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

Case Study of a Sequence CRDT : LogootSplit

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Supervised by Gérald Oster and Olivier Perrin

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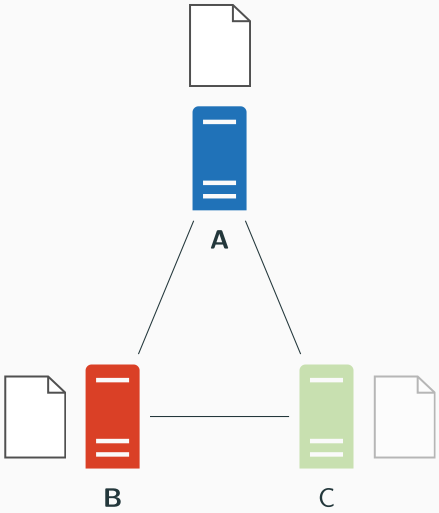
Conflict-free Replicated Data Types (CRDTs)[1]



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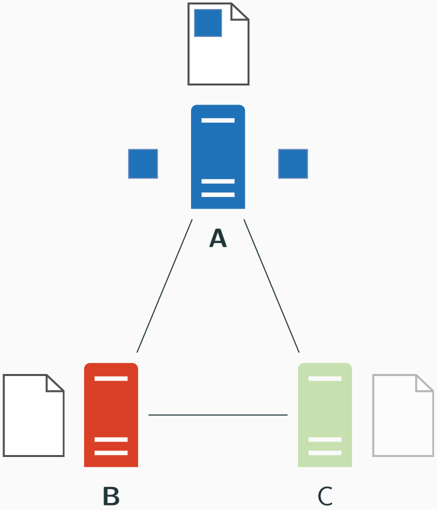

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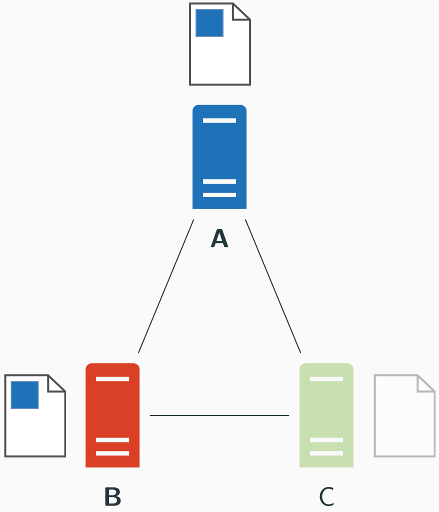

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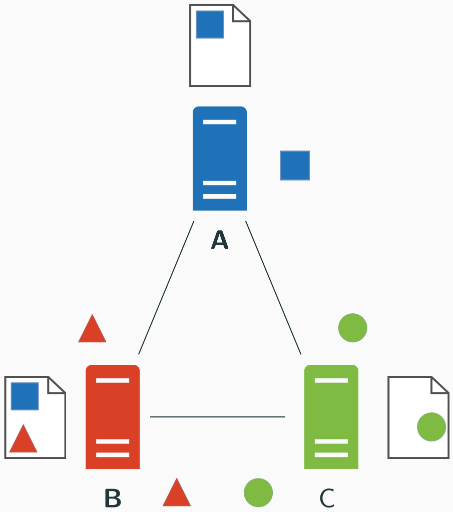

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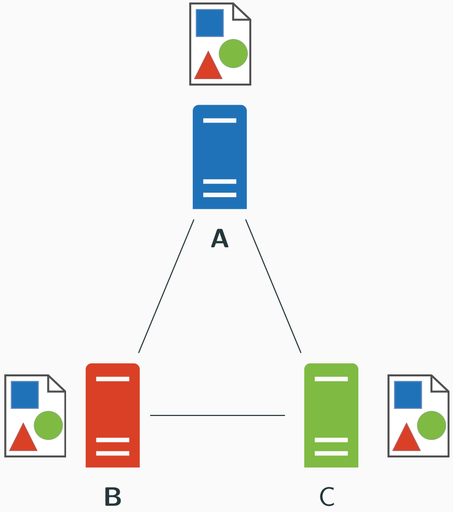

- Replicated data structure
- Updates performed without coordination
- Strong Eventual Consistency

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Identifier-based CRDTs

Main idea

- Attach an identifier to each element

Allow to design commutative updates

- Identifying uniquely elements
- Ordering concurrent updates
- ...

