Scalable Join Patterns

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Fine-grained parallelism requires communication

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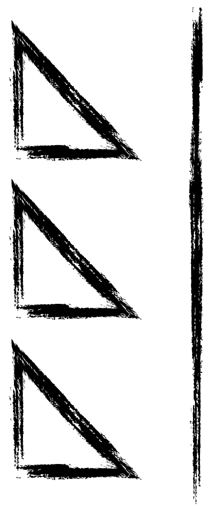
Barrier



Fine-grained parallelism requires communication

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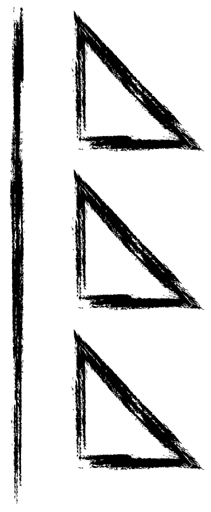

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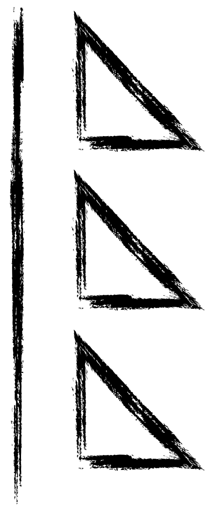
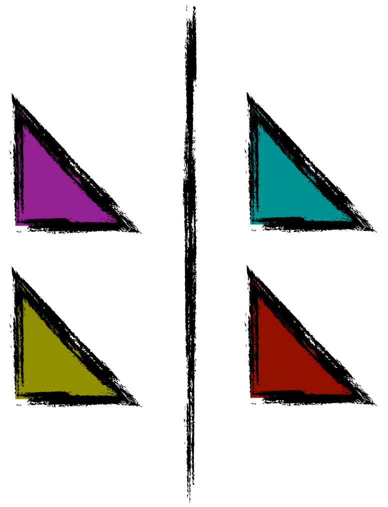


Exchanger



Fine-grained parallelism requires communication

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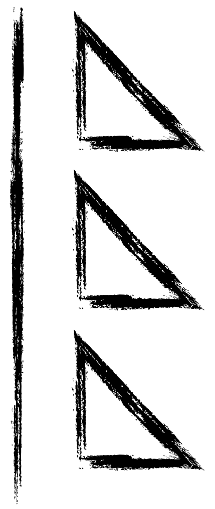

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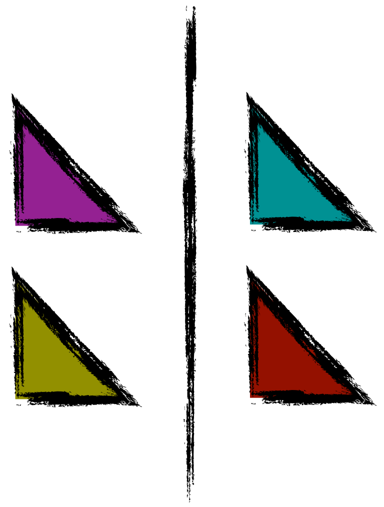

Lock

Fine-grained parallelism requires communication

Fine-grained parallelism requires communication

Synchronization protocols

Blocking & context switches

Cache coherence & memory bandwidth

State of the art?
Leave it to the experts:

$$\begin{tikzcd} \begin{array}{c}\text{Research}\\ \text{Literature}\end{array} \arrow[r, leftrightarrow] & \begin{array}{c}\text{Industrial-strength}\\ \text{Libraries}\end{array} \end{tikzcd}$$

$$\overbrace{\begin{array}{c}\text{java.util.concurrent}\\ \text{.NET 4.0}\\ \text{Intel TBB}\end{array}}$$

The problem

Libraries are an enormous undertaking, not extensible or customizable by users

This work

Use ***join patterns*** for synchronization: [Fournet & Gonthier]

Expressive

Write synchronization primitives declaratively and concisely

Scalable

Competitive with industrial libraries; can recover existing algorithms

Expressive

Joins: a crash course

```
class Lock {
  public Synchronous.Channel  Acquire = new ...
  public Asynchronous.Channel Release = new ...
  public Lock() {
    When(Acquire).And(Release).Do(() => {});

    // initially available
    Release();
  }
}
```

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Join pattern

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$\uparrow$

Join body

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    // initially available
    Release();
  }
}
```

Message send

Joins: a crash course

```
class Semaphore {
  public Synchronous.Channel  Acquire = new ...
  public Asynchronous.Channel Release = new ...
  public Semaphore(int n) {
    When(Acquire).And(Release).Do(() => {});

    // initially n available
    for (; n > 0; n--) Release();
  }
}
```

Joins: a crash course

```
class ProducerConsumer<T> {
  public Synchronous<T>.Channel  Get = new ...
  public Asynchronous.Channel<T> Put = new ...
  public ProducerConsumer() {
    When(Get).And(Put).Do(t => t);
  }
}
```

Joins: a crash course

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  }
}
```

Joins: a crash course

```
Synchronous.Channel[] hungry = new ...
Asynchronous.Channel[] chopstick = new ...

for (int i = 0; i < n; i++) {
  var left  = chopstick[i];
  var right = chopstick[(i+1) % n];
  When(hungry[i]).And(left).And(right).Do(() => {
    eat(); left(); right();
  });
}
```

Scalable

Existing joins implementations

Coarse-grained locks:

- Serialized matching
- Extra memory bus traffic

Our implementation (in C#)

Key idea:

