Ré-identification sans coordination dans les types de données répliquées sans conflits

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	Gérald Oster	Maître de conférences, Université de Lorraine, LORIA

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dépasser les frontières

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

1. Luc André et al. Supporting Adaptable Granularity of Changes for Massive-Scale Collaborative Editing. In *International Conference on Collaborative Computing : Networking, Applications and Worksharing - CollaborateCom 2013*, pages 50-59, Austin, TX, USA. IEEE Computer Society, octobre 2013. DOI : 10.4108/icst.collaboratecom.2013.254123.

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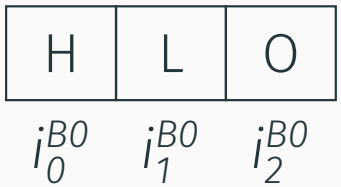

Figure 1 – State of a sequence which contains the elements ”HLO” and their corresponding identifiers

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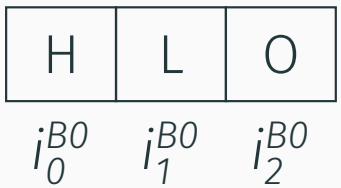

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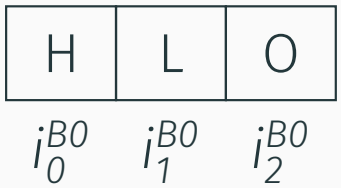

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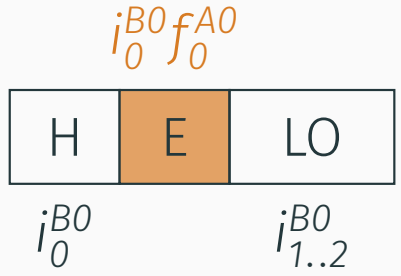

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Identifier constraints

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

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

Research issue

Evergrowing overhead : impacts memory, bandwidth and CPU

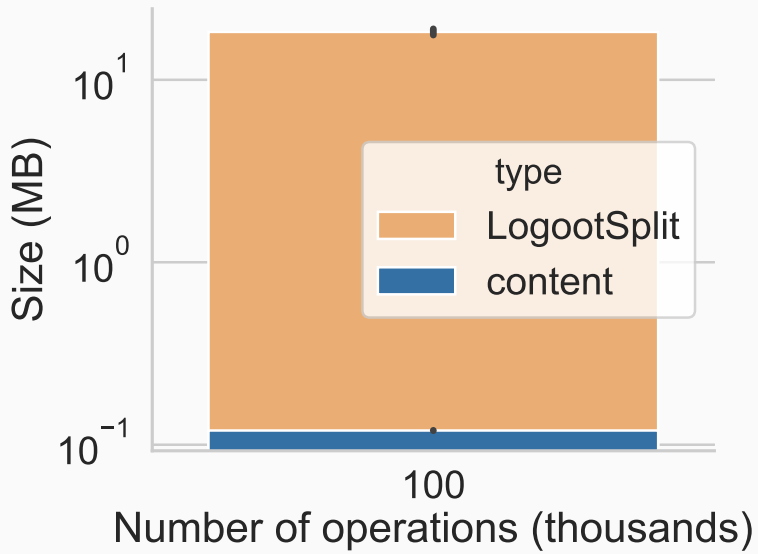

Figure 4 – Memory footprint of the data structure

Operation count : 100k

Size of content : 100KB

Size of data structure : 20MB

How to reduce the overhead introduced by the data structure ?

Related work

- Core-nebula approach [2]
  - Reassigns shorter identifiers to elements...
  - ...but requires consensus
- LSEQ [3]
  - Set of strategies to reduce the growth of identifiers ...
  - ...but overhead still proportional to number of elements

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2. 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.
3. Brice Nédelec et al. A scalable sequence encoding for collaborative editing. *Concurrency and Computation : Practice and Experience* :e4108. DOI : 10.1002/cpe.4108. eprint : https://onlinelibrary.wiley.com/doi/pdf/10.1002/cpe.4108. URL : https://onlinelibrary.wiley.com/doi/abs/10.1002/cpe.4108.

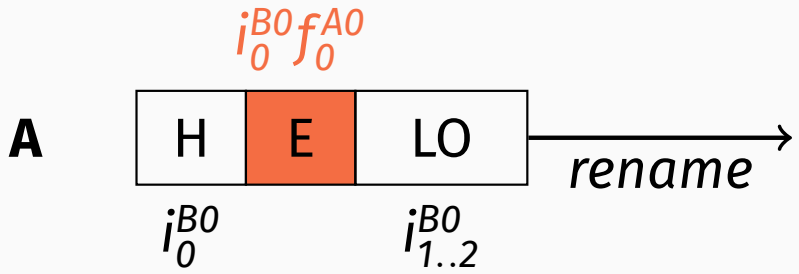
Our approach

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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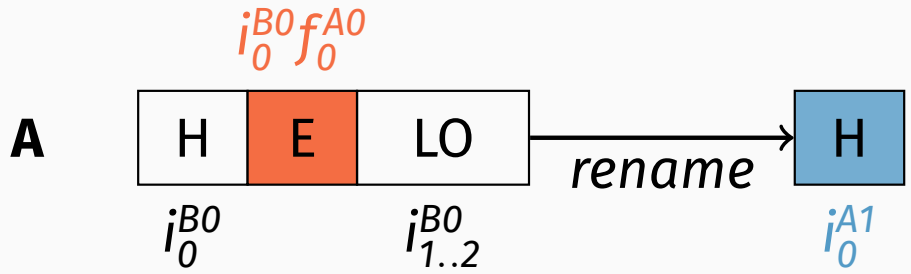

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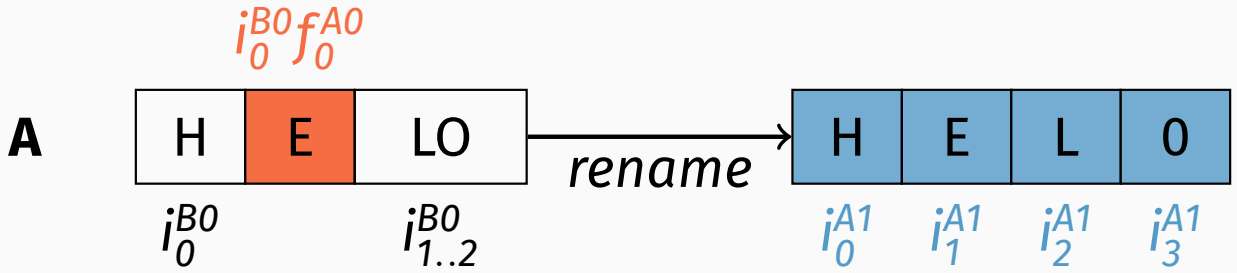

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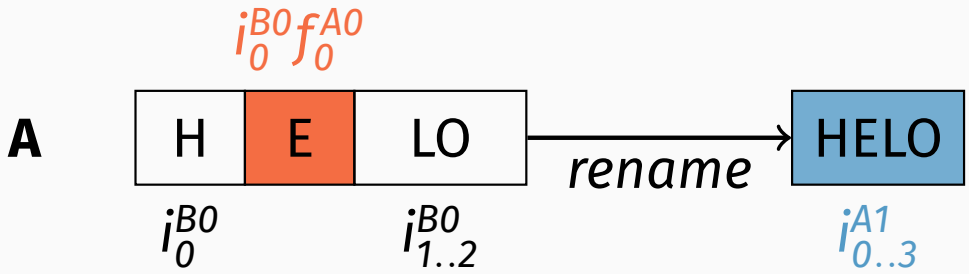

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Handling concurrent operations