Research issue

Limits

- Unbounded size of identifiers
- Overhead of the data structure increasing over time

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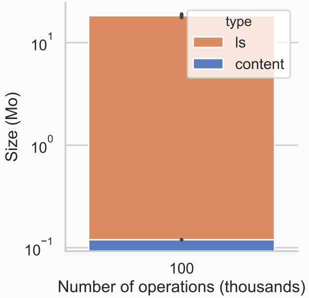

Figure 1: Footprint of the data structure

How to reduce the overhead introduced by the data structure ?

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Reassign shorter identifiers in a fully distributed manner

LogootSplit[2]

- State of the art of *Sequence CRDTs*
- Elements are ordered by their identifier, noted here as lowercase letters

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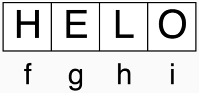

Figure 2: State of a sequence which contains the elements "helo" and their corresponding identifiers

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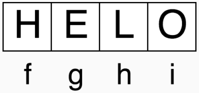

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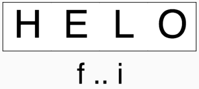

Figure 3: State of a sequence which contains the block "helo"

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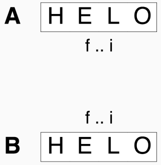
Example



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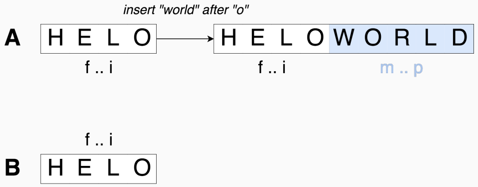

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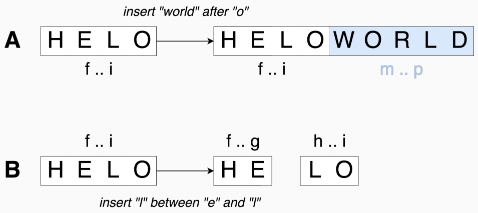

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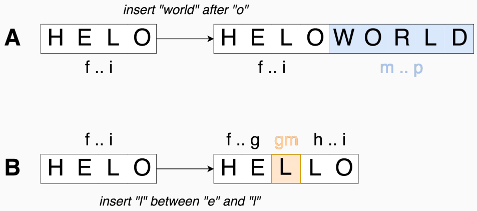

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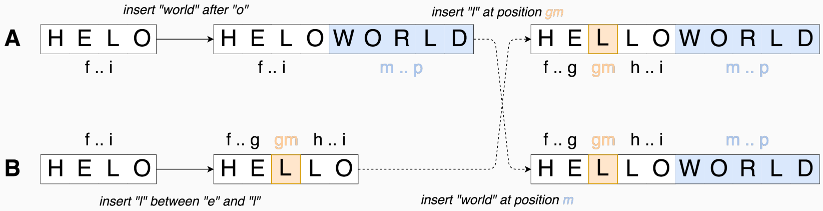

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Declining performances

- Updates performed may lead to an inefficient internal representation

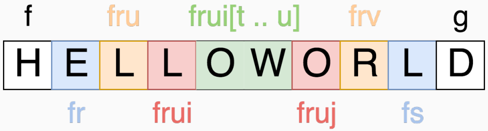


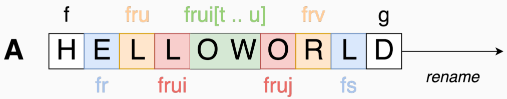
Figure 5: Example of inefficient internal representation

- The more blocks we have:
    - The more metadata we store
    - The longer it takes to browse the sequence to *insert* or *remove* an element

Our approach

RenamableLogootSplit

- Propose *RenamableLogootSplit*, *LogootSplit* with a *rename* operation
- Can be perform without coordination
- Today, focus on scenario without concurrent *rename* operations



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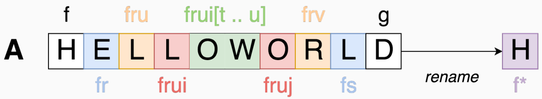

