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

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	Stephan Merz	Directeur de Recherche, Inria Nancy - Grand Est
Encadrants :	Olivier Perrin	Professeur des Universités, Université de Lorraine, LORIA
	Gérald Oster	Maître de conférences, Université de Lorraine, LORIA

Loria
Laboratoire lorrain de recherche en informatique et ses applications

Inria

cnrs
dépasser les frontières

Applications collaboratives

TODO : Voir comment représenter une appli collaboratice à ce stade

- Un système collaboratif est un système supportant ses utilisateur-rices dans leurs processus de collaboration pour la réalisation de tâches.

Démocratisation des applications collaboratives

TODO : Voir comment illustrer ce point. Screenshots et nombre d'utilisateurs en-dessous ?

Avantages d'une architecture basée sur le cloud…

TODO : Représenter collaboration via appli basée sur le cloud

- Disponibilité : Répond aux utilisateur-rices
- Tolérance aux pannes : Fonctionne malgré pannes
- Capacité de passage à l'échelle : Supporte activité massive

… et ses limites

TODO : Illustrer chacune des propriétés

- Confidentialité
- Souveraineté
- Pérennité
- Résistance à la censure

Pouvons-nous concevoir des applications collaboratives satisfaisant l'ensemble de ces propriétés ?

Applications collaboratives pair-à-pair [1]

TODO : Illustrer une appli P2P

Problématiques
En l'absence d'autorités centrales, comment

- résoudre les conflits de modifications ?
- authentifier les utilisateur-rices ?
- sécuriser les communications ?

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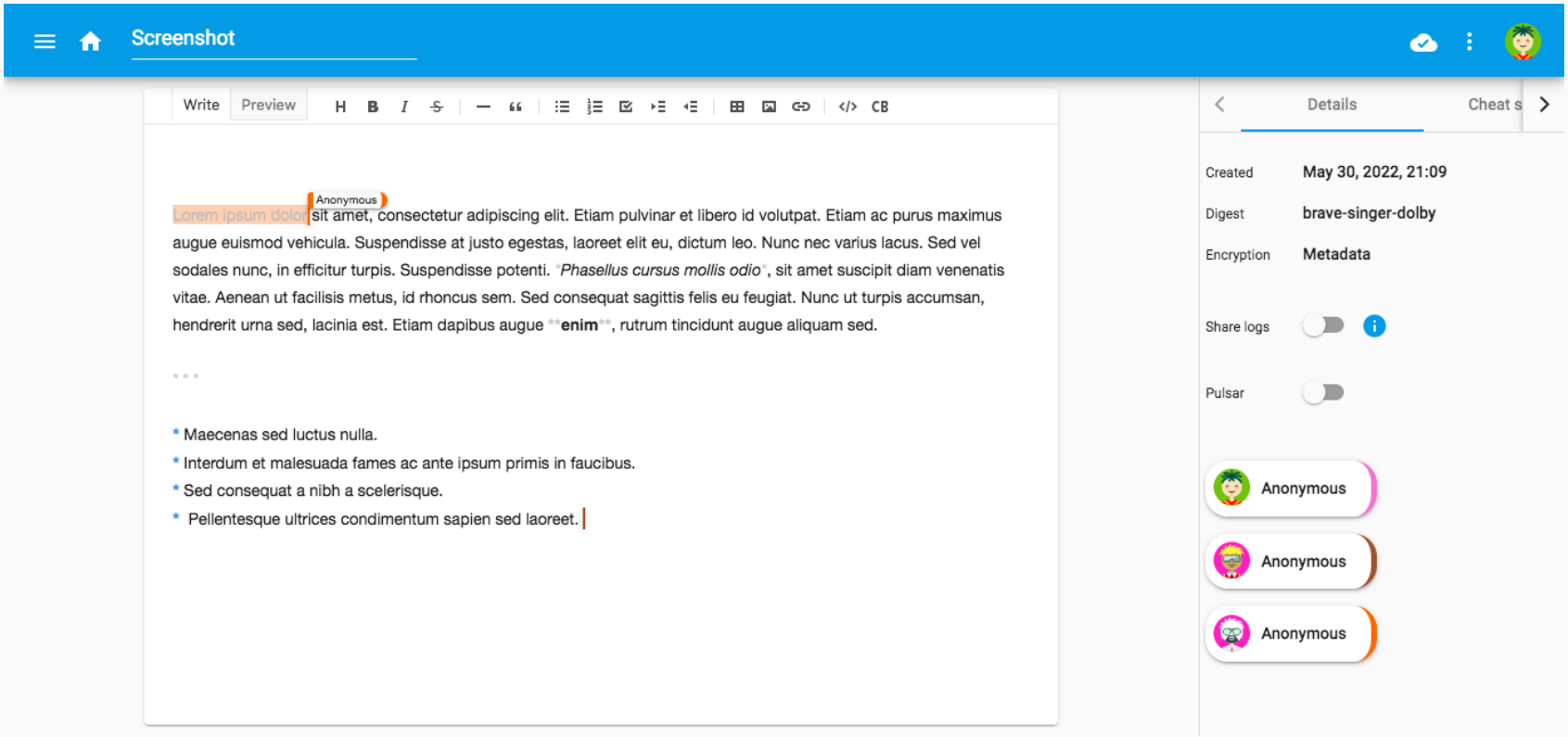
1. Martin Kleppmann et al. « Local-First Software : You Own Your Data, in Spite of the Cloud ». In : *Proceedings of the 2019 ACM SIGPLAN International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software*. Onward ! 2019. Athens, Greece : Association for Computing Machinery, 2019, p. 154-178. ISBN : 9781450369954. DOI : 10.1145/3359591.3359737. URL : https://doi.org/10.1145/3359591.3359737.

MUTE [2]



- Éditeur de texte collaboratif P2P temps réel chiffré de bout en bout
- Permet à l'équipe d'étudier et contribuer sur les problématiques des applications Local-First Software (LFS)

2. Matthieu Nicolas et al. « MUTE : A Peer-to-Peer Web-based Real-time Collaborative Editor ». In : *ECSCW 2017 - 15th European Conference on Computer-Supported Cooperative Work*. T. 1. Proceedings of 15th European Conference on

Mes contributions

- Conception d'un nouveau Conflict-free Replicated Data Type (CRDT) pour le type Séquence
- Implémentation et intégration de CRDTs dans MUTE

LogootSplit [3]

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

3. 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*. Austin, TX, USA : IEEE Computer Society, oct. 2013, p. 50-59. DOI : 10.4108/icst.collaboratecom.2013.254123.

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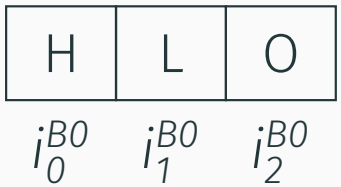

Figure 1 – State of a sequence which contains the elements ”HLO” and their corresponding identifiers

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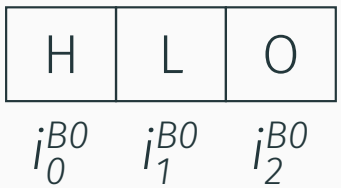

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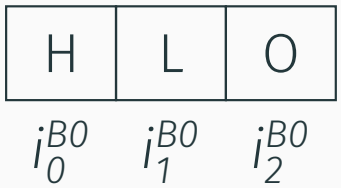

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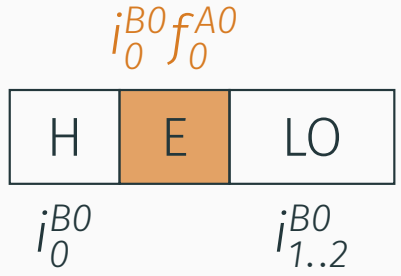

Figure 3 – State of a sequence which contains the elements ”HELO” and their corresponding identifiers

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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

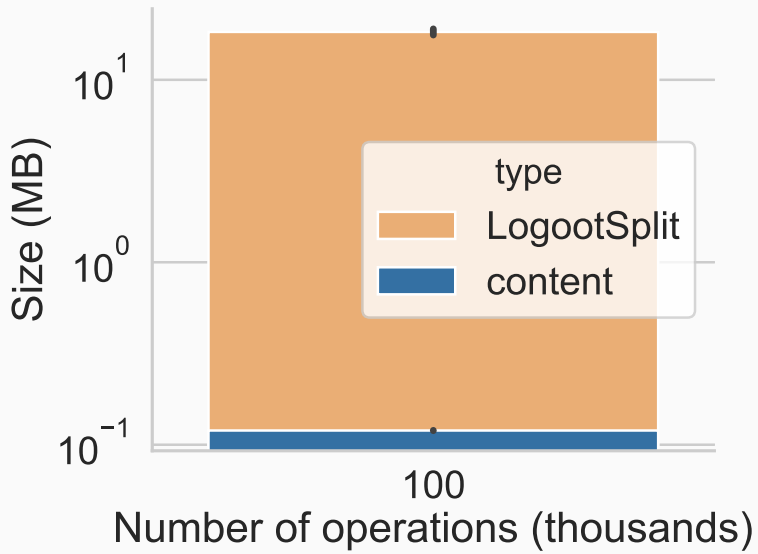
- To comply with these constraints, LogootSplit proposes identifiers composed of quadruplets of integers of the following form :

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

- *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



- **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 ?

