Fast Bounded-Concurrency Hash Tables

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Backtrace

Introduction

A general mechanism for achieving non-blocking progress guarantees cheaply.

- Support for any open-addressed collision resolution mechanism.
- No atomic operations, memory barriers or memory allocation on the fast path (for TSO).
- Writers never block.
- Readers only block for a small subset of executions.
- Dead simple.

Motivation

- Single-writer multi-reader (SWMR) workload.
- Constant stream of read operations but bursts of millions of writes every few minutes.
- Firm real-time requirements on read-side.
- Starvation-freedom on write-side.
- Systems were memory-constrained so memory efficiency is important.

Motivation

State-of-the-art entailed significant trade-off in complexity and performance.

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- Reliance on expensive operations.
- Limitations on collision resolution mechanism.

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- Complex object re-use constraints in absence of key duplication.
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What does specialization get us?

Constraints

- Termination-safety is not a requirement.
- SWMR allows us to rely on less complex instructions.
- Primarily executing on x86 processors.
  - Load to load ordering.
  - Store to store ordering.

Implementation

- **ck_pr_store_X**(a, b)
  atomically { *a = b }
- **ck_pr_load_X**(a)
  atomically { *a }
- **ck_pr_fence_store**()
  smp_wb()
- **ck_pr_fence_load**()
  smp_rb()

Implementation

```
1  struct slot {
2      /*
3       * The key field may be the key value or a reference to
4       * the key value.
5       */
6      void *key;
7
8      /*
9       * The value field may be the value value or a reference to
10      * the value value.
11      */
12     void *value;
13 };
```

Implementation

delete

```
1  ck_pr_store_ptr(&slot->key, T);
2  ck_pr_fence_store();
```

Implementation

delete

```
1  ck_pr_store_ptr(&slot->key, T);
2  ck_pr_fence_store();
```

insert

```
1  if (ck_pr_load_ptr(&slot->key) == T) {
2      ck_pr_store_uint(&D, D + 1);
3      ck_pr_fence_store();
4  }
5
6  ck_pr_store_ptr(&slot->value, value);
7  ck_pr_fence_store();
8  ck_pr_store_ptr(&slot->key, key);
```

Implementation

get

```
1  get(struct slot *result, void *key)
2  {
3    unsigned int d, d_p;
4
5    do {
6        d = ck_pr_load_uint(&D);
7        ck_pr_fence_load();
8        search(result, key);
9        ck_pr_fence_load();
10       d_p = ck_pr_load_uint(&D);
11   } while (d != d_p);
12
13   return;
14 }
```

Implementation

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6         d = ck_pr_load_uint(&D);
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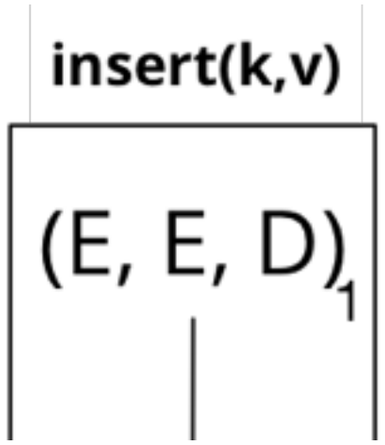
9         ck_pr_fence_load();
10        d_p = ck_pr_load_uint
11    } while (d != d_p);
12
13    return;
14  }
```

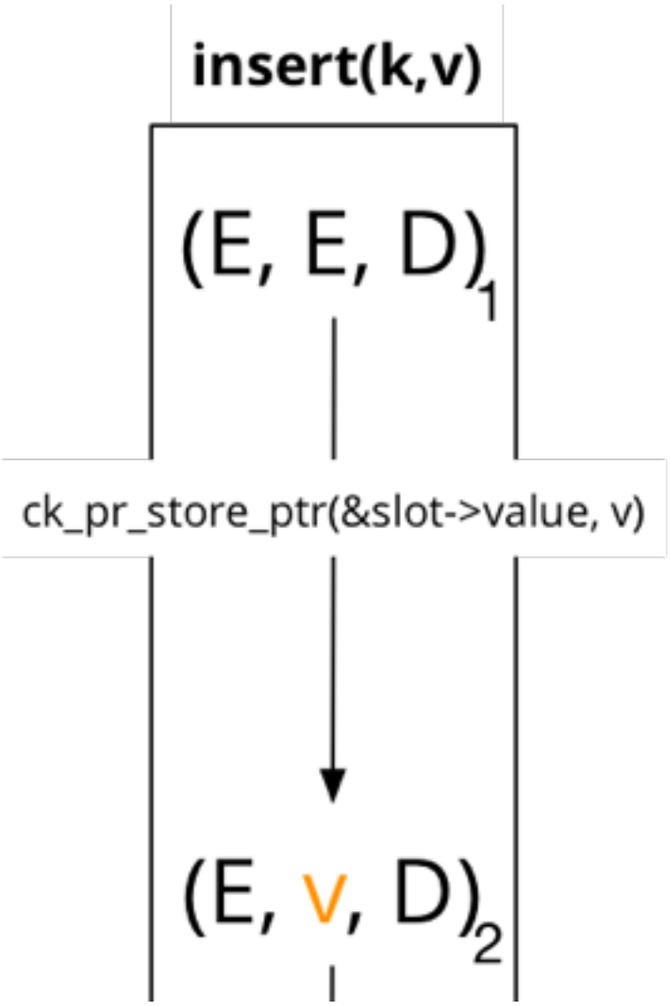
search