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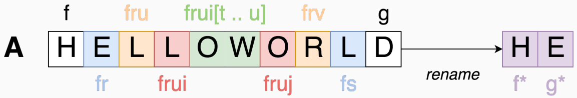

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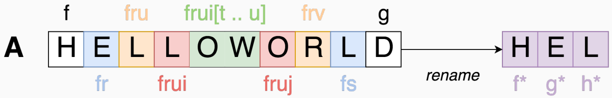

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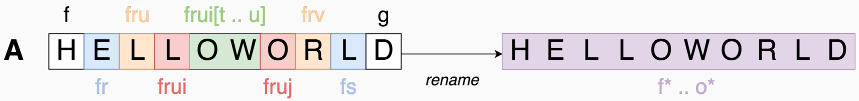

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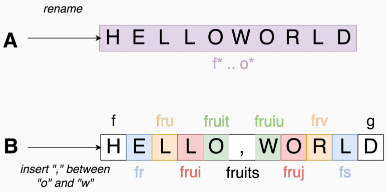
Handling concurrent operations

- Others may perform updates concurrently to a *rename* operation



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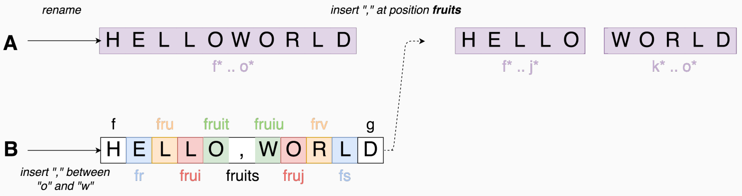

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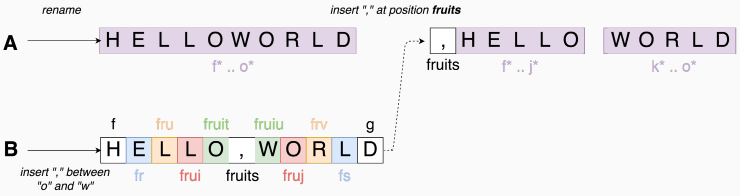

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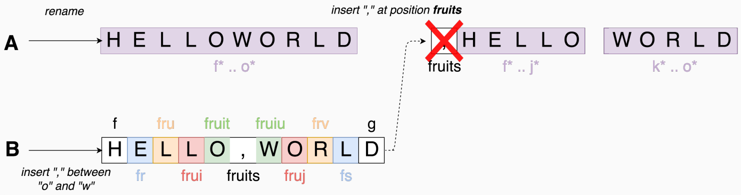

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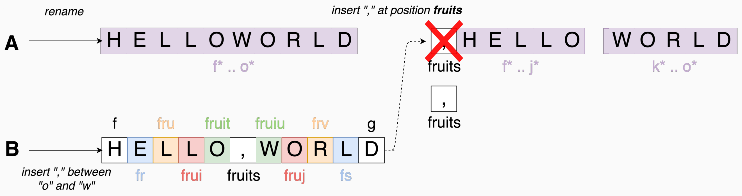

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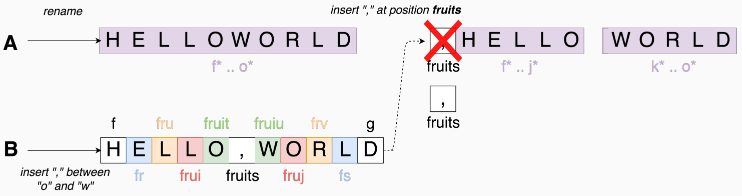

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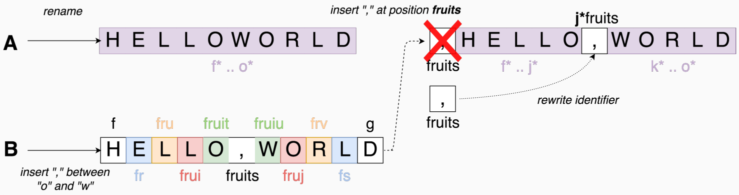