Messages are resources

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Store in lock-free bags

➡ parallelized matching

➡ decreased communication

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Messages are resources

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Acquire in global order

```
When(Get).And(PutA).And(PutB).Do(...)
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```

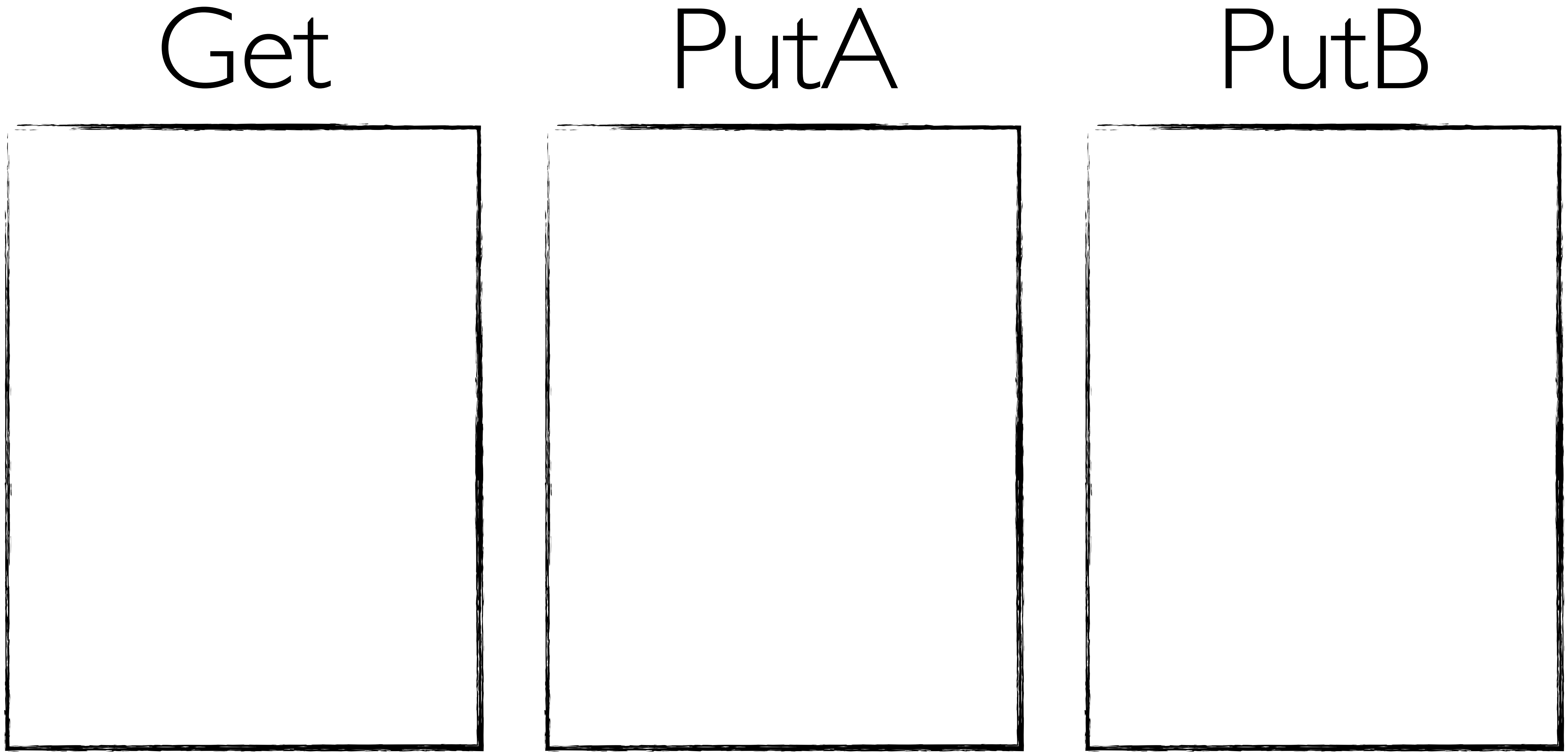

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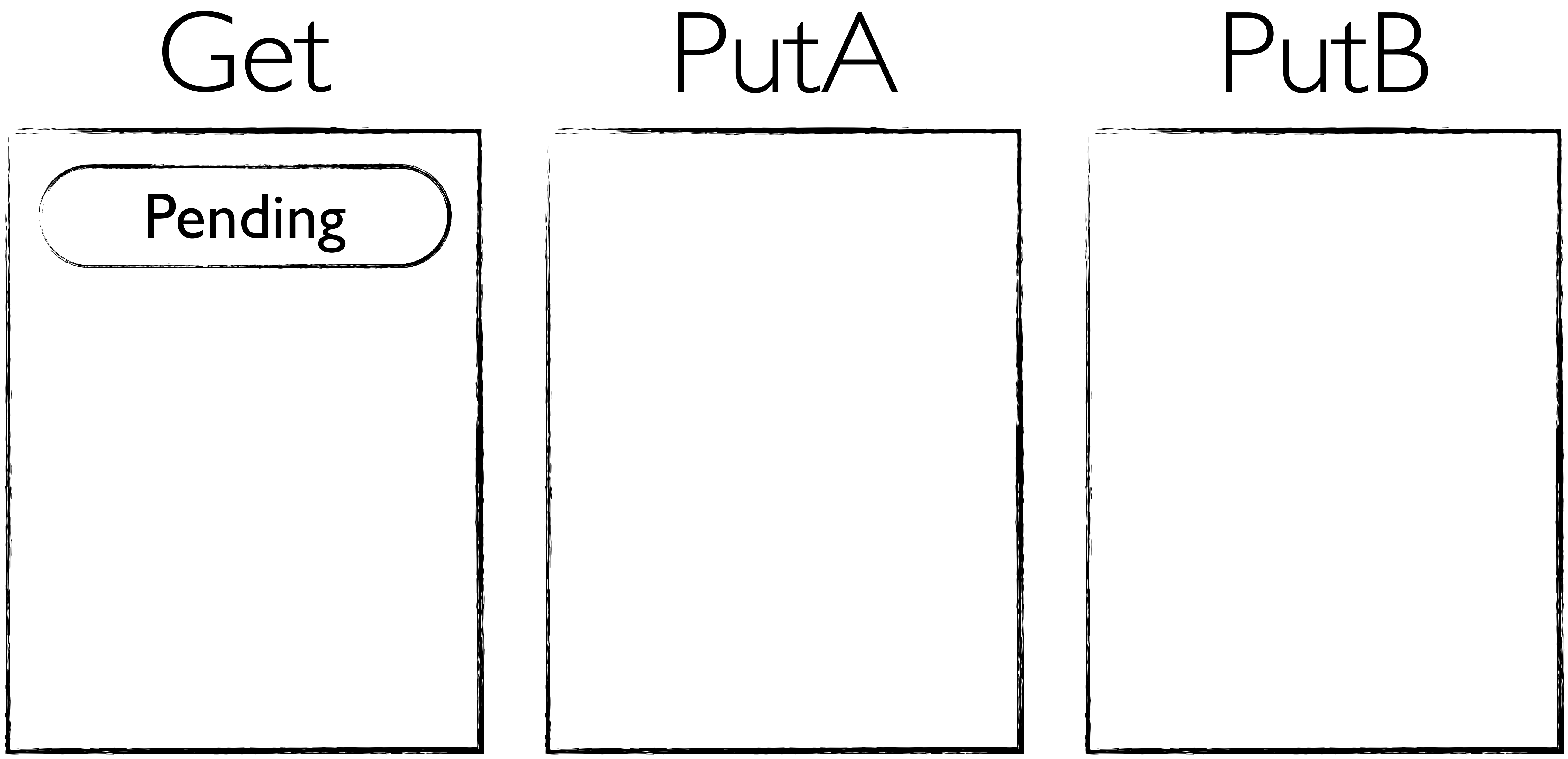