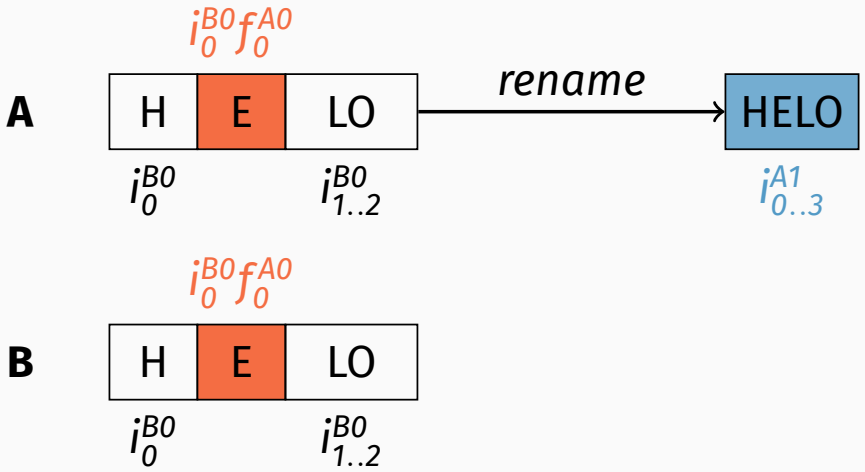

Figure 6 – Applying naively concurrent update

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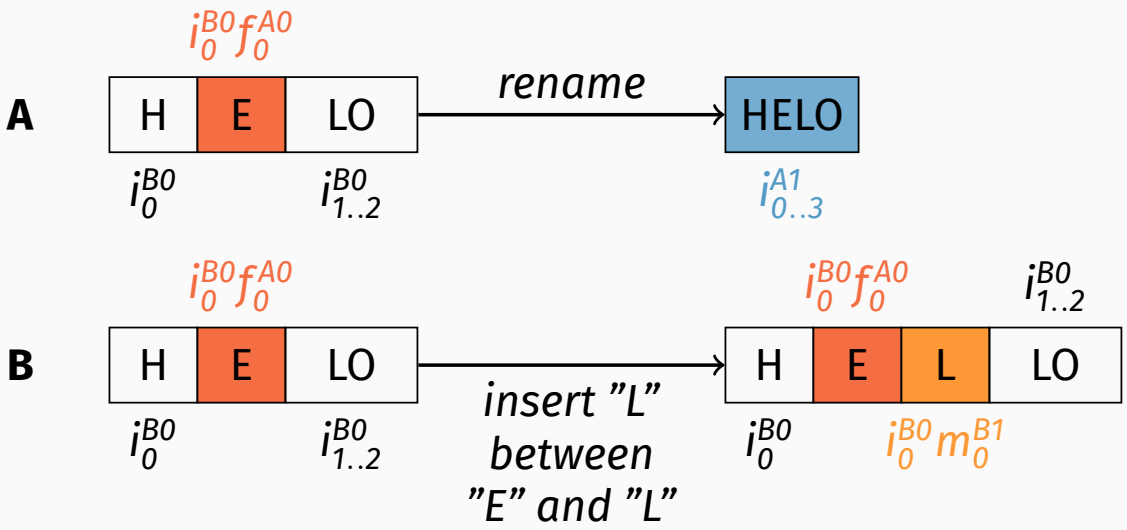

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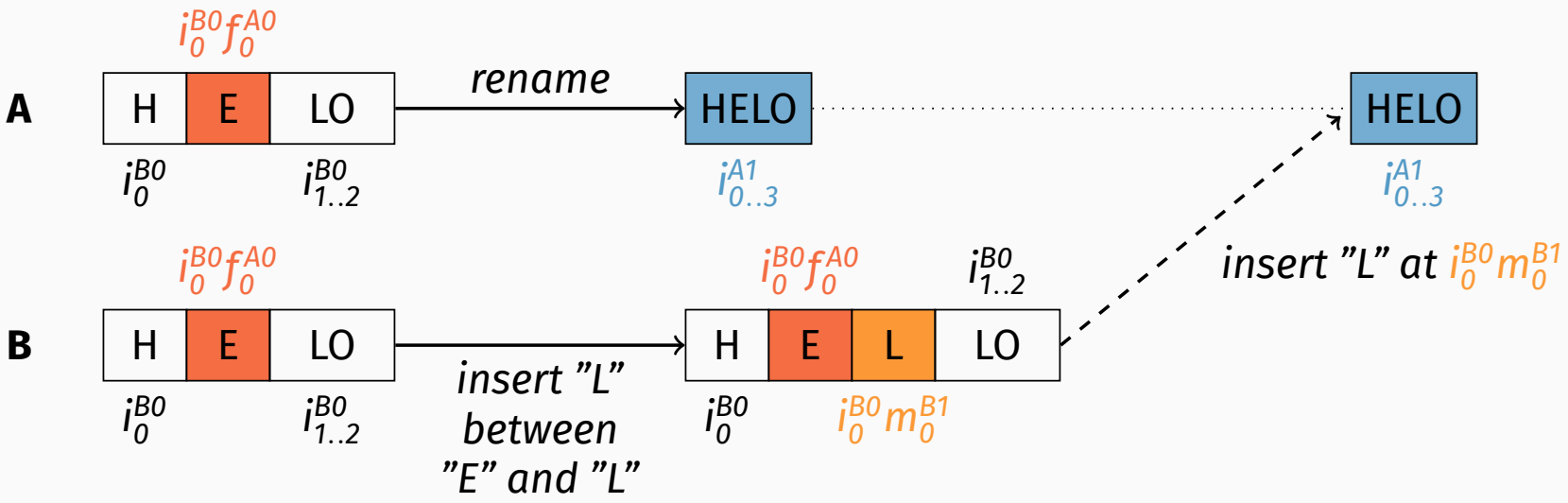

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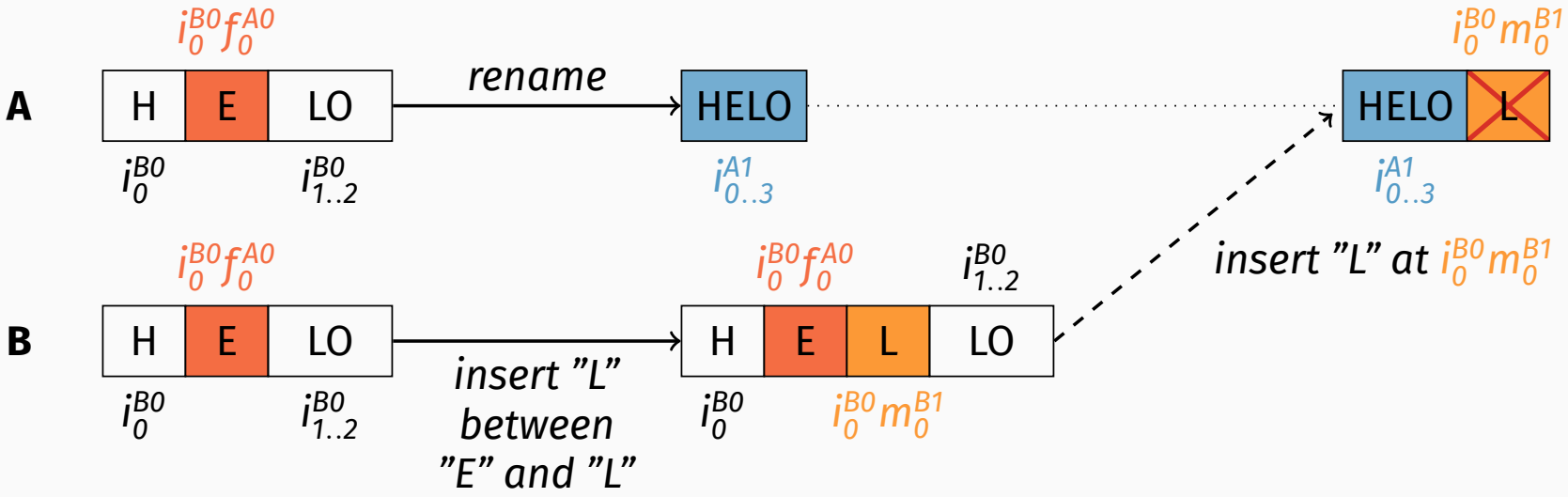

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Produce inconsistencies if applied naively

