Executing Code in the Past: Efficient In-Memory Object Graph Versioning

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ULB

OOPSLA, October 2009

In-Memory Object Versioning

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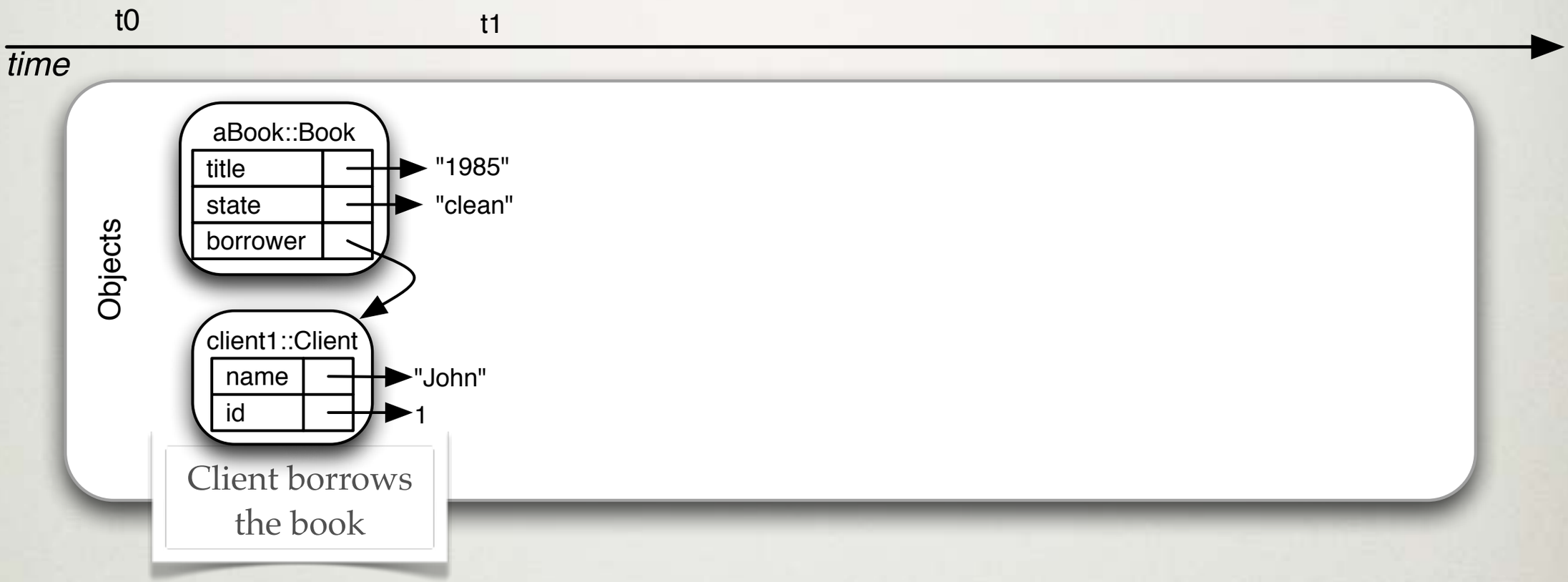

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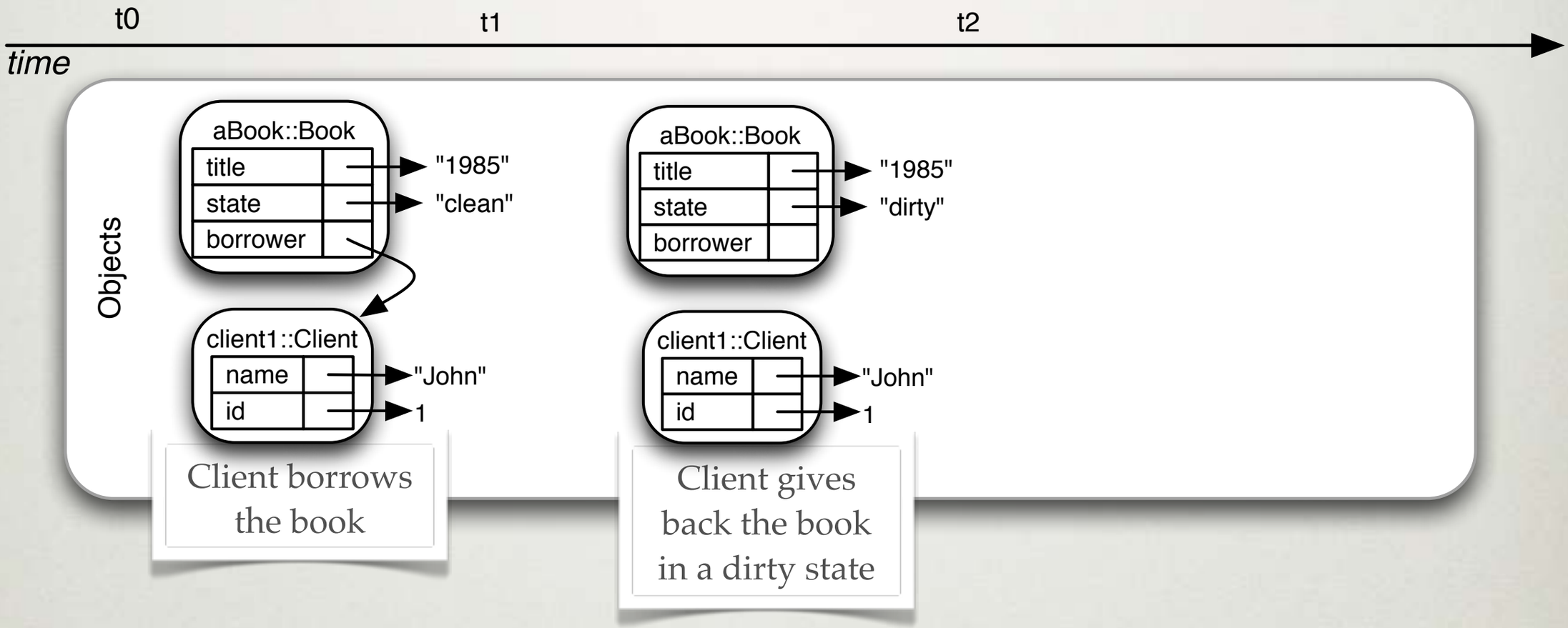

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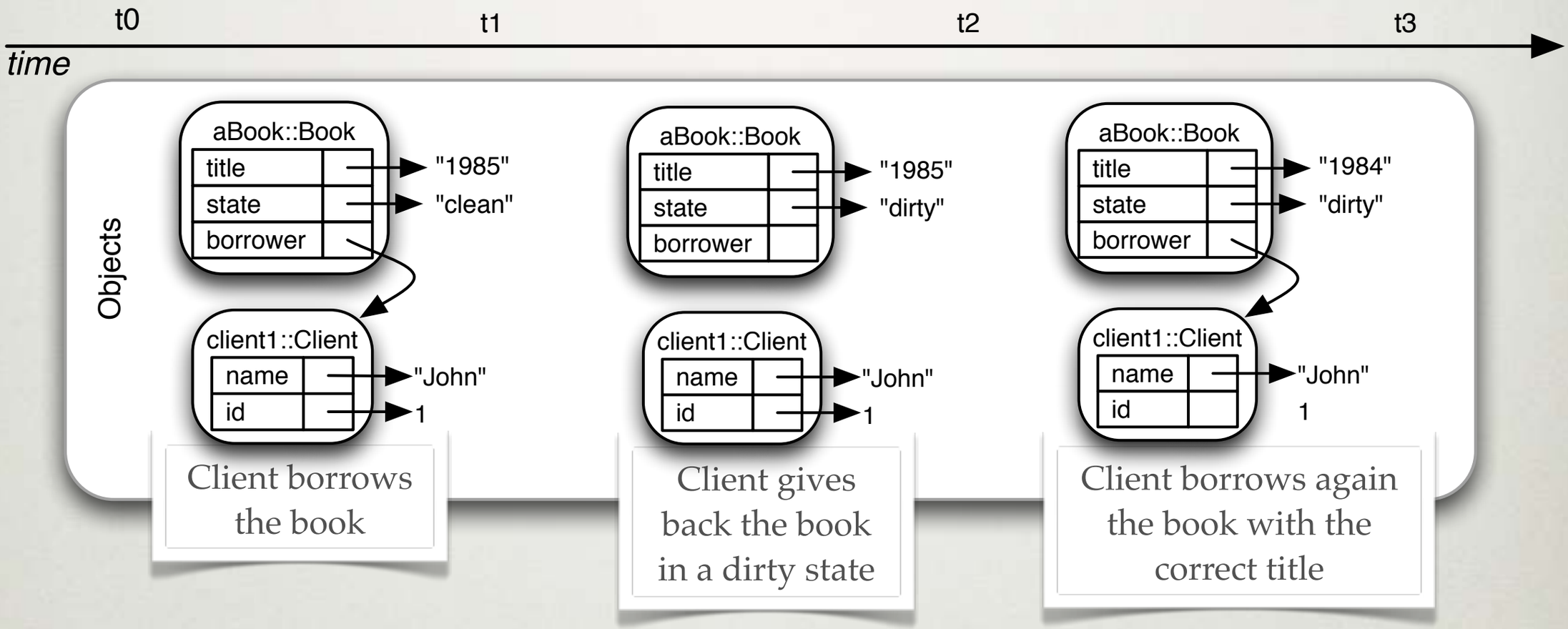

