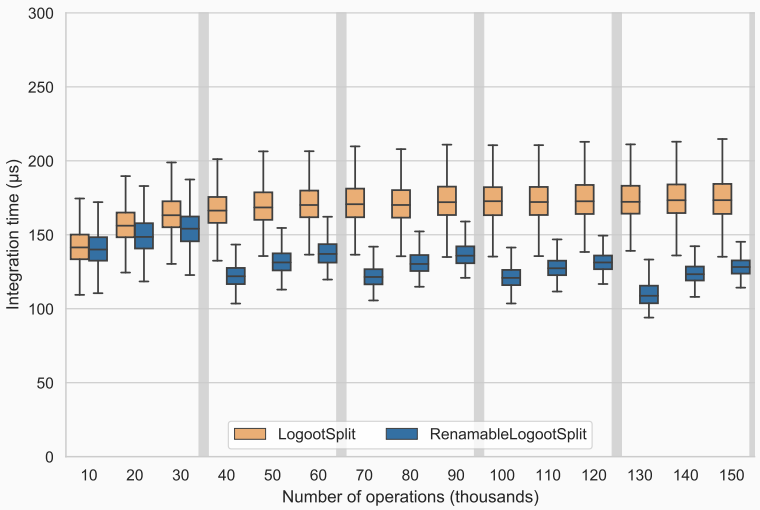
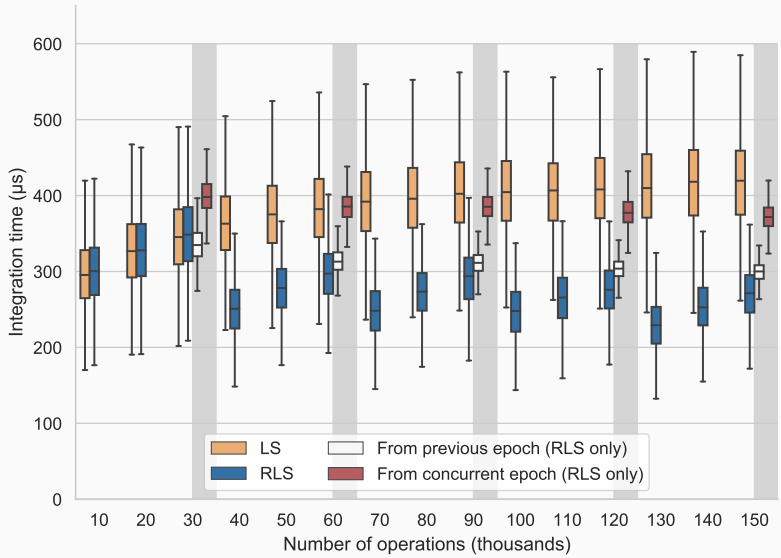



(a) Local operations




(b) Remote operations

**FIGURE 12 –** Evolution of the integration time of *insert* operations

*Rename* reduces integration times of future operations

Transforming concurrent operations is actually faster than applying them on former state

# Results - Integration time of *rename* operations

| Parameters | | Integration Time (ms) | | | |
|---|---|---|---|---|---|
| Type | Nb Ops (k) | Mean | Median | $99^{th}$ Quant. | Std |
| Local | 30 | 41.75 | 38.74 | 71.68 | 6.84 |
| | 90 | 119.19 | 118.87 | 124.22 | 2.49 |
| | 150 | 158.04 | 157.95 | 164.38 | 2.49 |
| Remote | 30 | 481.32 | 477.13 | 537.30 | 17.11 |
| | 90 | 1491.28 | 1481.83 | 1657.58 | 51.10 |
| | 150 | 1694.17 | 1675.95 | 1852.55 | 59.94 |

**Table 1 –** Integration time of rename operations

# Results - Integration time of *rename* operations

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**Table 1 –** Integration time of rename operations

Noticeable by users

# Results - Integration time of *rename* operations

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**Table 1 –** Integration time of rename operations