Fixing handling concurrent operations

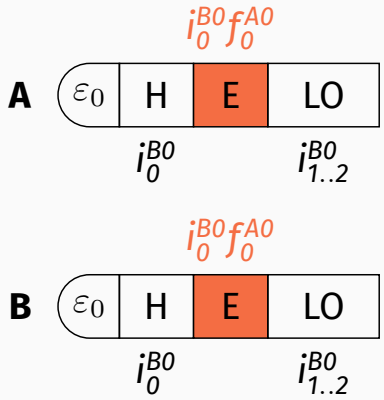
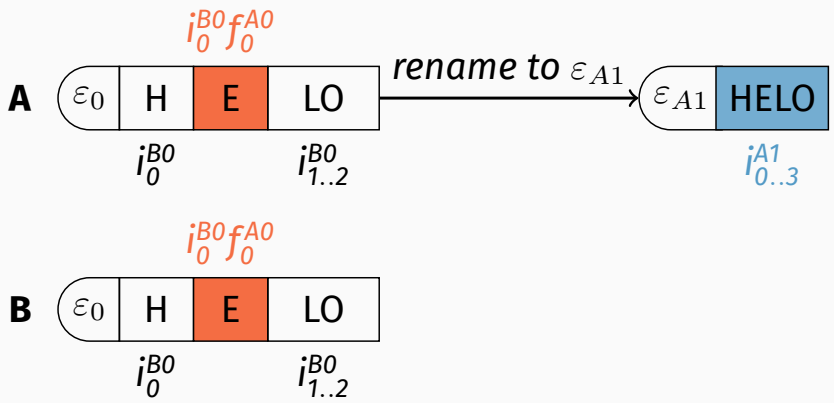


Figure 7 – Handling properly concurrent update

Use *epoch-based* system to track concurrent operations

Fixing handling concurrent operations



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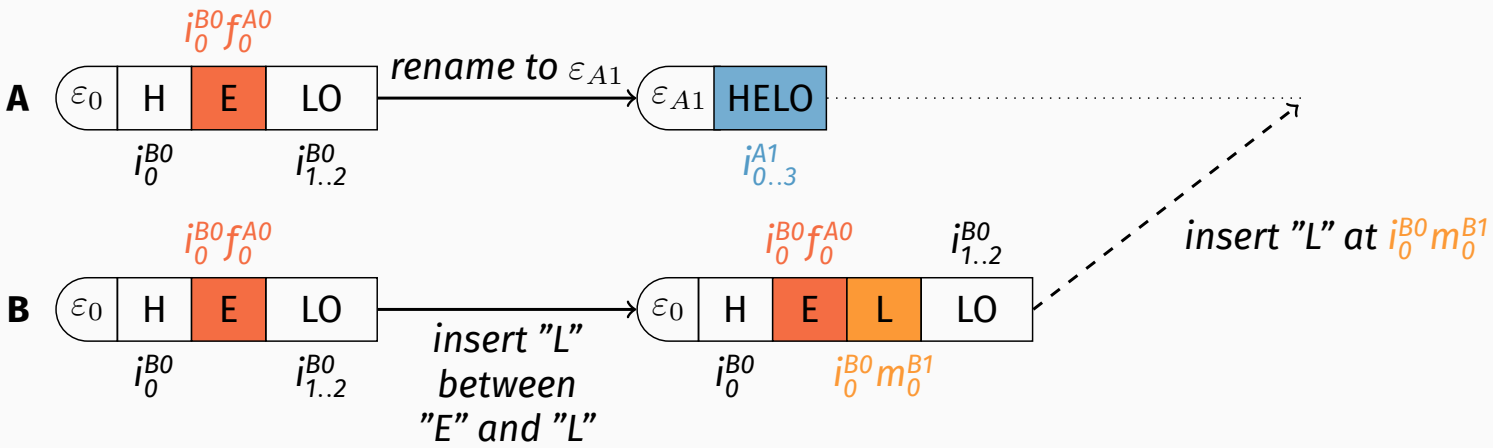

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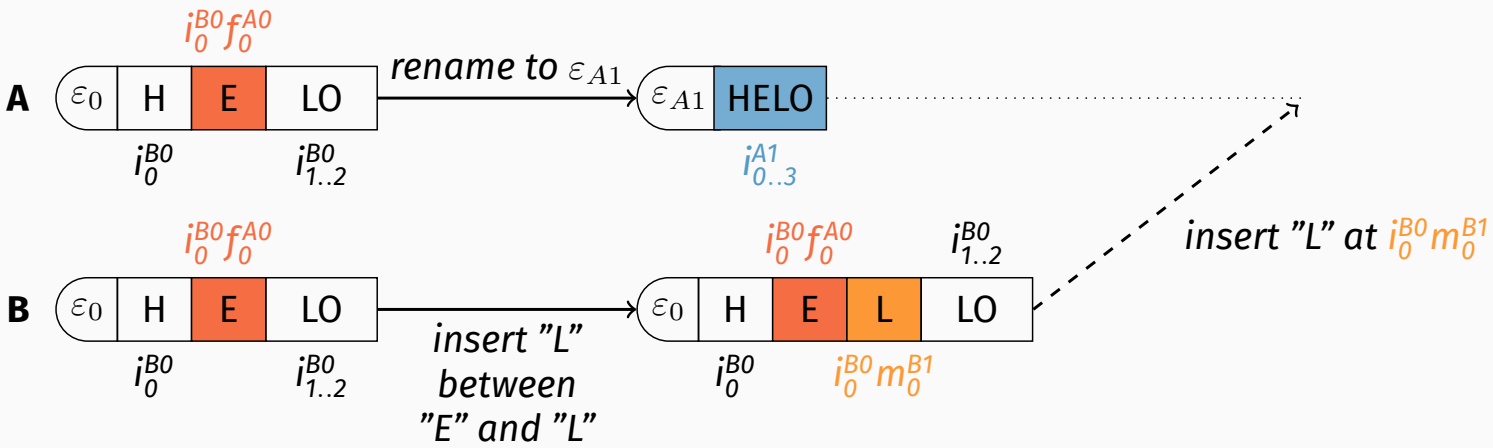

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Transform operations against *rename* ones (*OT*)

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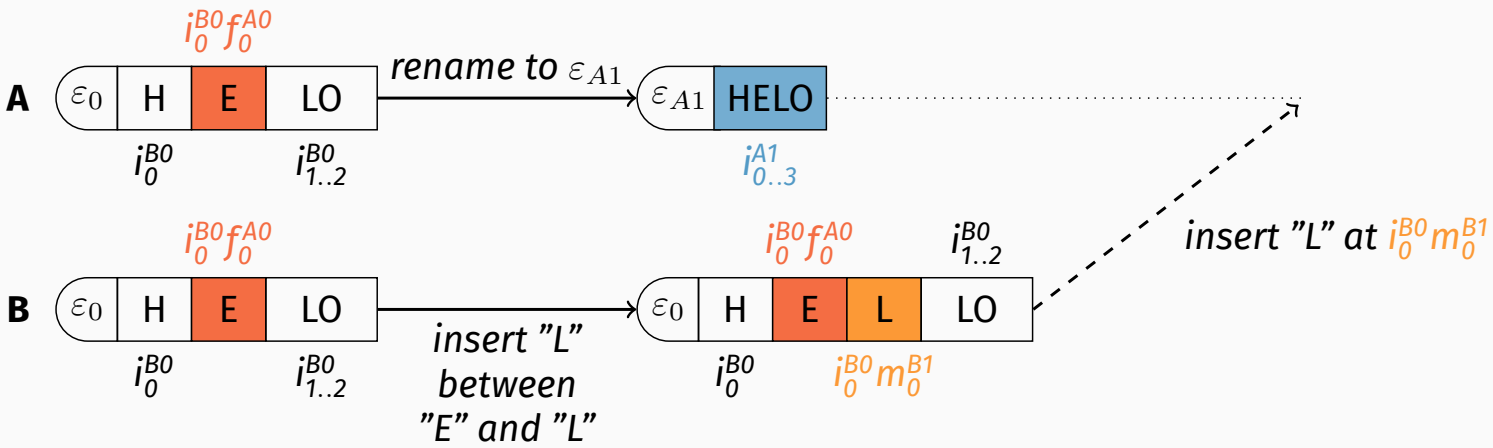