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Downsides

Need to store former state until no more concurrent operations

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- Can garbage collect it once the *rename* operation is causally stable[3]
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Need to propagate former state to other nodes

- Can compress the operation to minimize bandwidth consumption

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Evaluation

Scenario

- **Assumption:** Only one node can issue *rename* operations

Ran simulations to evaluate proposed approach:

- 10 nodes share and edit a document collaboratively
- Nodes use either LogootSplit or RenamableLogootSplit according to session

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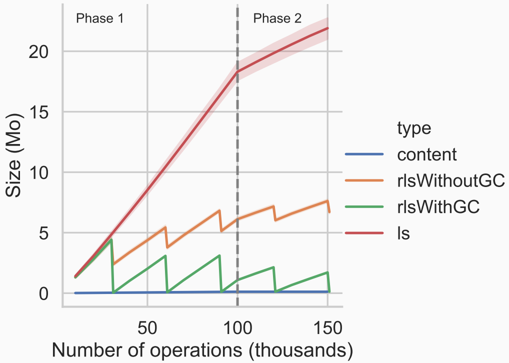
- Nodes switch to phase 2 when document reaches critical size (15 pages - 60k elements)
- Overall, nodes perform 150k operations on the document
- In the case of *RenamableLogootSplit*, trigger a *rename* operation every 30k operations

Experimental settings

- Use Node.js version 13.1.0
- Obtained documents sizes using our fork of *object-sizeof* [4]
- 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()`

[4] `https://www.npmjs.com/package/object-sizeof`

Results - Overhead of the data structure



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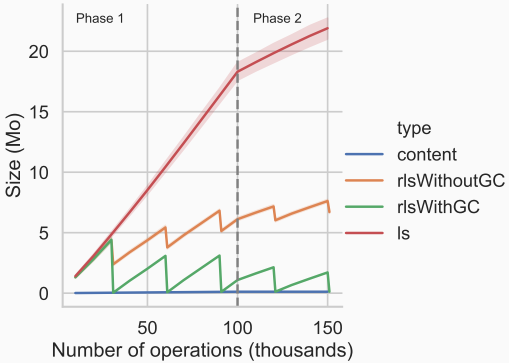

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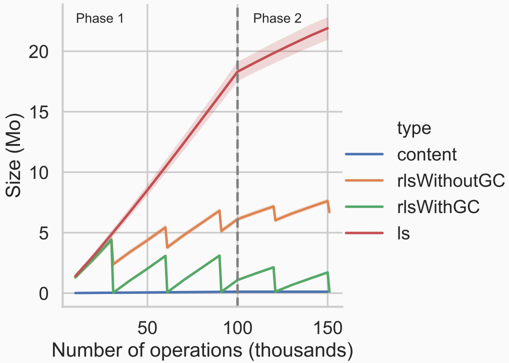

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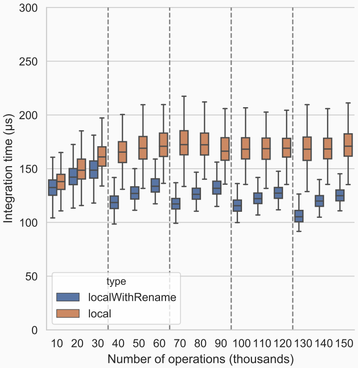
Results - Integration time of insert operations



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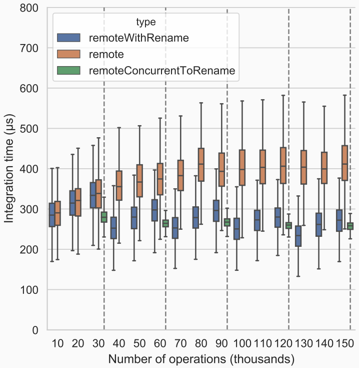

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Figure 9: Evolution of the integration time of *insert* operations

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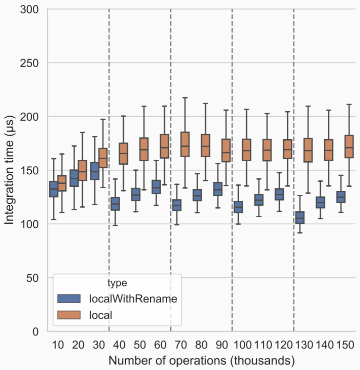