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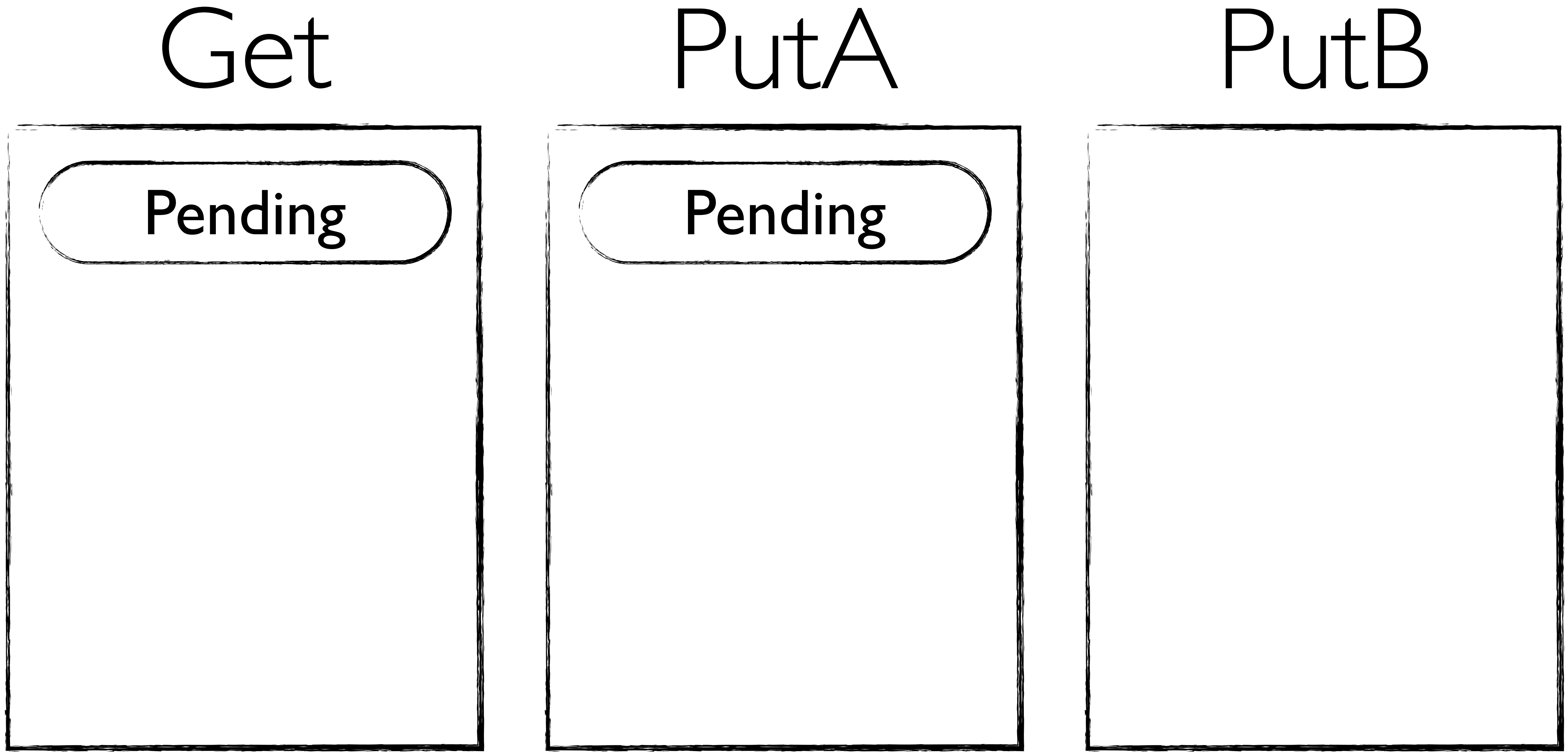

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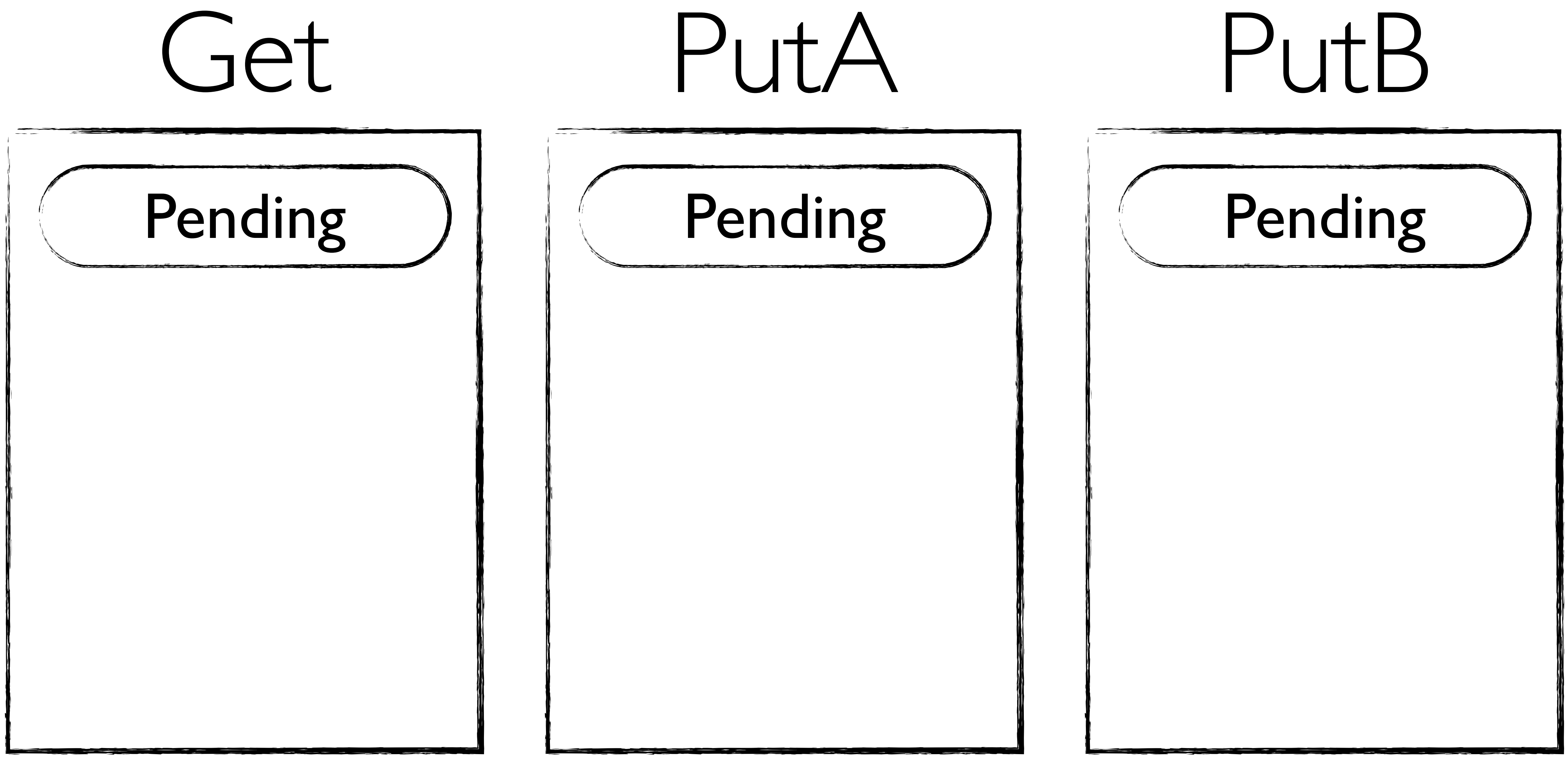

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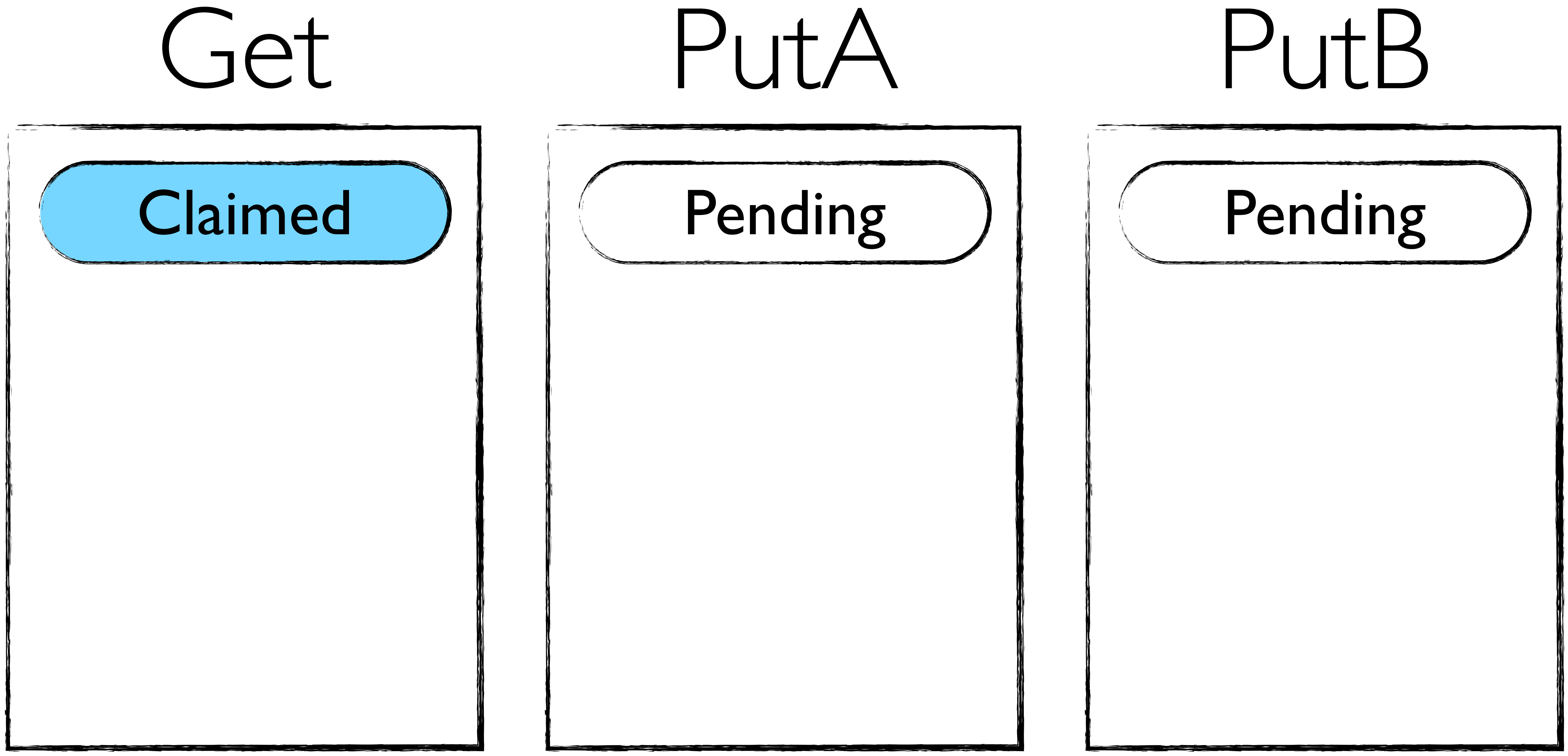

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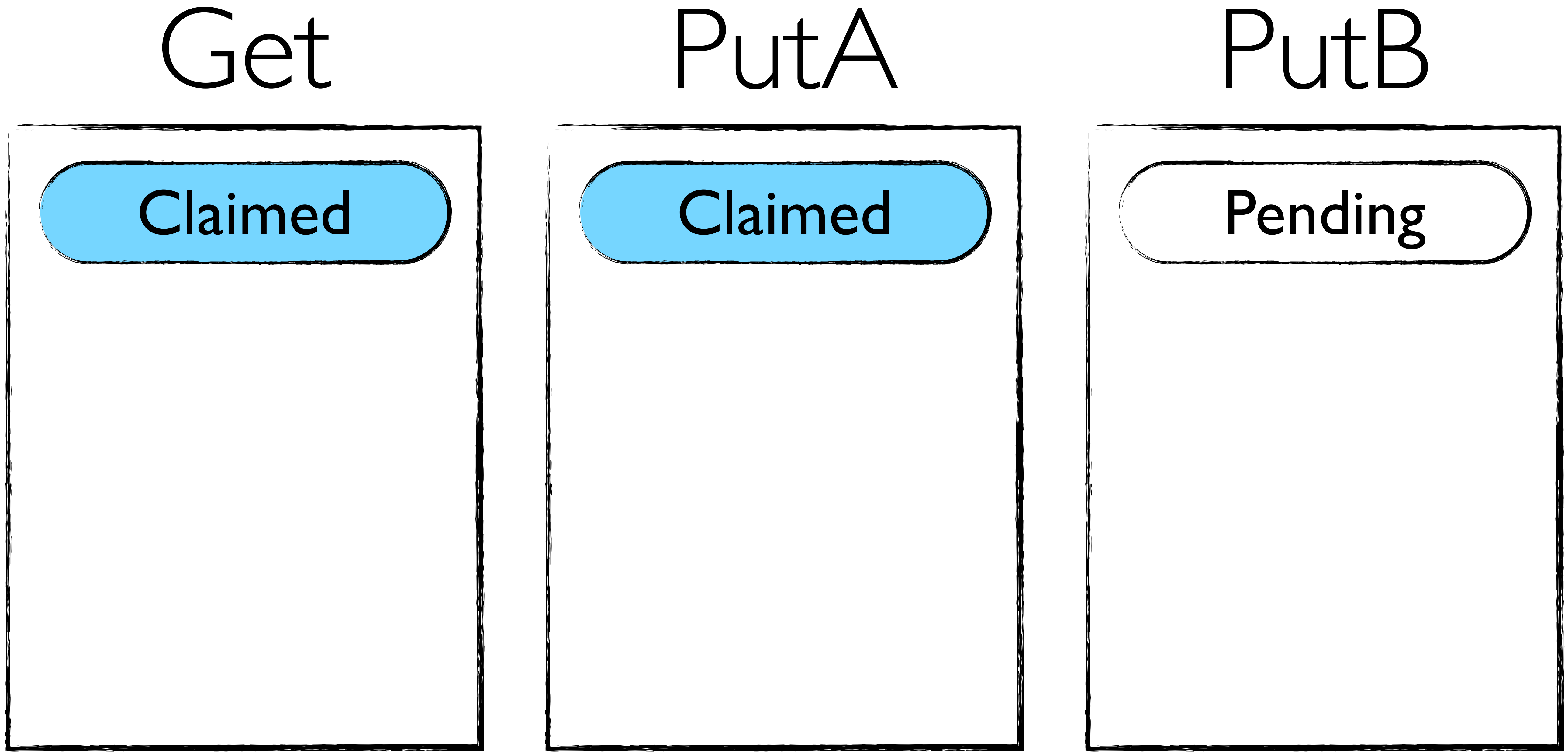

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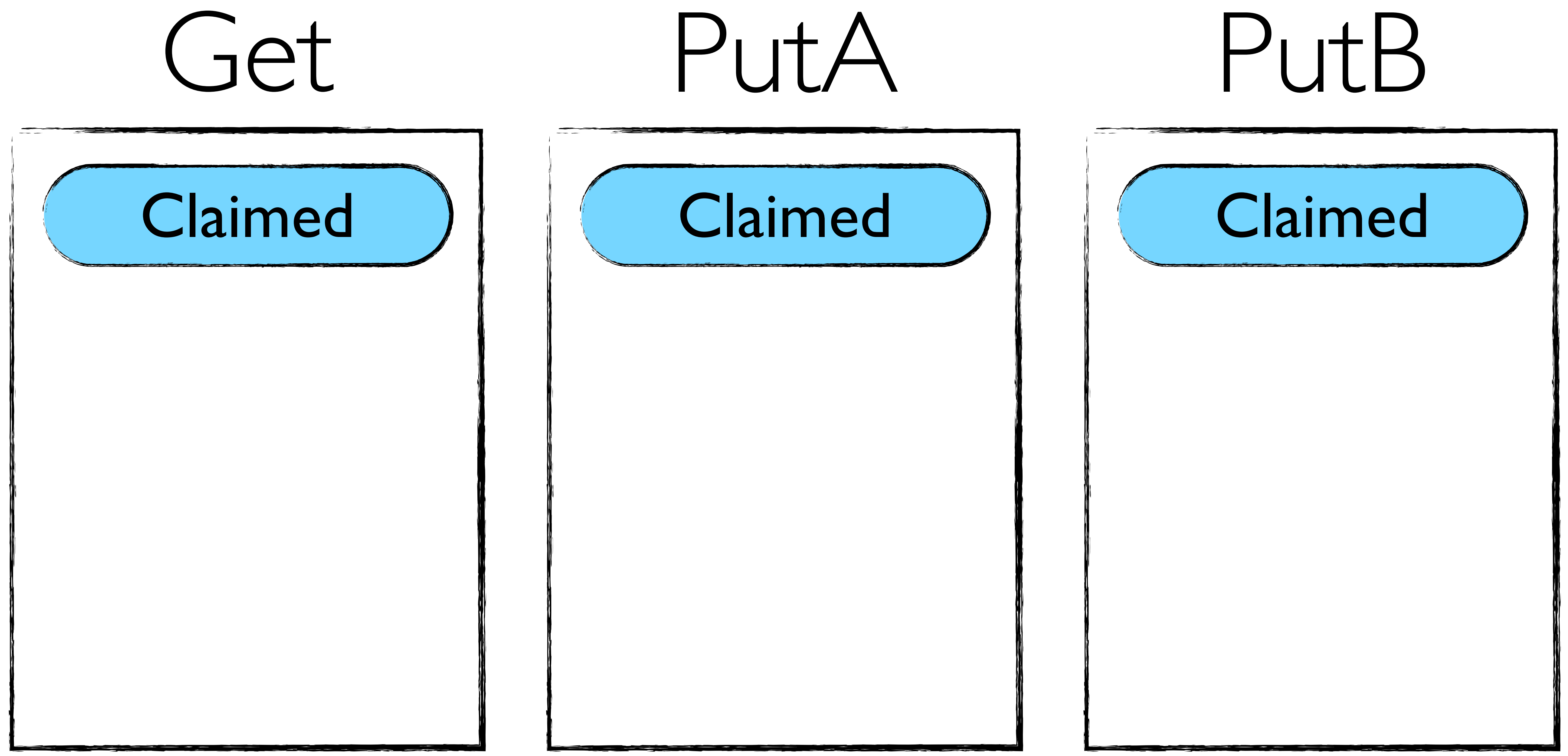

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When(Get).And(PutA).And(PutB).Do(...)
```