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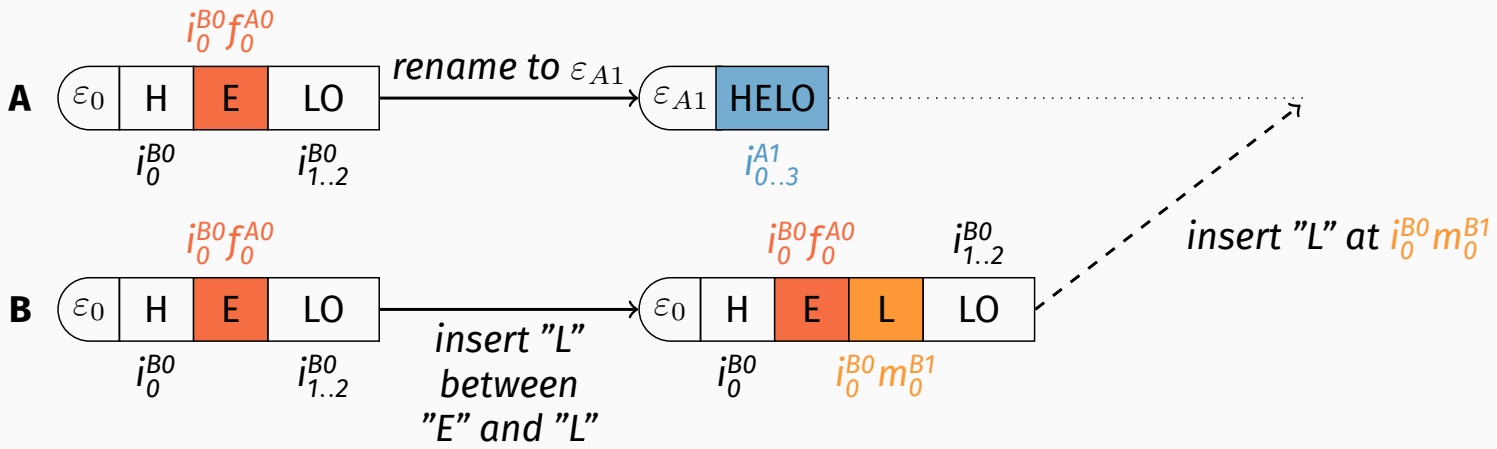

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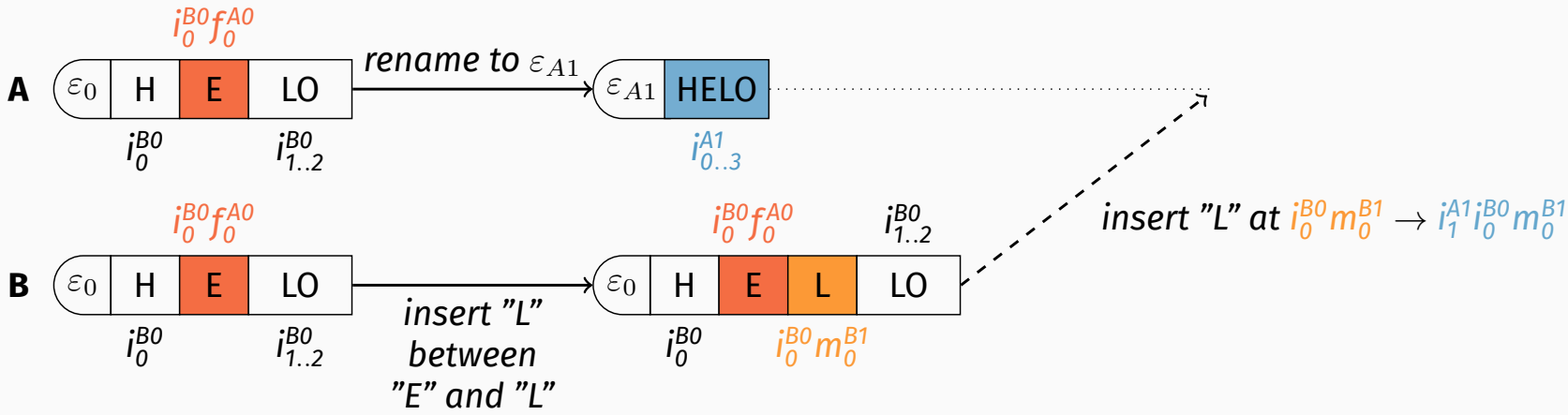

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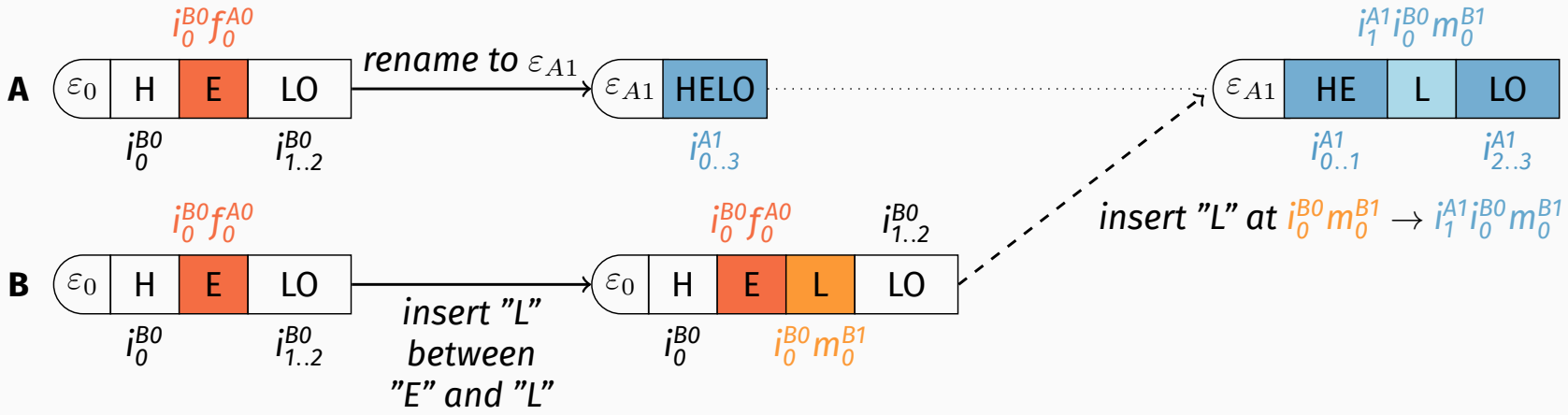