```
1   search(struct slot *result, void *key)
2   {
3   [...]
4
5       result->key = ck_pr_load_ptr(&slot->key);
6       ck_pr_fence_load();
7       result->value = ck_pr_load_ptr(&slot->value);
8
9   [...]
10  }
```

Correctness



Correctness



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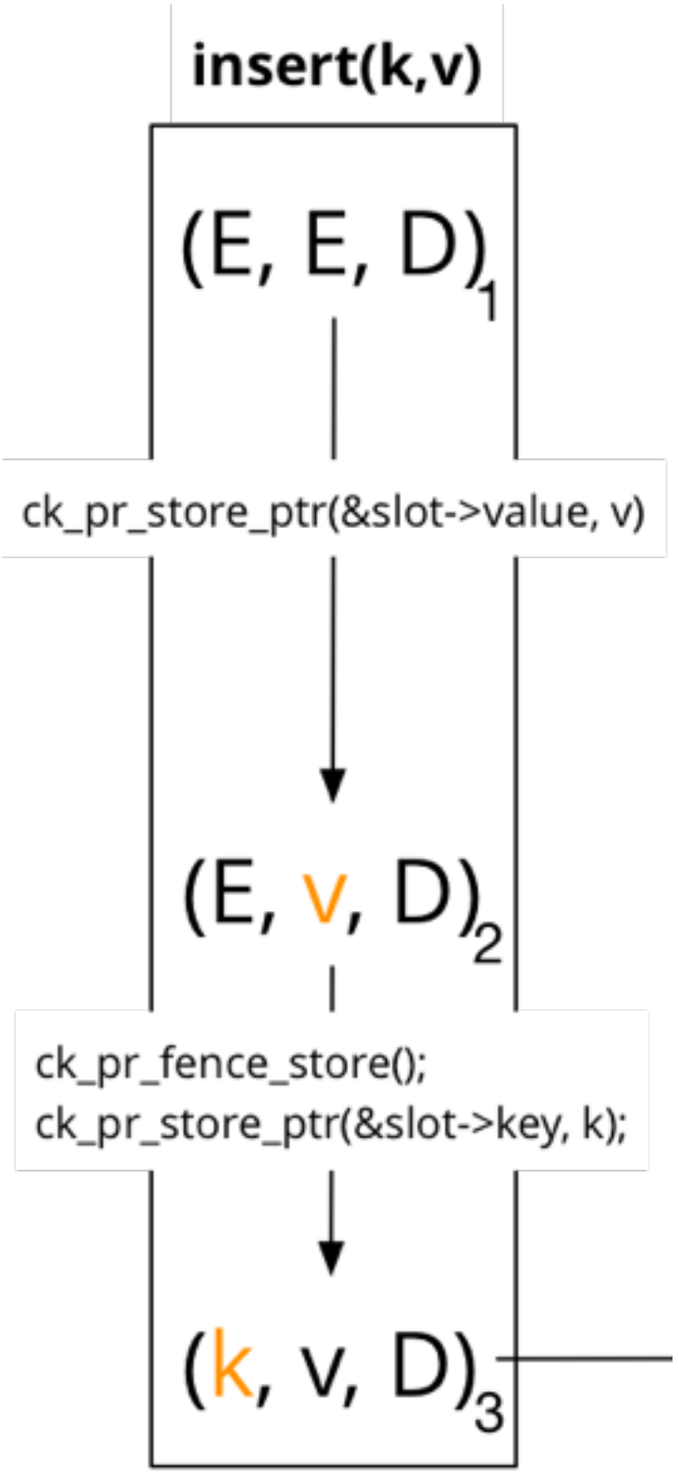
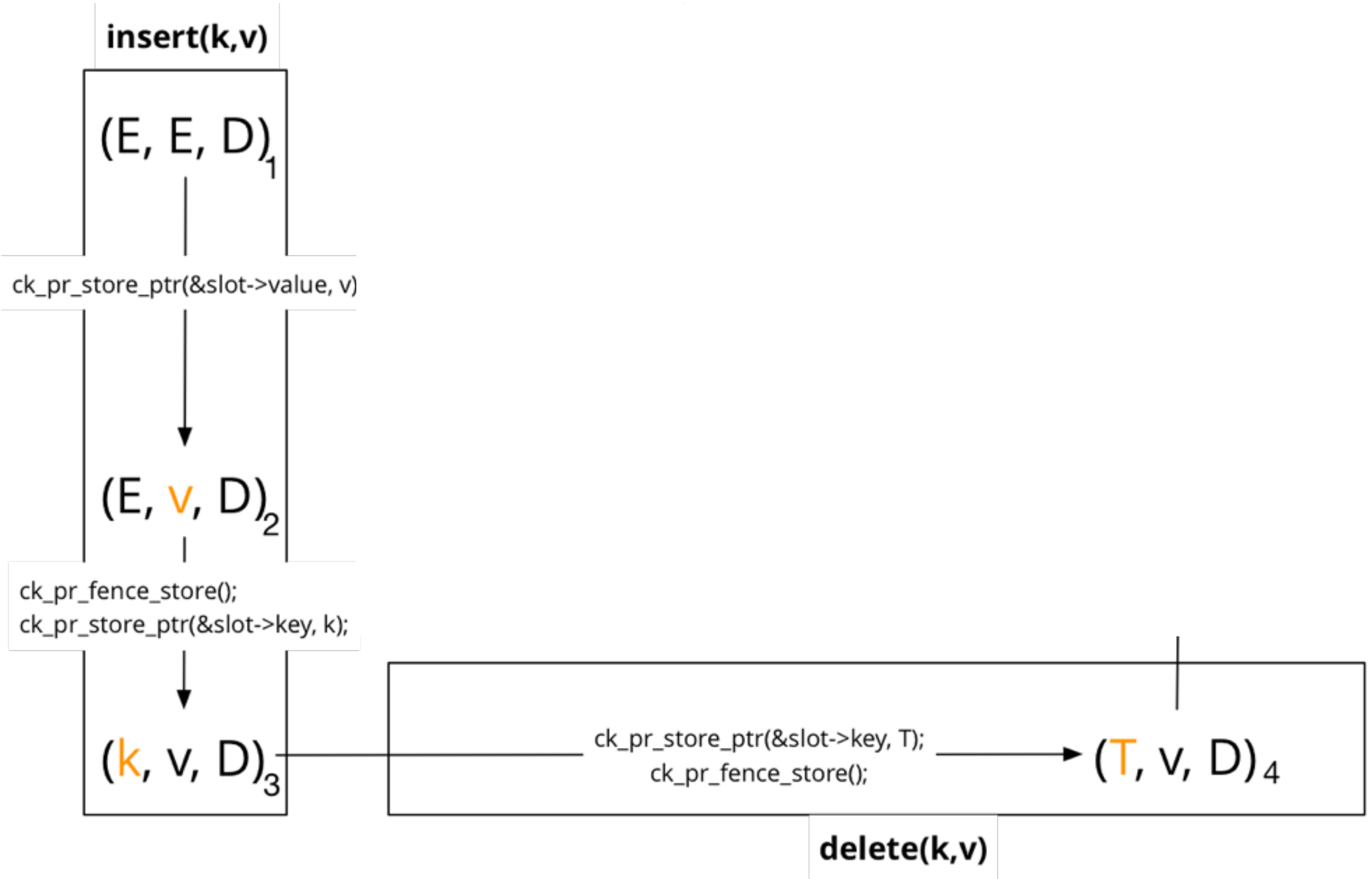


Backtrace

Correctness



Backtrace

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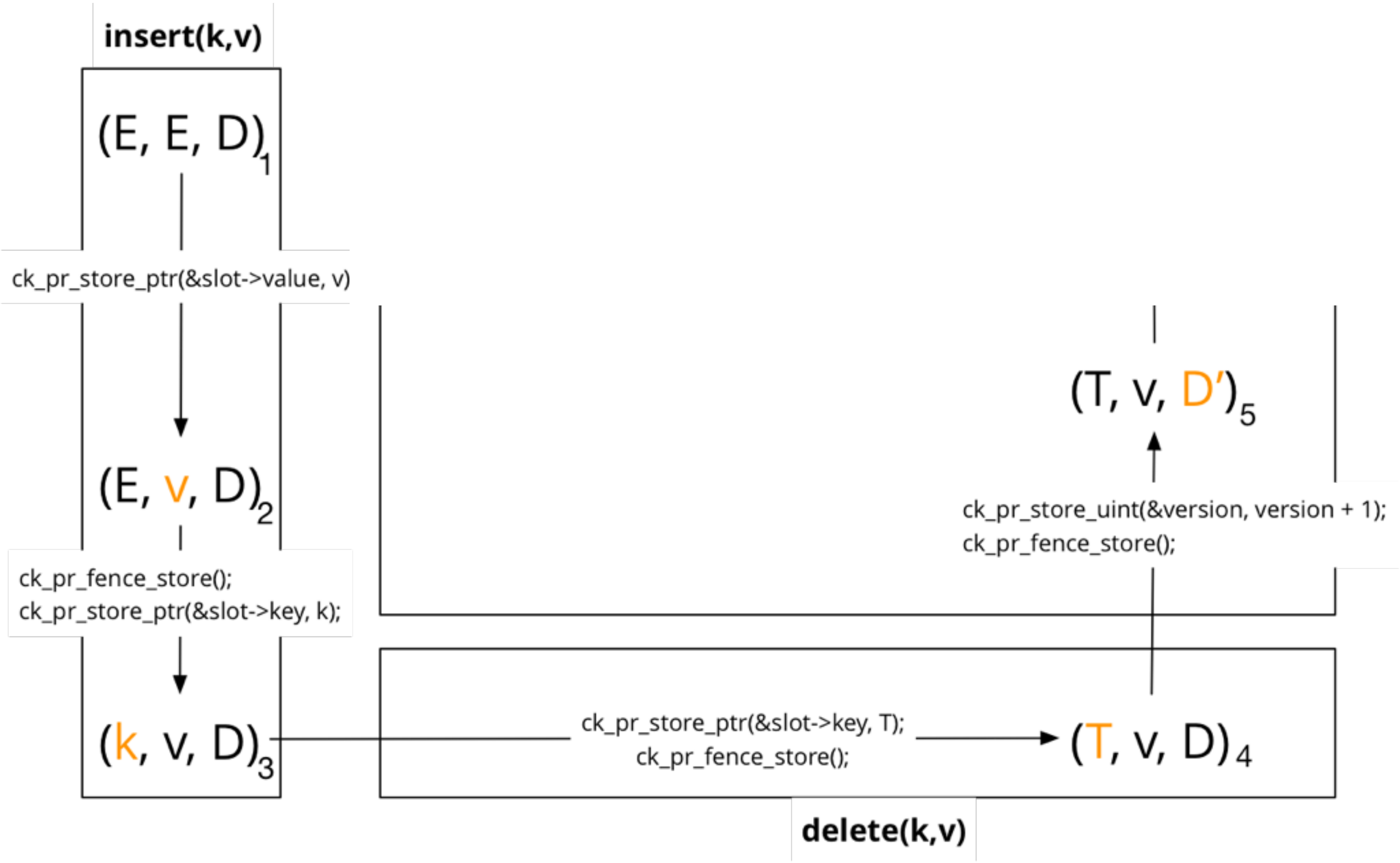