Related work

- Core-nebula approach [4]
  - Reassigns shorter identifiers to elements...
  - ...but requires consensus
- LSEQ [5]
  - Set of strategies to reduce the growth of identifiers ...
  - ...but overhead still proportional to number of elements

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4. Marek Zawirski et al. « Asynchronous rebalancing of a replicated tree ». In : *Conférence Française en Systèmes d'Exploitation (CFSE)*. Saint-Malo, France, mai 2011, p. 12. URL : https://hal.inria.fr/hal-01248197.
5. Brice Nédelec et al. « A scalable sequence encoding for collaborative editing ». In : *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

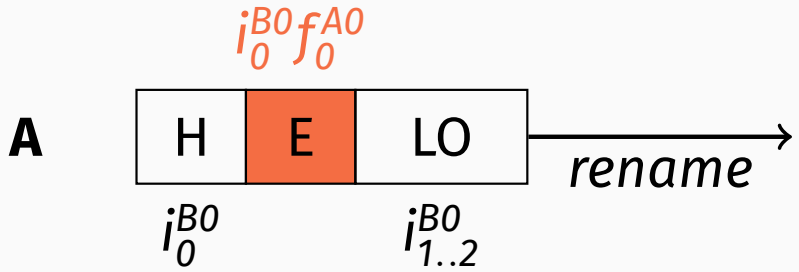

Figure 5 – Example of renaming

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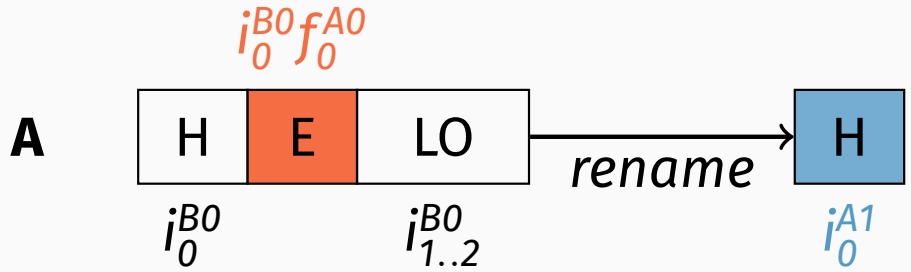

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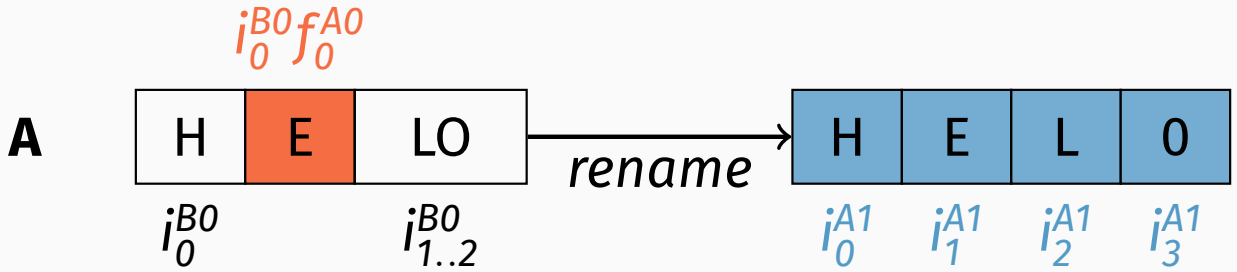

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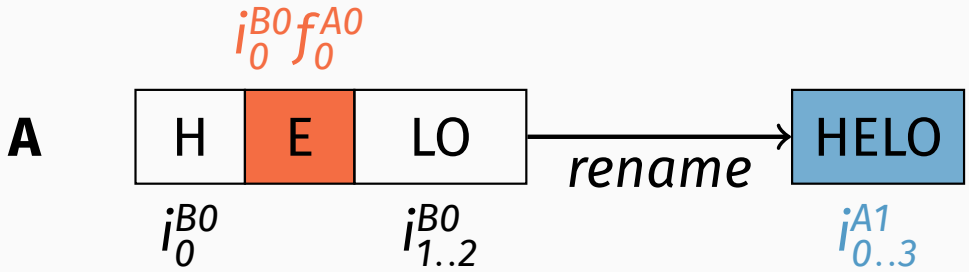

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Handling concurrent operations

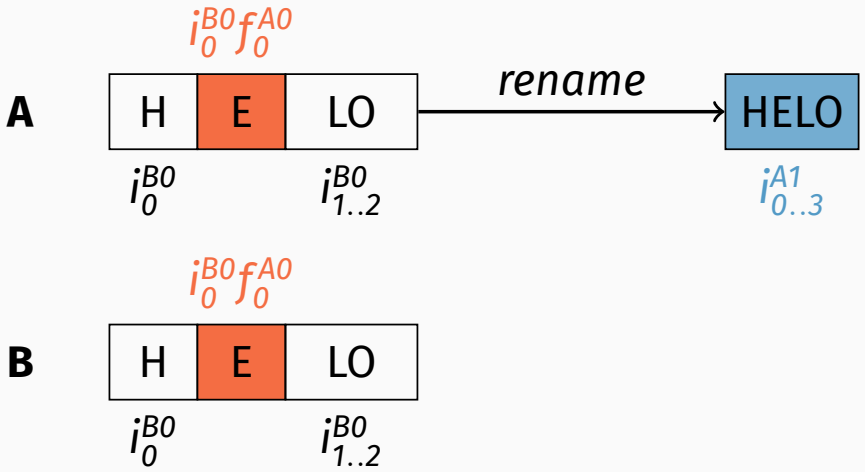
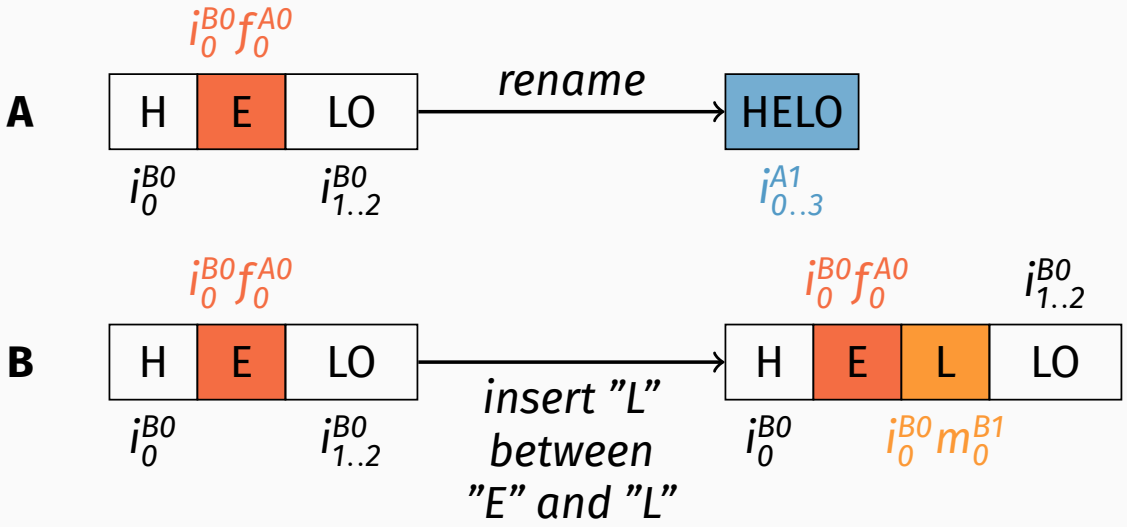


Figure 6 – Applying naively concurrent update

Handling concurrent operations



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- Can issue operations concurrently to *rename*