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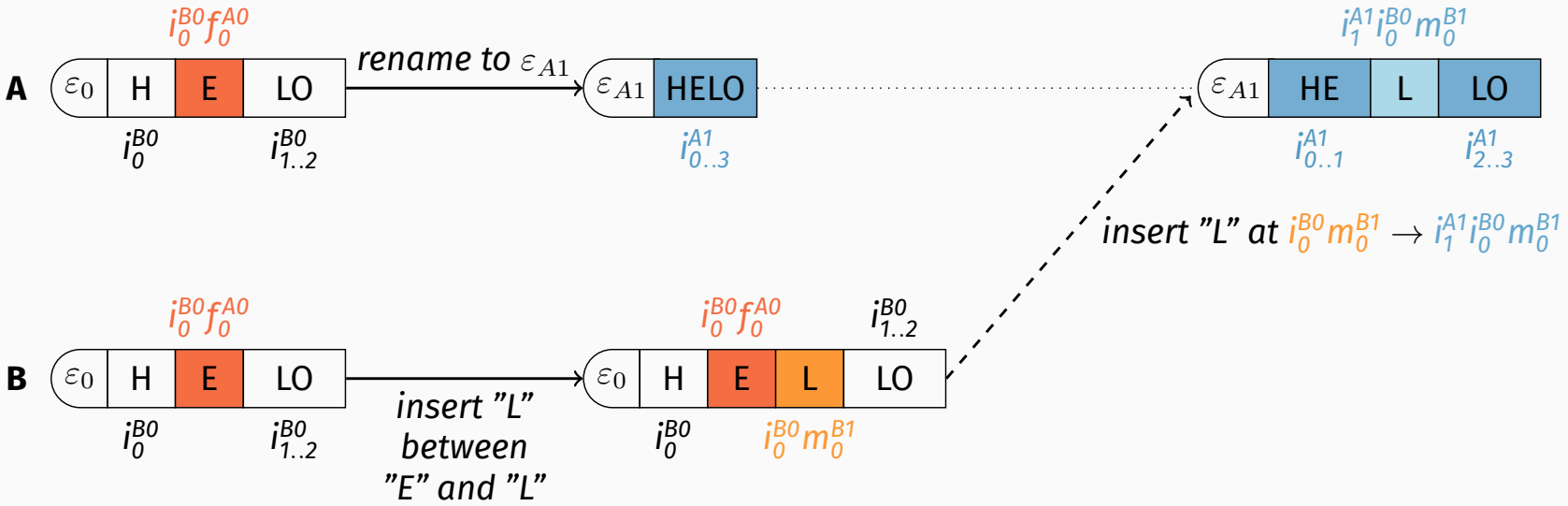

Figure 8 – Concurrent *rename* operations leading to divergent states

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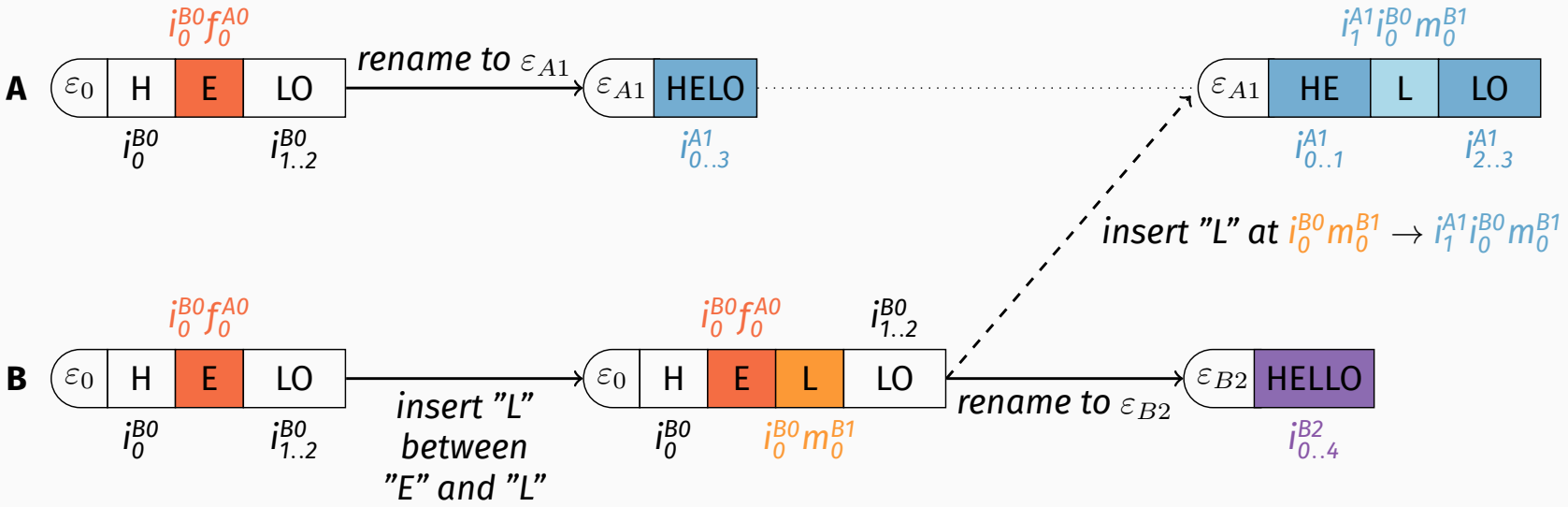

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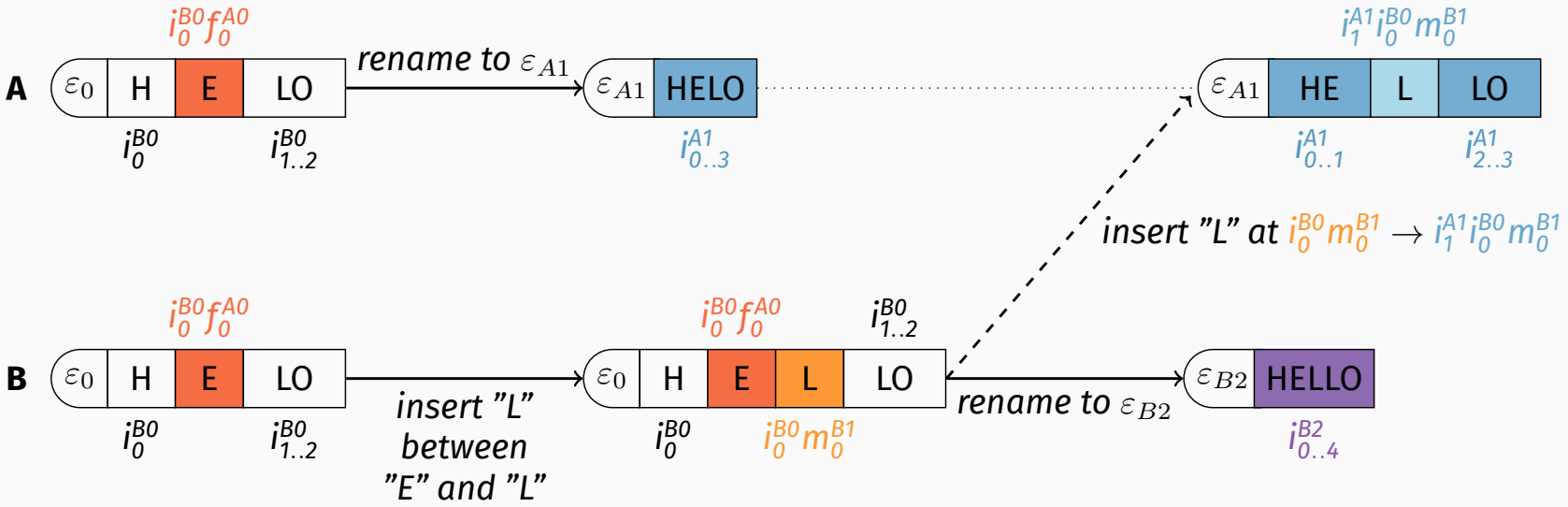