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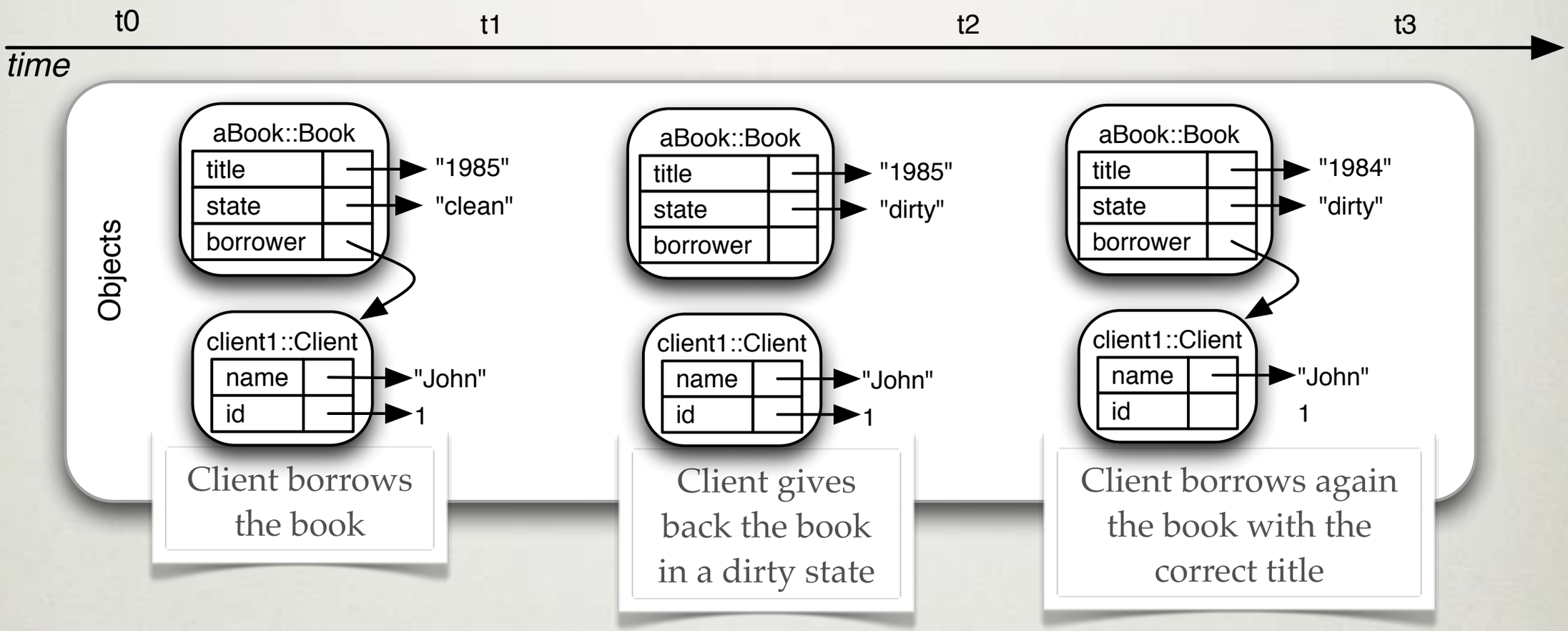
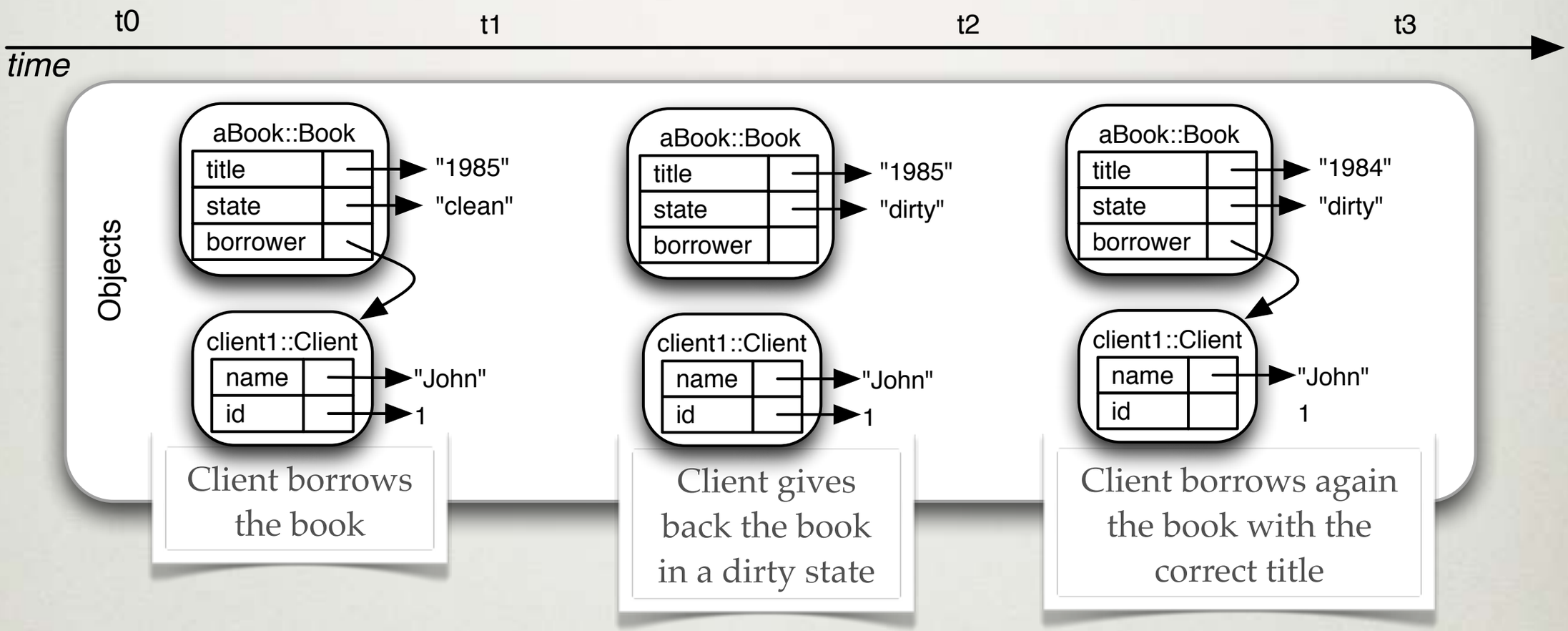


«If I want revisit these 3 versions, how can I do it ?»

In-Memory Object Versioning



«If I want revisit these 3 versions, how can I do it ?»

⇨ An ad hoc solution must be built

But...

- It is a recurring problem !
  - Eiffel-like Checked Post-Conditions
  - Stateful Tracer, Debugger, Google Wave
  - More than 20 applications in the theoretical algorithmic domain (computational geometry,...)
  - ...

Our Solution

Introduce In-Memory Object Versioning in any Object-Oriented Language

- What are the challenges ?
  - Be **generally applicable** !
  - Be **expressive** !
  - Be **efficient** in time and in space !

Intuitive approaches

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- Deep copy of the system after each change

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- Use database

Intuitive approaches

- Deep copy of the system after each change
  - ➡ The memory fills up very quickly
- Deep copy of the system at each given interval of time
  - ➡ Some useful values can be not saved
- Use database
  - ➡ Not the same goal

What we really want

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- Only keep

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- Only keep
  - **interesting** old values

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  - **interesting** old values
    - of **interesting** fields

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  - of **interesting** fields
  - of **interesting** objects

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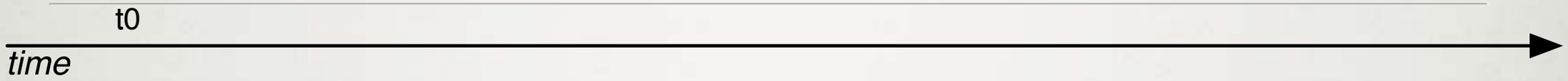
Field selection

What we really want

- Only keep
  - **interesting** old values ⇨ *Snapshots*
  - of **interesting** fields
  - of **interesting** objects ⇨ *Field selection*