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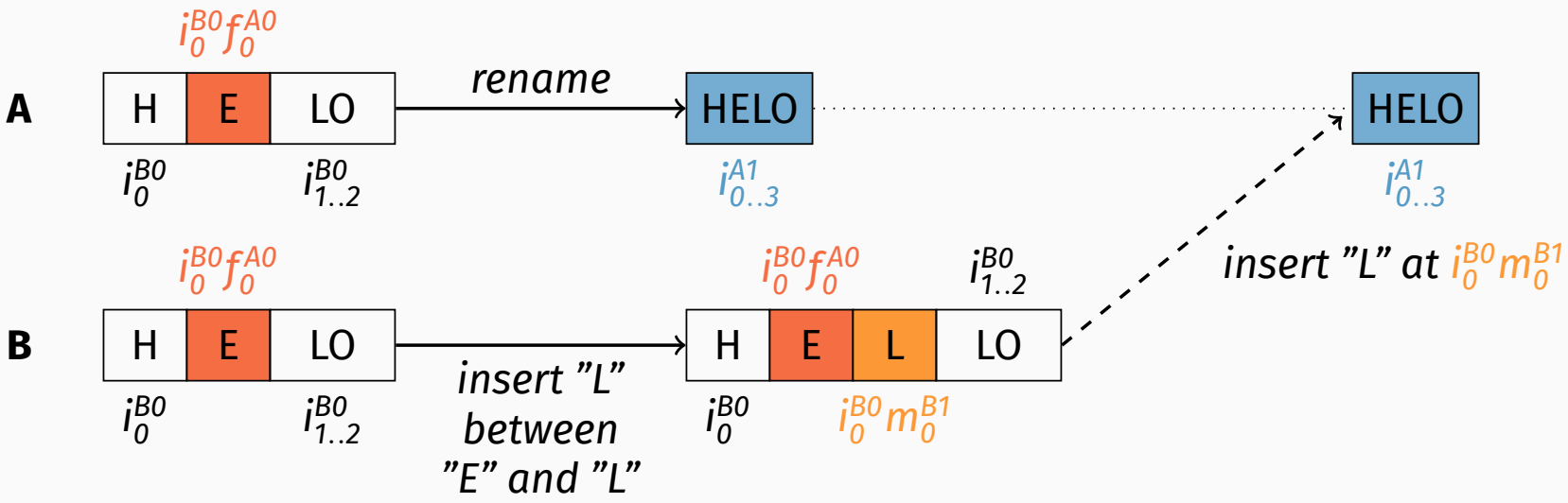

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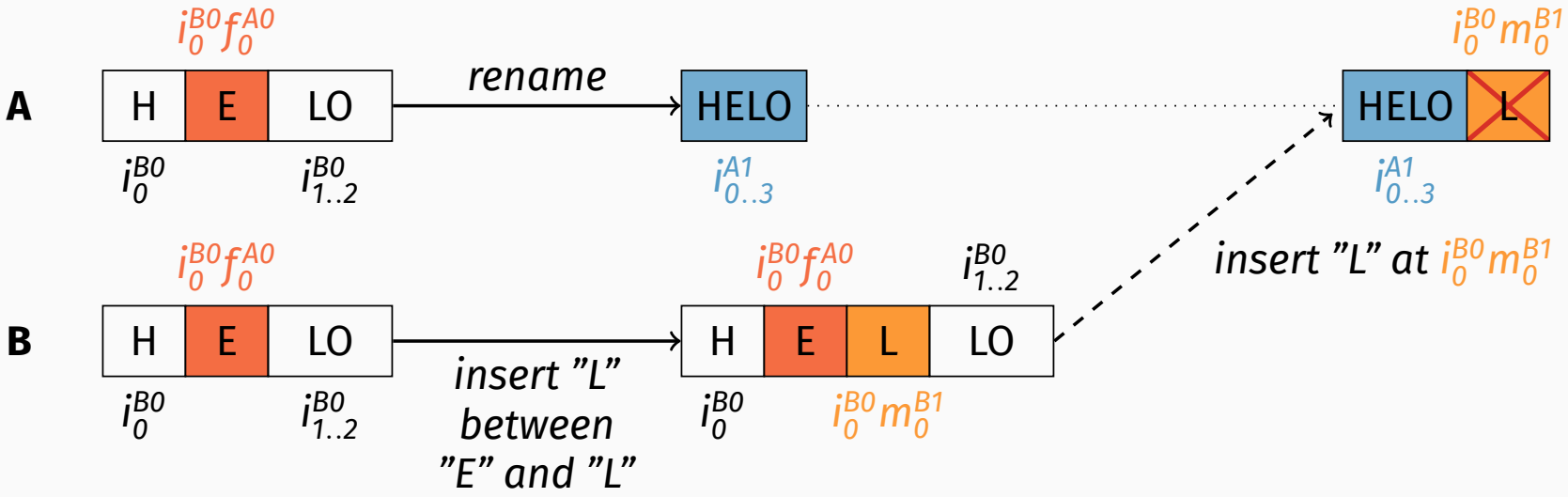

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- Can issue operations concurrently to *rename*
- Produce inconsistencies if applied naively

Fixing handling concurrent operations

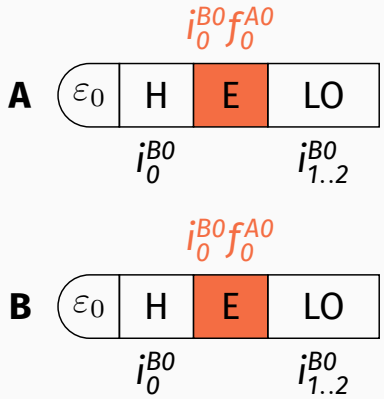

Figure 7 – Handling properly concurrent update

- Use *epoch-based* system to track concurrent operations

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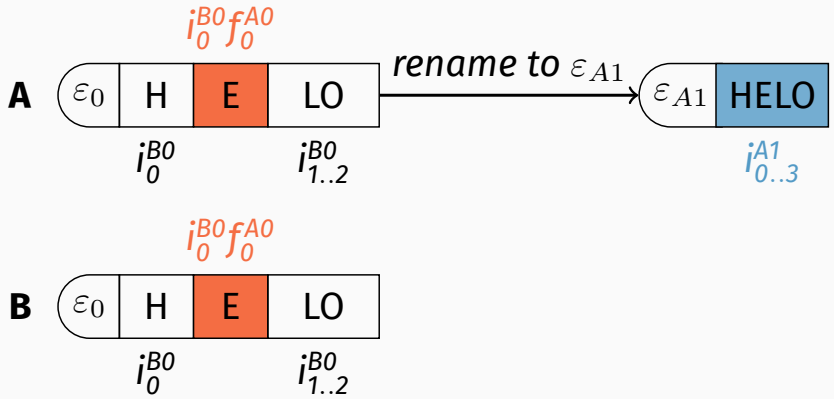

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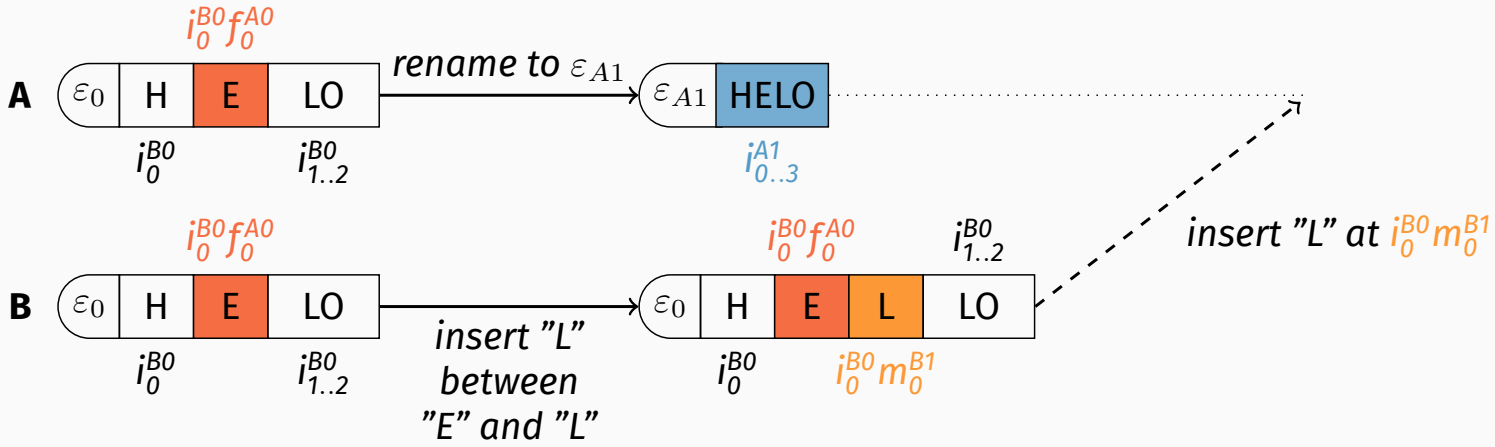