Get	PutA	PutB
Consumed	Consumed	Consumed

```
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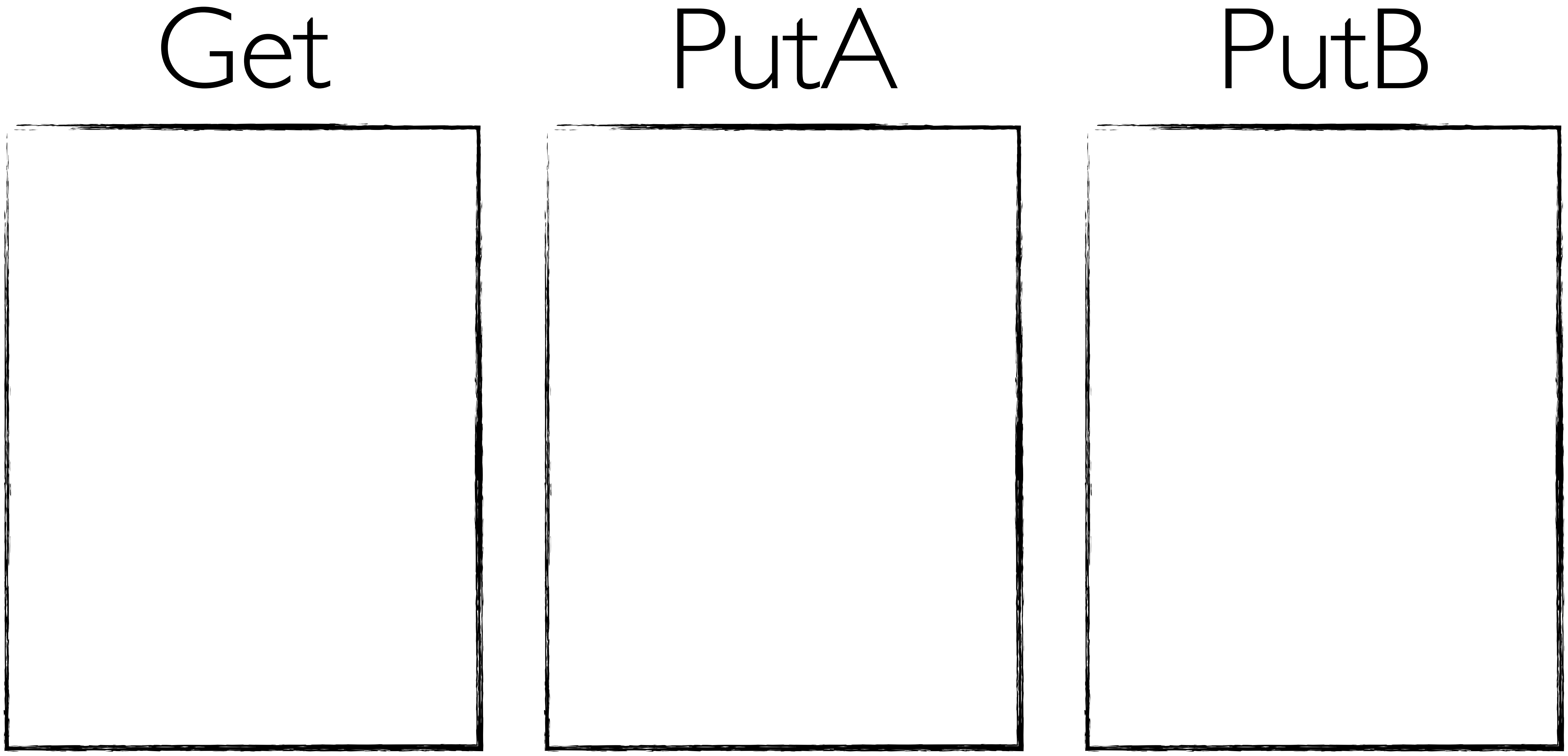

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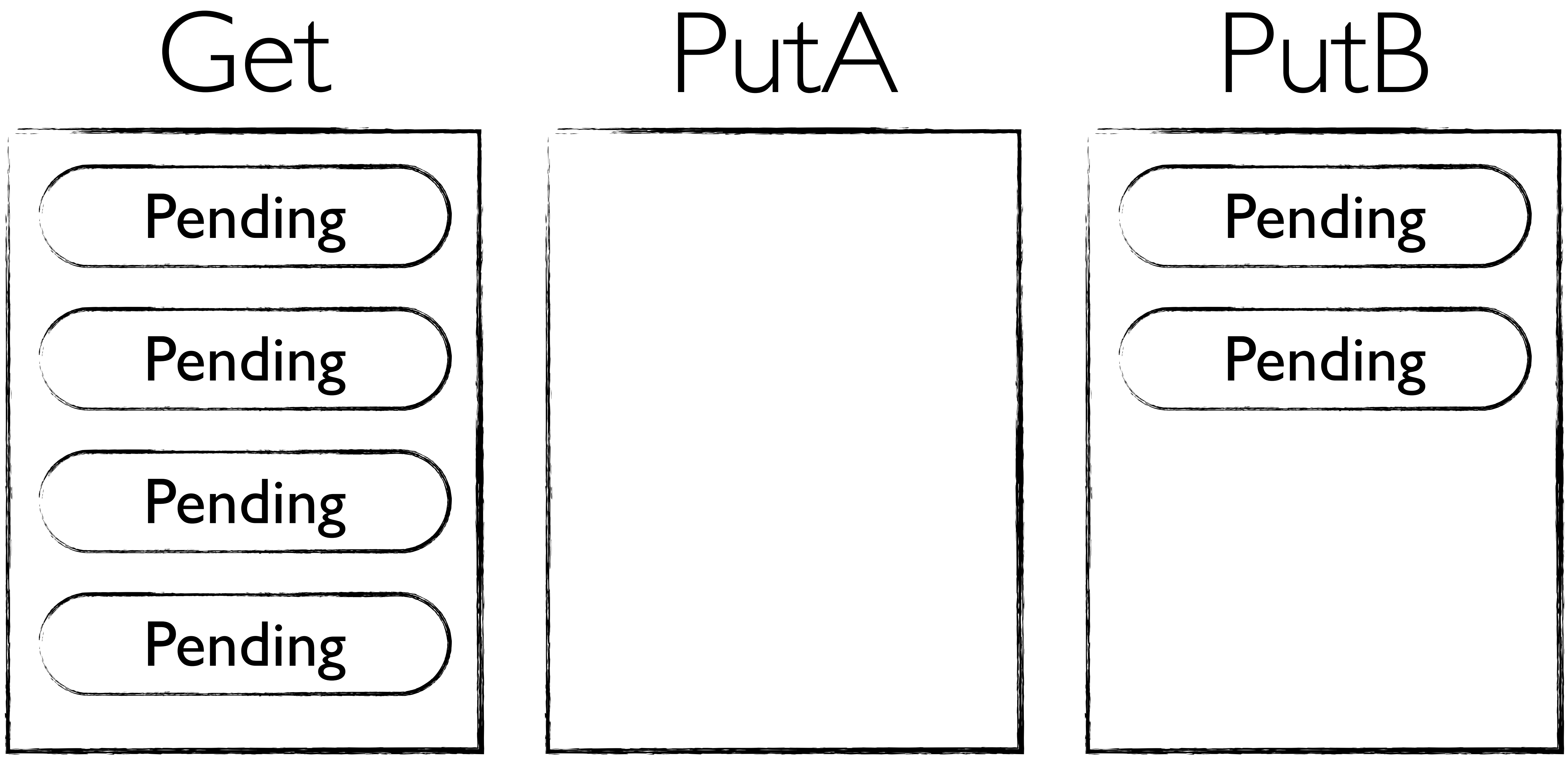

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