Example

Example



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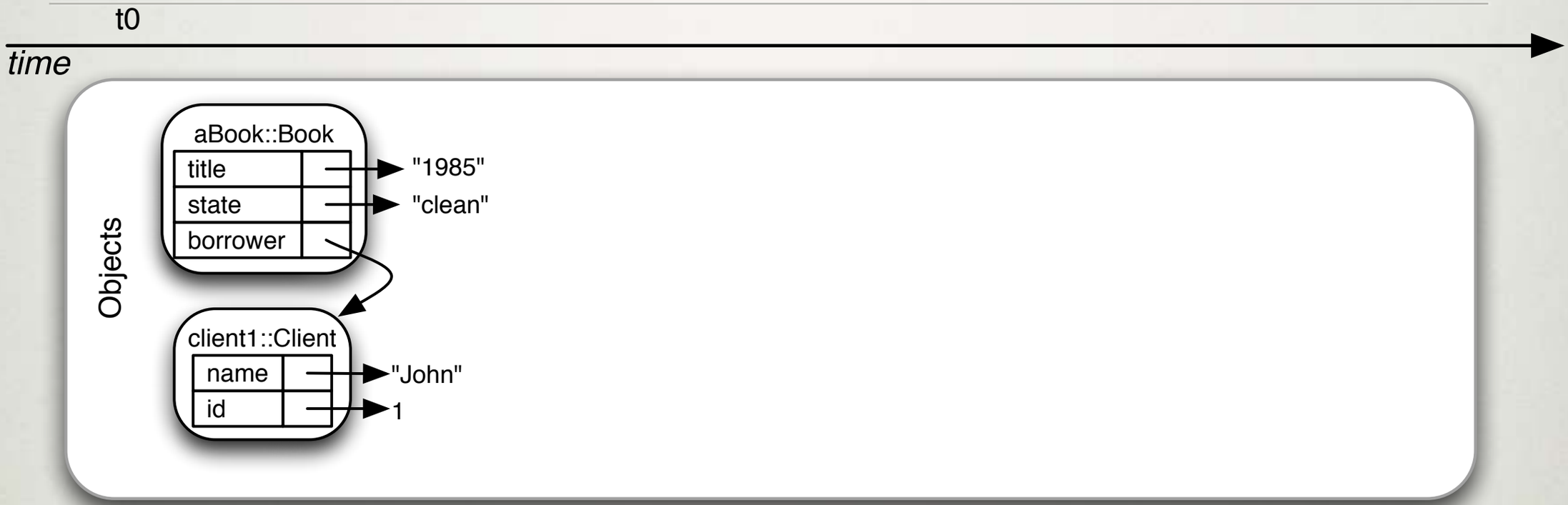
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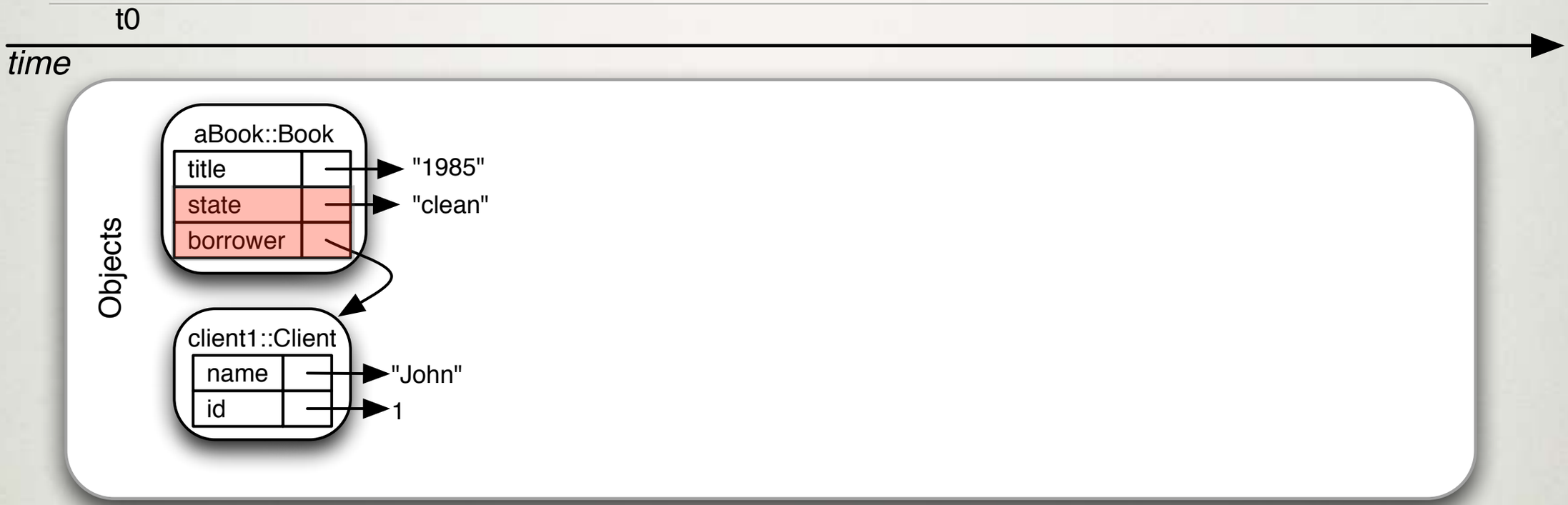
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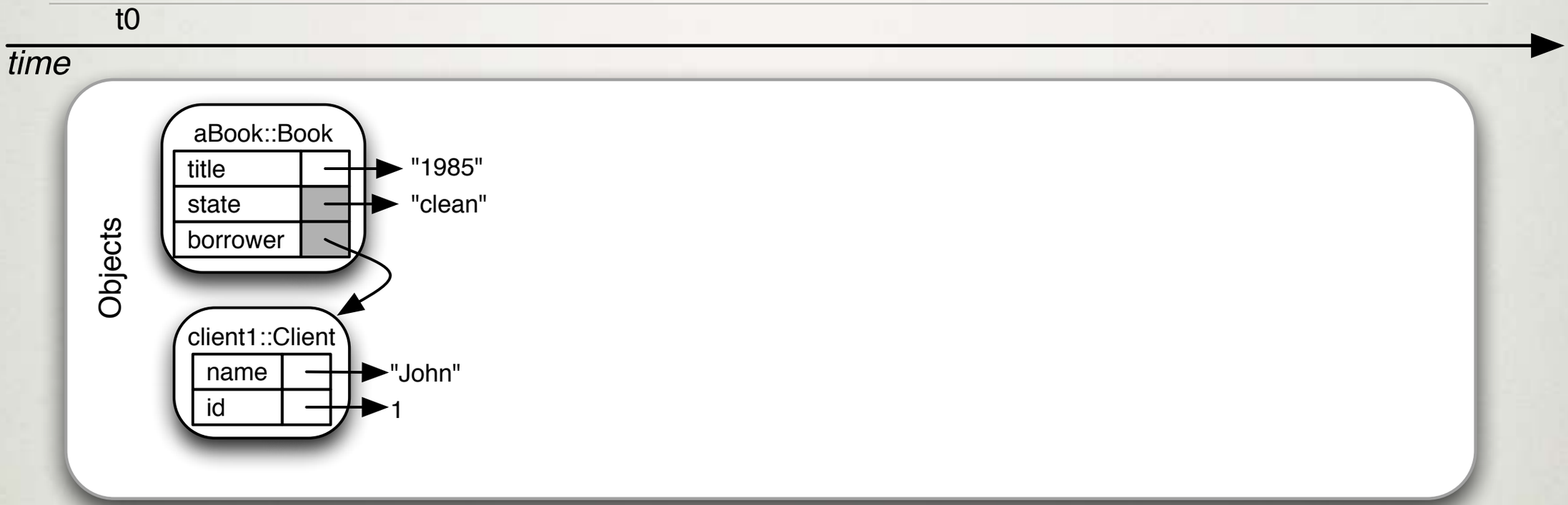
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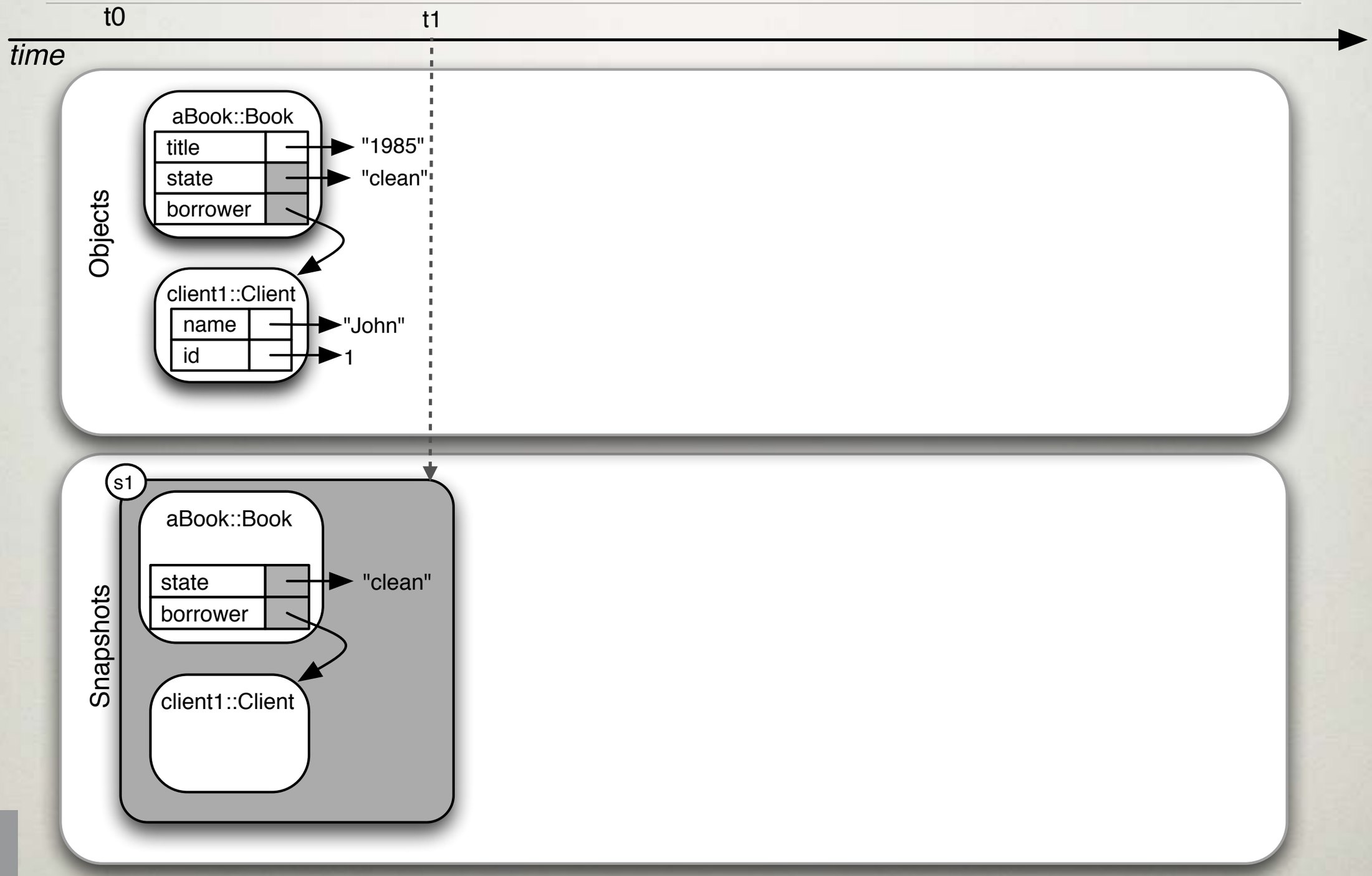