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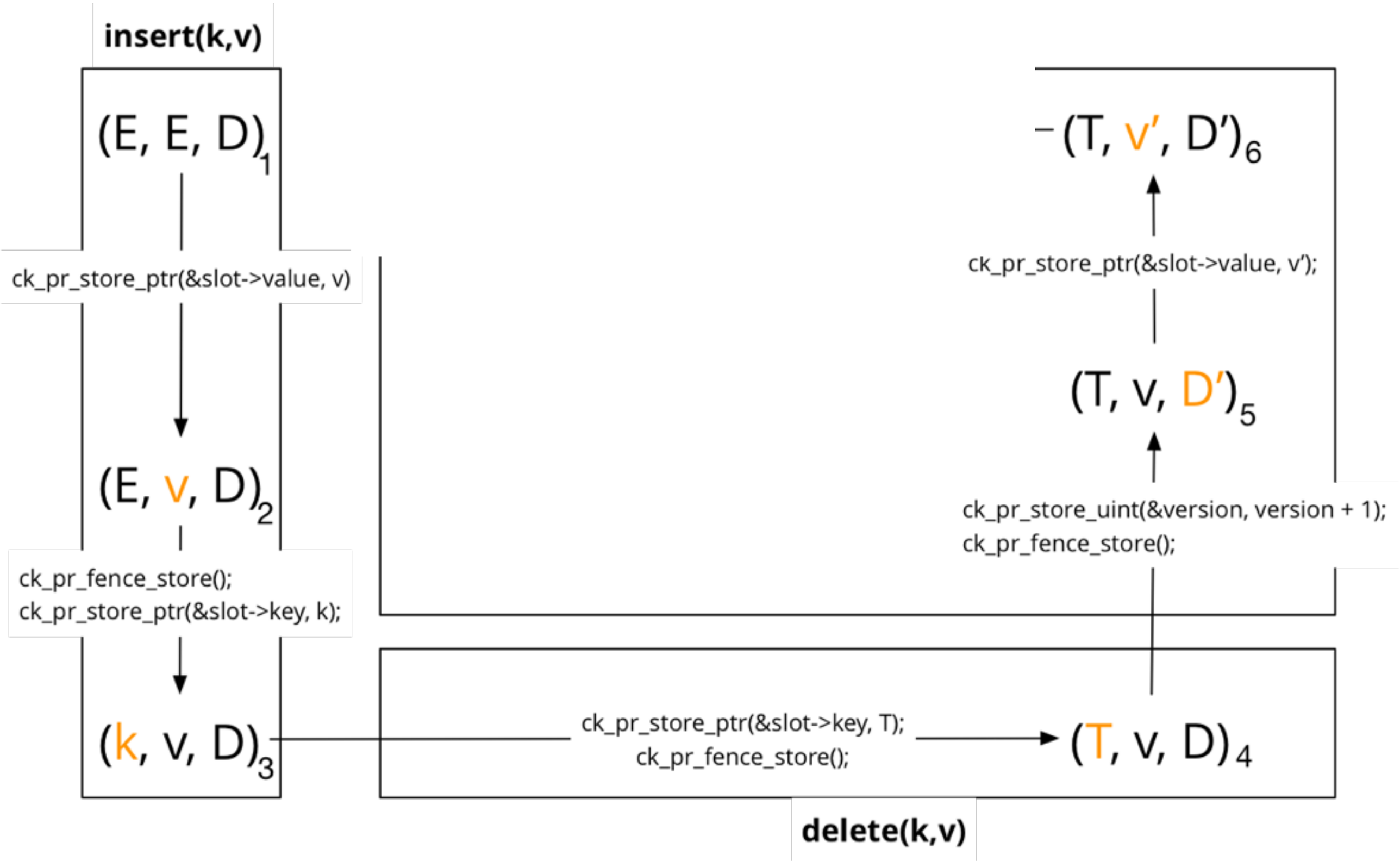

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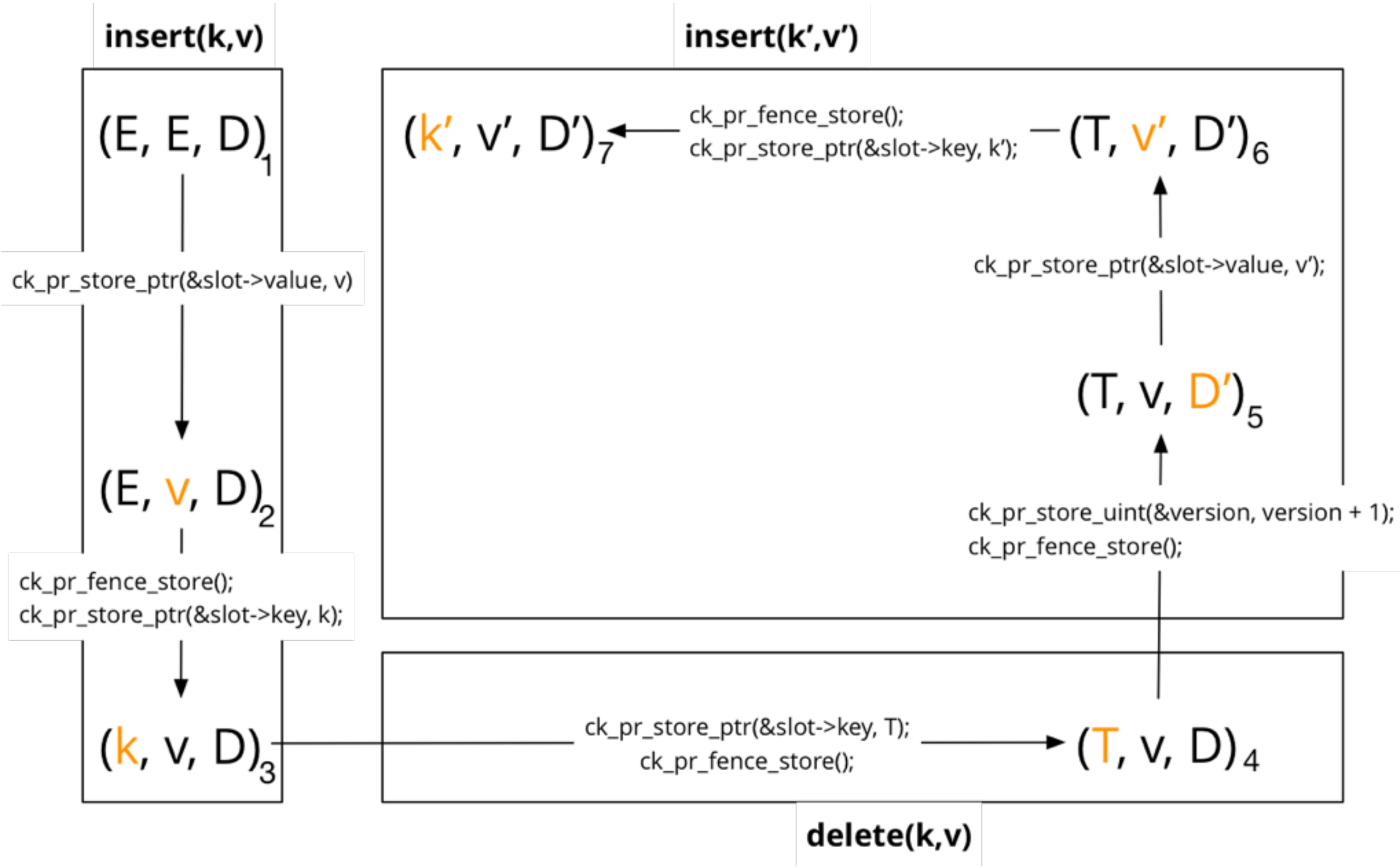

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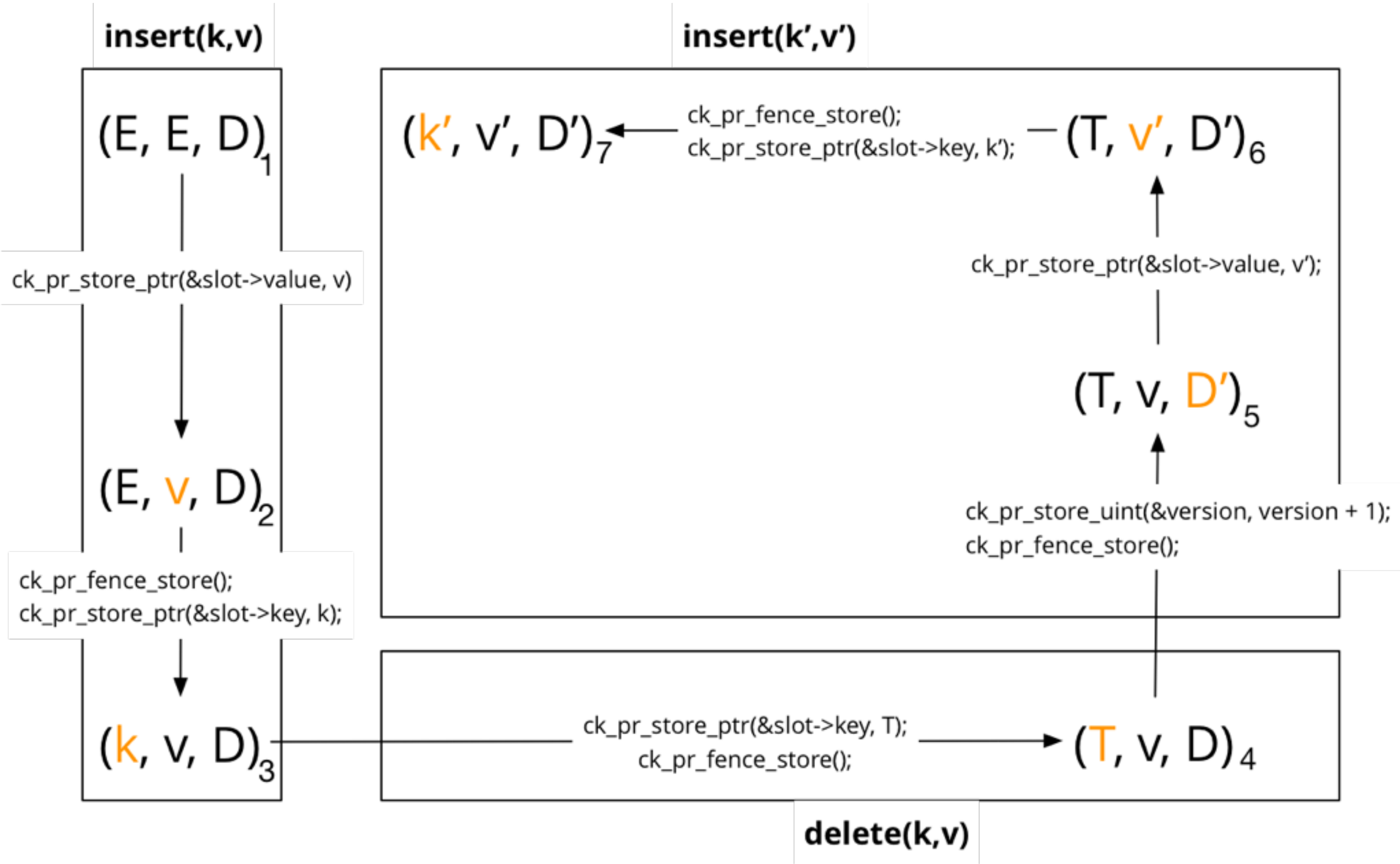

Observed (D, E, v, D)

Backtrace

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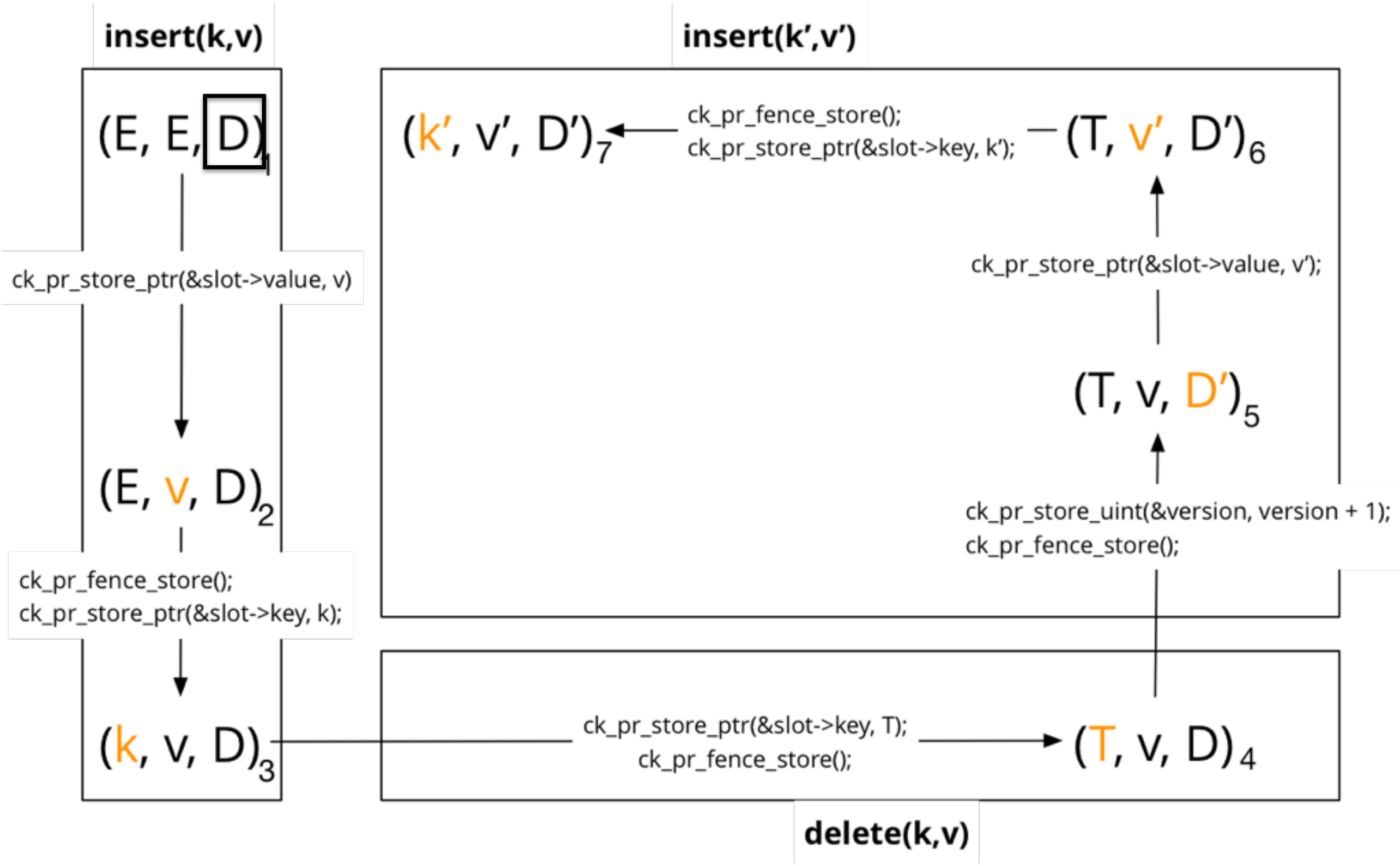

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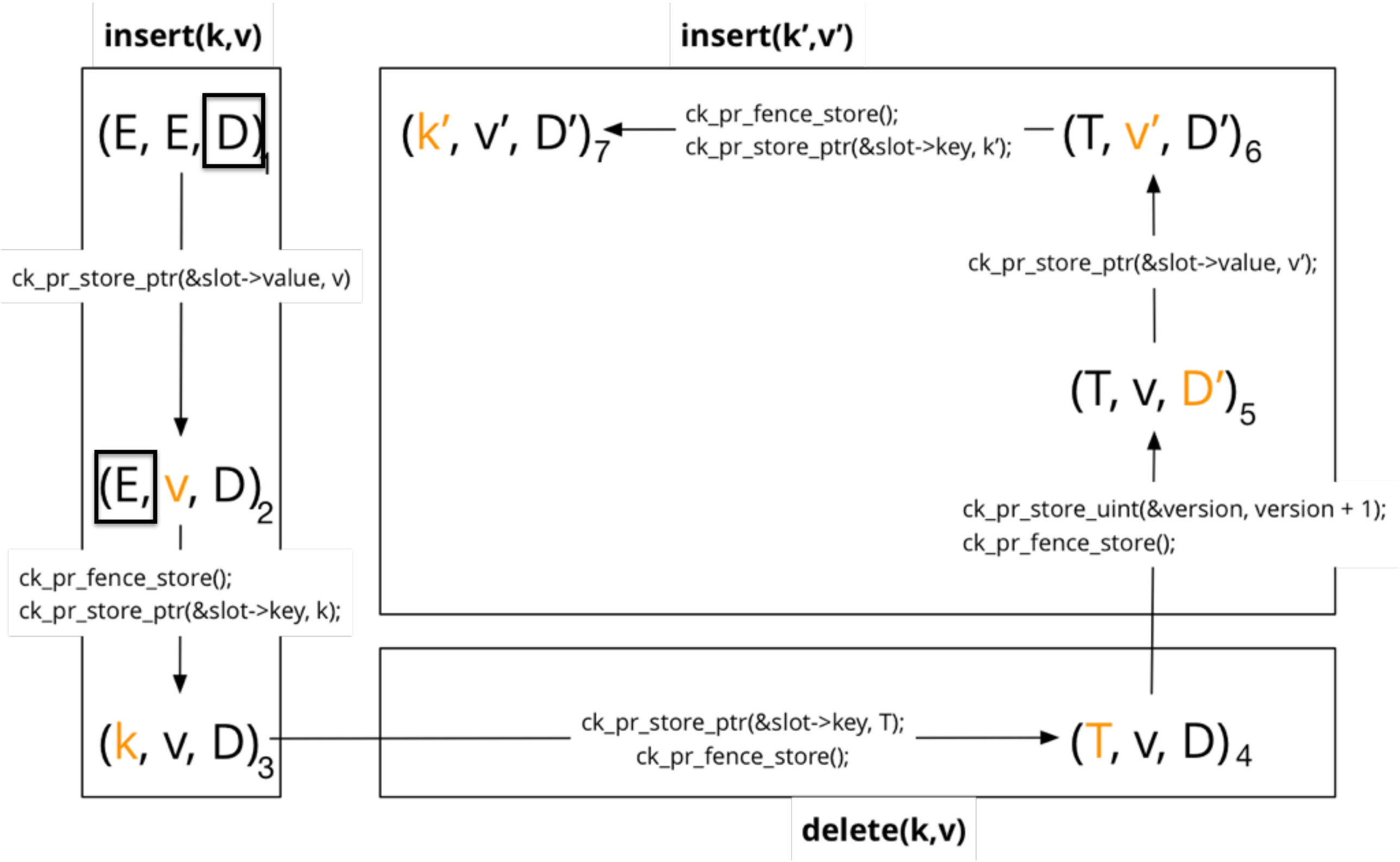

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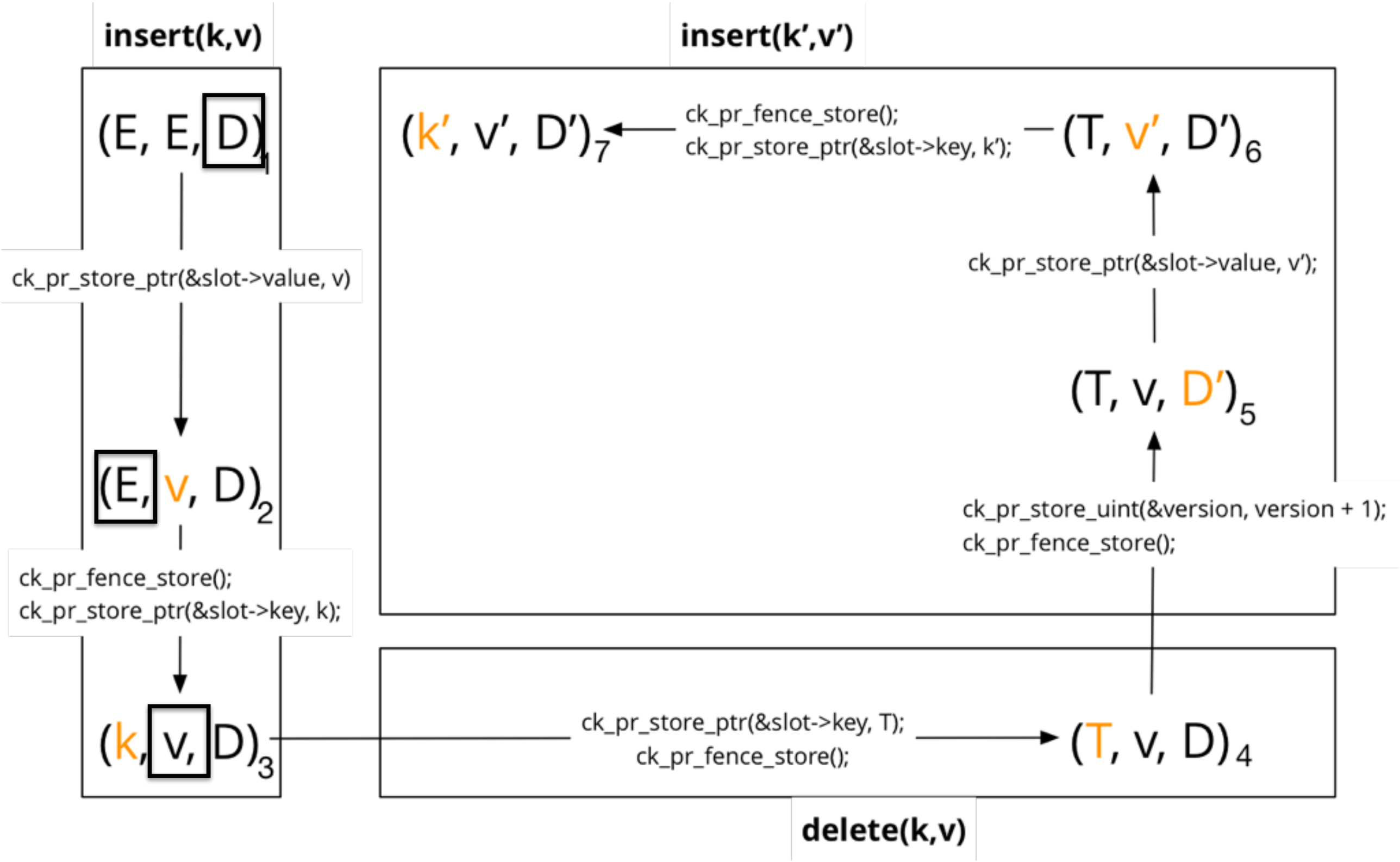