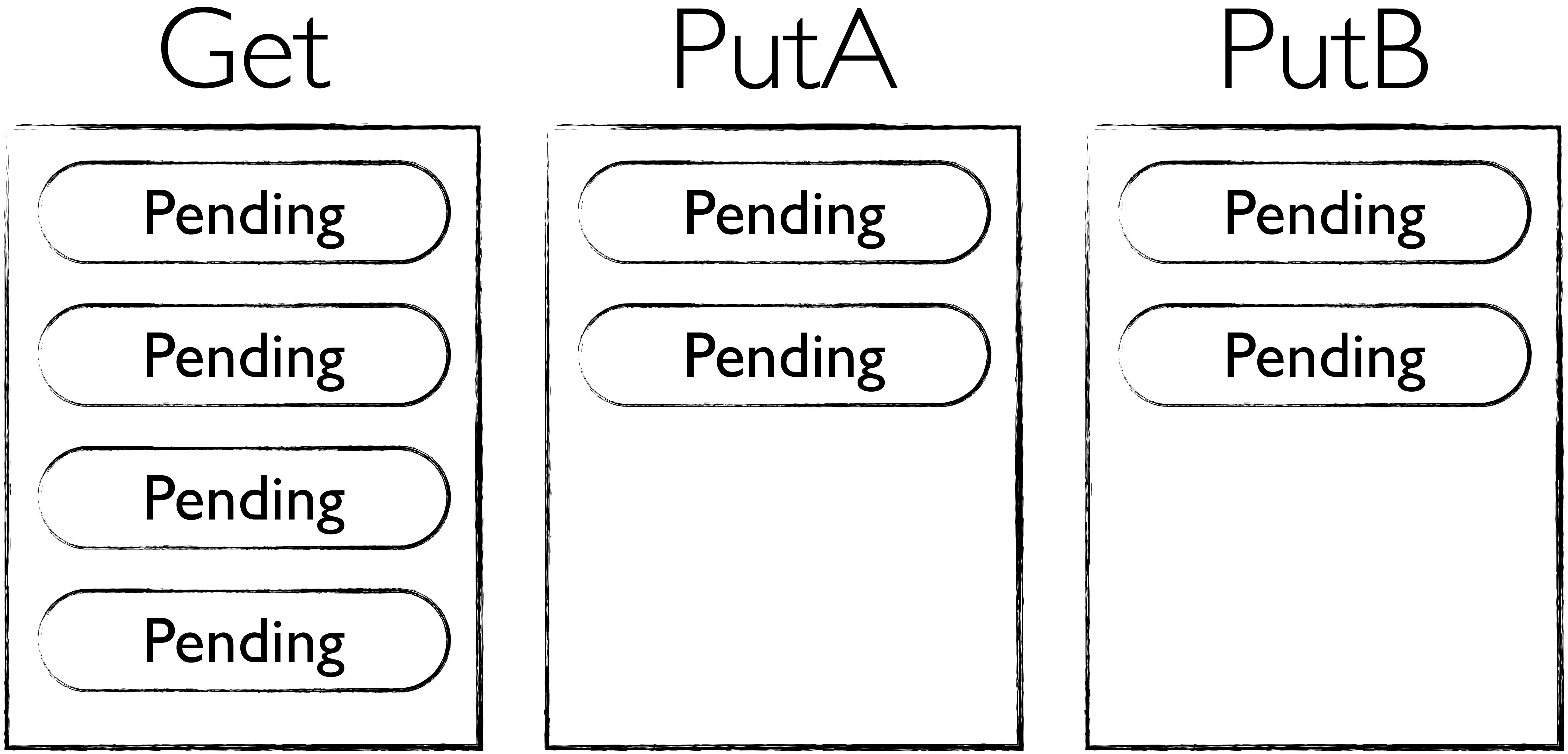

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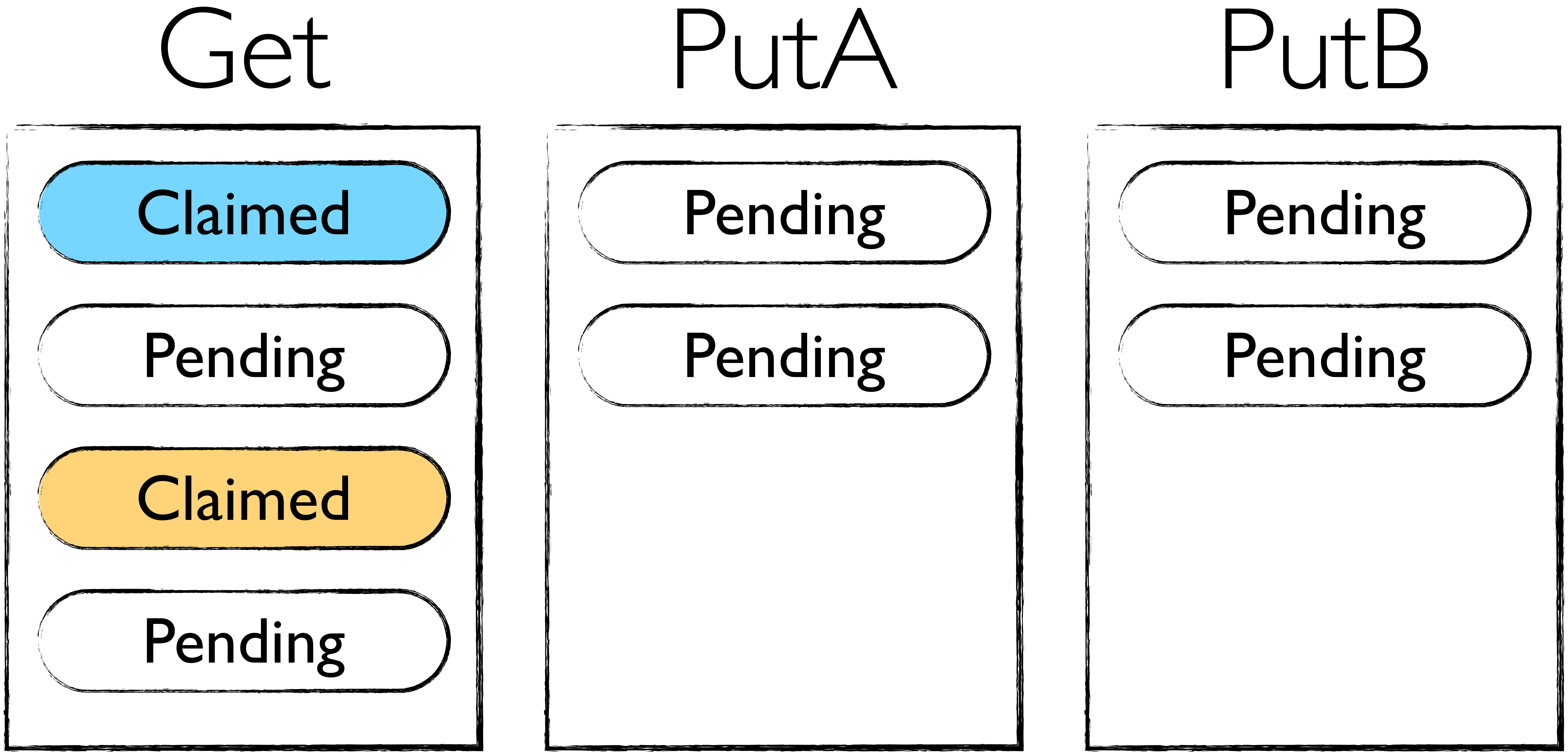

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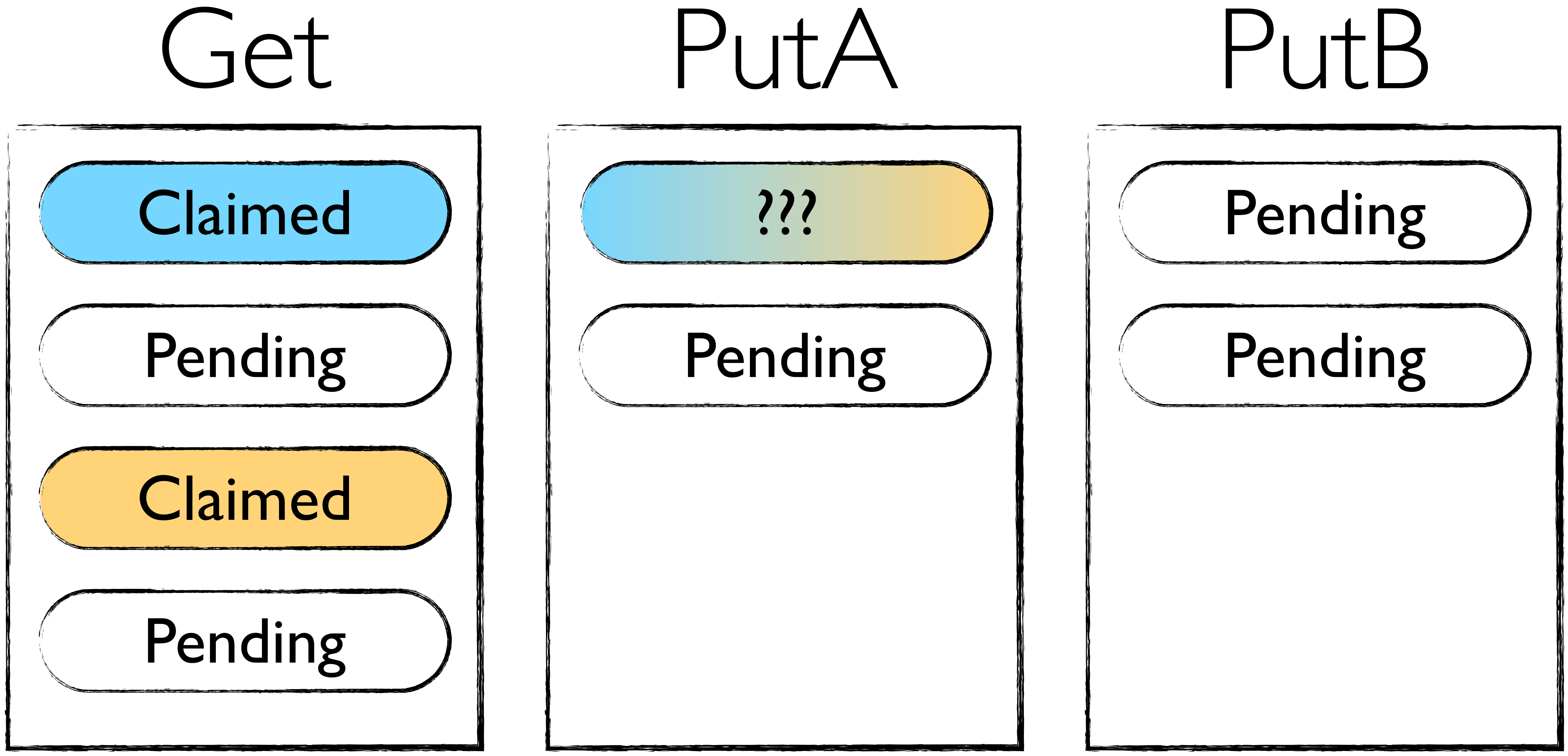

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