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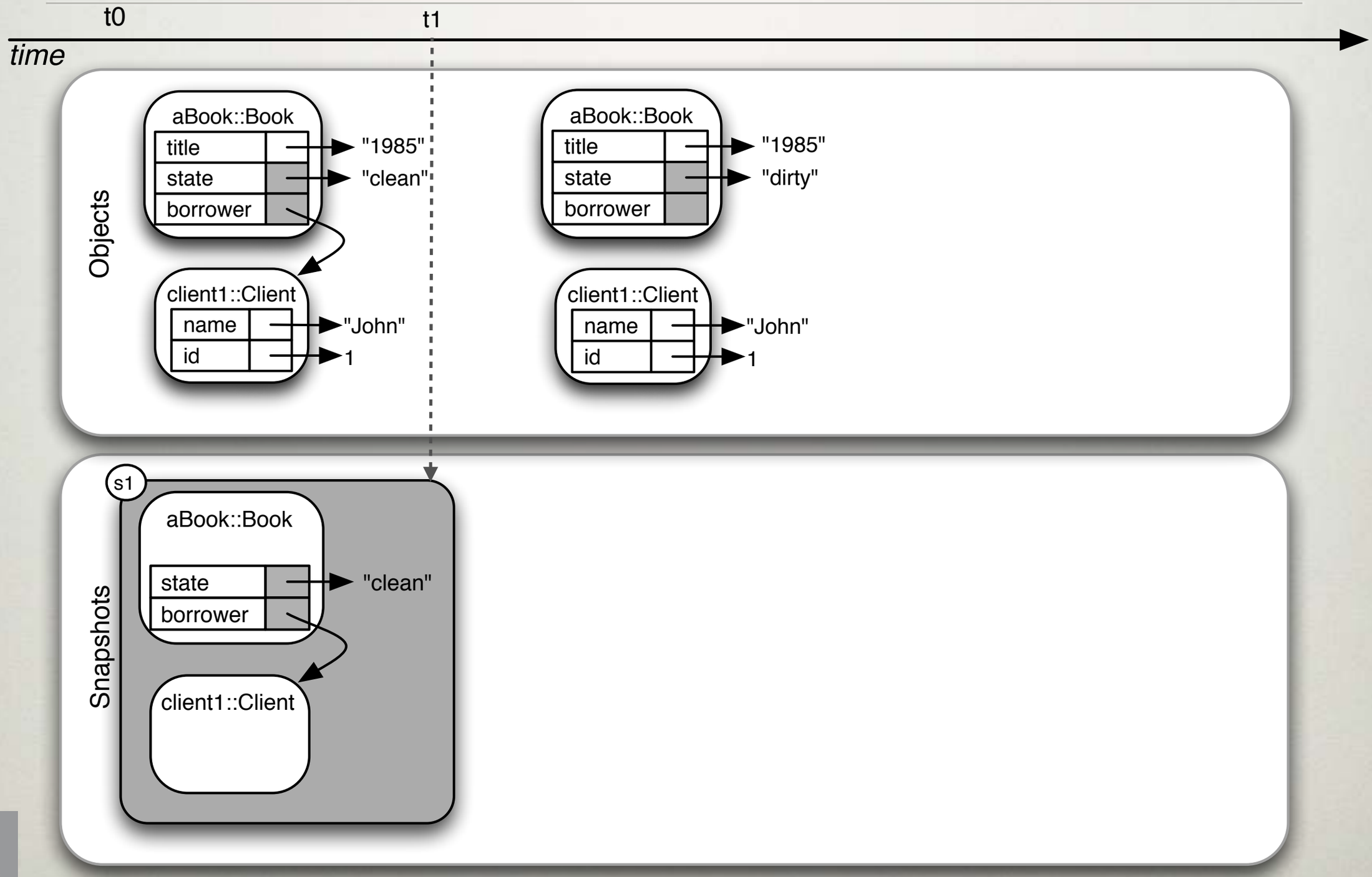
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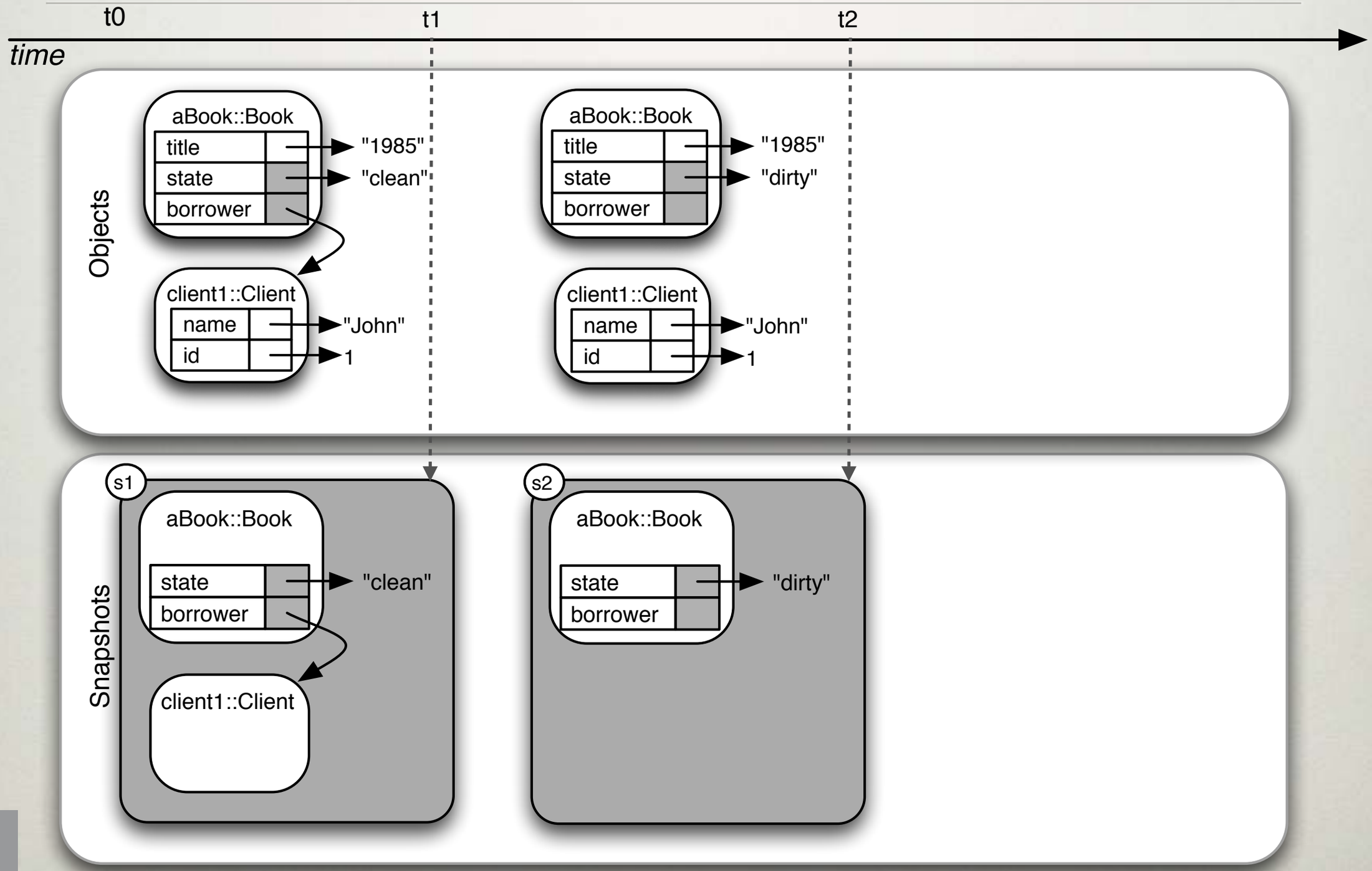
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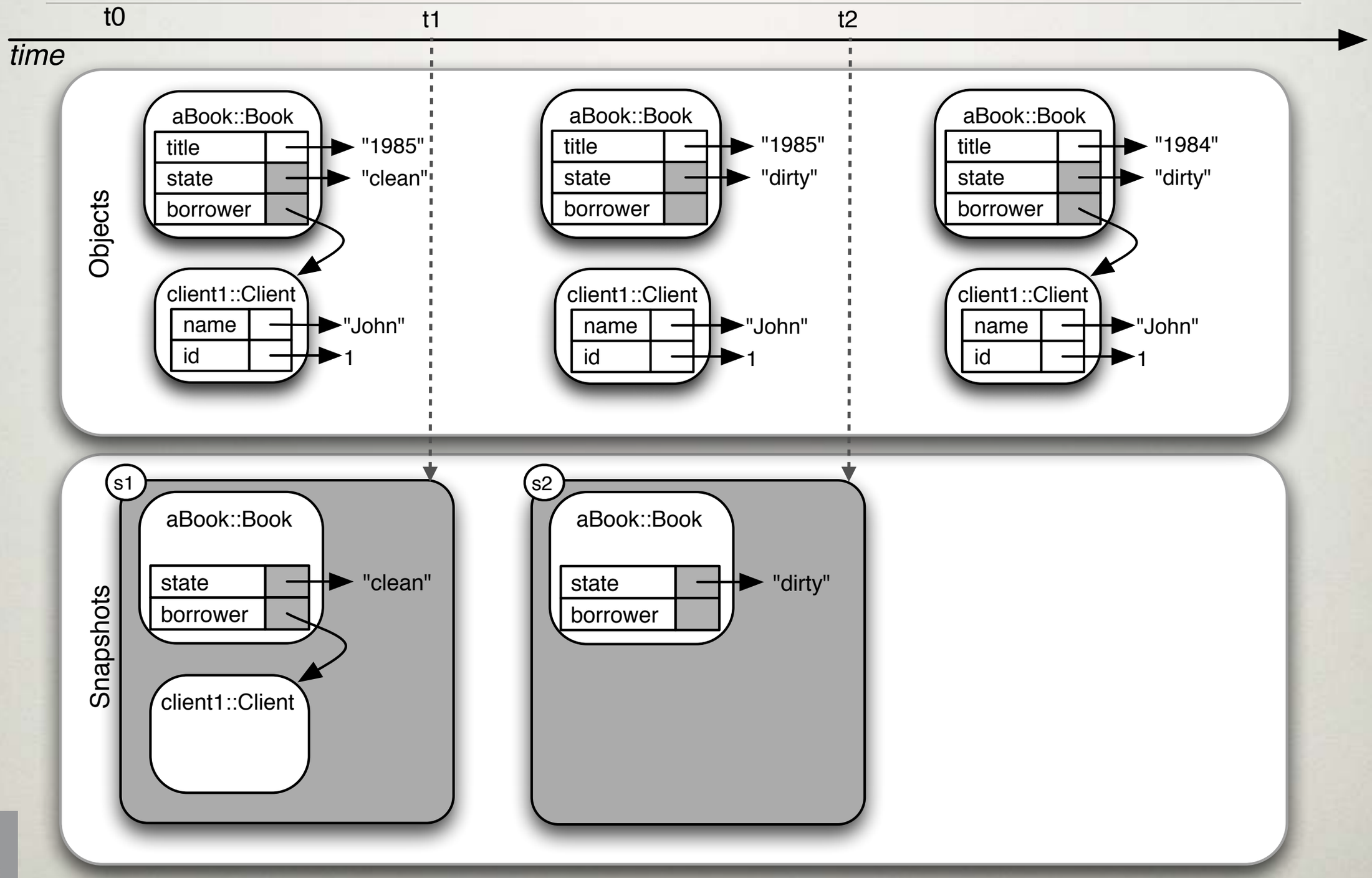
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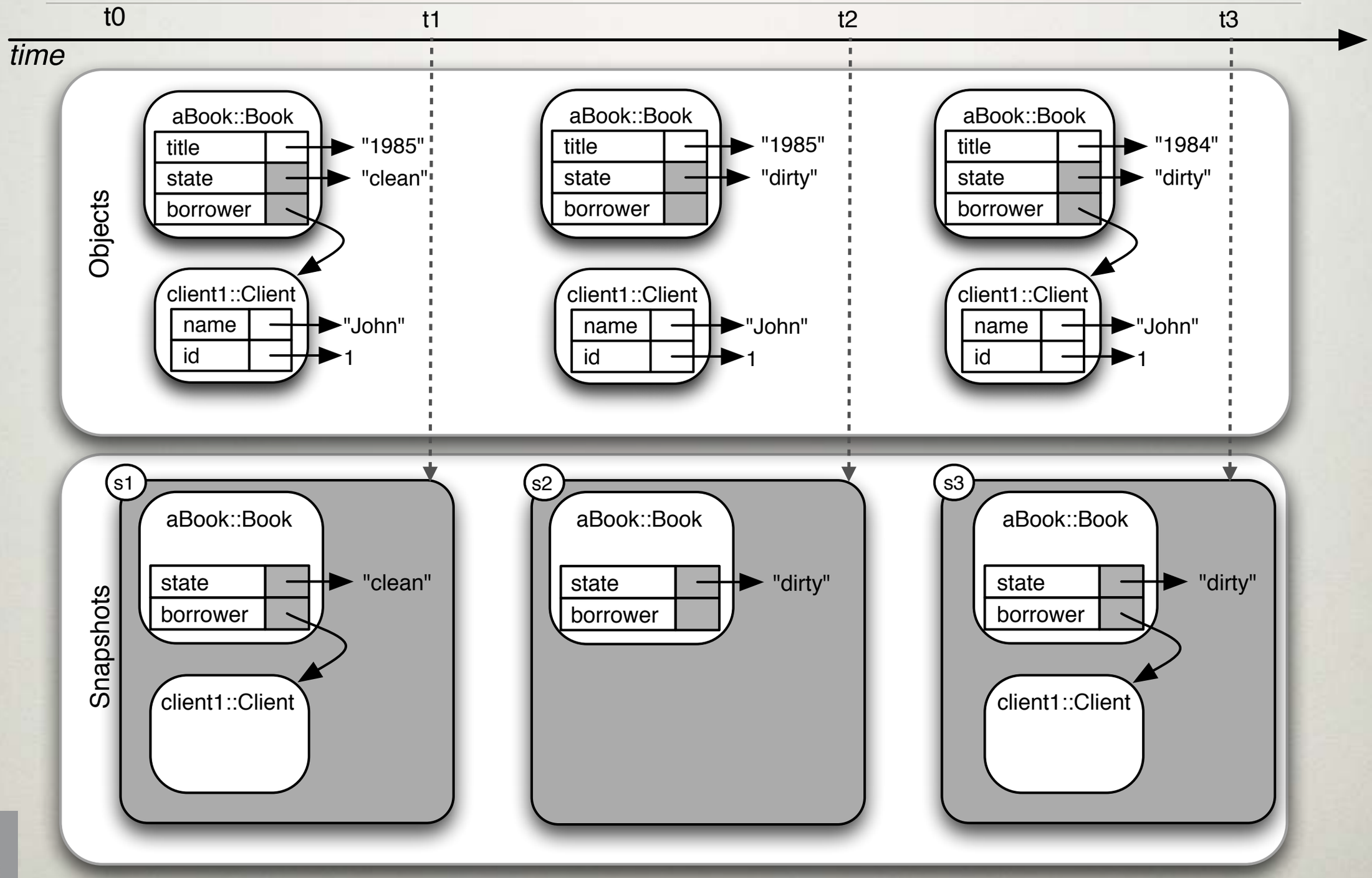
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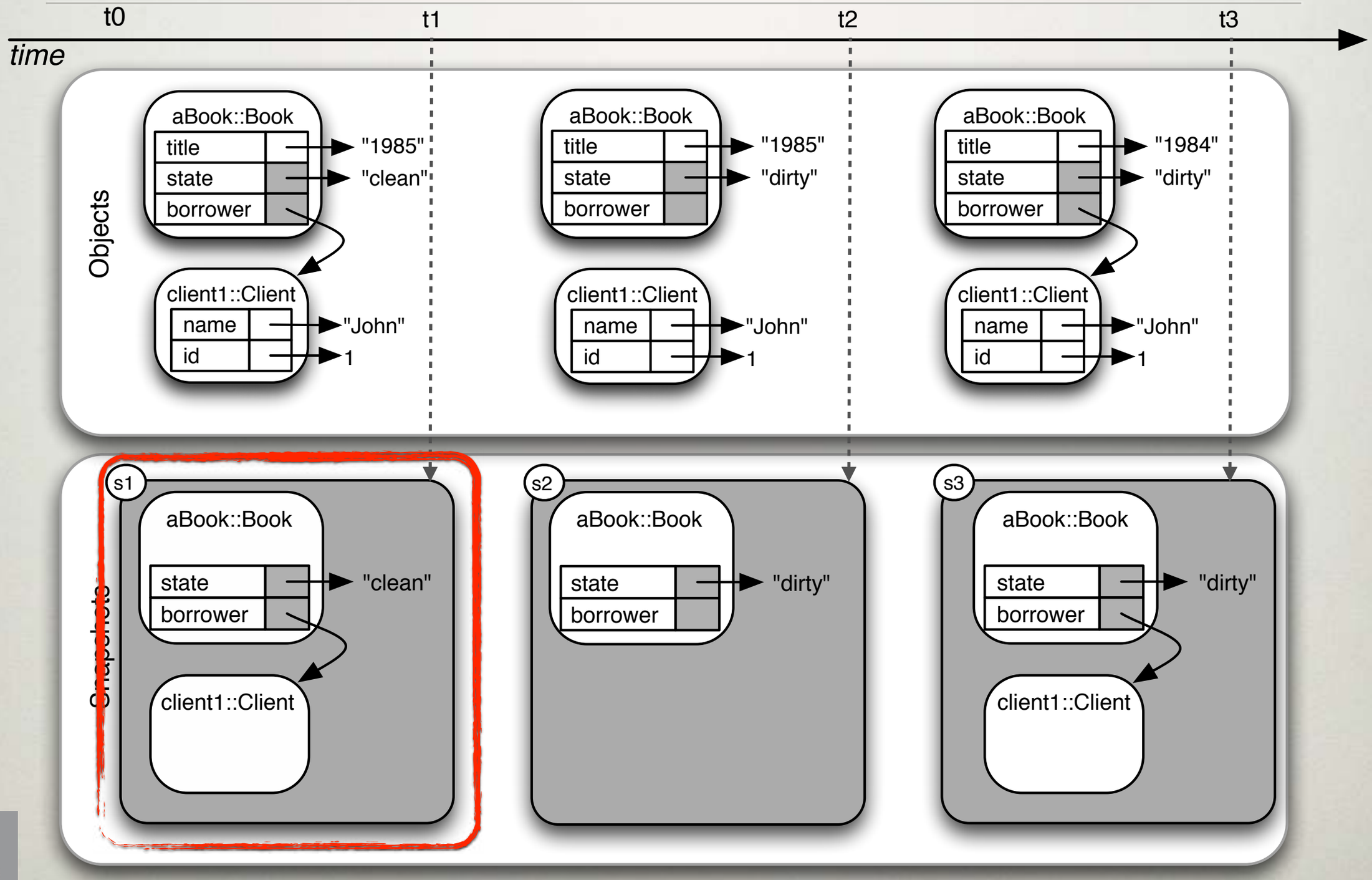