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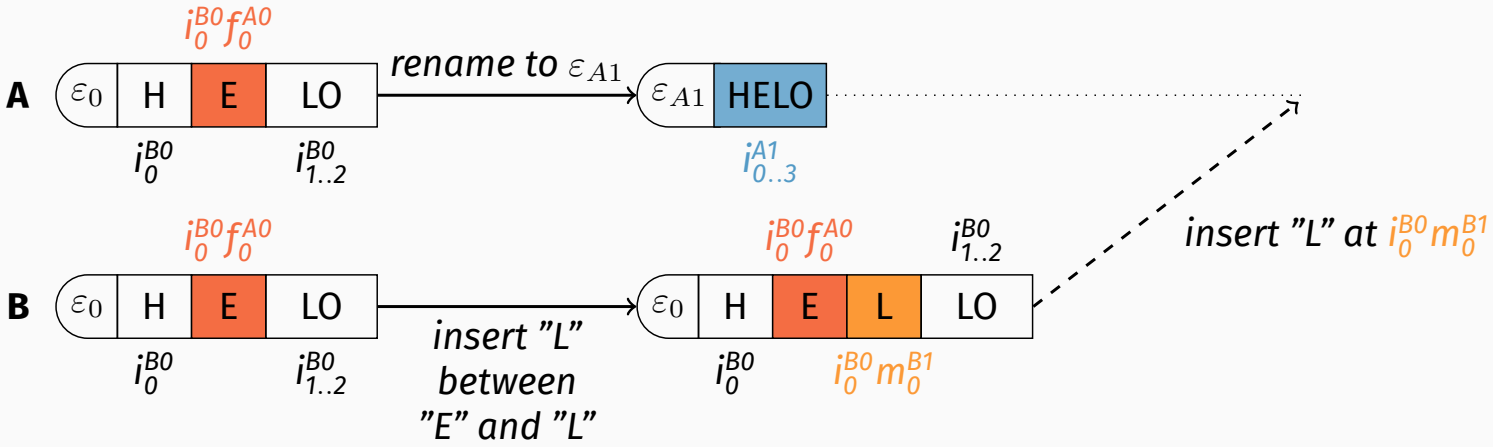

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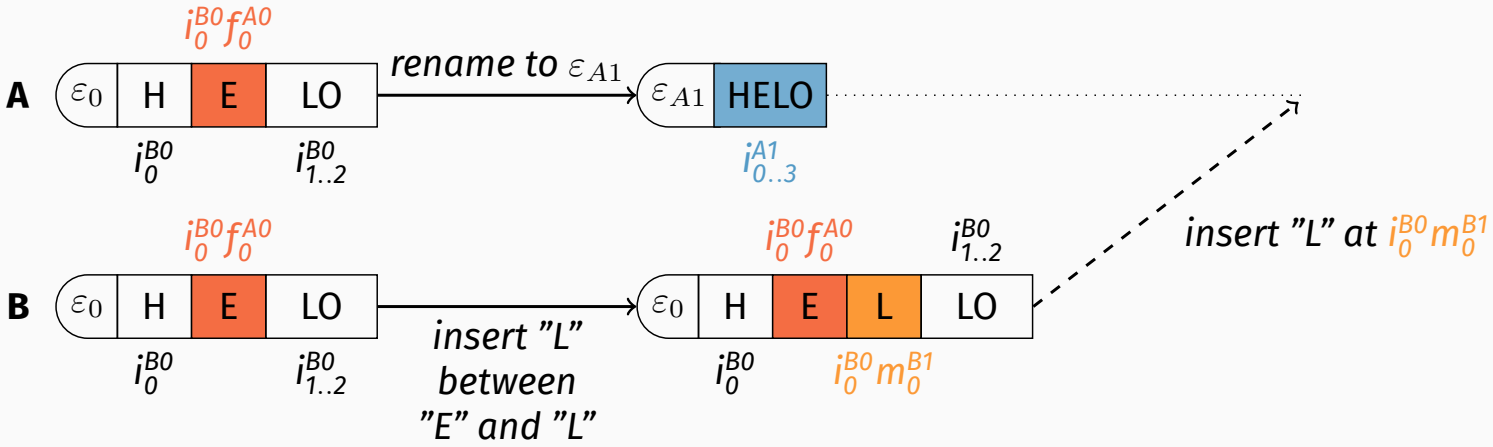

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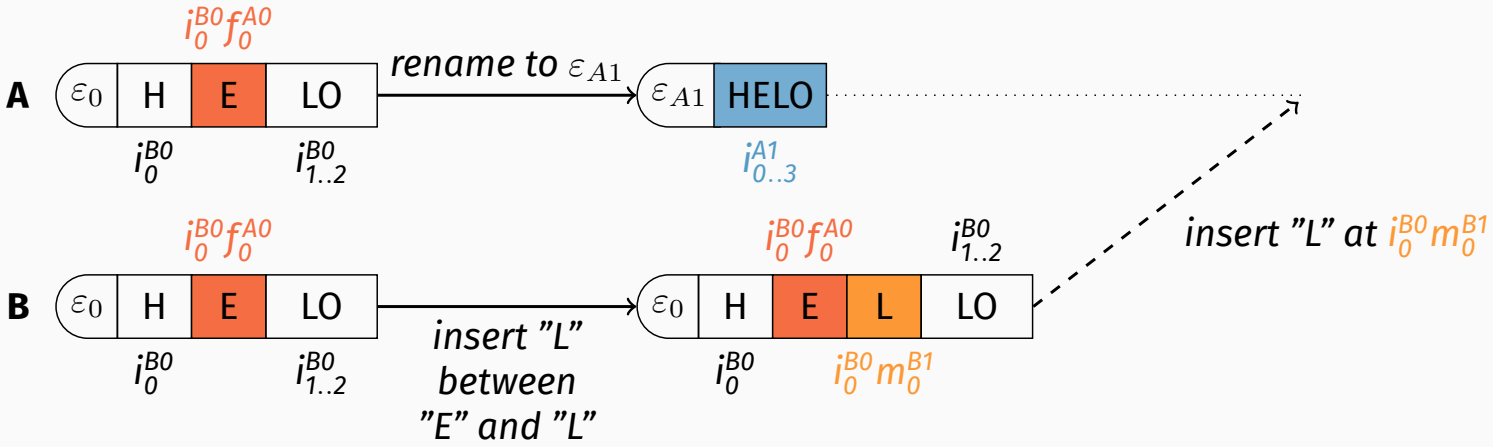

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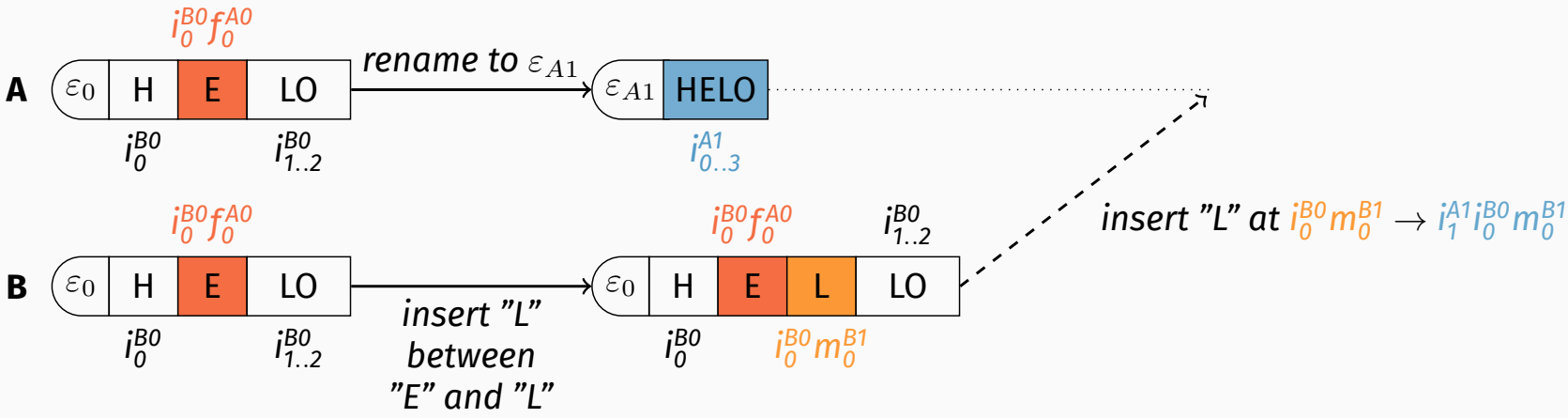