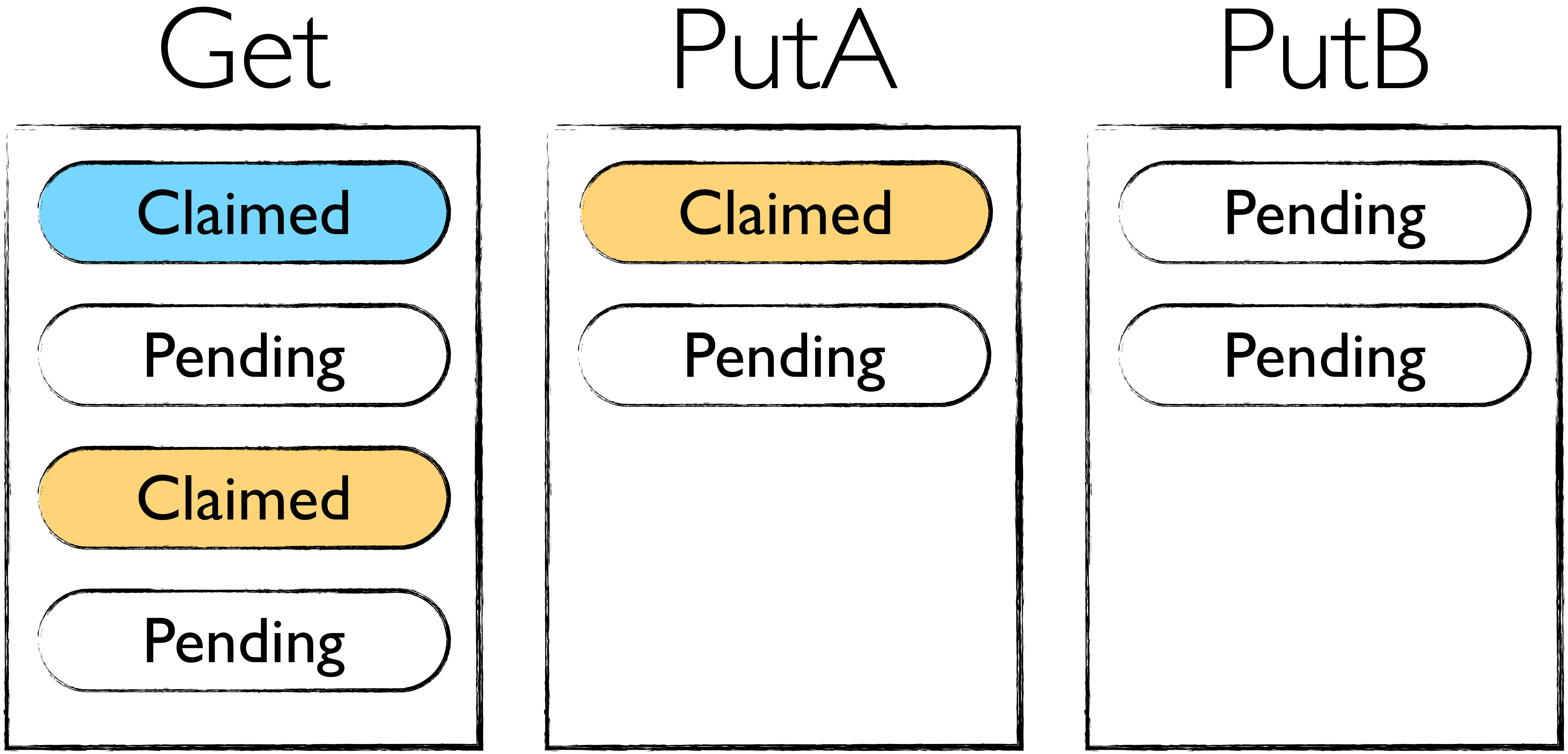

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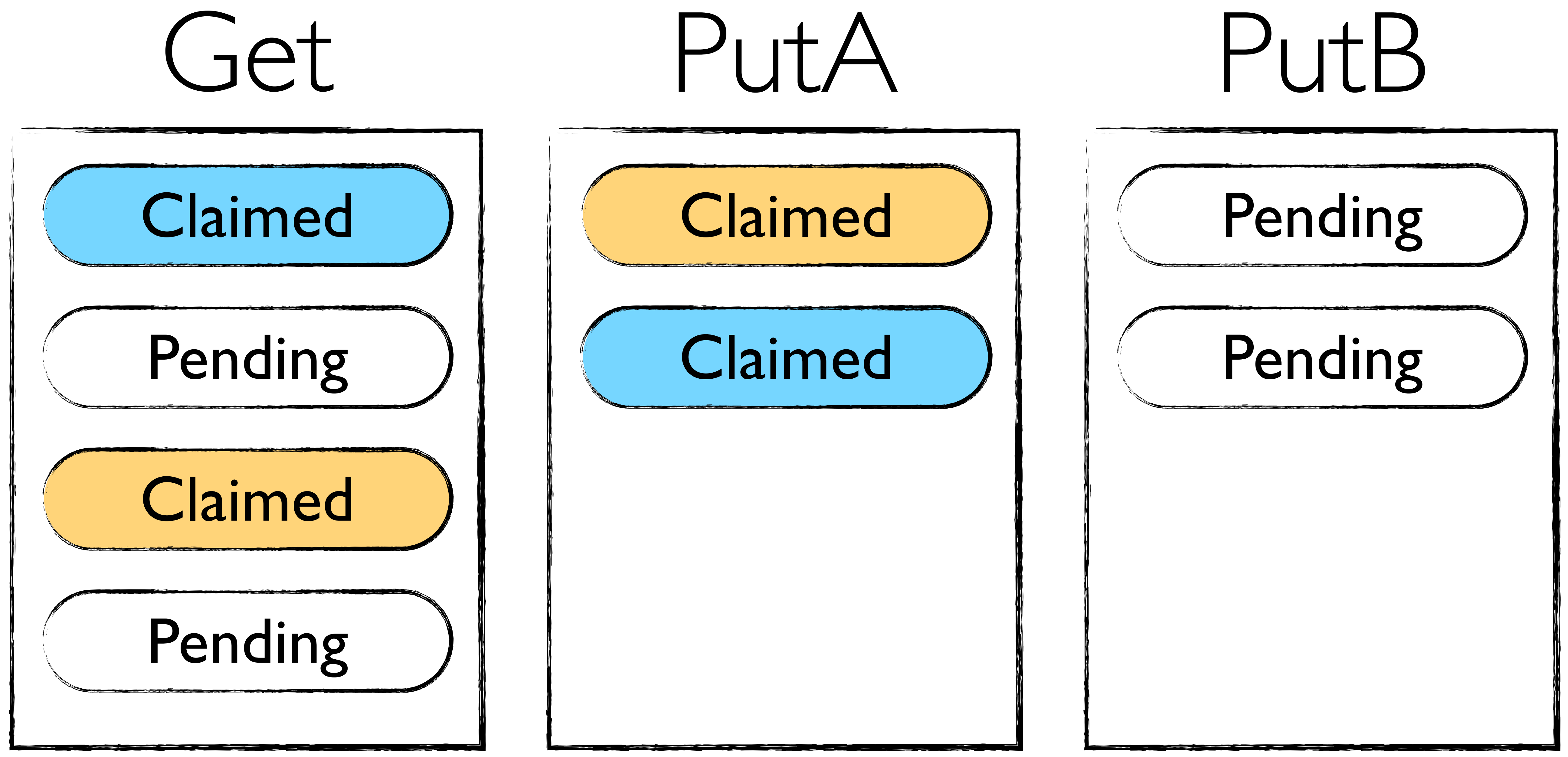

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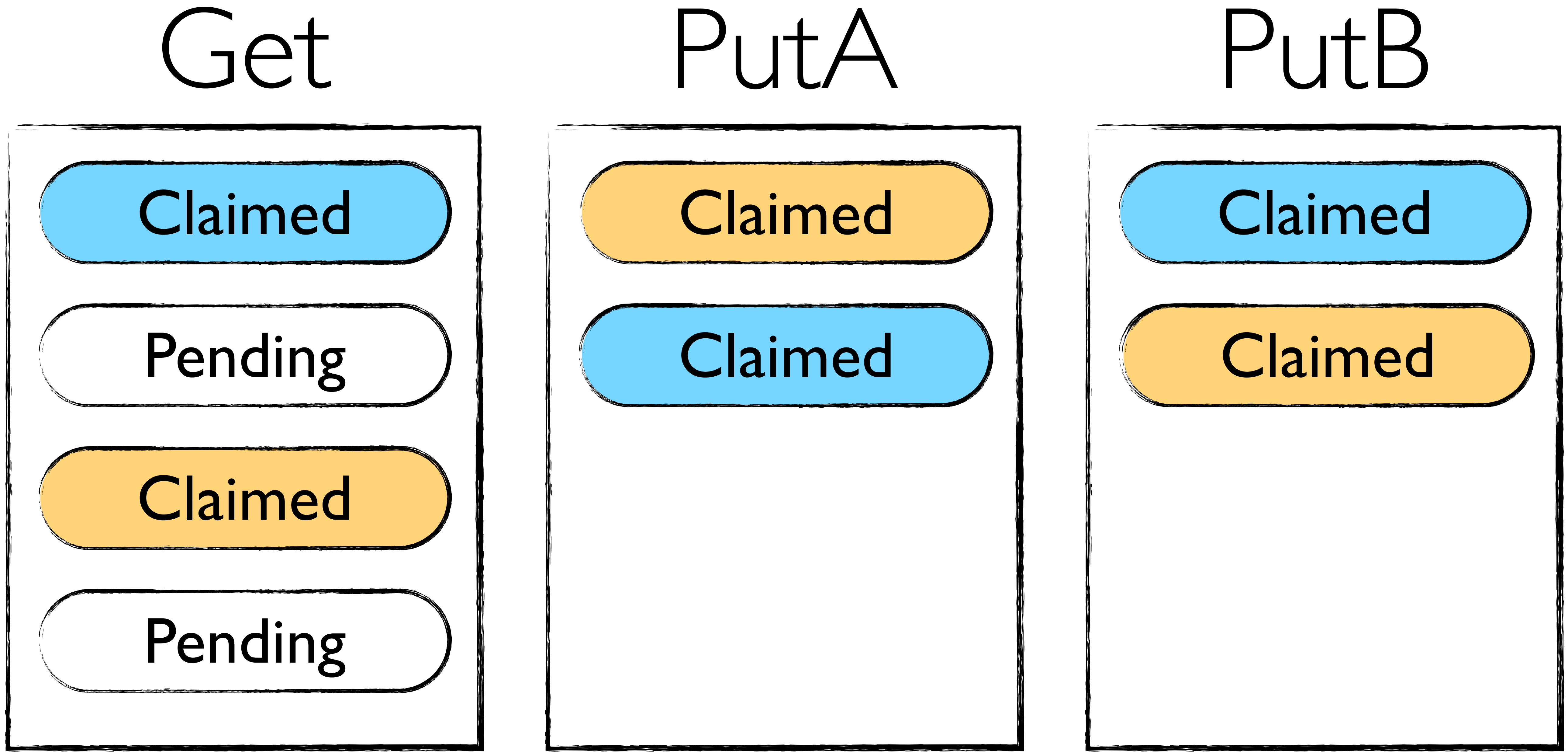

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