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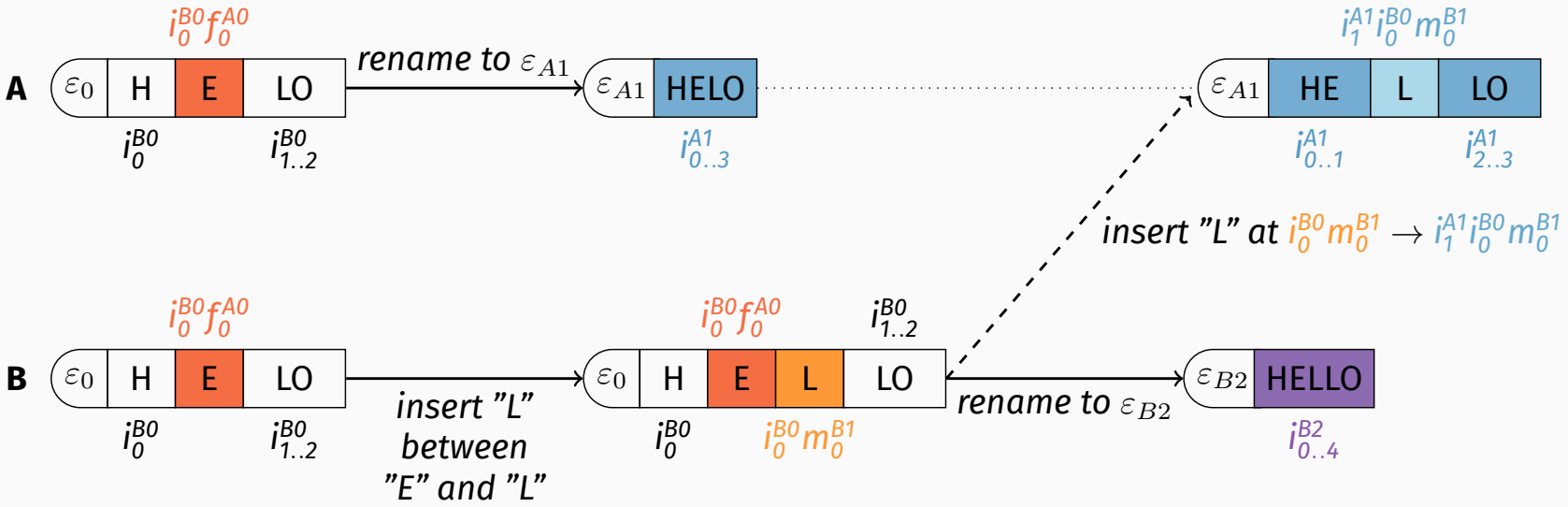

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Can resolve conflict by only applying one of them

How to do so ?

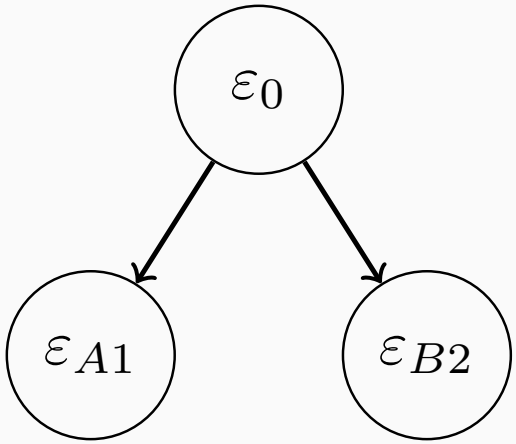

Figure 9 – *Epoch tree* corresponding to previous scenario

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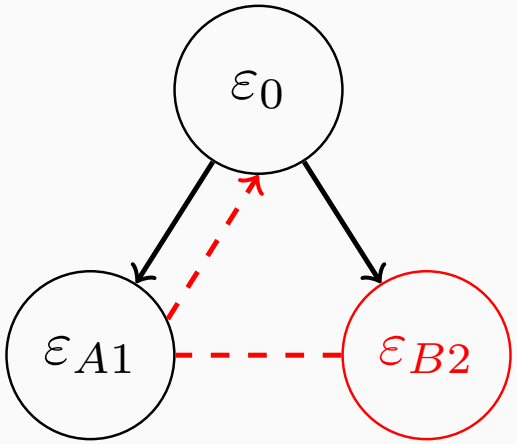

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Have to pick an epoch as the target one

Define total order on epochs

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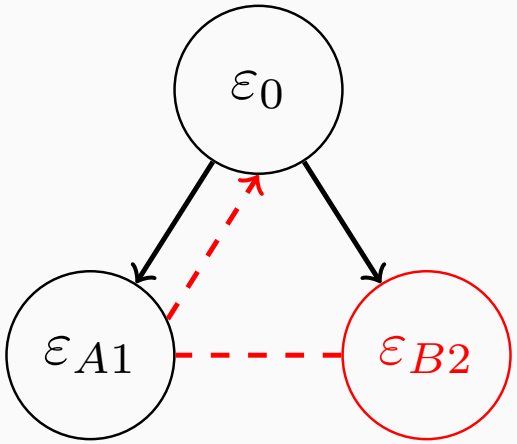

Figure 9 – *Epoch tree* corresponding to previous scenario

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

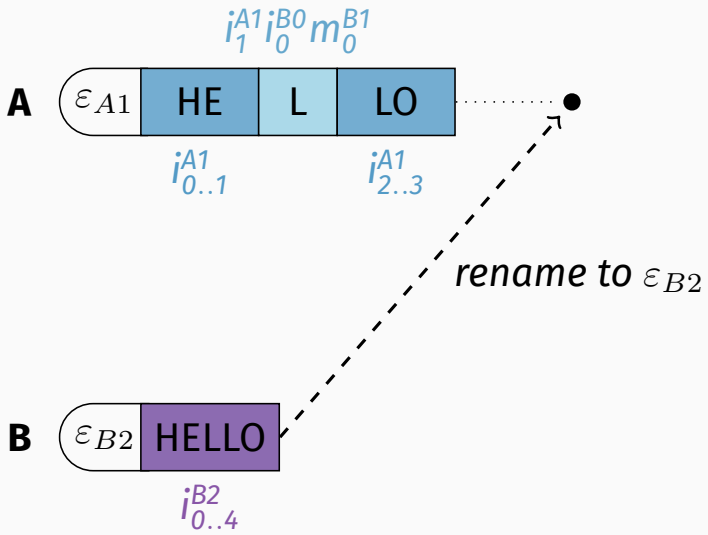

Figure 10 – Applying a concurrent *rename* operation

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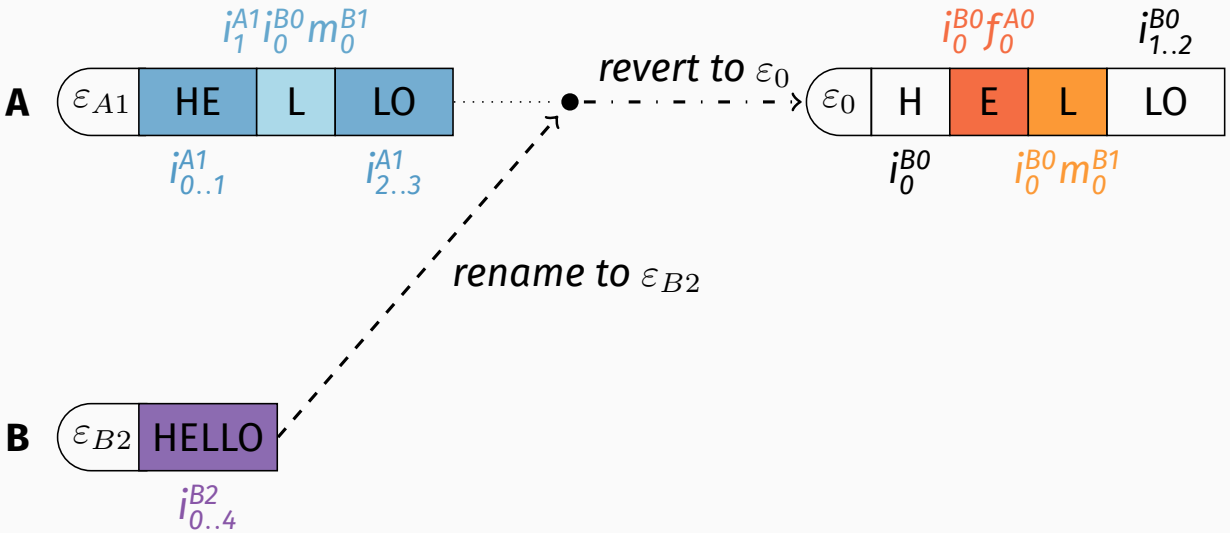

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Revert state to equivalent one at LCA epoch

