

# Efficient renaming in Conflict-free Replicated Data Types (CRDTs)

Case Study of a Sequence CRDT : LogootSplit

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COAST team

April 23, 2020



- Working on data replication in Local-first softwares<sup>[1]</sup>
- Focusing on *Sequence Conflict-free Replicated Data Types (CRDTs)*
  - Real-time collaborative text editing

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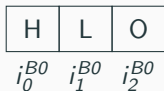
<sup>[1]</sup>Martin Kleppmann et al. Local-first software: you own your data, in spite of the cloud. In *Proceedings of the 2019 ACM SIGPLAN International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software, Onward!* 2019, pages 154–178, Athens, Greece. Association for Computing Machinery, 2019. ISBN: 9781450369954. DOI: 10.1145/3359591.3359737. URL: <https://doi.org/10.1145/3359591.3359737> .

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

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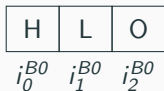


**Figure 1:** State of a sequence which contains the elements "hlo" and their corresponding identifiers

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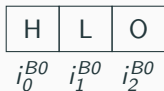


**Figure 2:** State of a sequence which contains the block "hlo"

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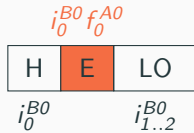
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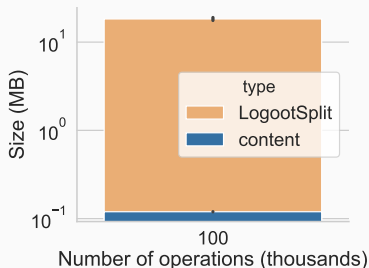


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- **Evergrowing overhead:** impacts memory, bandwidth and CPU



- **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?

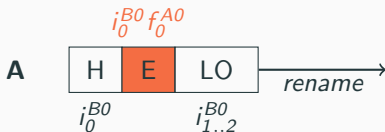
## Our approach

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



# RenamableLogootSplit

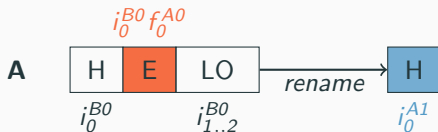
- Propose *RenamableLogootSplit*, *LogootSplit* with a *rename* operation
- Can be performed without coordination
- In this talk, focus on scenario without concurrent *rename* operations



**Figure 5:** Example of renaming

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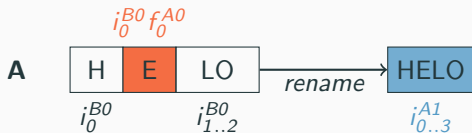


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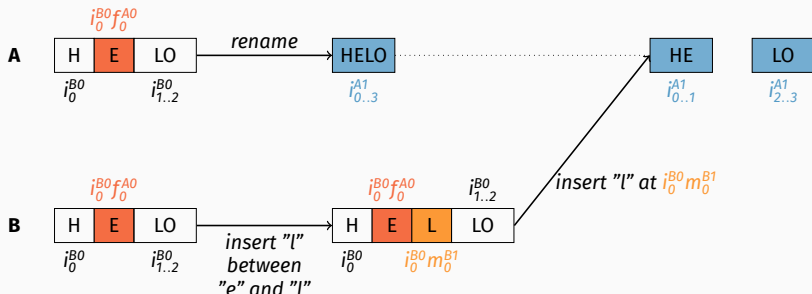
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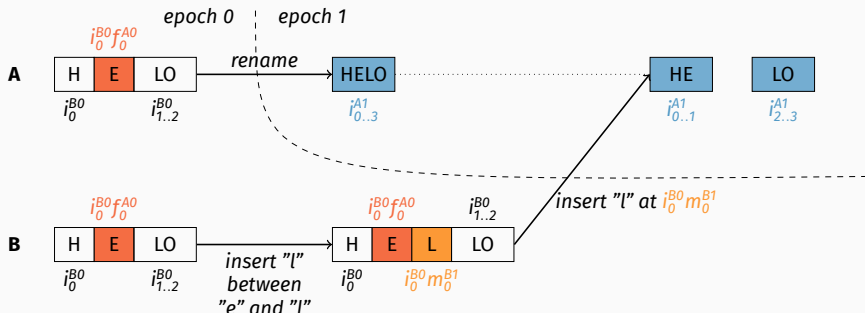
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# Handling concurrent operations