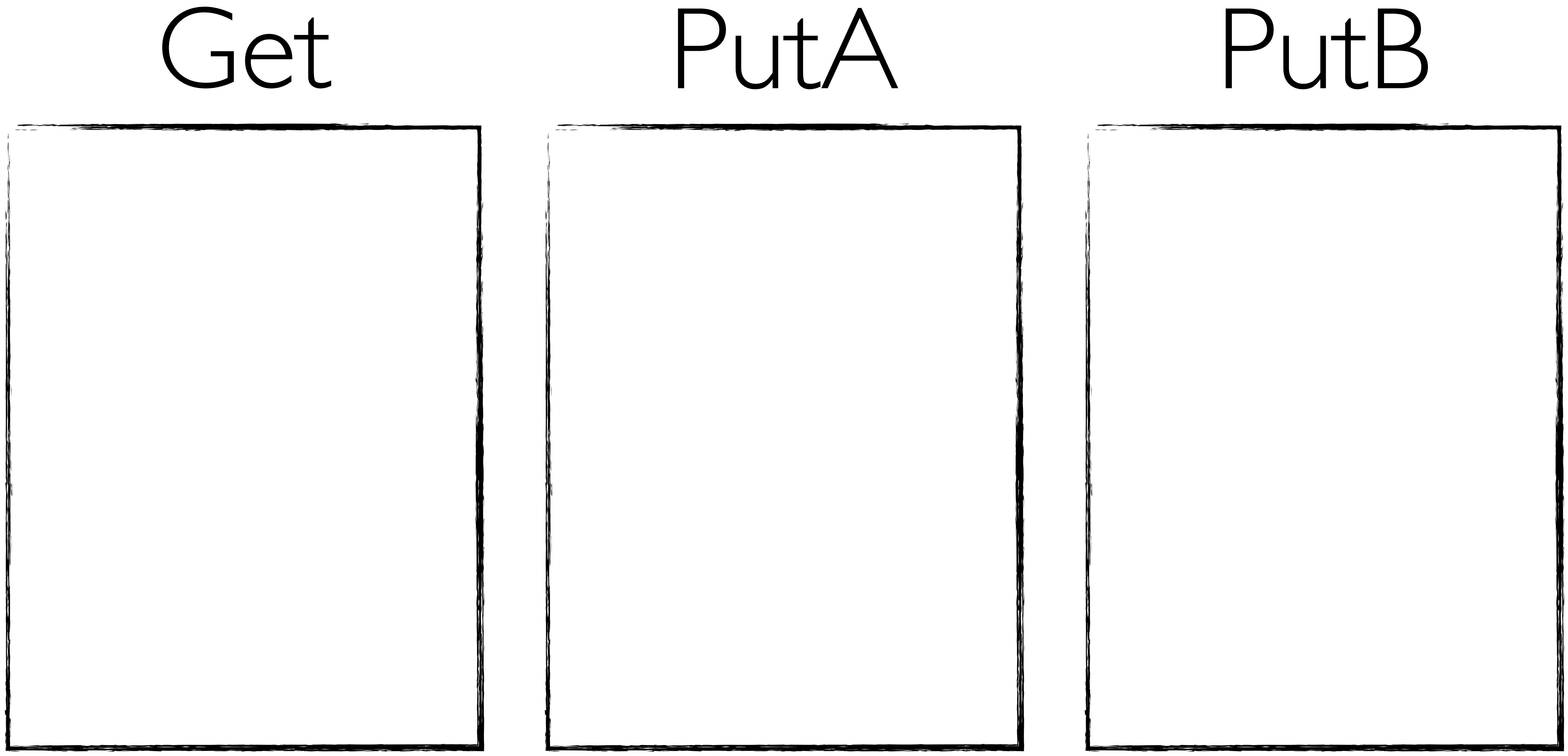

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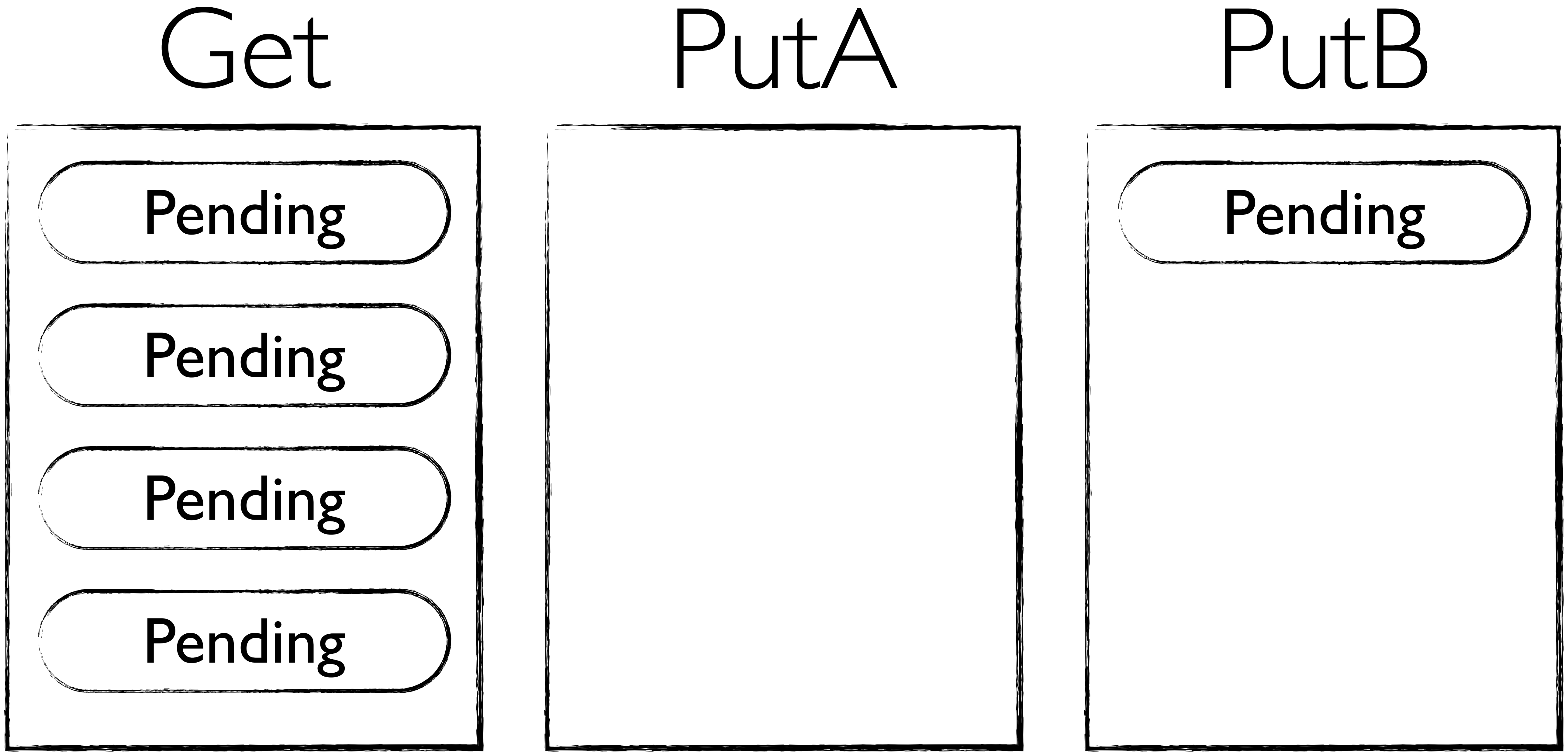

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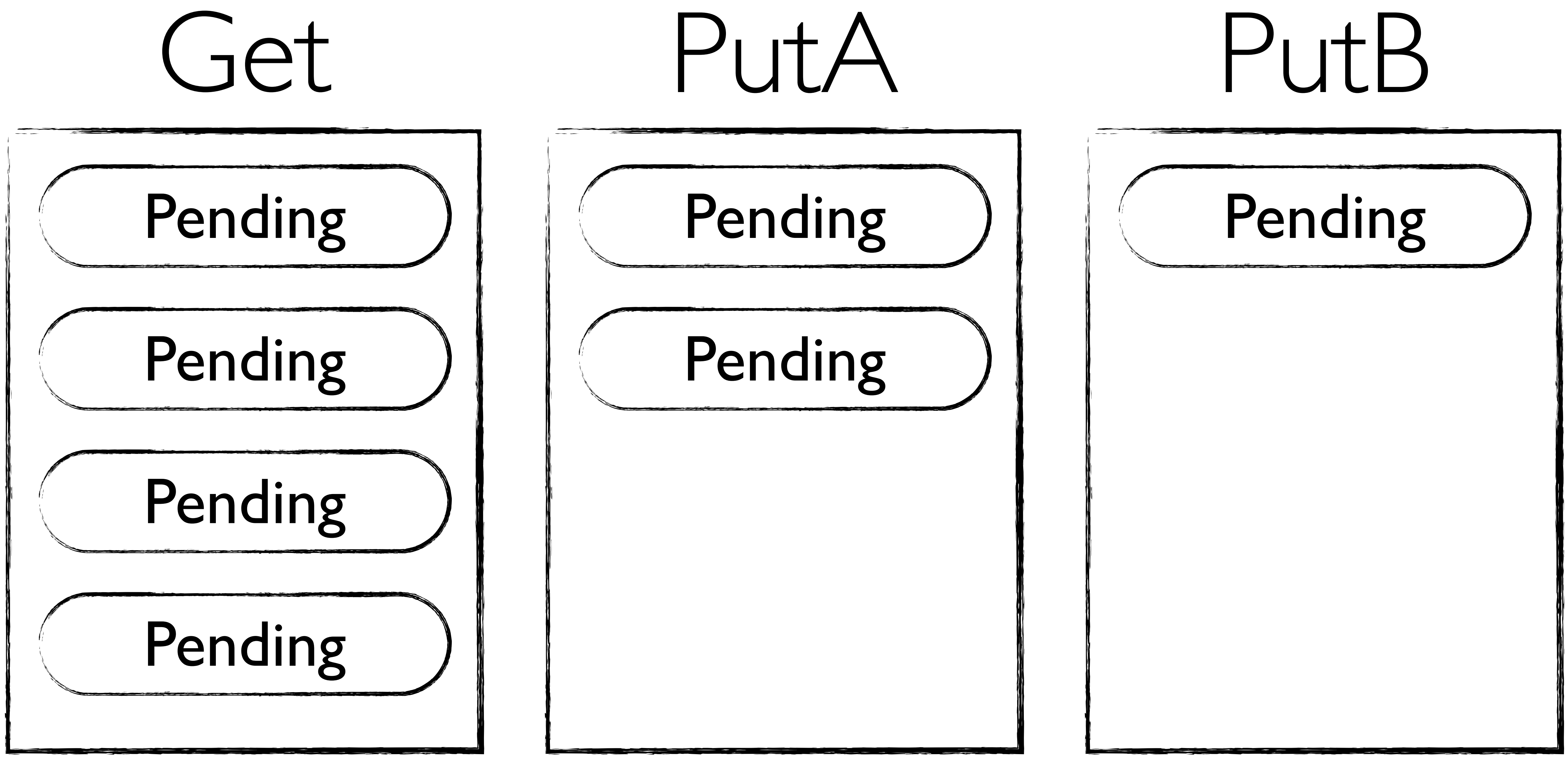

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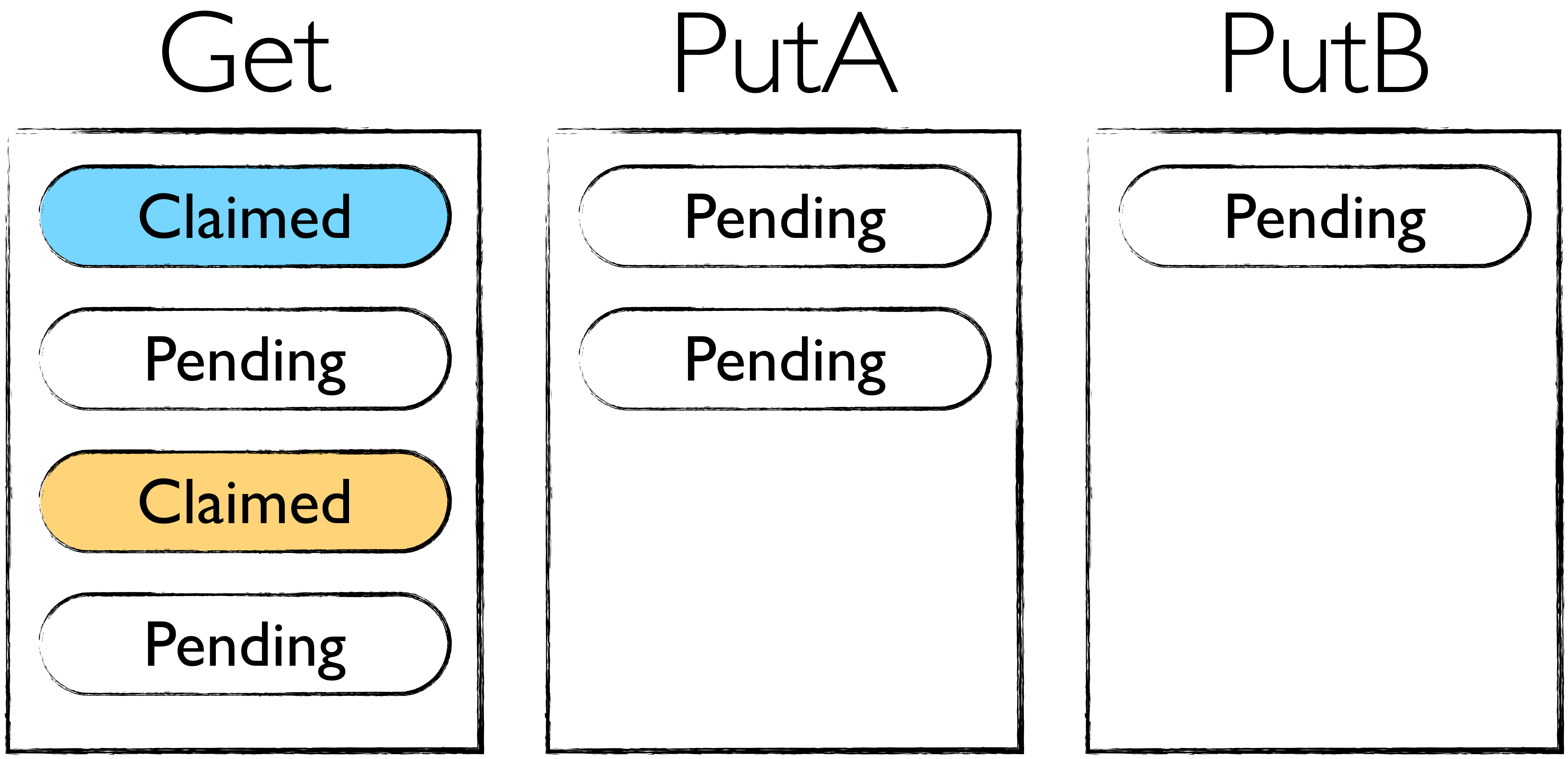