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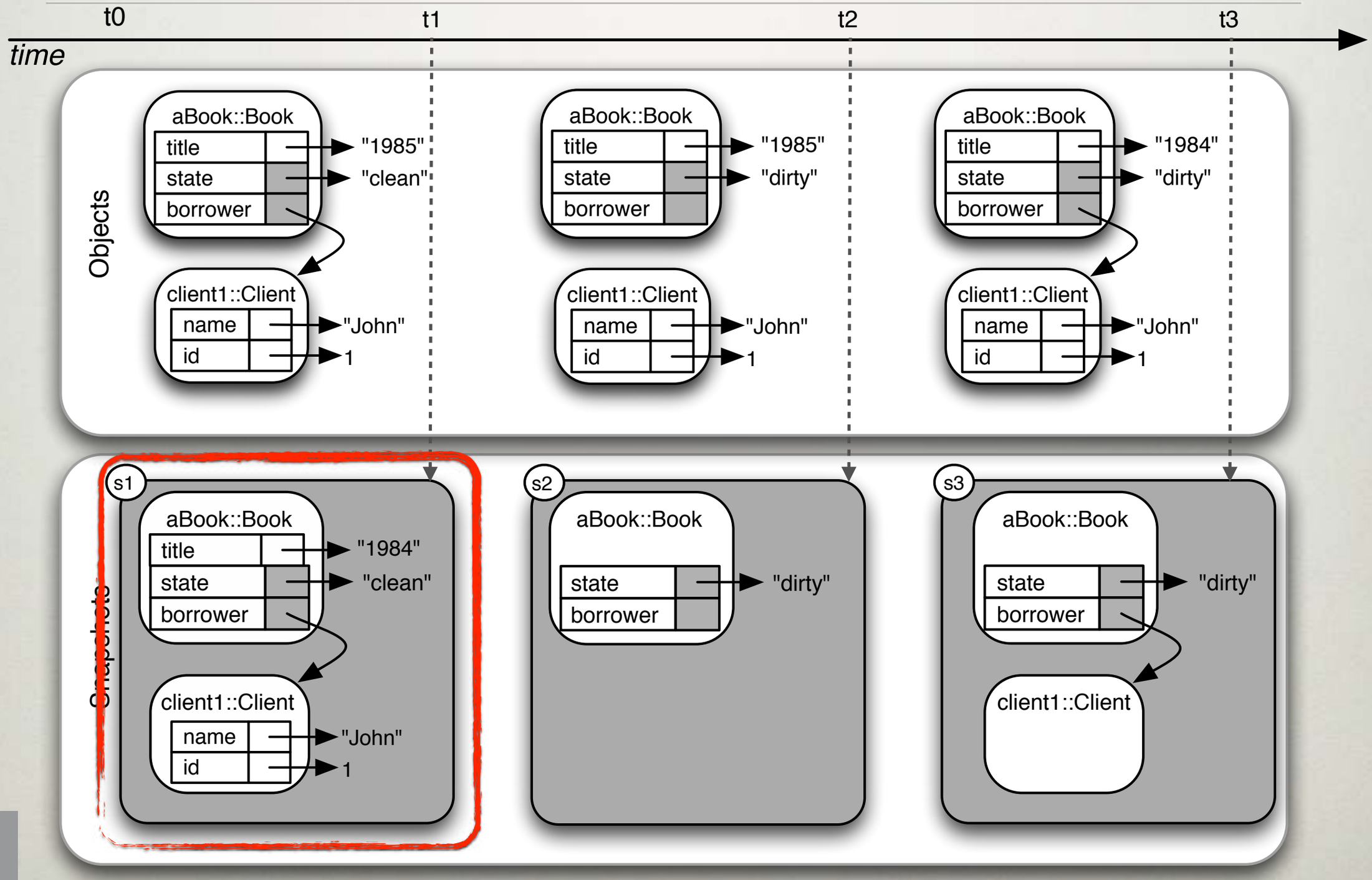
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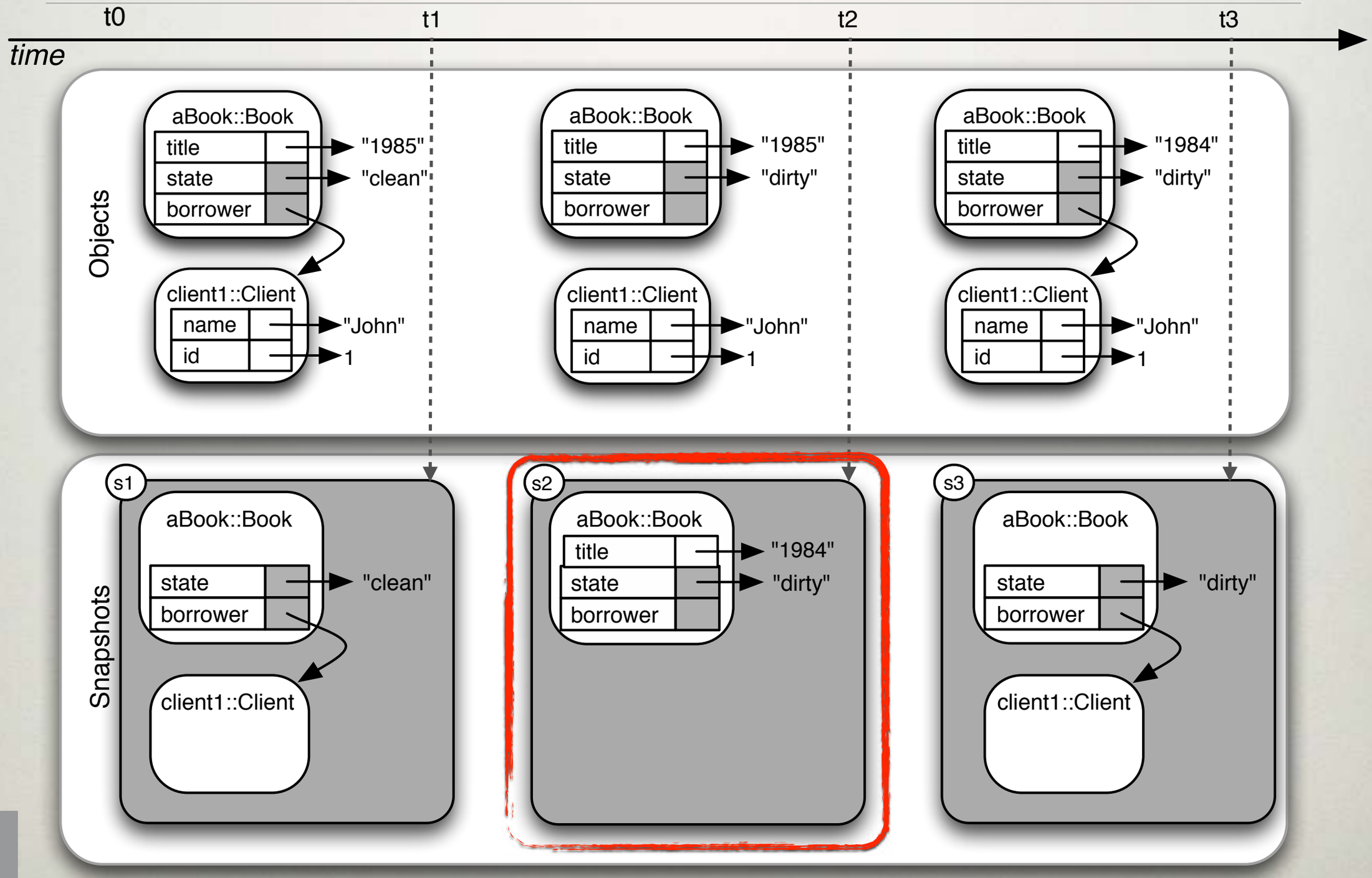
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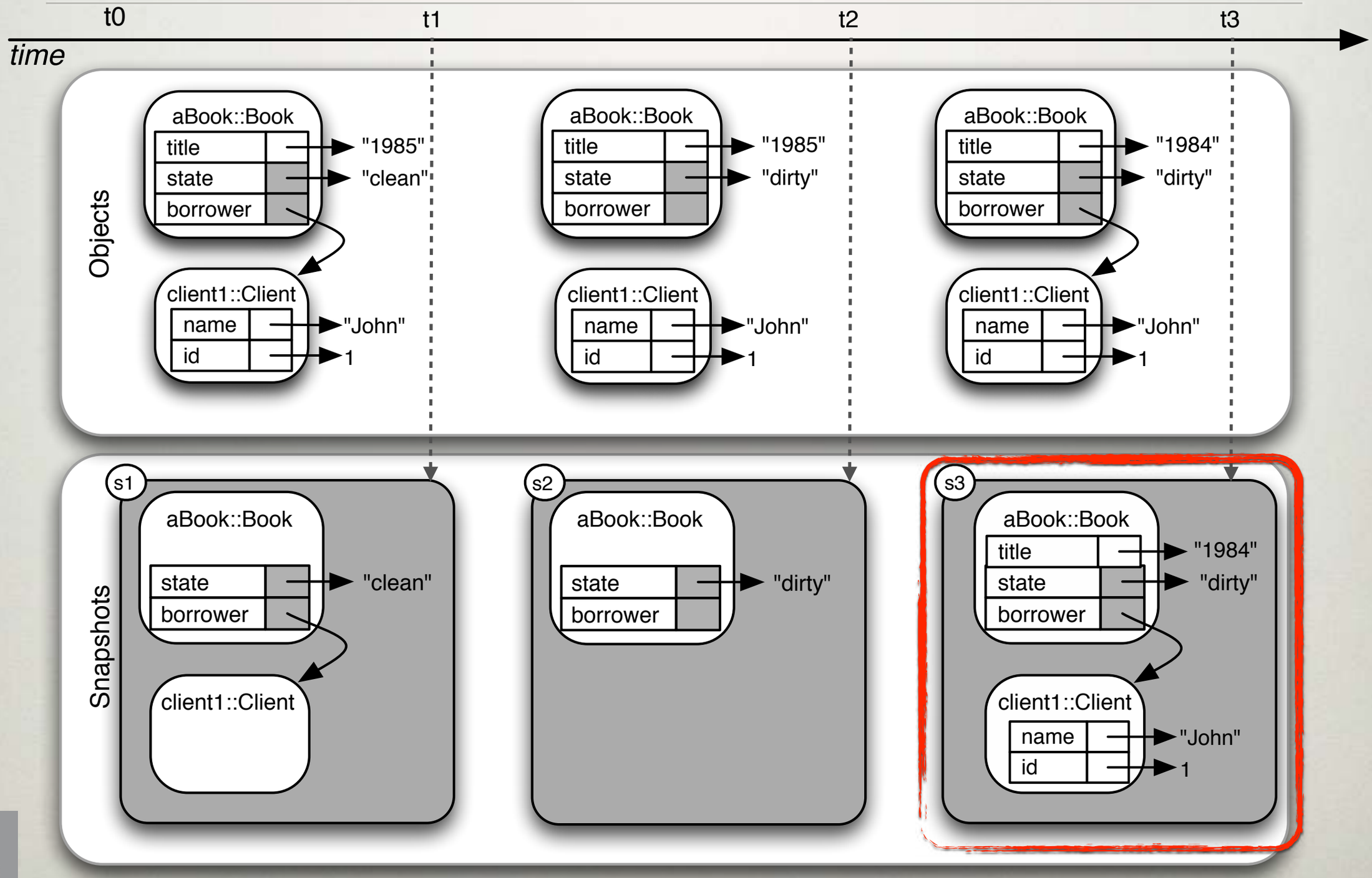
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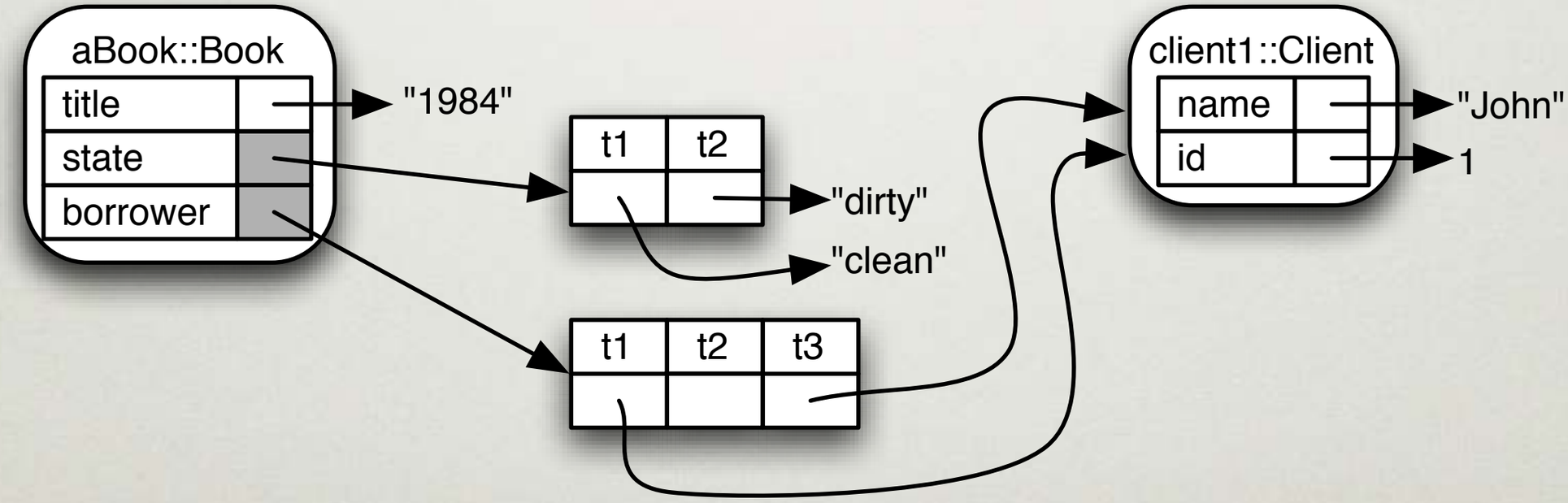
How to efficiently store old values ?