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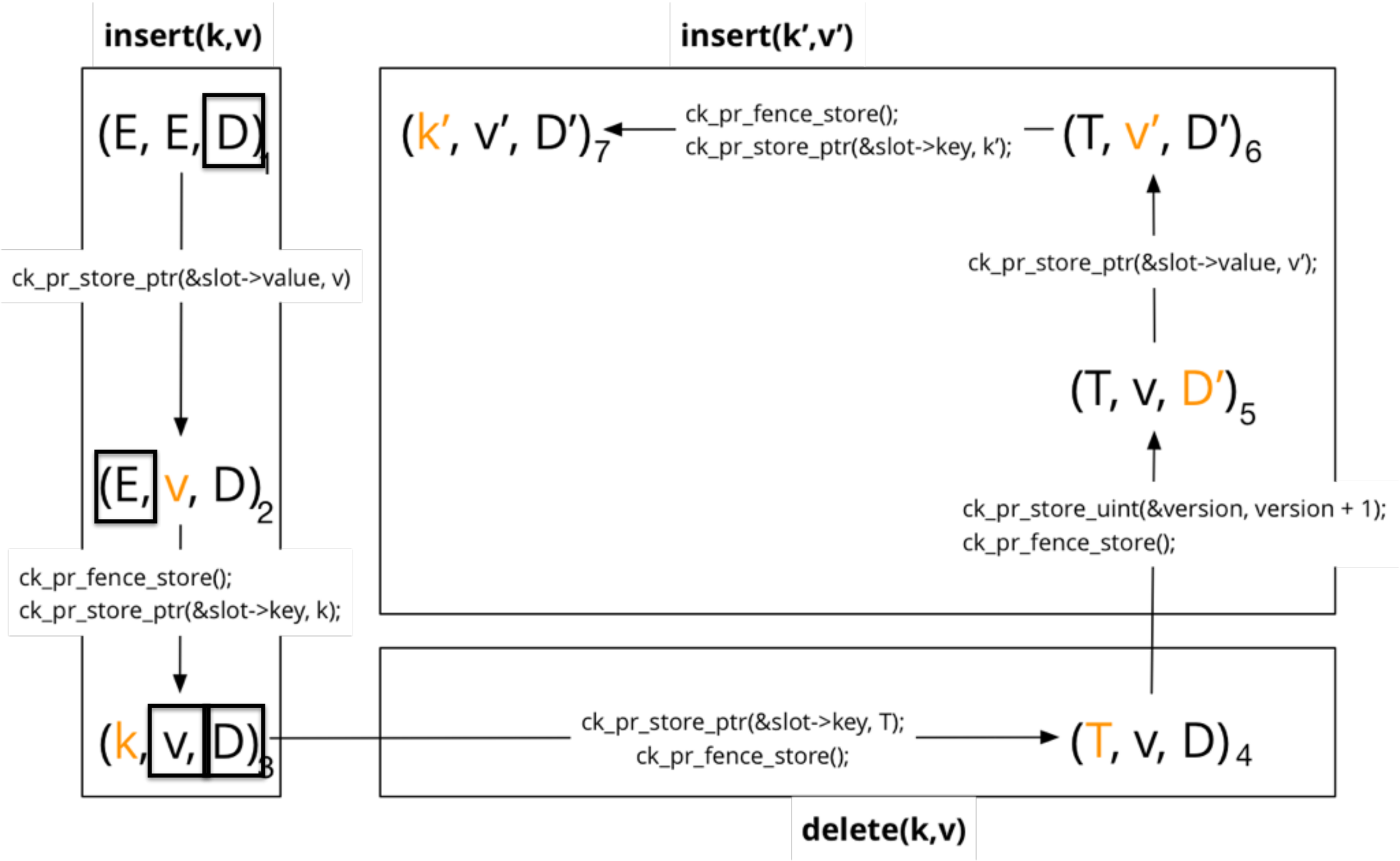

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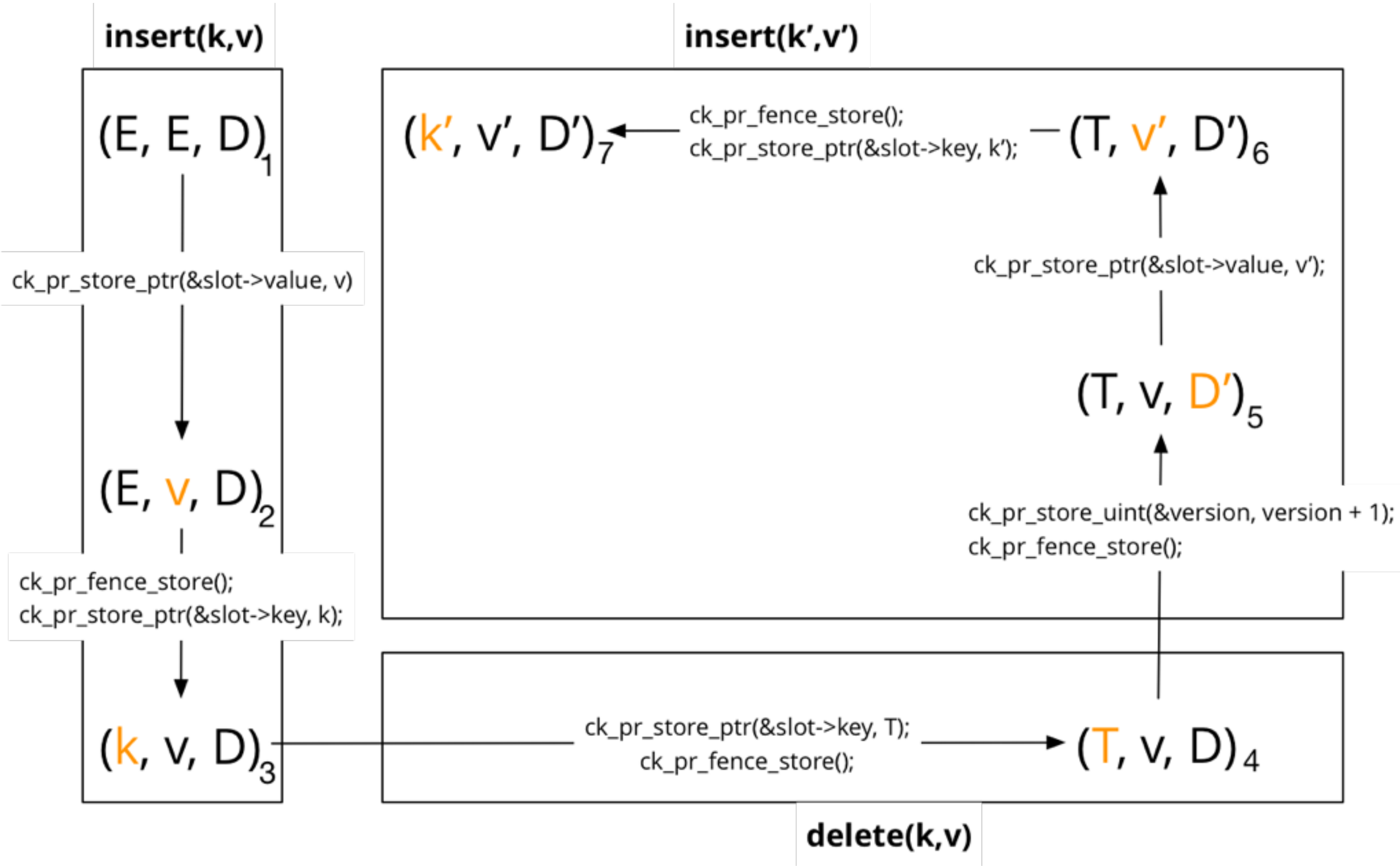

Cannot observe (D', E, v, D)

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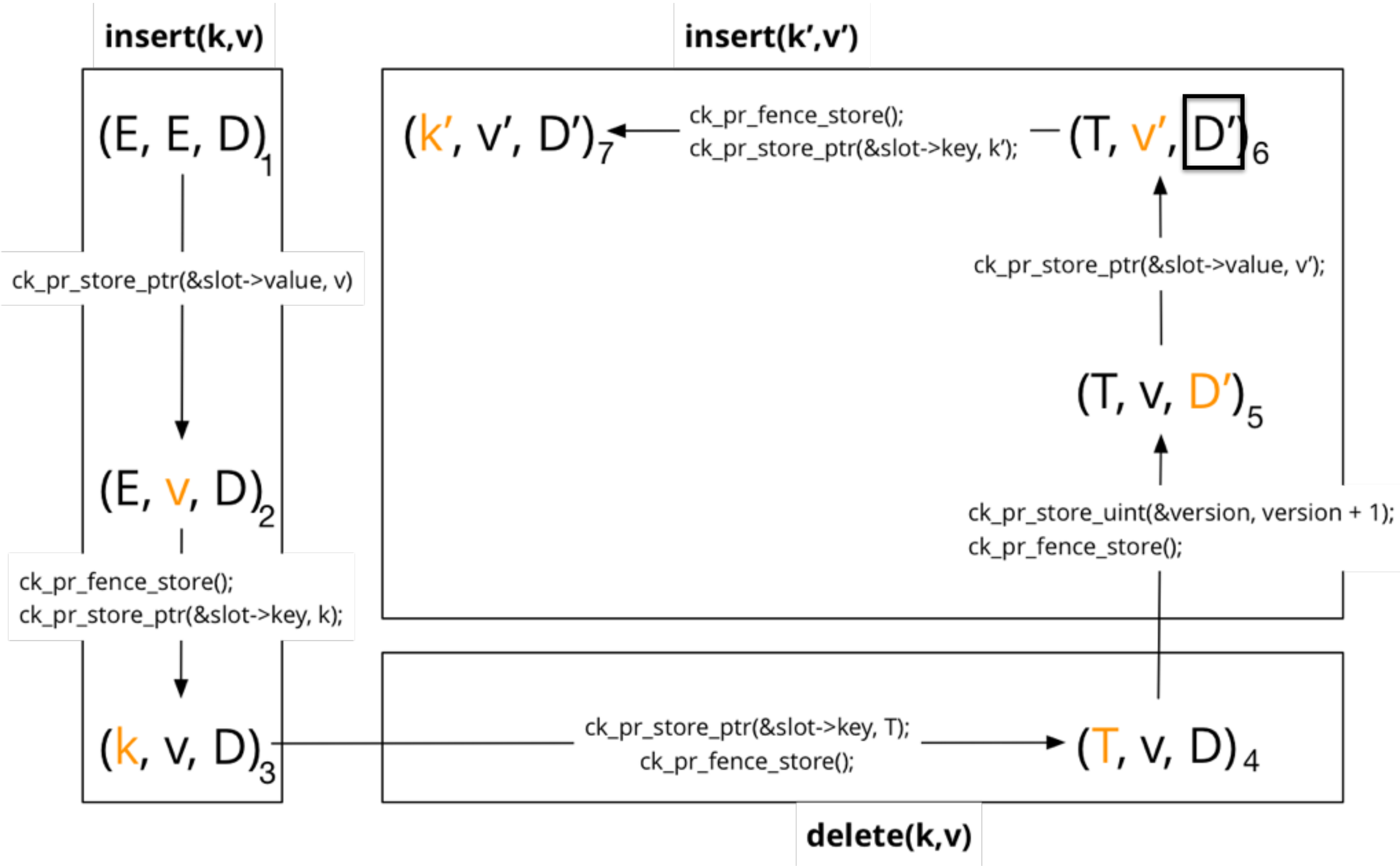

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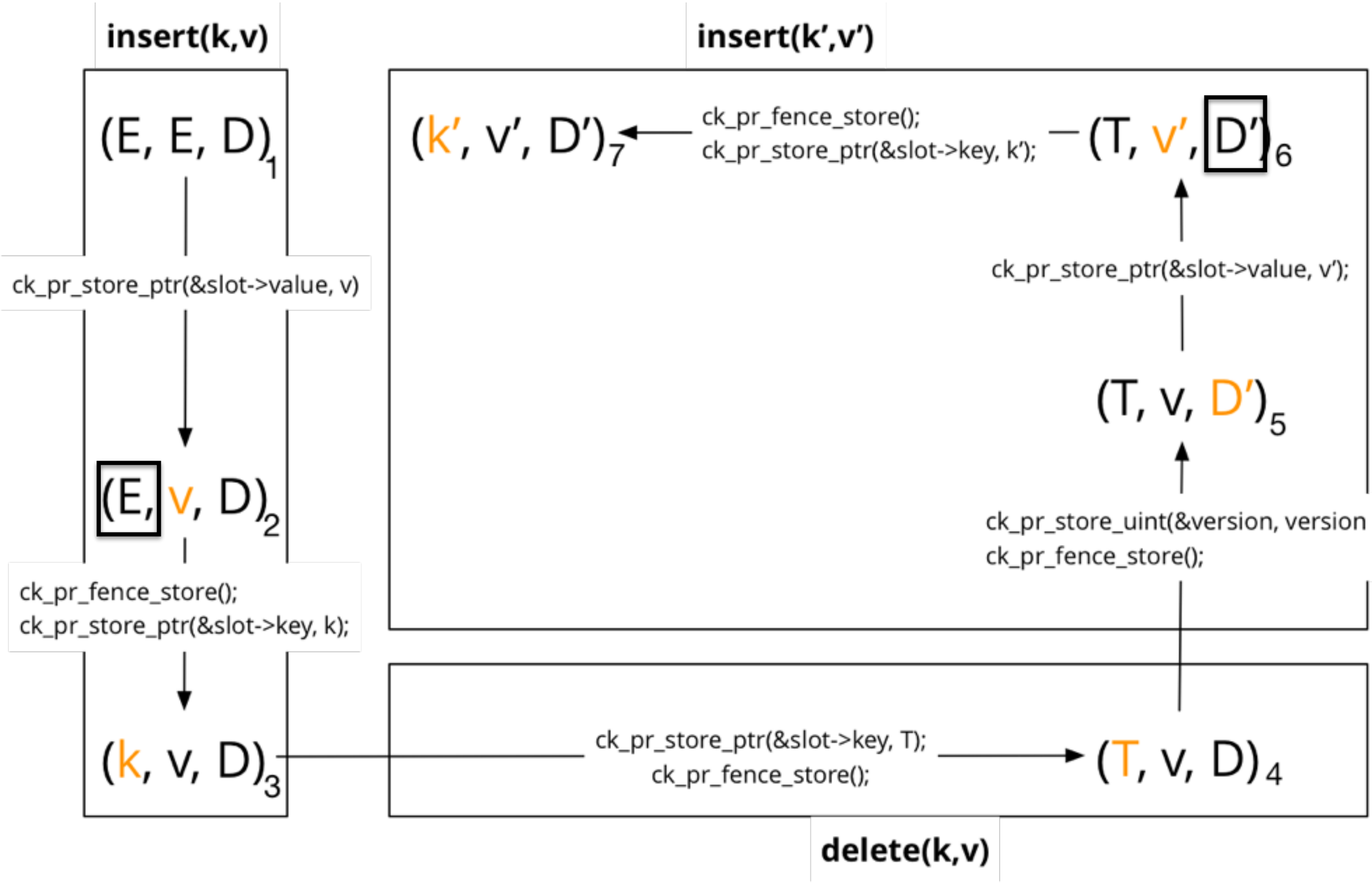

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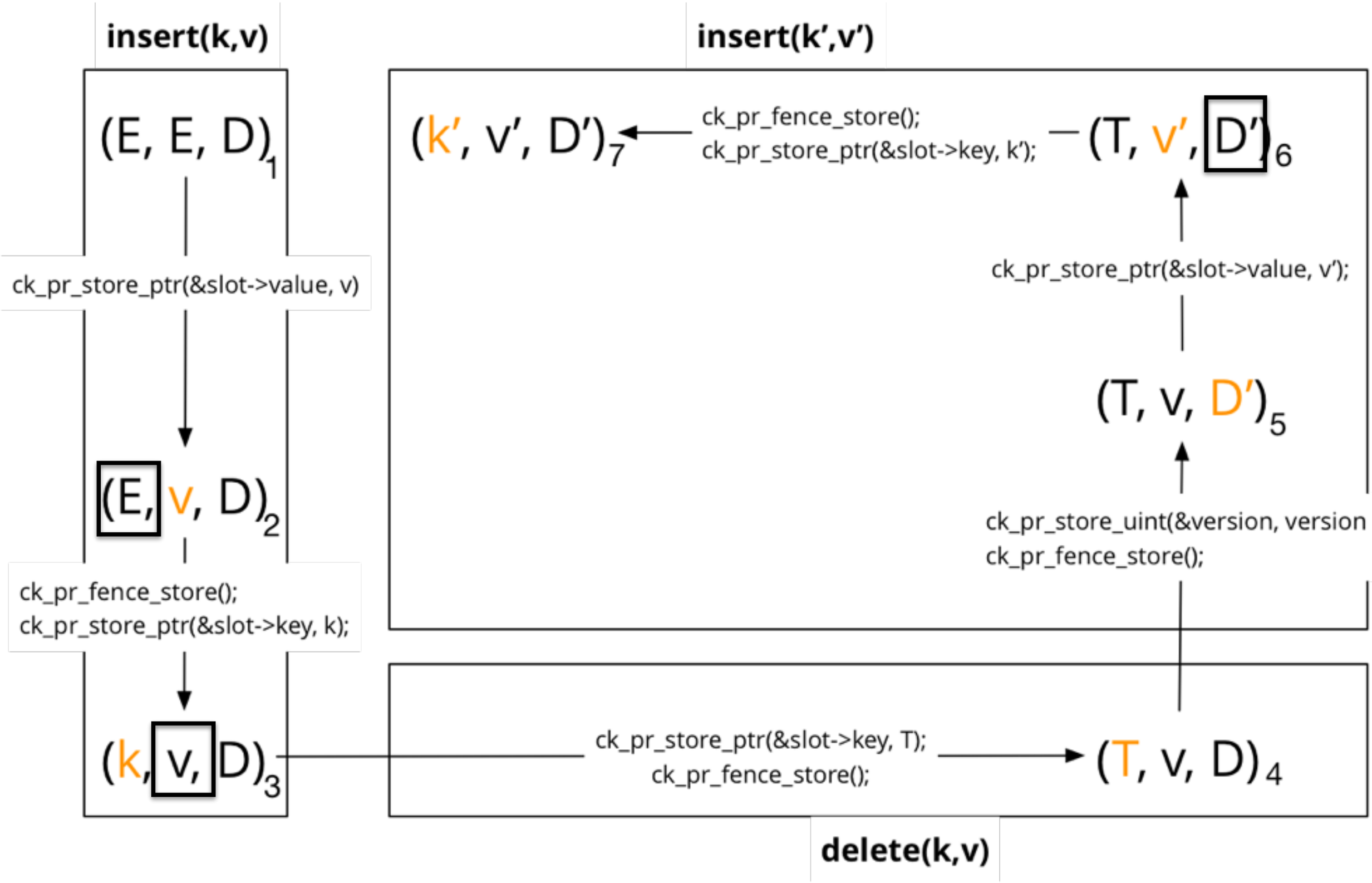