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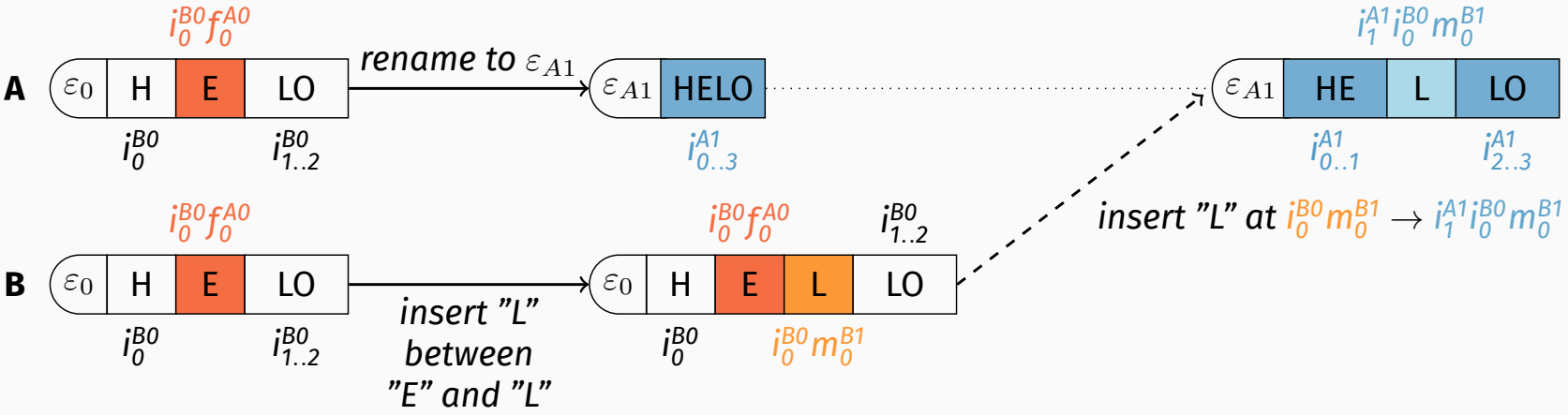

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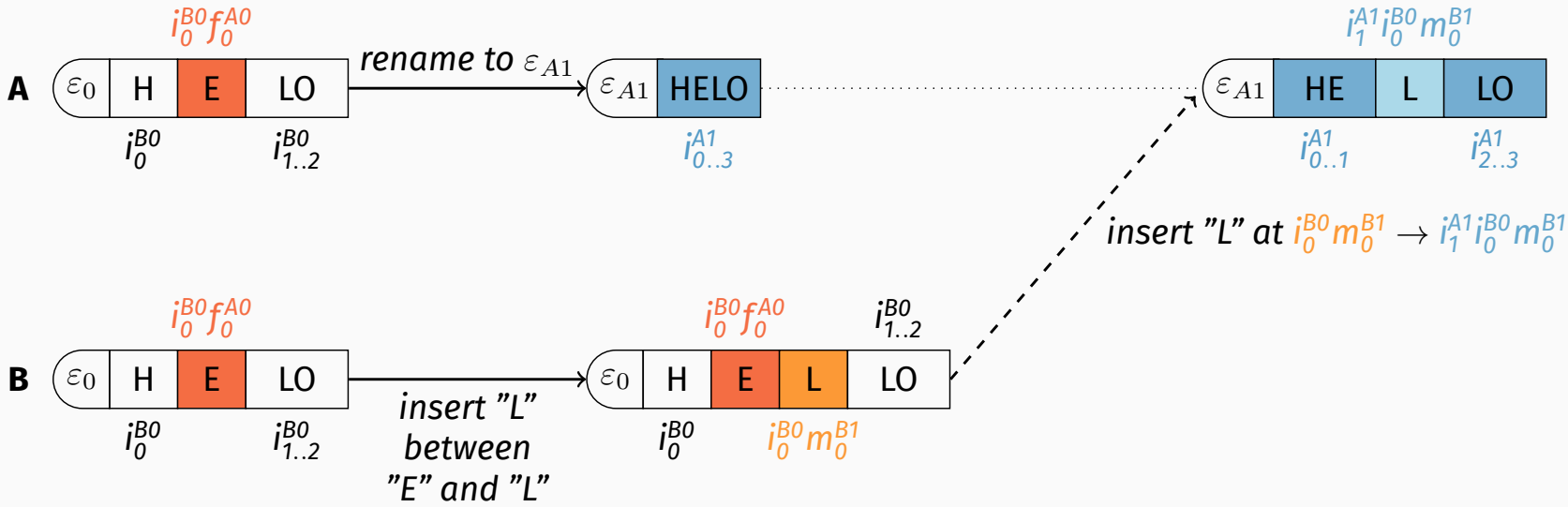

Figure 8 – Concurrent *rename* operations leading to divergent states

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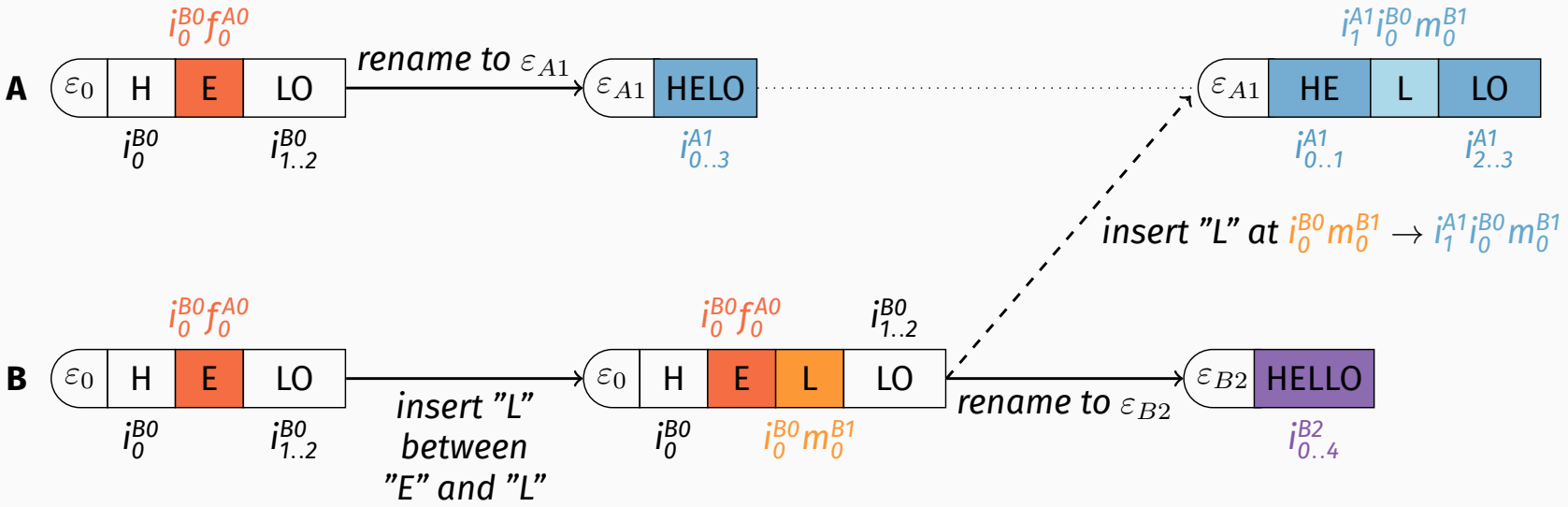

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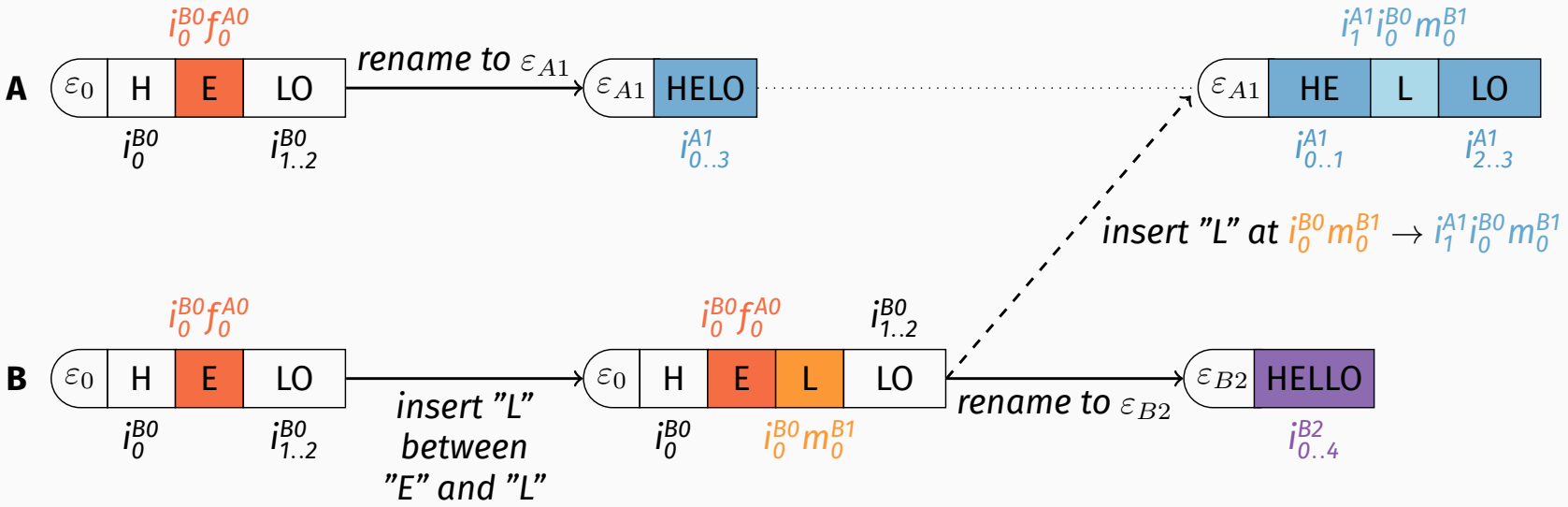