- *Fat Node Method* [Driscoll et al,1986].
  - Store the old values of a field in the field itself



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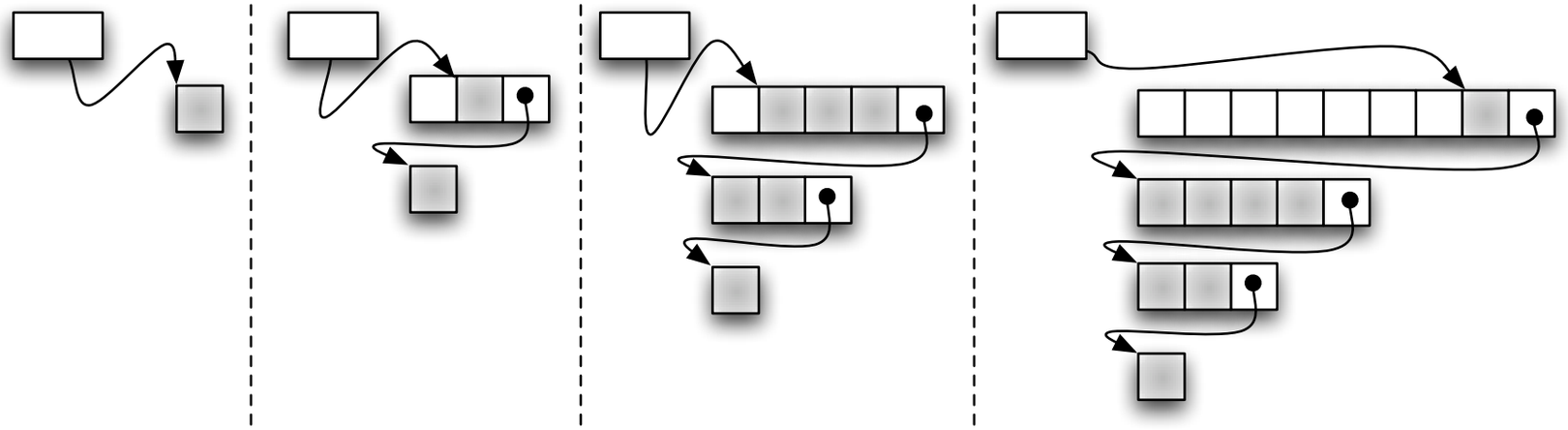

(a) 1 element | (b) 2 elements | (b) 6 elements | (b) 8 elements

Insert a new value	**O(1)**
Access last value	**O(1)**
Look up for a value	O(log(*#values*))

Complexities

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	Worst case
Take a snapshot	O(1)

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Take a snapshot	O(1)
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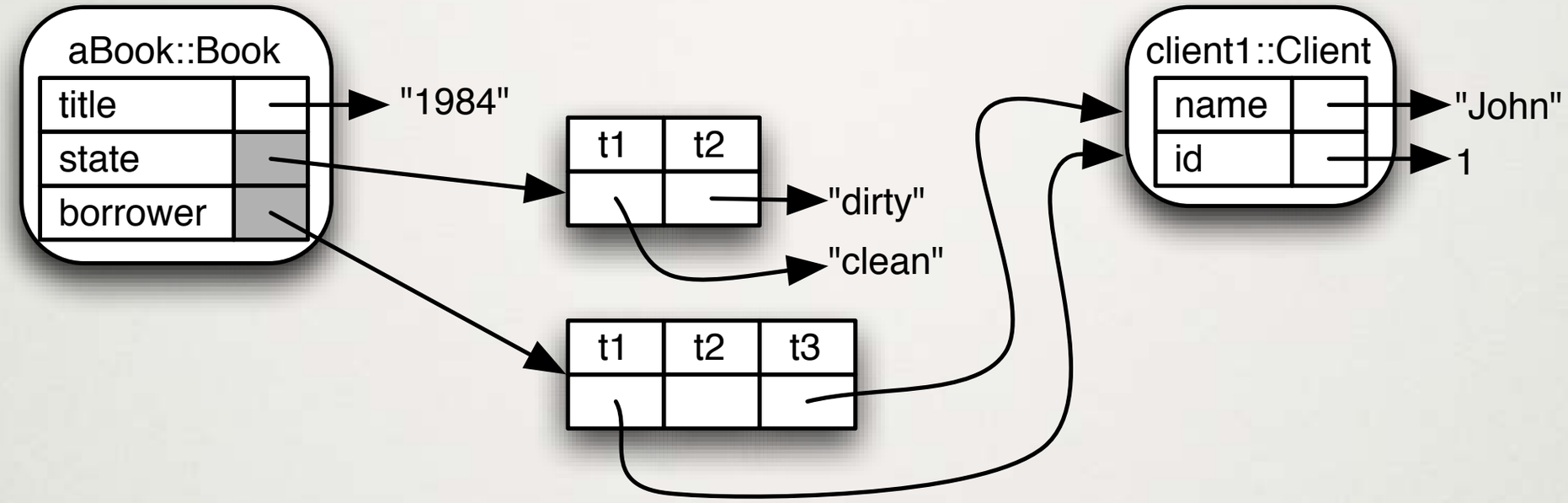
Complexities

	Worst case
Take a snapshot	O(1)
Perform an ephemeral update	O(1)
Perform a versioned update	O(1)
Read last value of a field	O(1)
Read old value of a field	O(log #values)

And of course

- Don’t lose time to save useless data
- Developer selects !