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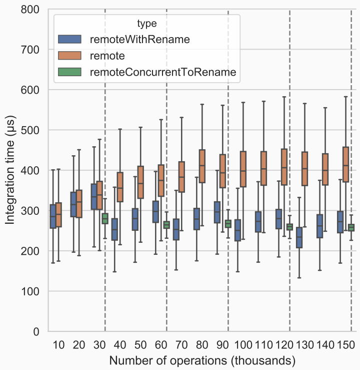

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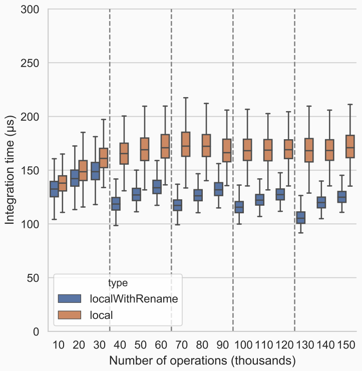

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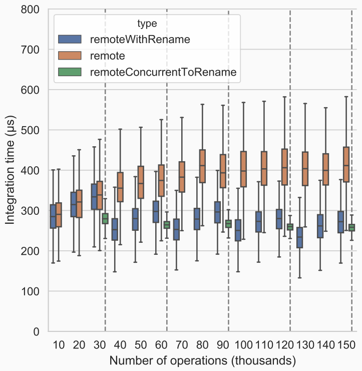

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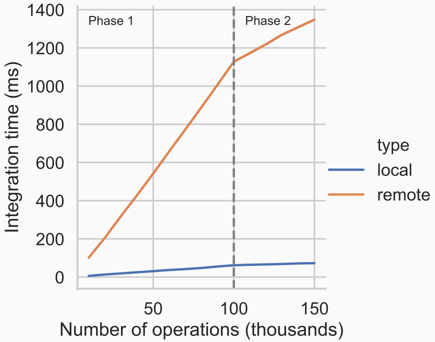
- Transforming concurrent operations is actually faster than applying them on former state

Results - Integration time of rename operations



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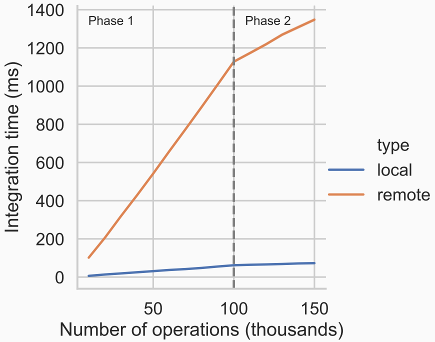

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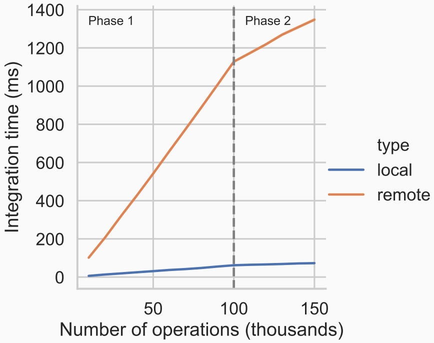

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- Noticeable by users if delayed too much
- When to trigger *rename* operations?

To wrap up

Done

- Designed a *rename* operation for LogootSplit
- Defined rewriting rules to deal with concurrent updates

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Work in progress

- Implementing in MUTE[5], our P2P collaborative text editor
- Benchmarking its performances
- Designing the strategy to trigger *rename* operations

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To do

- Publish it
- Prove formally the correctness of the mechanism

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Thanks for your attention, any questions?

Perspectives

Propose a strategy to avoid conflicting rename operations

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Propose a smarter strategy to choose the "winning" renaming

- How to minimize the overall computations?

LogootSplit identifiers

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

$$< \mathit{priority}, \mathit{siteId}, \mathit{seq}, \mathit{offset} >$$

- *priority* allows to determine the position of this identifier compared to others
- *siteId* refers to the node's identifier, assumed to be unique
- *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

Handling concurrent rename

The topic of a later contribution

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rename operation not commutative

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To fix this:

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