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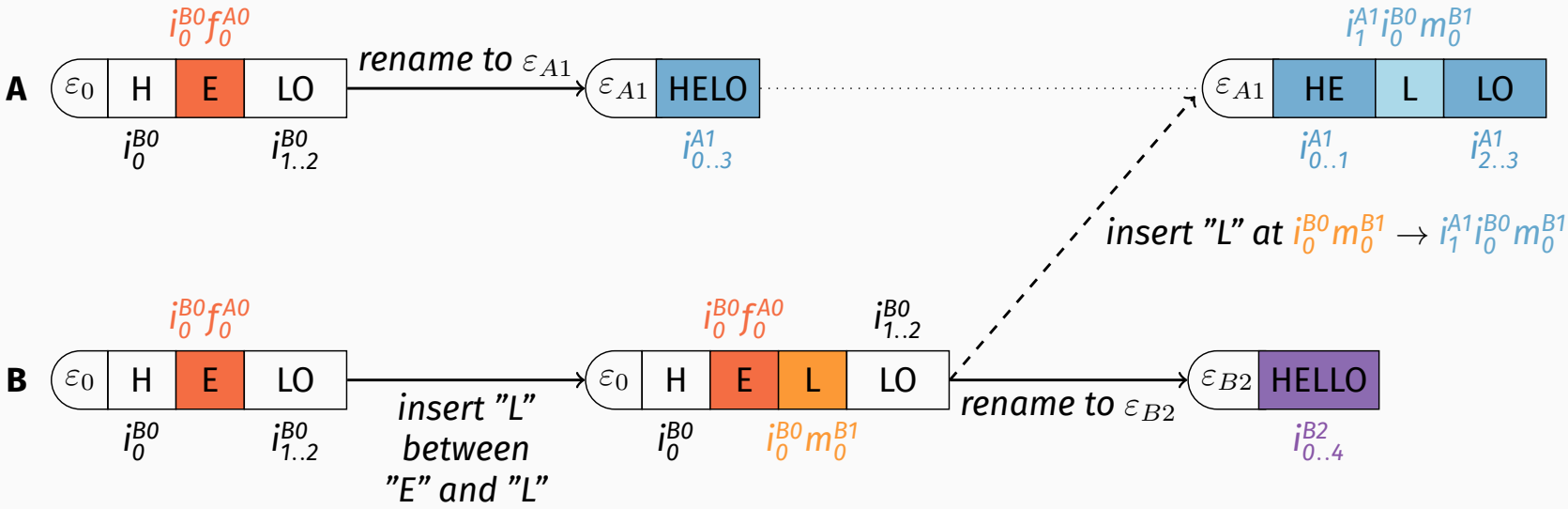

Figure 8 – Concurrent *rename* operations leading to divergent states

- *Rename* operations are system operations
- Can resolve conflict by only applying one of them

How to do so?

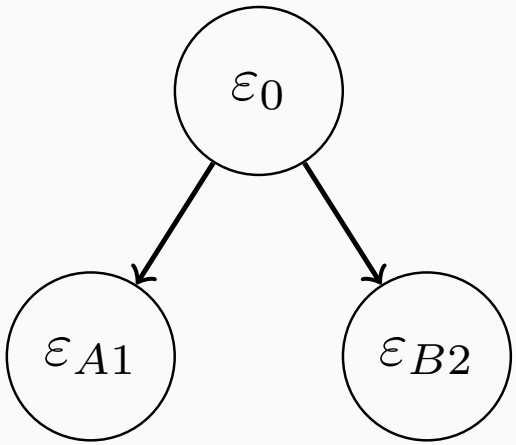

Figure 9 – *Epoch tree* corresponding to previous scenario

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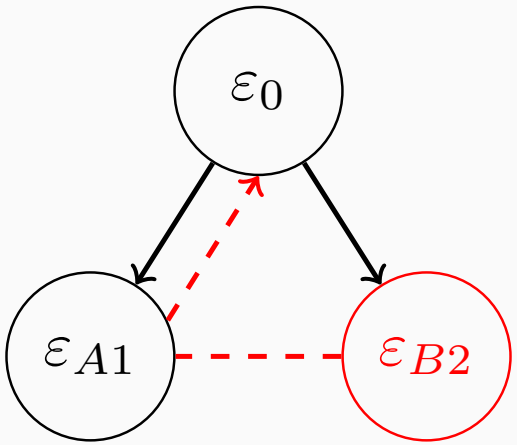

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  - Define total order on epochs

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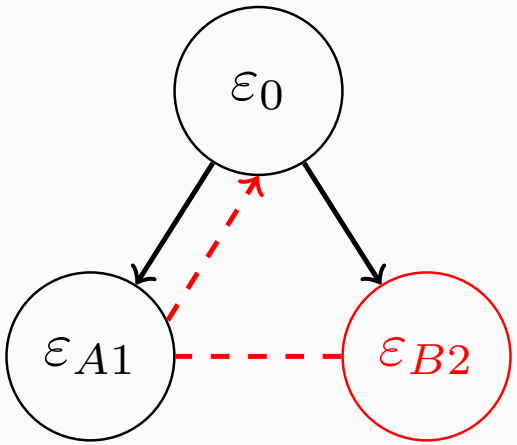

Figure 9 – *Epoch tree* corresponding to previous scenario

- 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

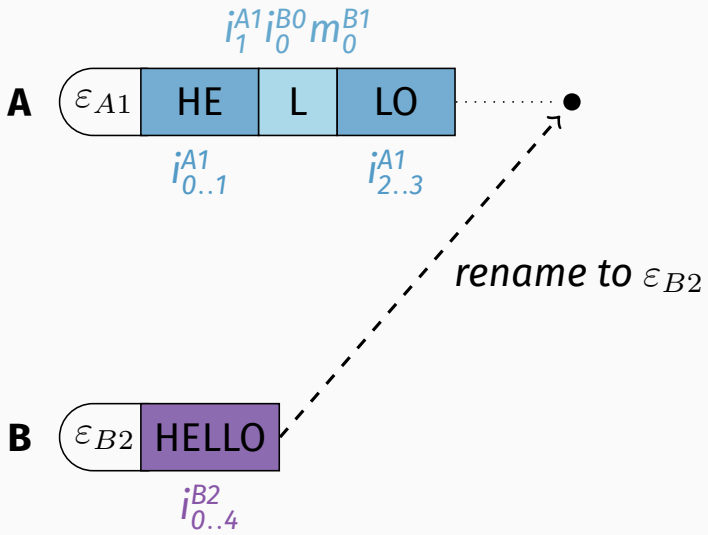

Figure 10 – Applying a concurrent *rename* operation

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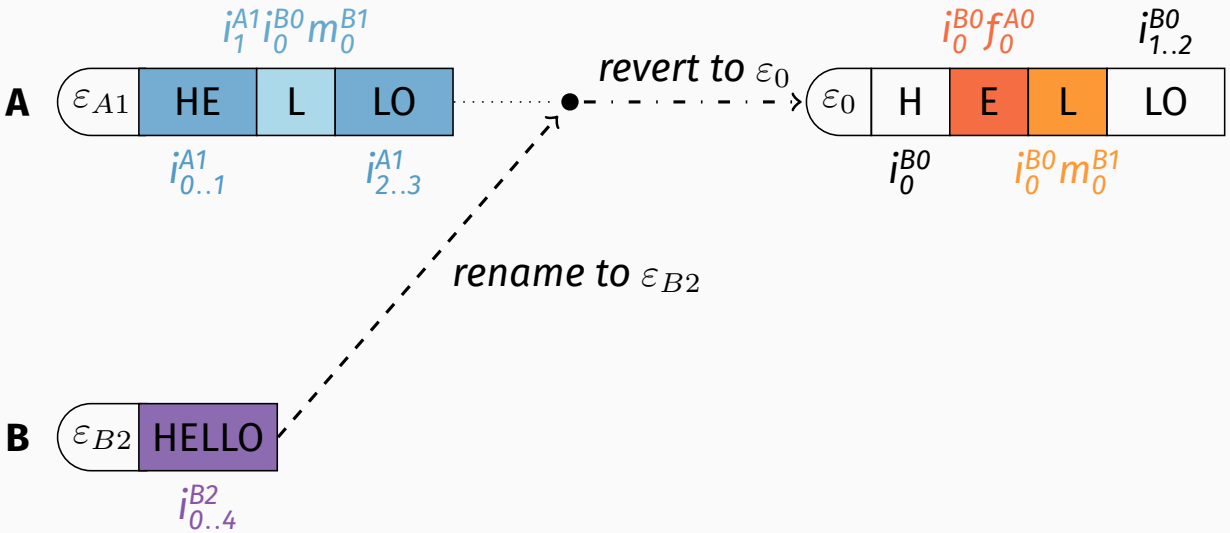