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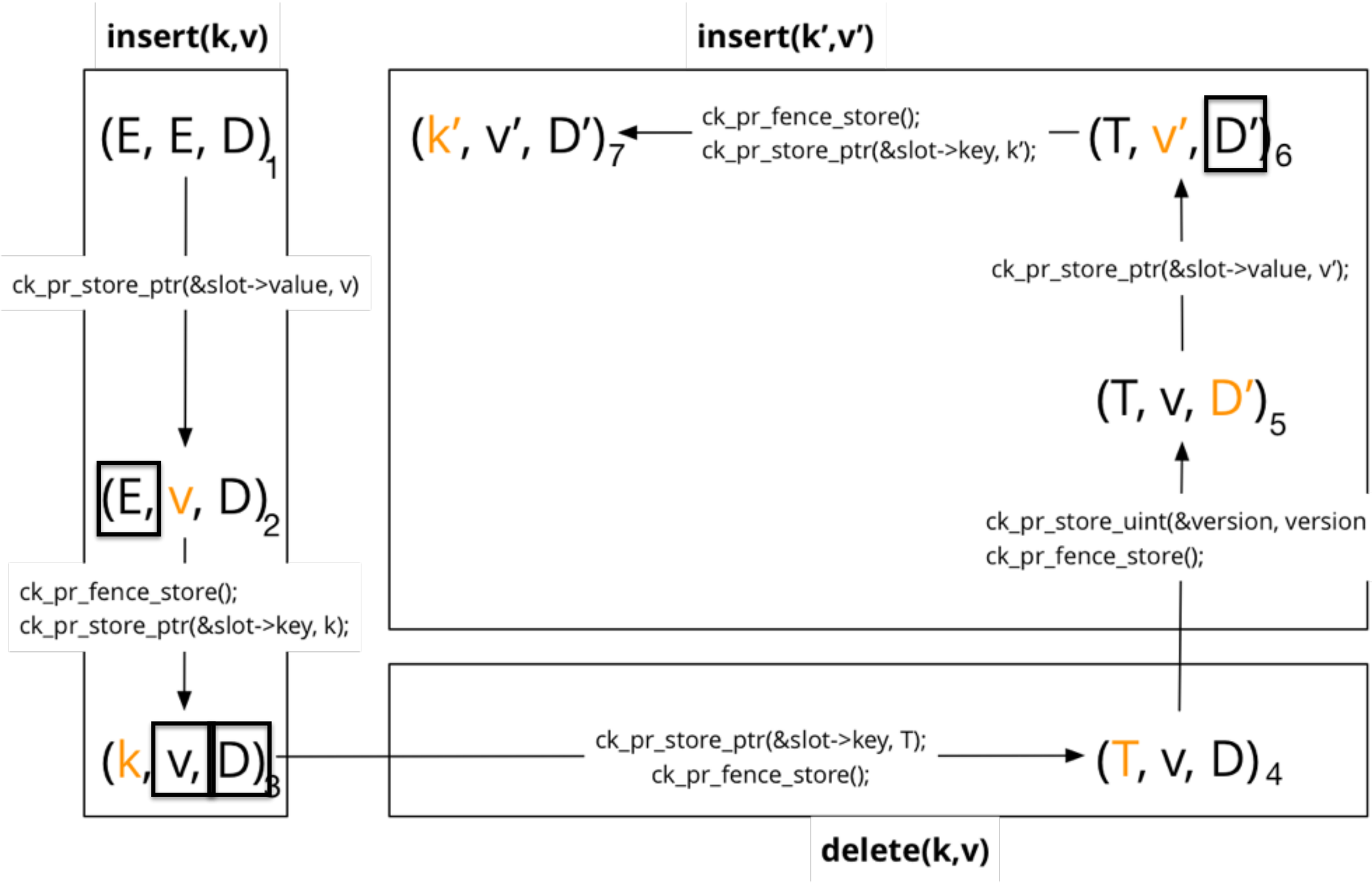

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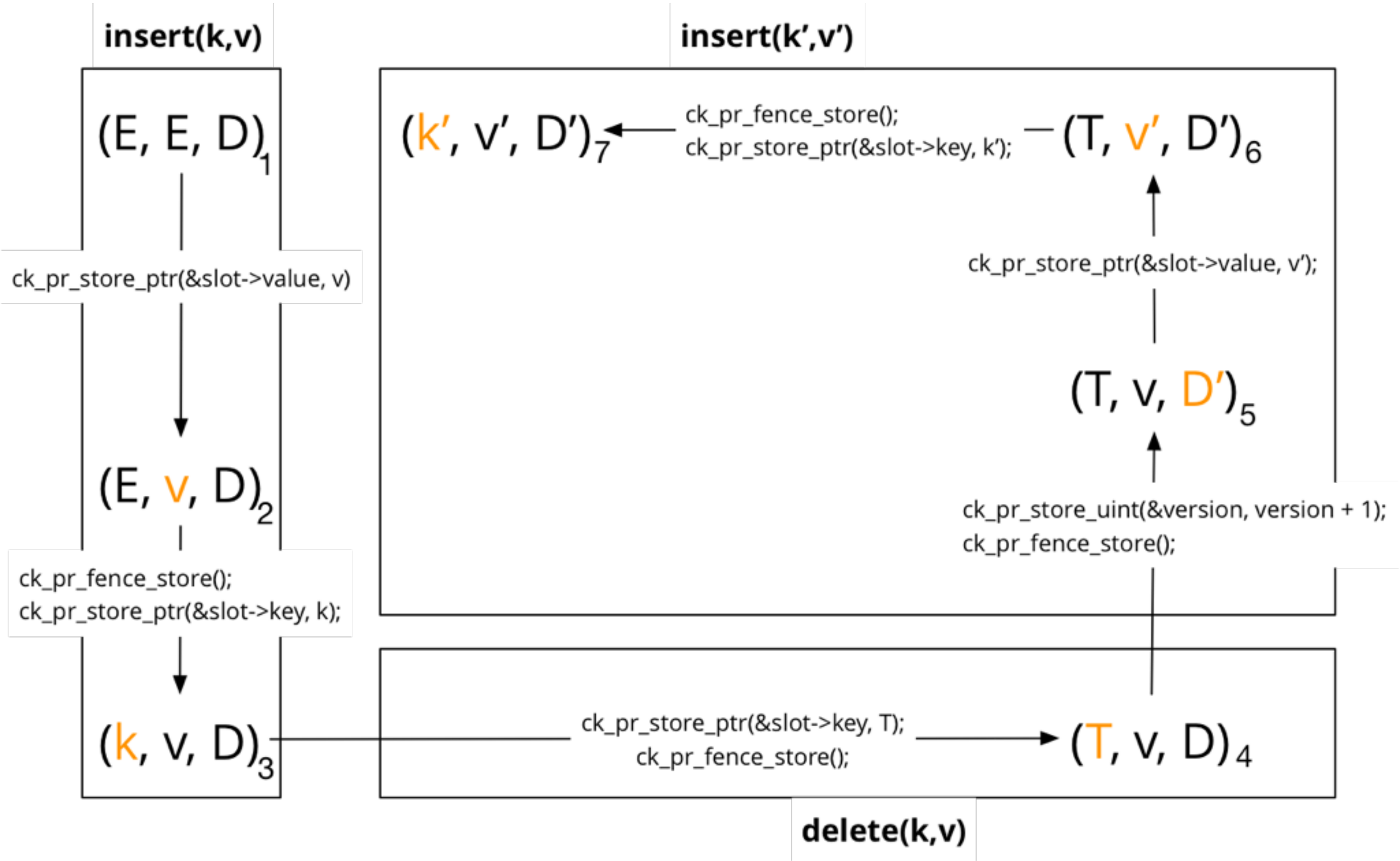
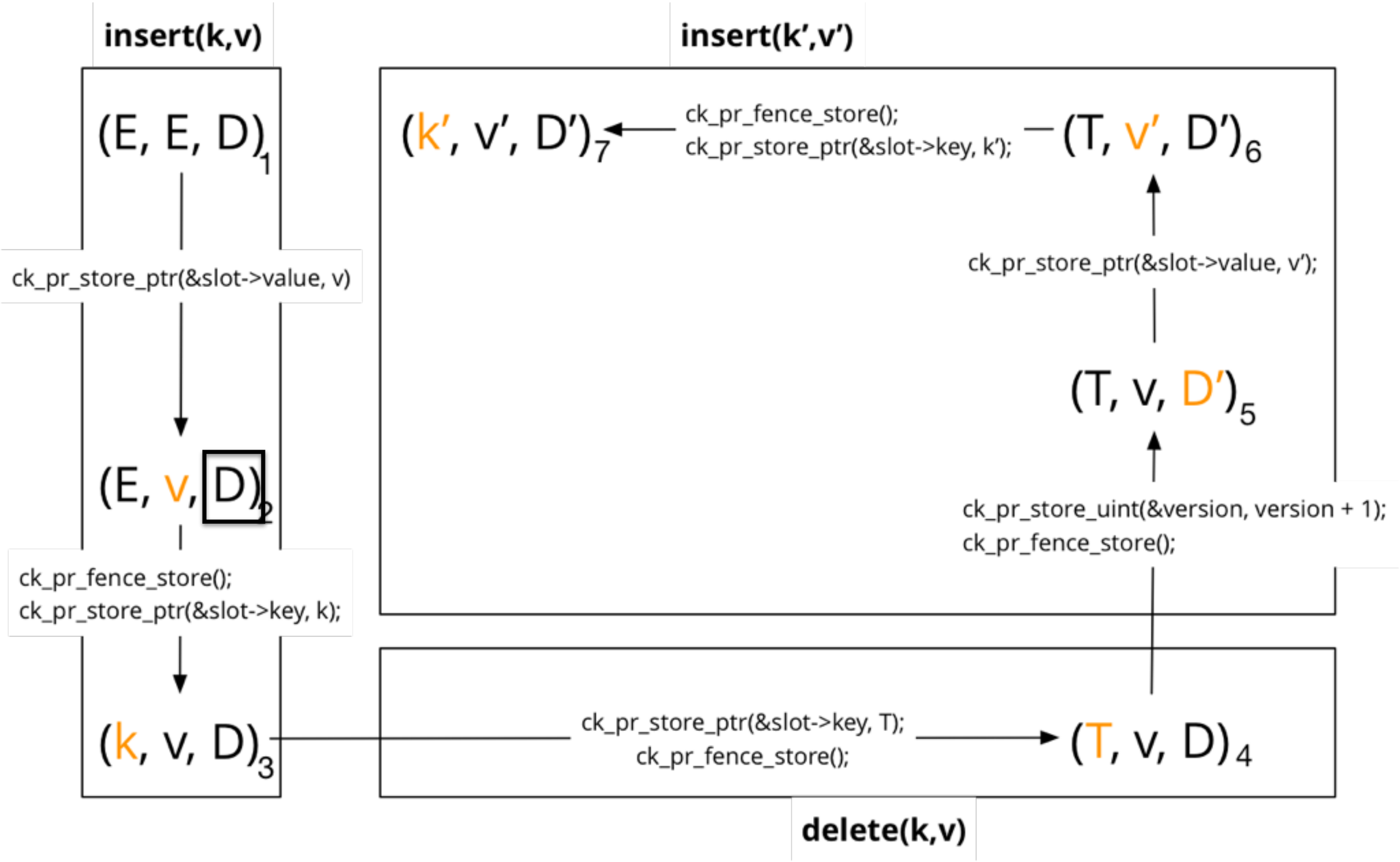


If (k, v') is observed, then so is D and D'.

Backtrace

Correctness



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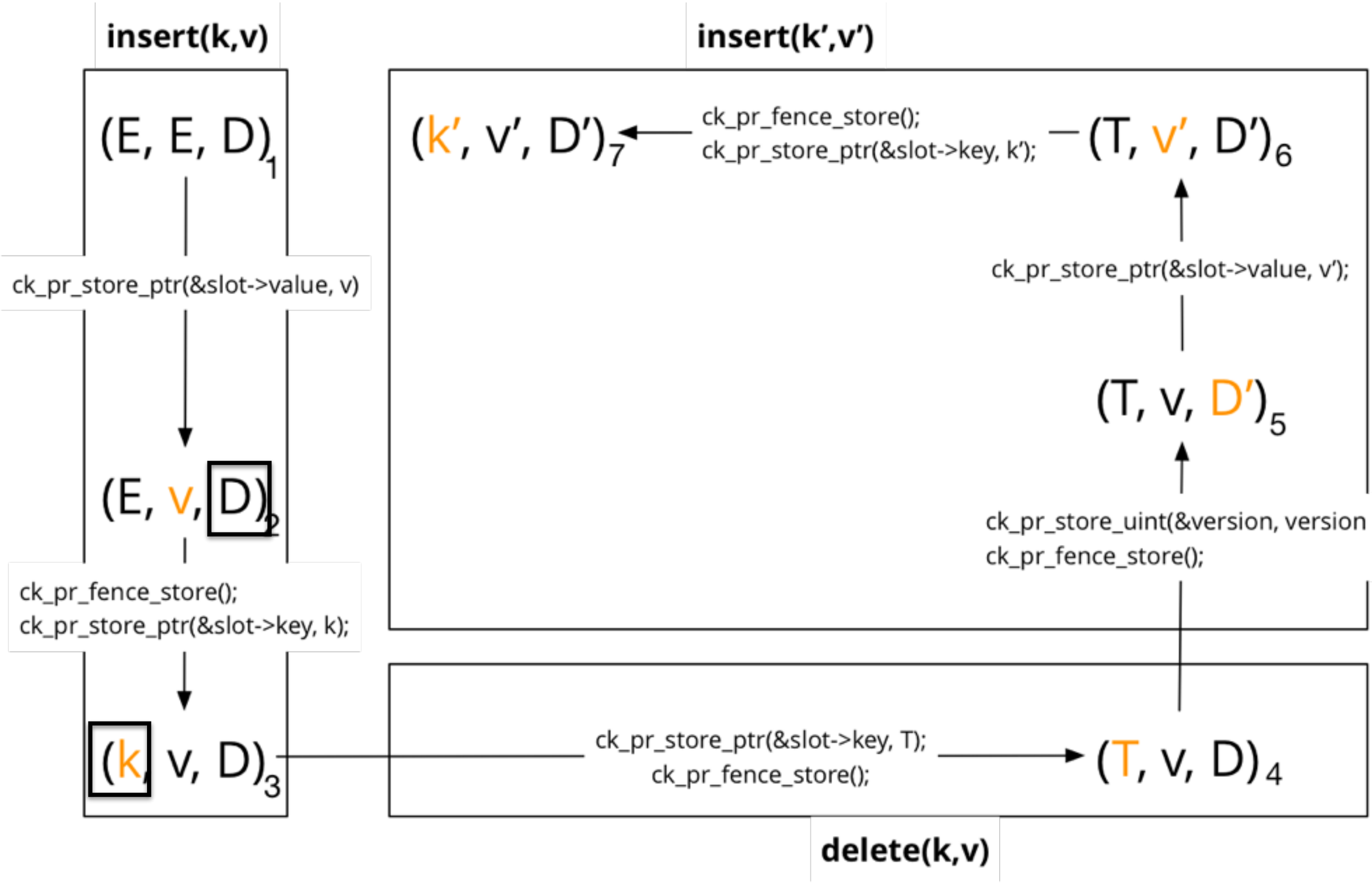

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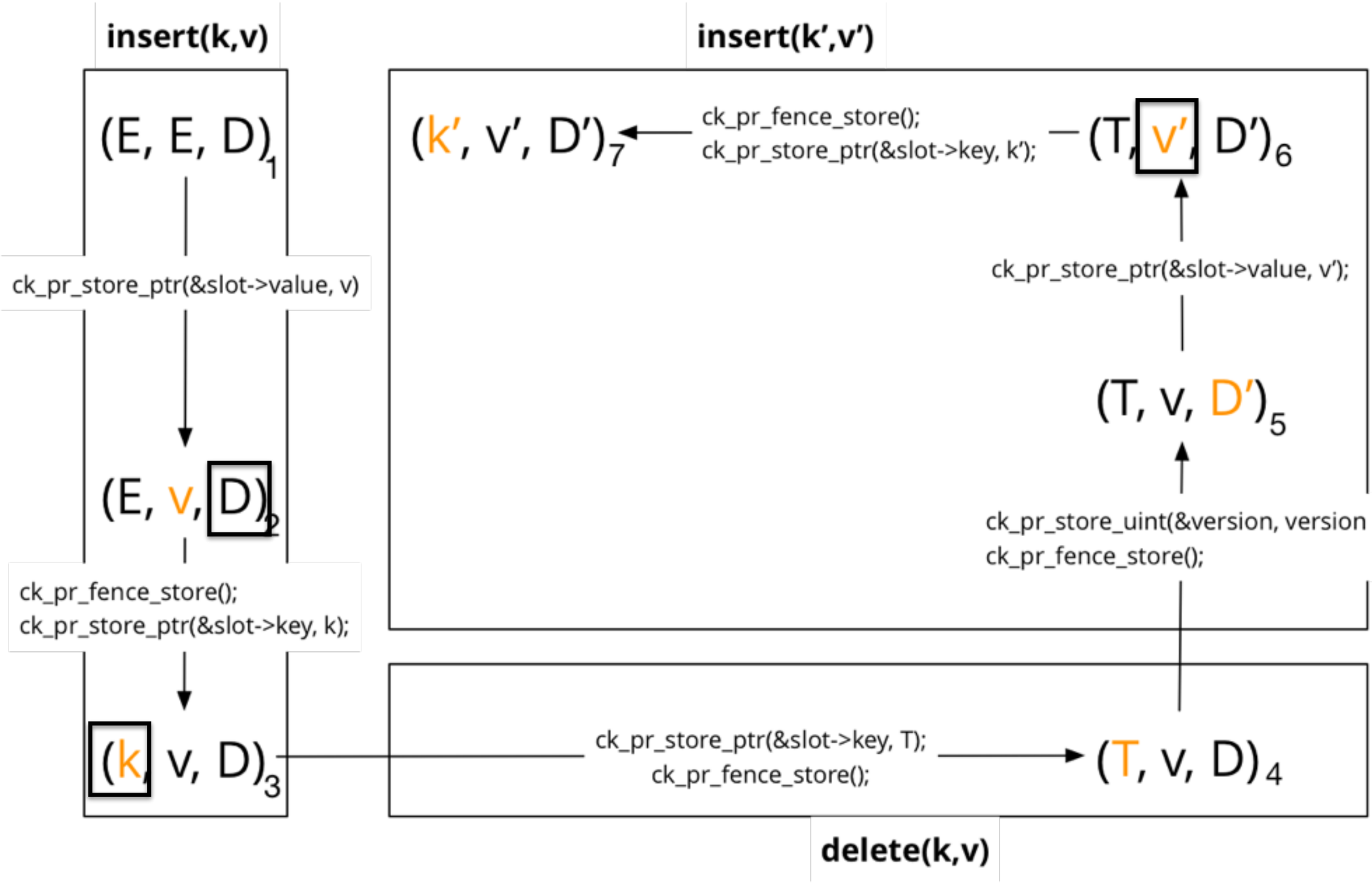

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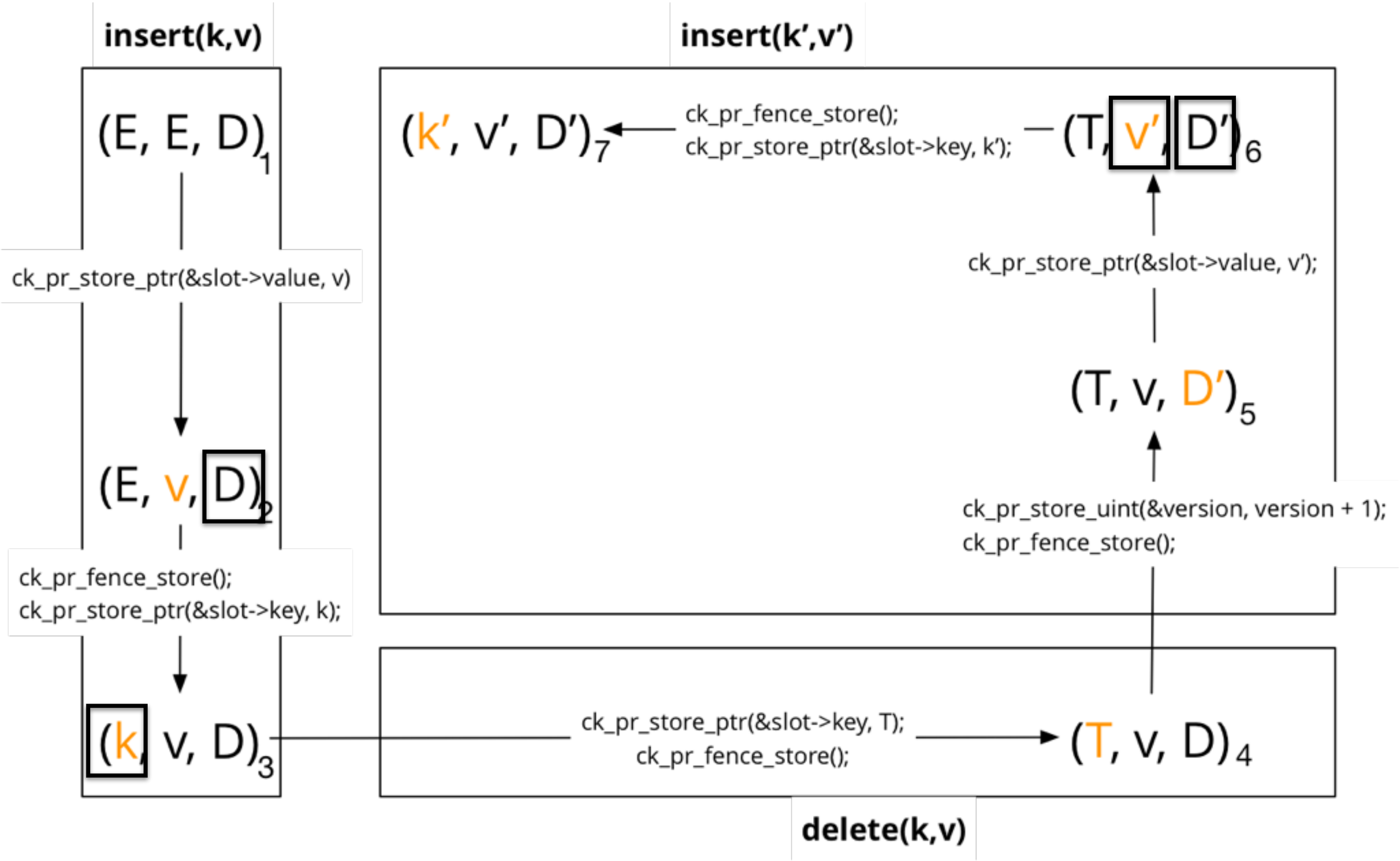