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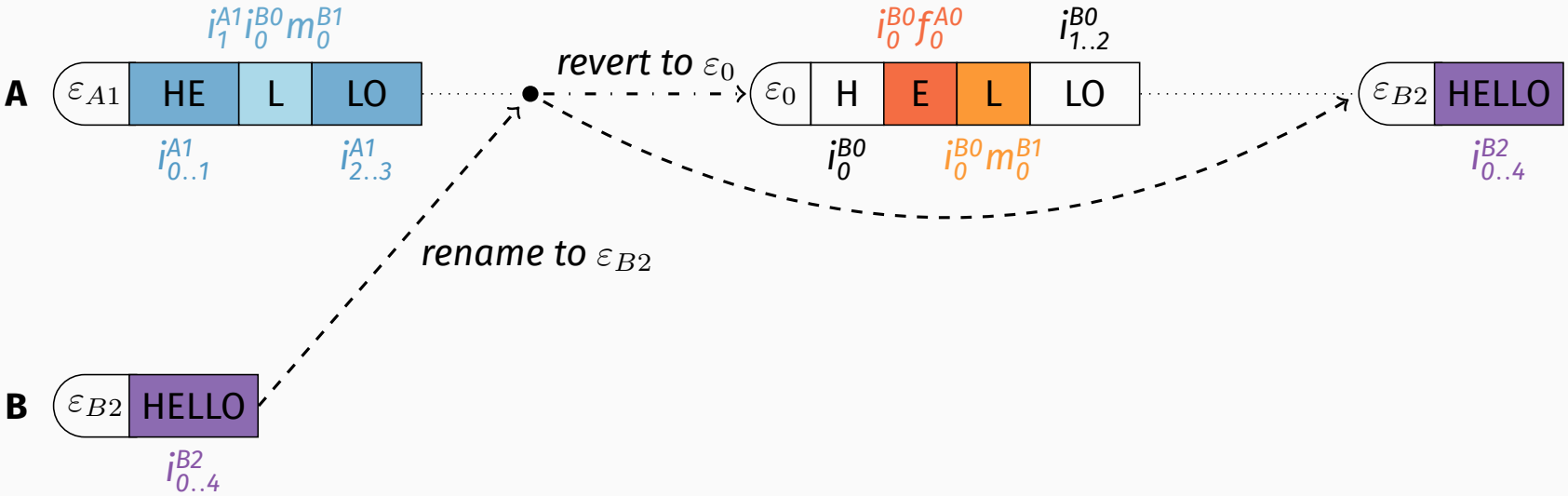


Figure 10 – Applying a concurrent *rename* operation

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 [4]
- 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

4. 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)

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`

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

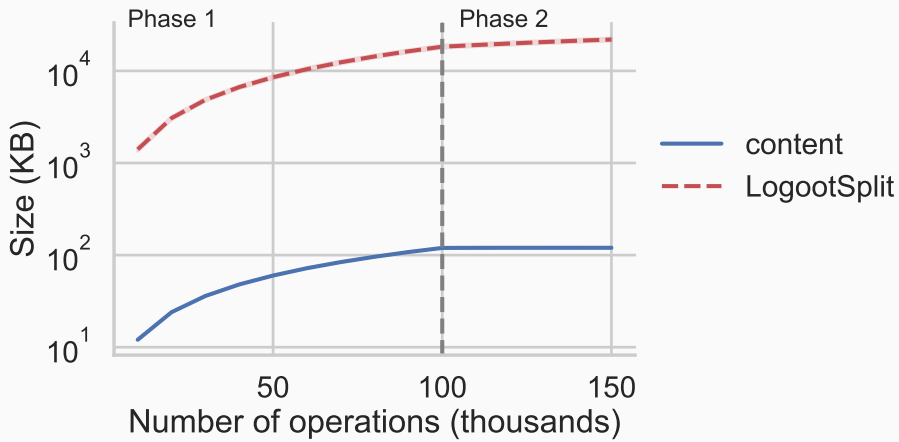
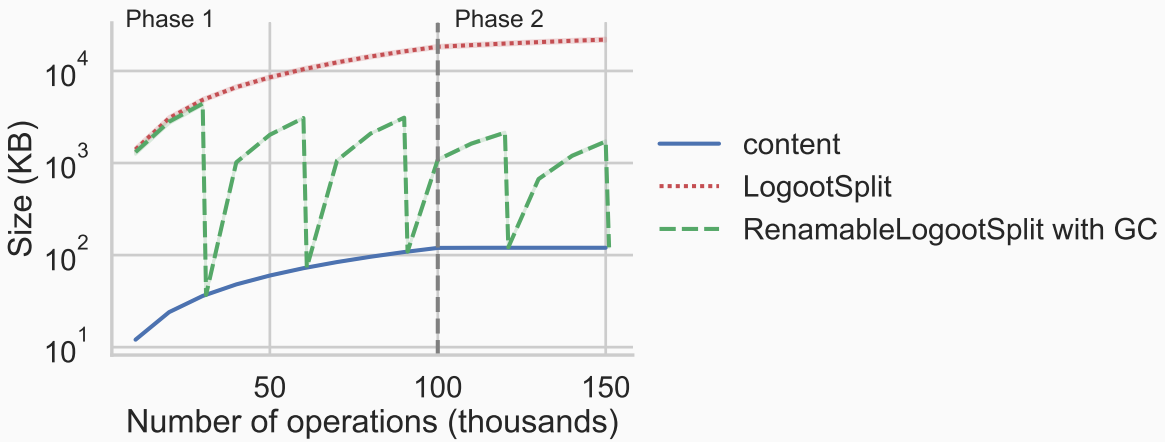


Figure 11 – Evolution of the size of the document

Results - Memory footprint



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

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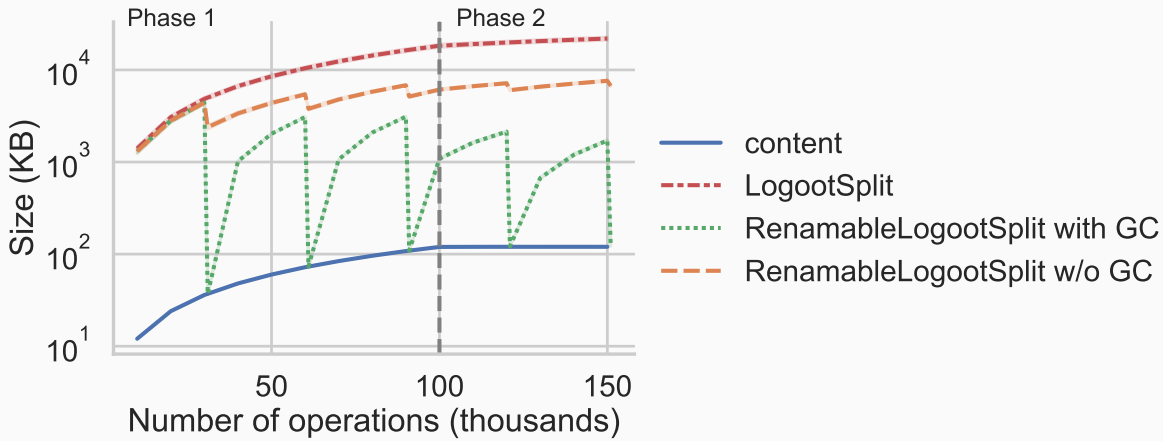