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- Revert state to equivalent one at LCA epoch

Applying concurrent *rename* operations

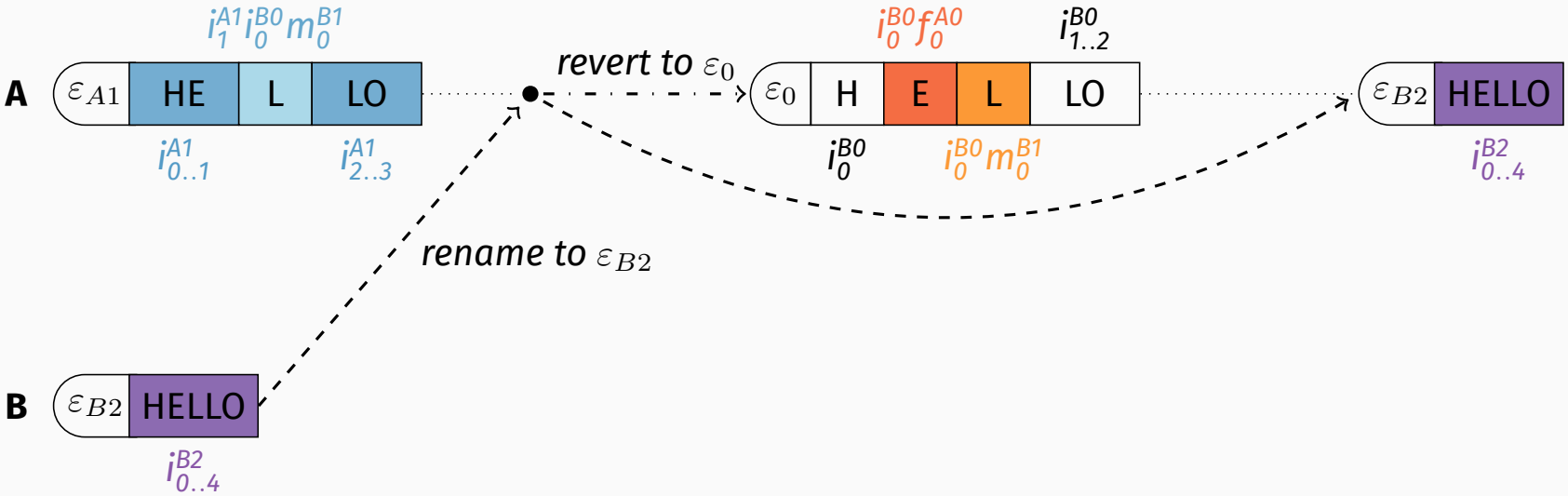


Figure 10 – Applying a concurrent *rename* operation

- 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 [6]
- 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

6. Carlos Baquero et al. « Making Operation-Based CRDTs Operation-Based ». In : *Distributed Applications and Interoperable Systems*. Sous la dir. de Kostas Magoutis et al. Berlin, Heidelberg : Springer Berlin Heidelberg, 2014, p. 126-140.

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*[7]
- 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()`