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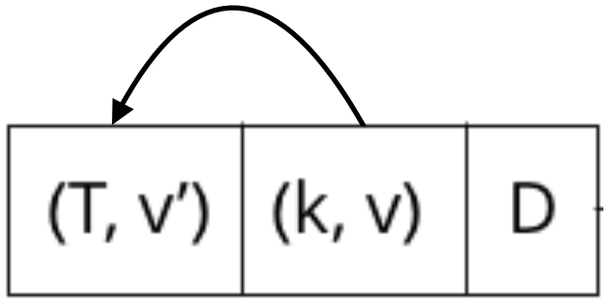
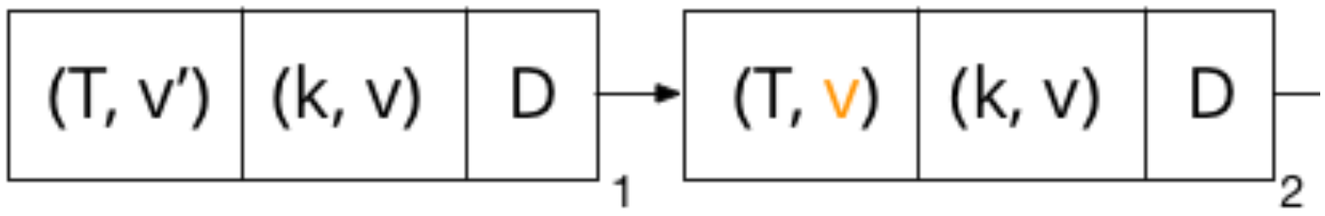
What about more sophisticated collision resolution techniques?

Probe Sequence Mutation



Probe Sequence Mutation

Insert new key-value pair.



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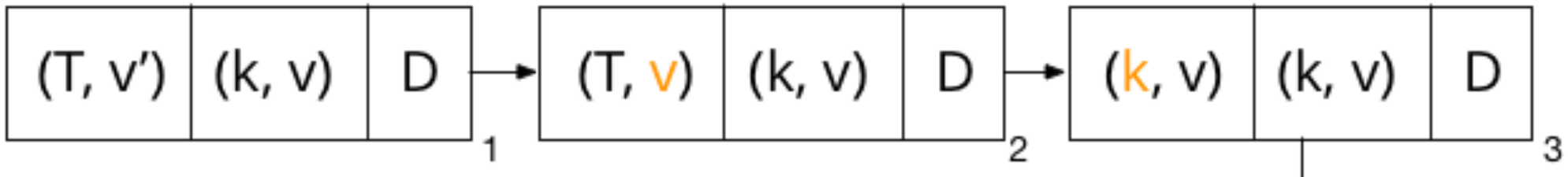
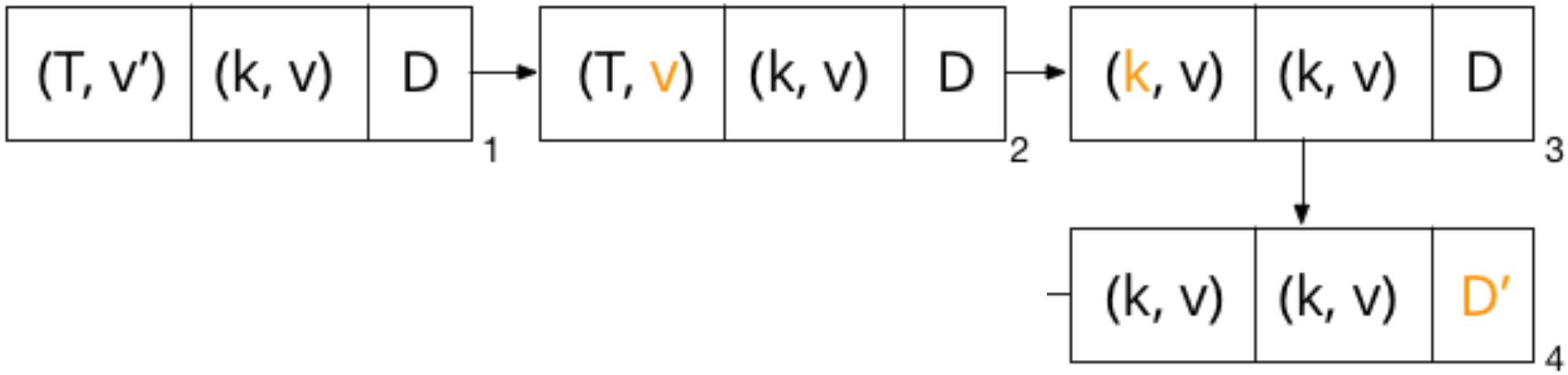


Probe Sequence Mutation

Delete old key-value pair.



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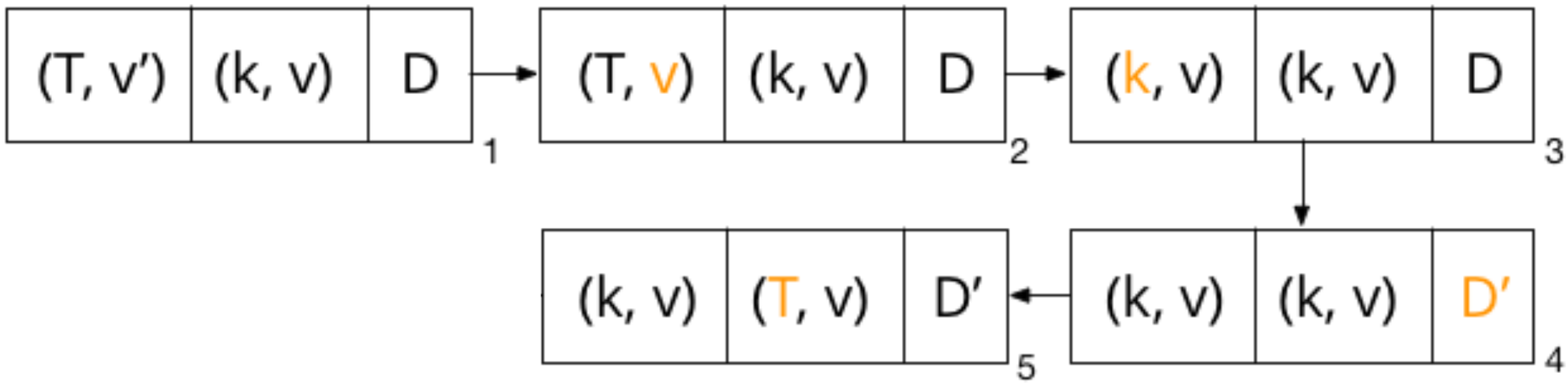