Efficiency in Size



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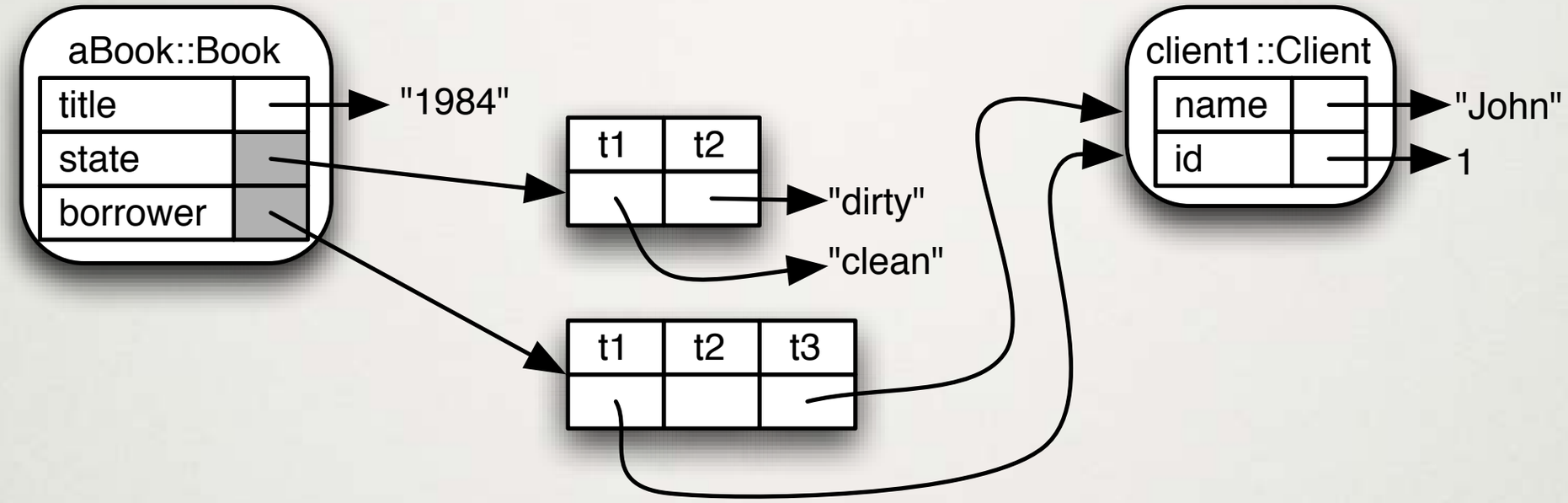

- States are shared between snapshots

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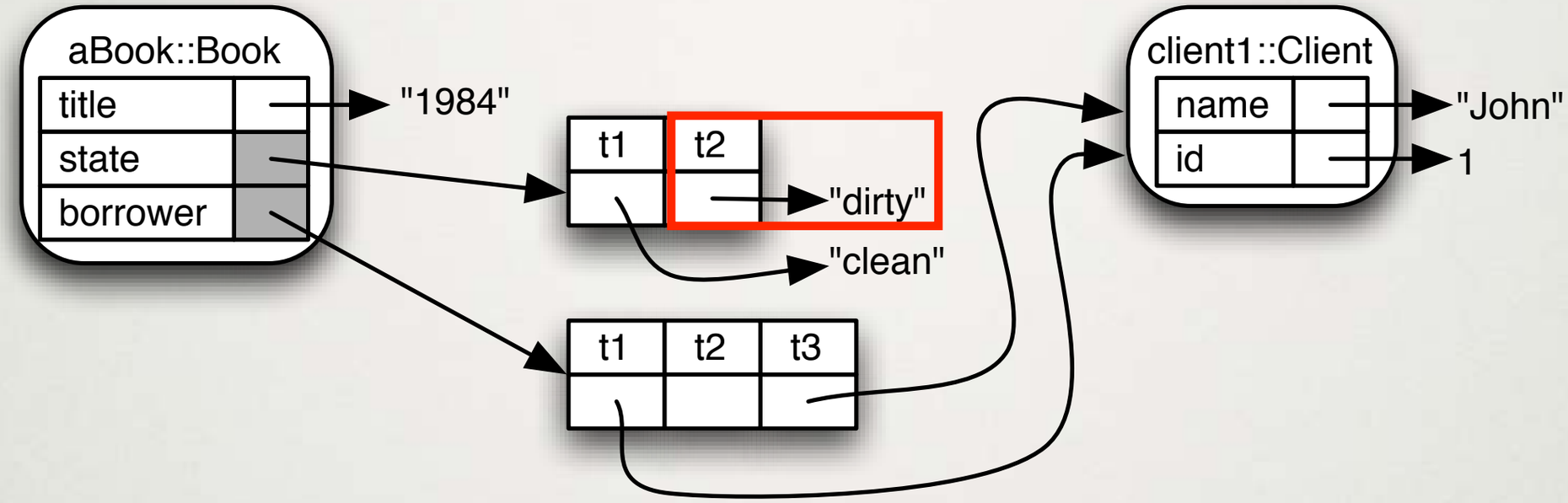

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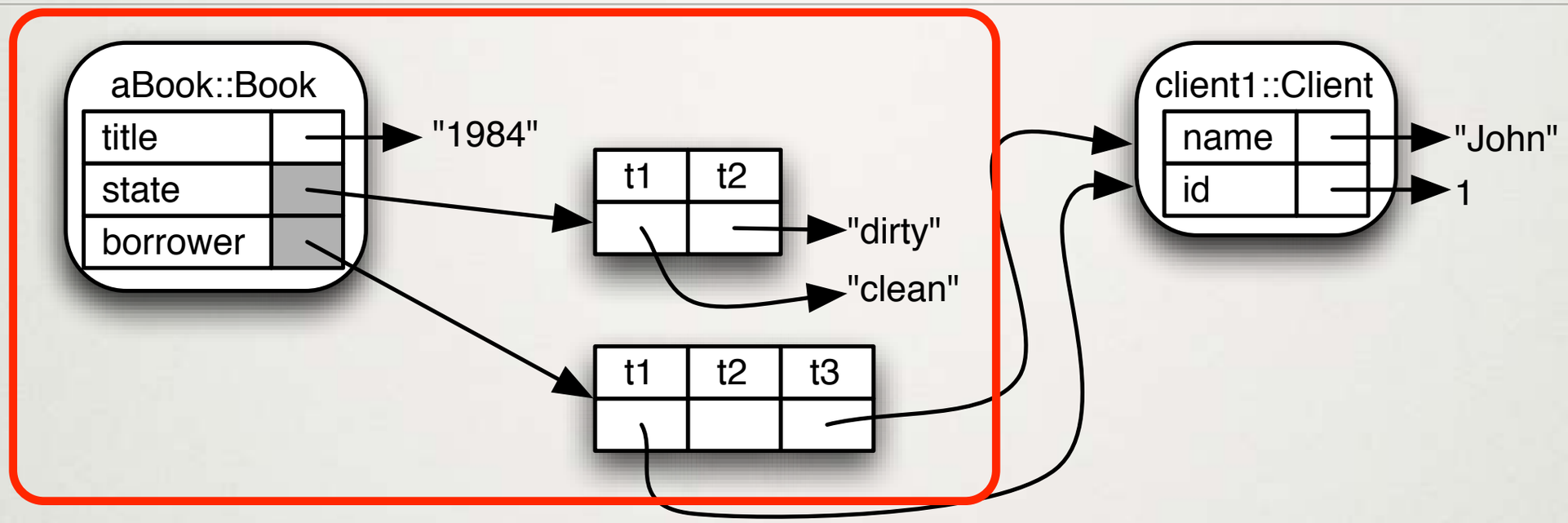

- States are shared between snapshots
- The states are in the object itself
  - If an object is no longer reachable, it is garbage collected
  - Including all of its fields history

Implementation

History

- Early version in Java
- Stable version in Smalltalk

Smalltalk integration

- A standard library
  - Can be loaded in any application
  - Existing code does not need modification
- Three primitives
  - `anObject` **`selectFields`**
  - `s :=` **`HSnapshot atNow`**
  - `s` **`execute:`** `aBlock`
- Easy to learn and use

Smalltalk integration

borrowing

```
aClient := Client named: ‘John’.
aBook := Book titled: ‘1985’.
aBook state: ‘clean’.
aBook borrower: aClient.
```