7. `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

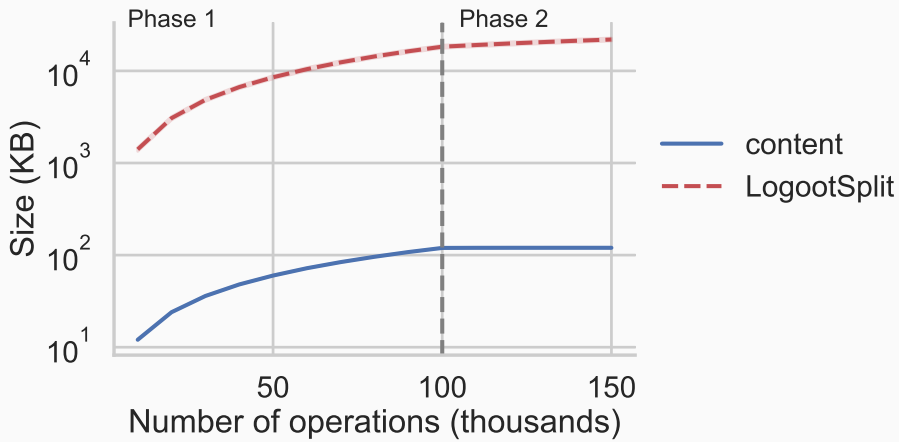


Figure 11 – Evolution of the size of the document

Results - Memory footprint

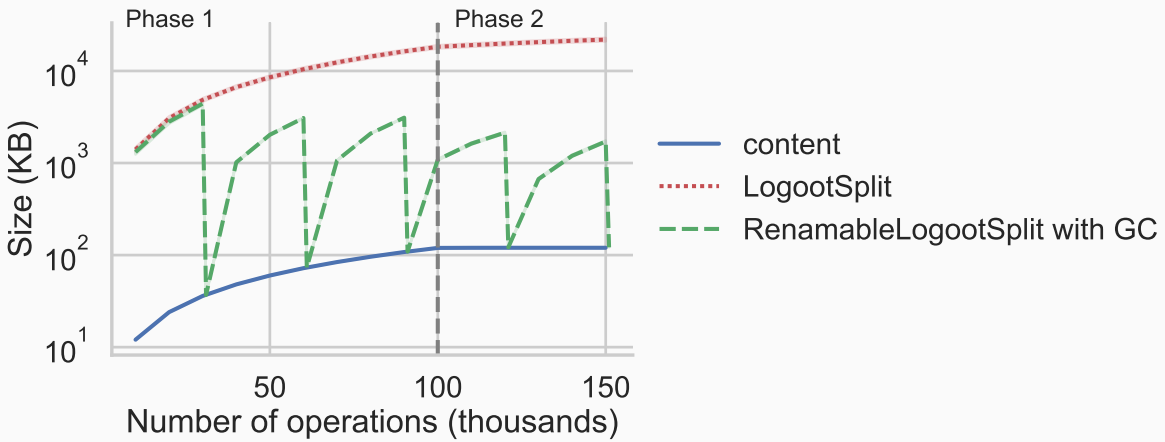


Figure 11 – Evolution of the size of the document

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

Results - Memory footprint

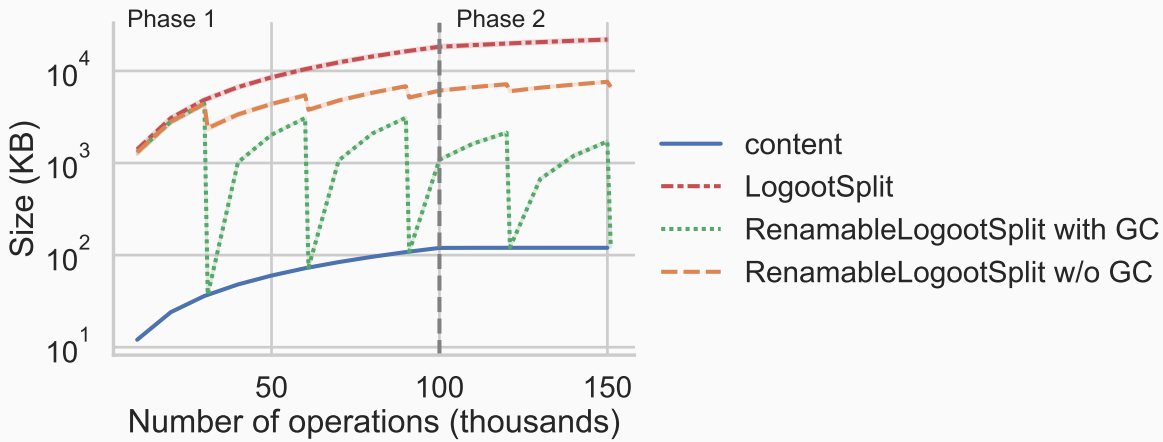
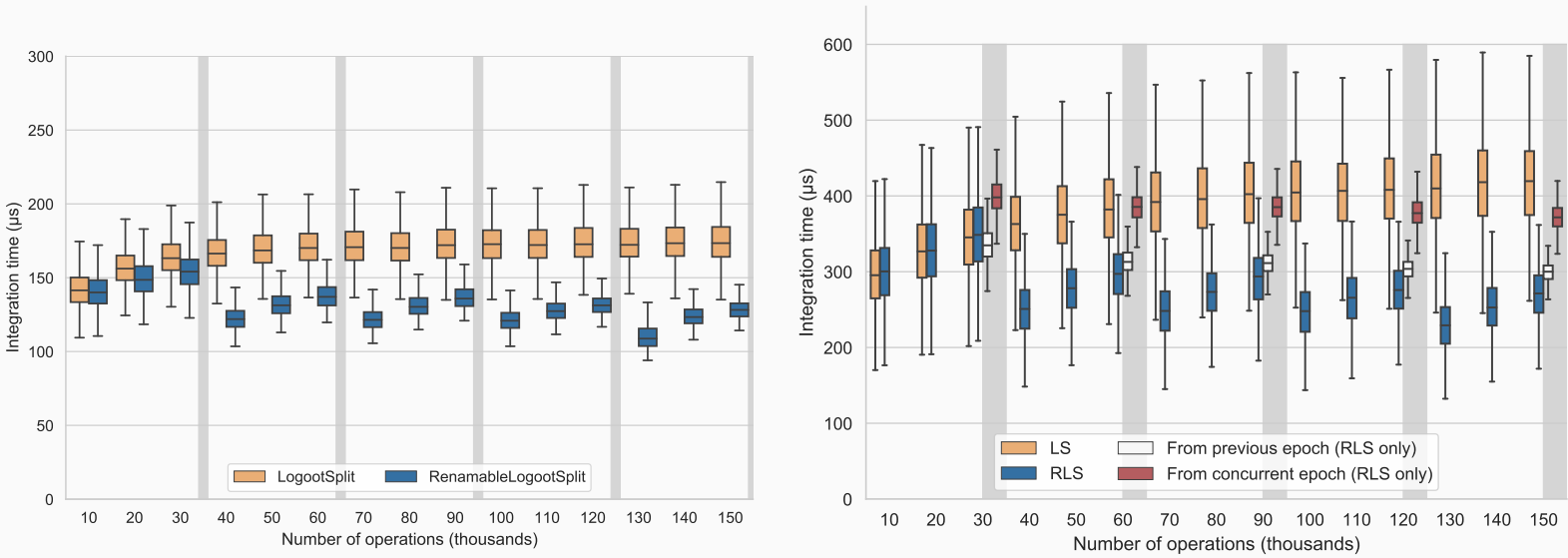


Figure 11 – Evolution of the size of the document

- *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

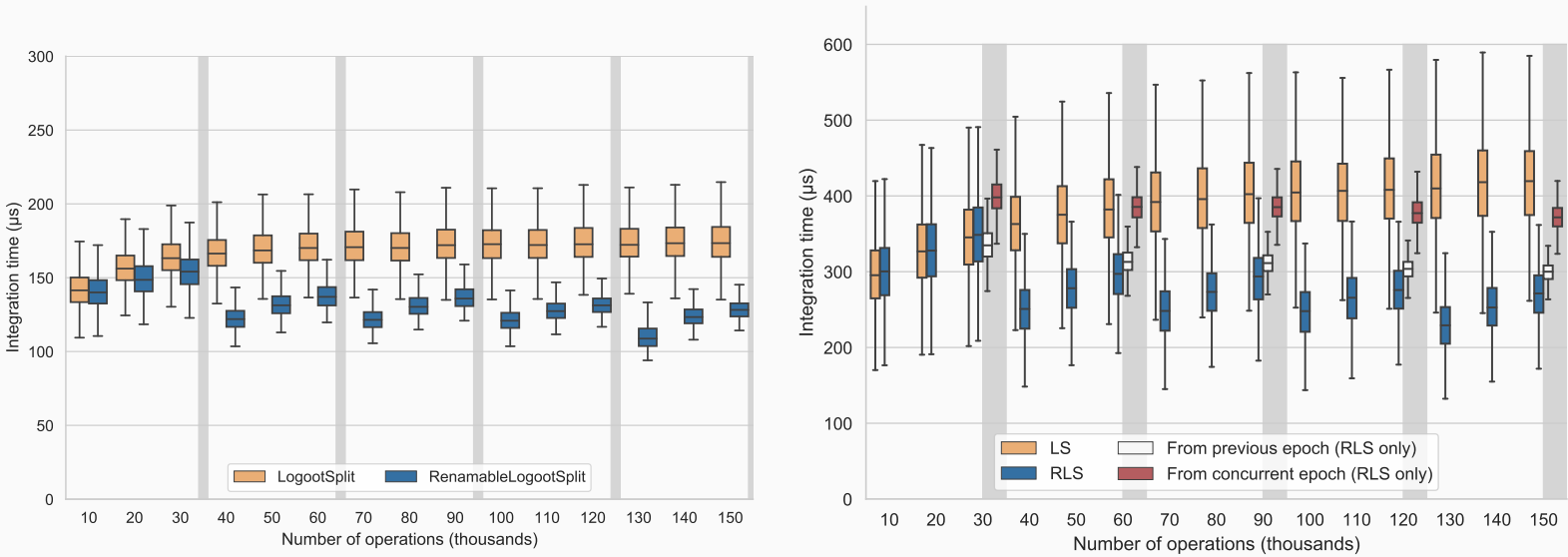


(a) Local operations

(b) Remote operations

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

Results - Integration time of *insert* operations



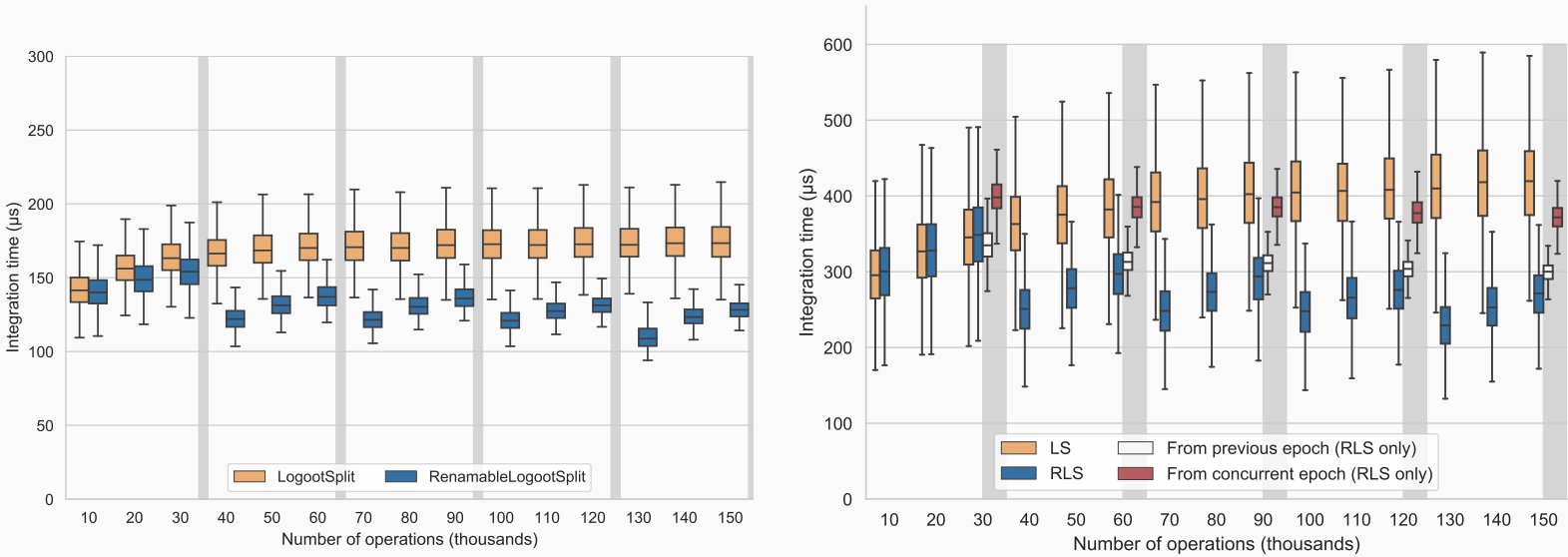
(a) Local operations

(b) Remote operations

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

- *Rename* reduces integration times of future operations

Results - Integration time of *insert* operations



(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

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
- Validated it through experimental evaluation

Work in progress

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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?