Noticeable by users

Need to improve remote integration time

# Conclusion

## Done

- Designed a new Sequence CRDT : RenamableLogootSplit
- Validated it through experimental evaluation

# Conclusion

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- Designed a new Sequence CRDT : RenamableLogootSplit
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## Work in progress

- Publishing it
- Writing the manuscript

# Conclusion

## Done

- Designed a new Sequence CRDT : RenamableLogootSplit
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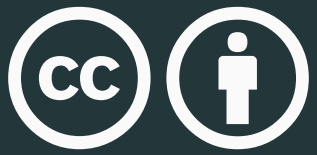
## Work in progress

- Publishing it
- Writing the manuscript

## To do

- Prove formally the correctness of the mechanism
- Design better strategies to select the target epoch
- Improve performance of *rename* operations

Thanks for your attention, any questions?



# LogootSplit identifiers

To comply with these constraints, LogootSplit proposes identifiers composed of quadruplets of integers of the following form :

$$position_{offset}^{node\_id\ \ node\_seq}$$

*position* allows to determine the position of this identifier compared to others

*node_id* refers to the node's identifier, assumed to be unique

*node_seq* refers to the node's logical clock, which increases monotonically with local operations

*offset* refers to the element position in its original block

# Identifier constraints

To fulfill their role, identifiers have to comply to several constraints :

### Globally unique

Identifiers should never be generated twice, neither by different users nor by the same one at different times

### Totally ordered

We should always be able to compare and order two elements using their identifiers

### Dense set

We should always be able to add a new element, and thus a new identifier, between two others

# Related work

Core-nebula approach [3]

- Reassigns shorter identifiers to elements...
- ...but requires consensus

LSEQ [4]

- Set of strategies to reduce the growth of identifiers ...
- ...but overhead still proportional to number of elements

---

3. Marek Zawirski et al. Asynchronous rebalancing of a replicated tree. In *Conférence Française en Systèmes d'Exploitation (CFSE)*, page 12, Saint-Malo, France, mai 2011. URL : `https://hal.inria.fr/hal-01248197` .
4. doi :10.1002/cpe.4108.

# Perspectives

**Propose a strategy to avoid conflicting *rename* operations**

How to minimise likelihood of concurrent *rename* operations without coordinating ?

**Propose a smarter strategy to choose the ”winning” renaming**

How to minimise the overall computations ?

# Results - Integration time of *rename* operations (complete)

| Parameters | | Integration Time (ms) | | | |
|---|---|---|---|---|---|
| Type | Nb Ops (k) | Mean | Median | $99^{th}$ Quant. | Std |
| Local | 30 | 41.75 | 38.74 | 71.68 | 6.84 |
| | 90 | 119.19 | 118.87 | 124.22 | 2.49 |
| | 150 | 158.04 | 157.95 | 164.38 | 2.49 |
| Direct remote | 30 | 481.32 | 477.13 | 537.30 | 17.11 |
| | 90 | 1491.28 | 1481.83 | 1657.58 | 51.10 |
| | 150 | 1694.17 | 1675.95 | 1852.55 | 59.94 |
| Cc. int. greater epoch | 30 | 643.53 | 643.57 | 682.80 | 13.42 |
| | 90 | 1998.23 | 1994.08 | 2111.98 | 45.37 |
| | 150 | 2241.92 | 2233.61 | 2351.02 | 52.20 |
| Cc. int. lesser epoch | 30 | 1.36 | 1.30 | 3.53 | 0.37 |
| | 90 | 4.45 | 4.23 | 5.81 | 0.71 |
| | 150 | 5.53 | 5.26 | 8.70 | 0.79 |

TABLE 2 – Integration time of rename operations

# Experimental settings

Use Node.js version 13.1.0

Obtained documents sizes using our fork of *object-sizeof*[5]

Ran benchmarks on a workstation equipped of a Intel Xeon CPU E5-1620 (10MB Cache, 3.50 GHz) with 16GB of RAM running Fedora 31

Measured times using `process.hrtime.bigint()`

5. `https://www.npmjs.com/package/object-sizeof`