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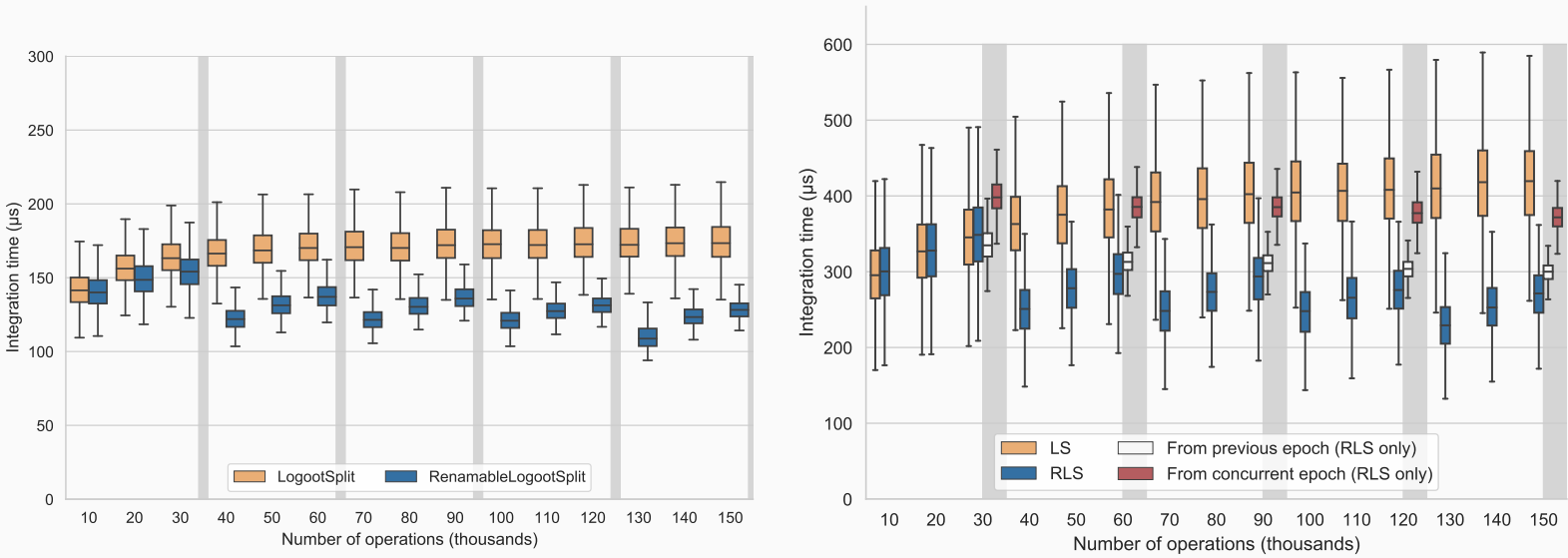
Rename still reduces by 66% the size otherwise

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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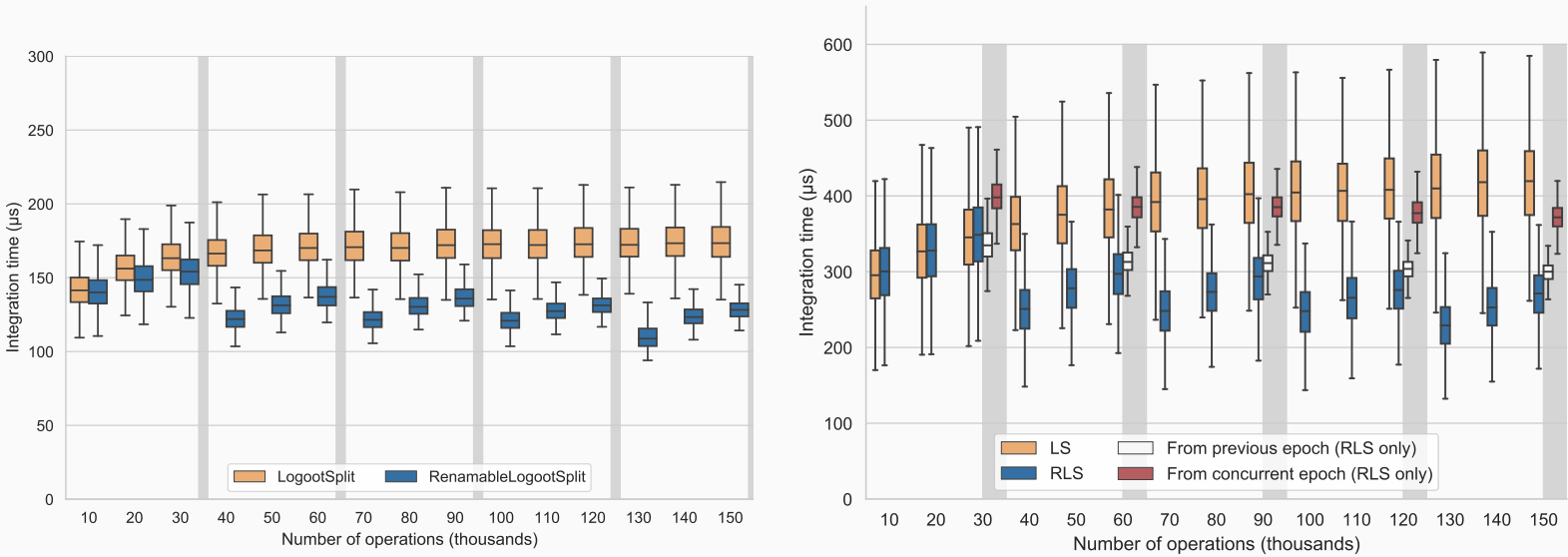

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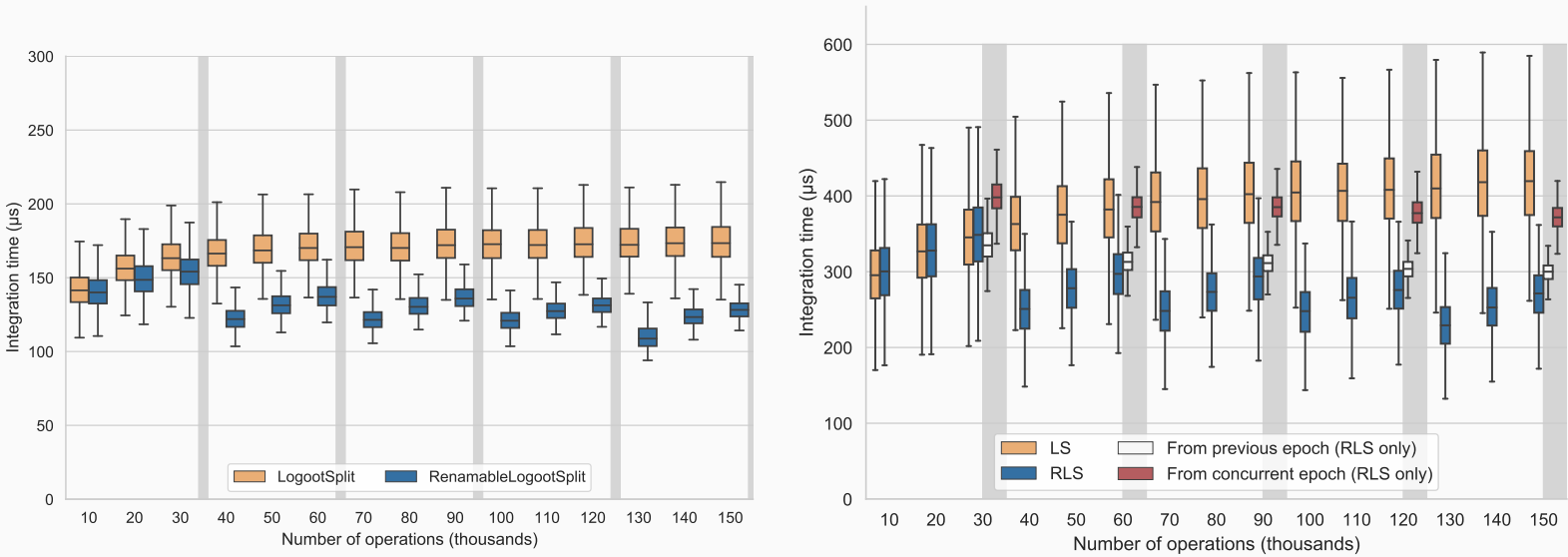
Figure 12 – Evolution of the integration time of *insert* operations

Rename reduces integration times of future operations

Results - Integration time of *insert* operations



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(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

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Table 1 – Integration time of rename operations

Noticeable by users

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Table 1 – Integration time of rename operations

Noticeable by users

Need to improve remote integration time

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

Conclusion

Done

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

Conclusion

Done

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

Work in progress

- Publishing it
- Writing the manuscript

Conclusion

Done

- Designed a new Sequence CRDT : RenamableLogootSplit
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To do

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

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 ?

Thanks for your attention, any questions?