returning

```
aBook state: ‘dirty’.
aBook borrower: nil.
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Smalltalk integration

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aBook state.
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aBook state.                    → ‘dirty’
s1 execute: [aBook state].
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aBook state.  ⟶ ‘dirty’
s1 execute: [aBook state].  ⟶ ‘clean’
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returning

Performance

Performance

	Slowdown factor
Synthetic worst case update	7

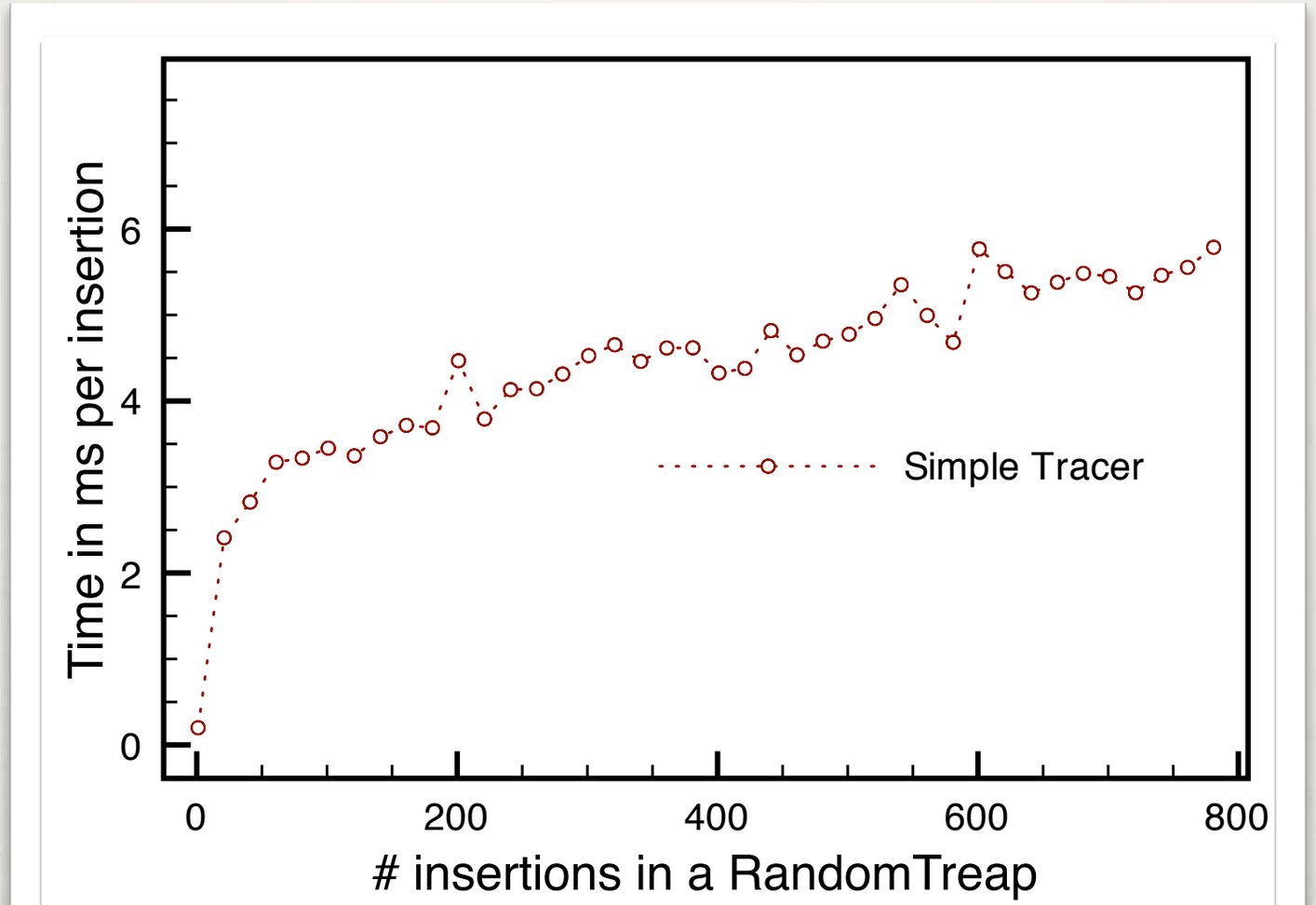
Performance

	Slowdown factor
Synthetic worst case update	**7**
Real cases update	**1.3 to 2**

Applications

- We implemented
  - Eiffel-like Checked Post-Conditions for Smalltalk
  - Execution tracer with states
  - Planar Point Location

Benchmarks



Stores messages sent in a collection

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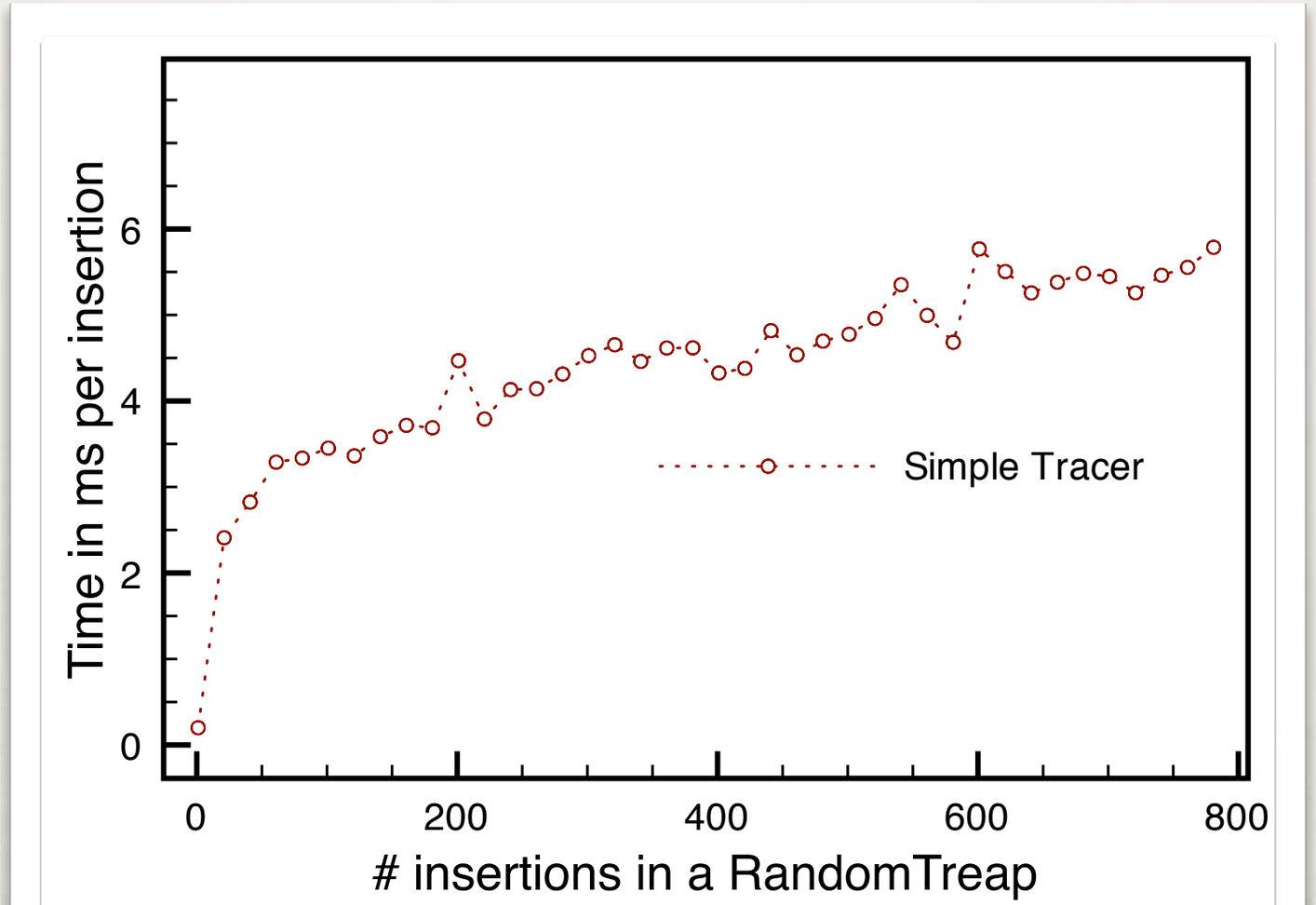

Stores messages sent in a collection

Also stores states of receiver and arguments

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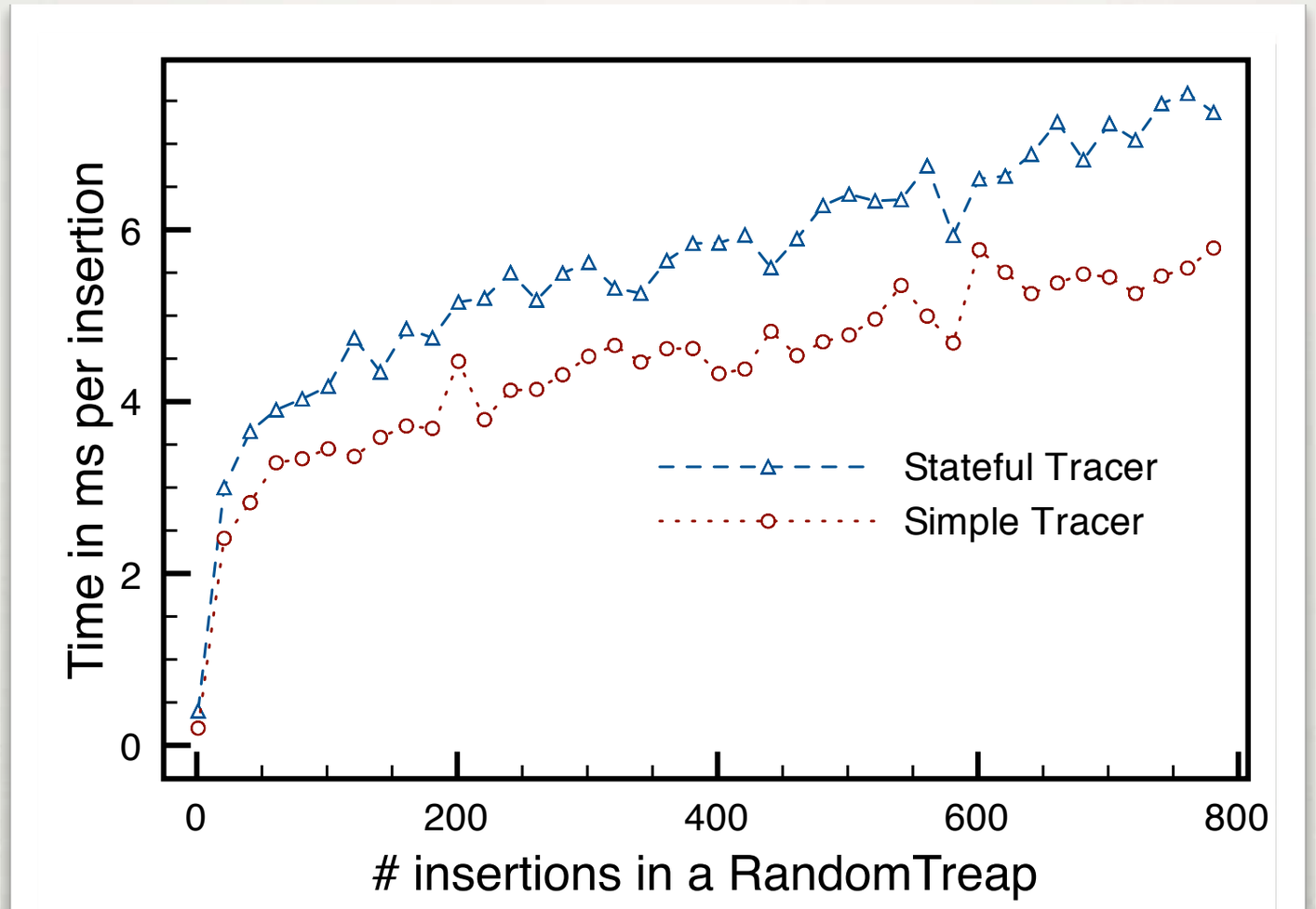

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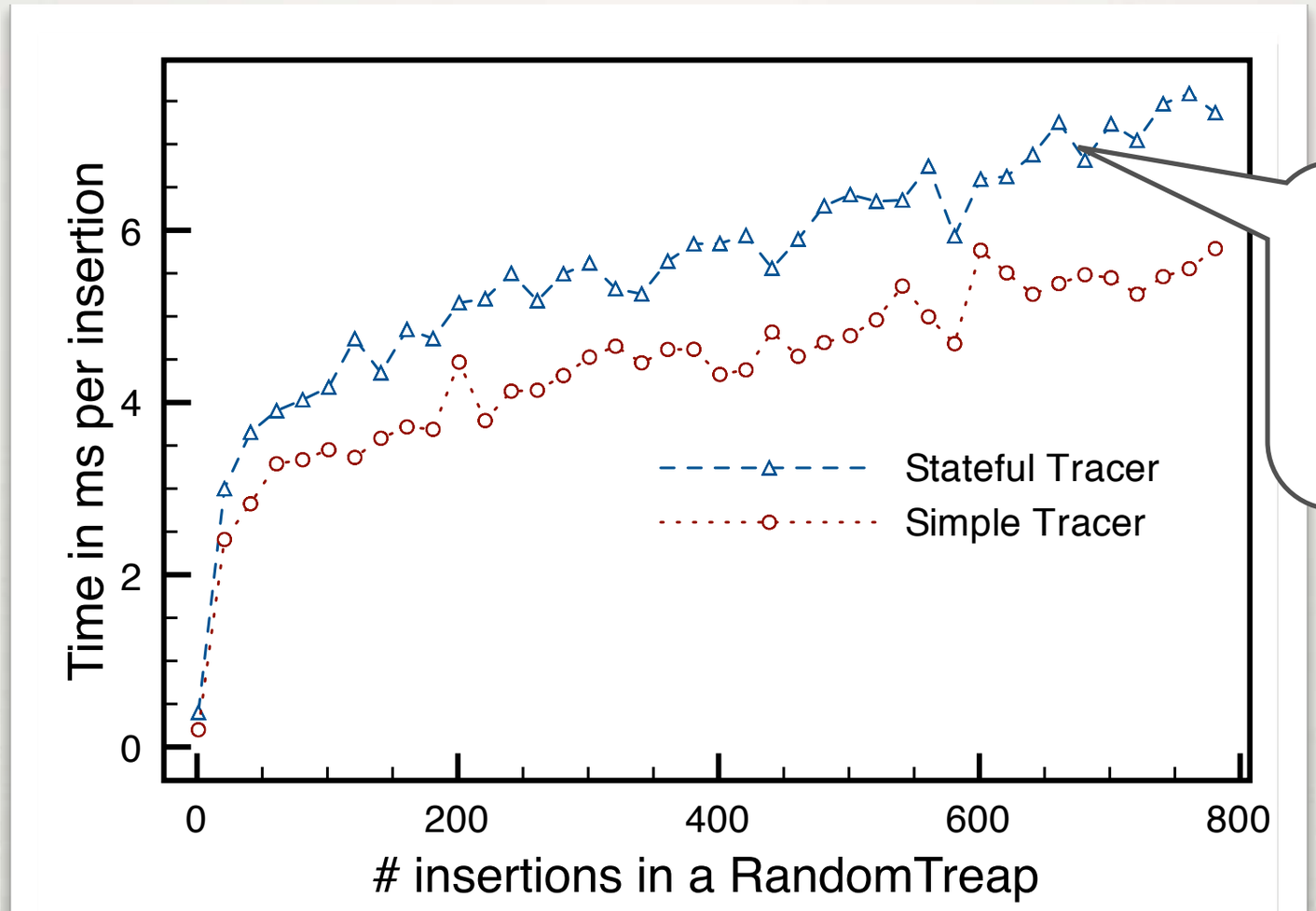

Only 30% slower !

Stores messages sent in a collection

Also stores states of receiver and arguments

Conclusion

- A general and efficient model for in-memory object versioning for object-oriented languages
- We implemented it in Smalltalk
  - 3 primitives
  - Non-intrusive library
  - Efficient

Thank you !

- fpluquet@ulb.ac.be
- HistOOry on Google
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