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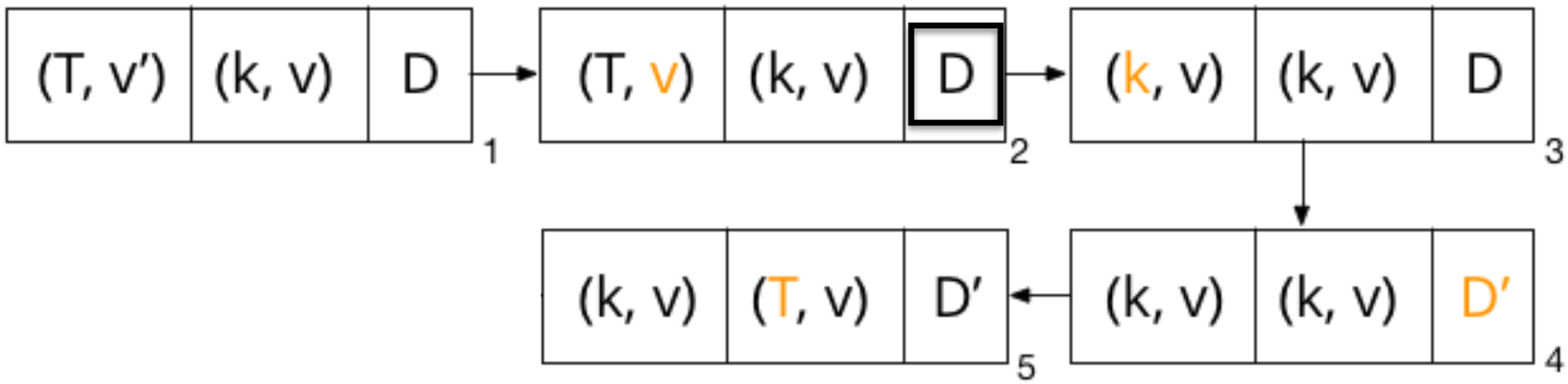

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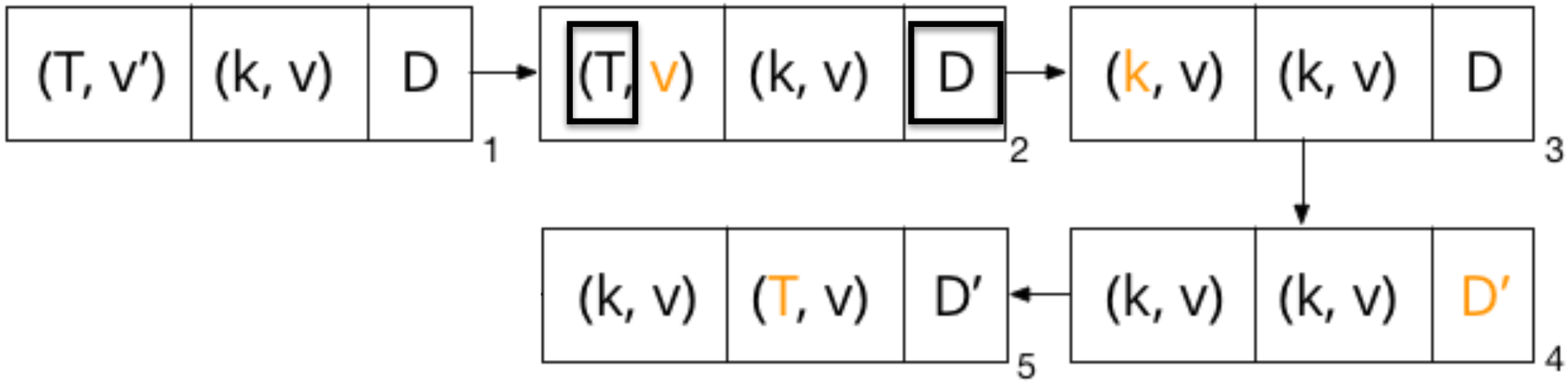

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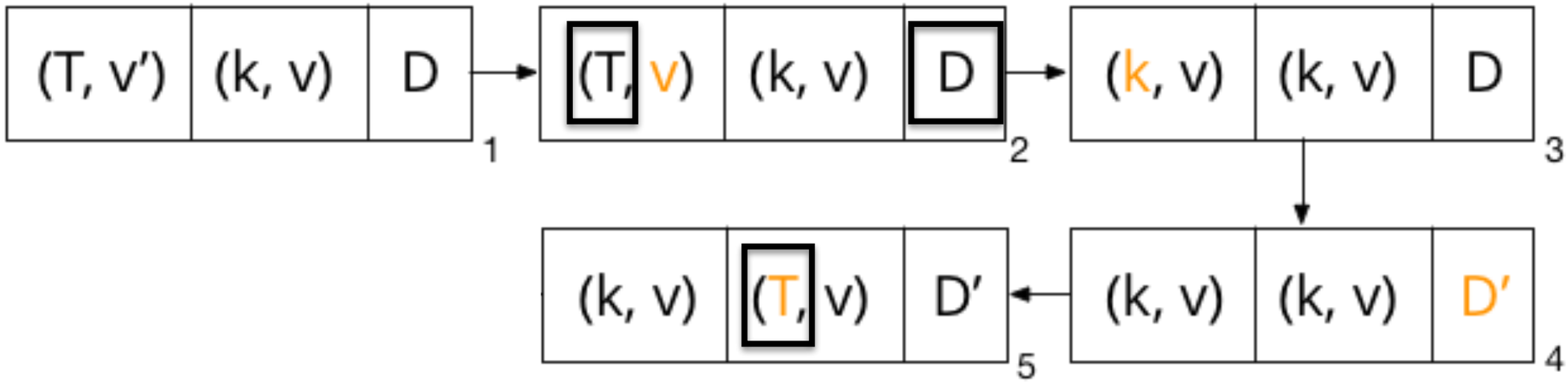

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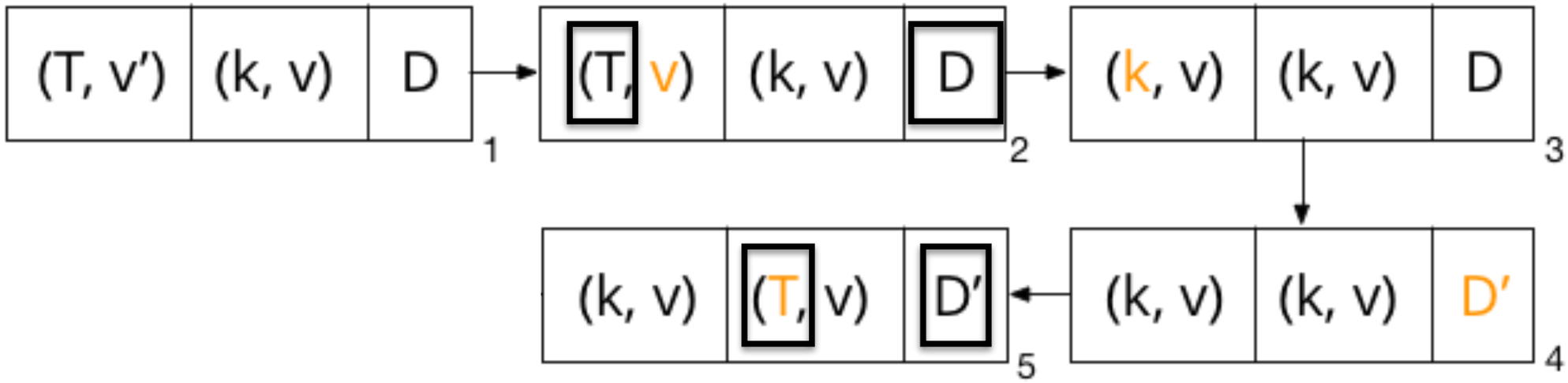

Further Specialization

Sacrifice write-side progress guarantees for read-side wait-freedom.

Recent Updates

Technical Report

Designing ASCY-compliant Concurrent Search Data Structures

A hash table and a binary search tree

Tudor David Rachid Guerroui Che Tong Vasileios Trigonakis *
Distributed Programming Lab (LPD), EPFL
name.surname@epfl.ch

Algorithmic Improvements for Fast Concurrent Cuckoo Hashing

Xiaozhou Li[1], David G. Andersen[2], Michael Kaminsky[3], Michael J. Freedman[1]

[1]*Princeton University,* [2]*Carnegie Mellon University,* [3]*Intel Labs*

The End

Write-up at:

http://backtrace.io/blog

Implementations at:

http://concurrencykit.org

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