**Figure 6:** Example of concurrent insert

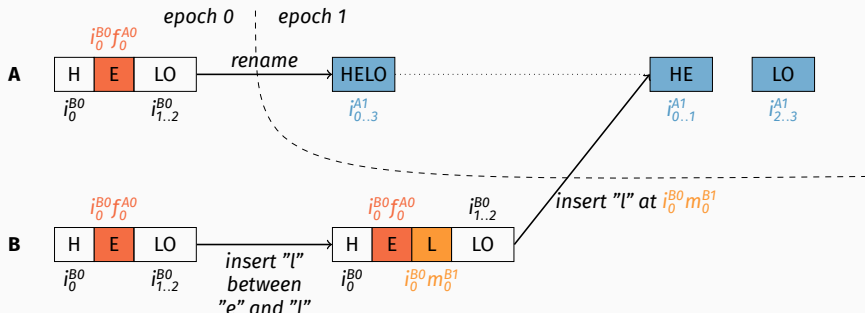
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**Figure 6:** Example of concurrent insert

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

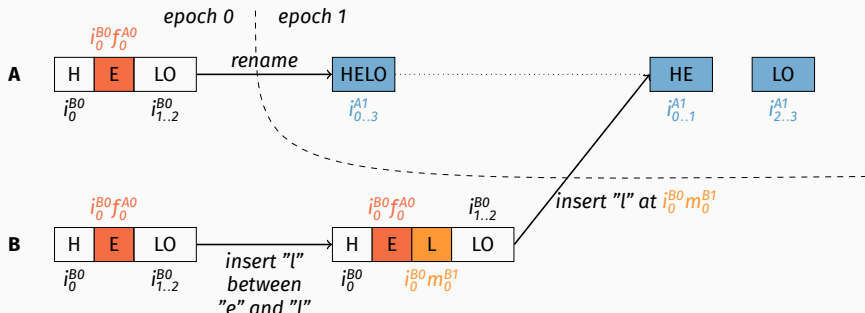
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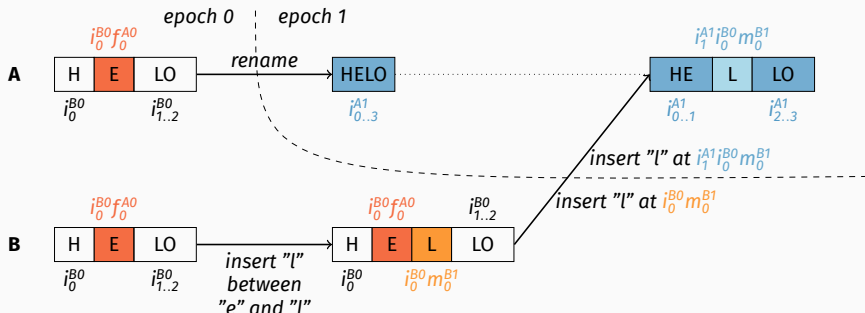


**Figure 6:** Example of concurrent insert

- Use *epoch-based* system to track concurrent operations
- Transform operations against *rename* ones (*OT*)
  1. Find predecessor in former state ( $i_0^{B0} f_0^{A0}$ )
  2. Find its counterpart in new state ( $i_1^{A1}$ )
  3. Prepend it to given id to form new id ( $i_1^{A1} i_0^{B0} f_0^{A0}$ )



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## Evaluation

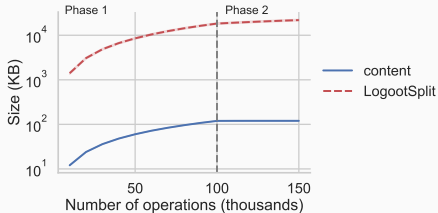
Ran simulations to compare  
RenamableLogootSplit performances to  
LogootSplit ones

## 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

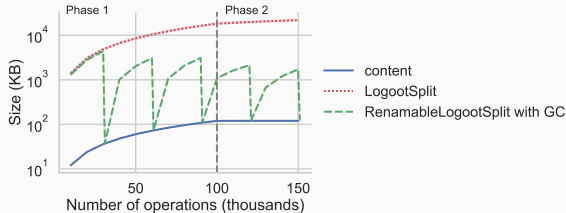
- **Phase 1 (content generation):** 80/20% of *insert/remove*
- **Phase 2 (editing):** 50/50% of *insert/remove*
- Nodes switch to phase 2 when document reaches critical size (15 pages - 60k elements)



**Figure 7:** Evolution of the size of the document

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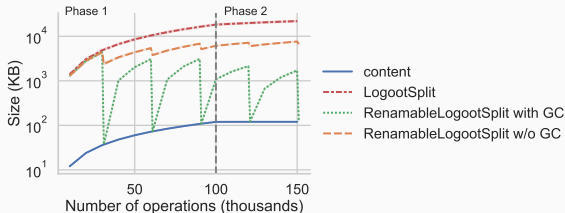


**Figure 7:** Evolution of the size of the document

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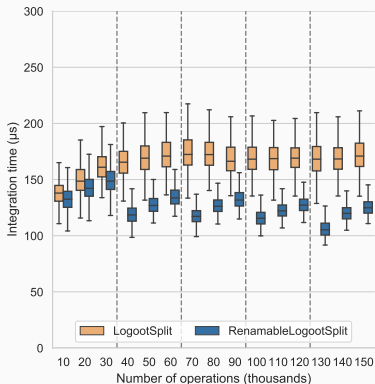
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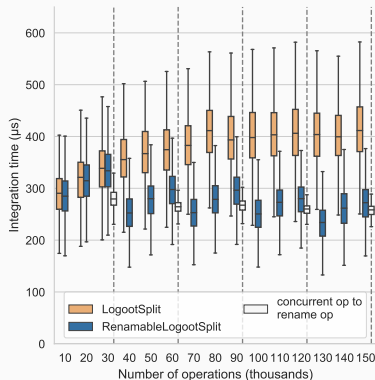
**Figure 7:** Evolution of the size of the document

- *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

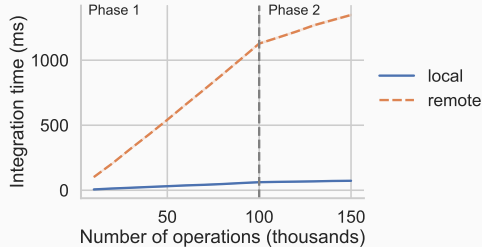


(b) Remote operations

**Figure 8:** Evolution of the integration time of *insert* operations

- *Rename* resets integration times of future operations
- Transforming concurrent operations is actually faster than applying them on former state

# Results - Integration time of rename operations



**Figure 9:** Evolution of the integration time of *rename* operations

- Noticeable by users if delayed too much

Research trail: propose strategies to retain acceptable integration time for *rename* operations



## Done

- Designed a *rename* operation for LogootSplit
- Defined transformation functions to deal with concurrent updates

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[3]Matthieu Nicolas et al. MUTE: A Peer-to-Peer Web-based Real-time Collaborative Editor. In Proceedings of European Conference on Computer-Supported Cooperative Work - Panels, Posters and Demos, 2017 .

# Conclusion

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- Designed a *rename* operation for LogootSplit
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## Work in progress

- Implementing support of concurrent *rename* operations in MUTE<sup>[3]</sup>, our P2P collaborative text editor
- Proceeding to its validation
- Designing strategies to trigger *rename* operations

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## To do

- Prove formally the correctness of the mechanism
- Investigate the combination of OT techniques and CRDTs

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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

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

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<sup>[4]</sup>Marek Zawirski et al. Asynchronous rebalancing of a replicated tree. In *Conférence Française en Systèmes d'Exploitation (CFSE)*, page 12, Saint-Malo, France, May 2011. URL: <https://hal.inria.fr/hal-01248197> .

<sup>[5]</sup>Brice Nédelec et al. A scalable sequence encoding for collaborative editing. *Concurrency and Computation: Practice and Experience*:e4108. URL: <https://onlinelibrary.wiley.com/doi/abs/10.1002/cpe.4108>.

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

- Can garbage collect it once the *rename* operation is causally stable<sup>[6]</sup>
- Can offload it to the disk meanwhile

## Need to propagate former state to other nodes

- Can compress the operation to minimise bandwidth consumption

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<sup>[6]</sup>Carlos Baquero et al. Making operation-based crdts operation-based. In Kostas Magoutis et al., editors, *Distributed Applications and Interoperable Systems*, pages 126–140, Berlin, Heidelberg. Springer Berlin Heidelberg, 2014 .



# Handling concurrent rename

*The topic of a later contribution*

**rename operation not commutative**

**To fix this:**

- Define a total order between *rename* operations
- Pick a "winner" operation between concurrent *renames*
- Define additional transformation functions to *undo* the effect of "losing" ones

## **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?

# Experimental settings

- Use Node.js version 13.1.0
- Obtained documents sizes using our fork of *object-sizeof* <sup>[7]</sup>
- 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()`

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<sup>[7]</sup><https://www.npmjs.com/package/object-sizeof>