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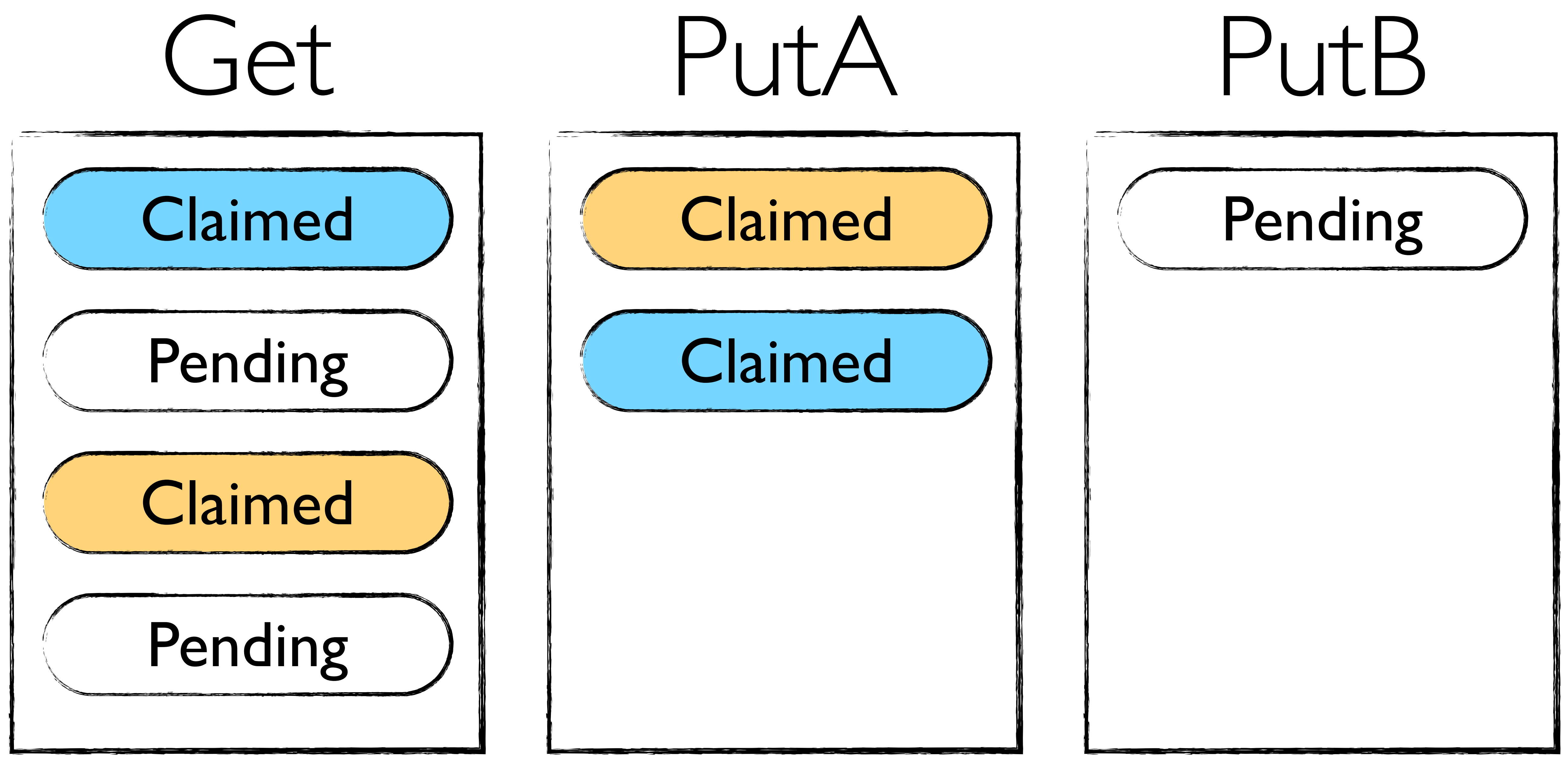

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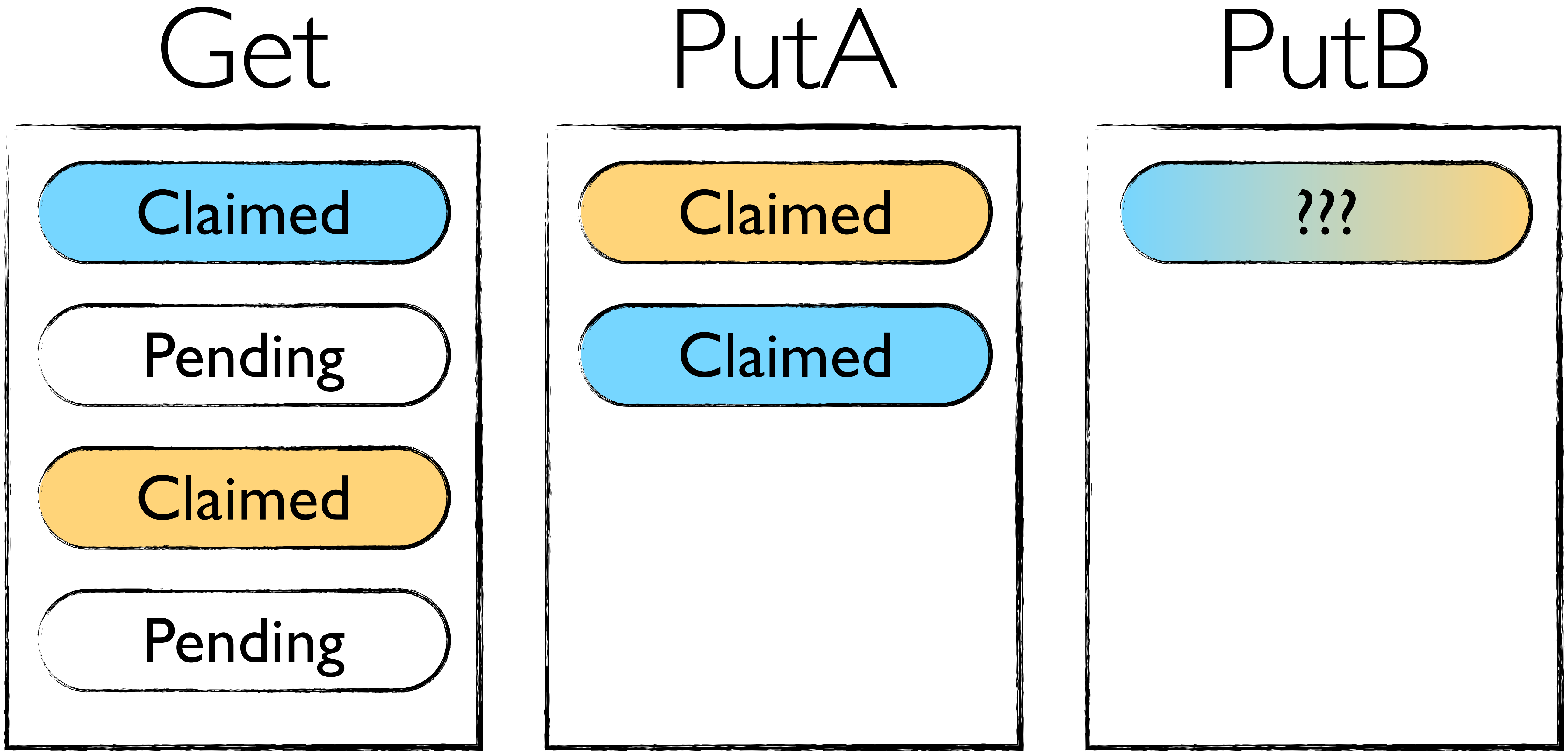

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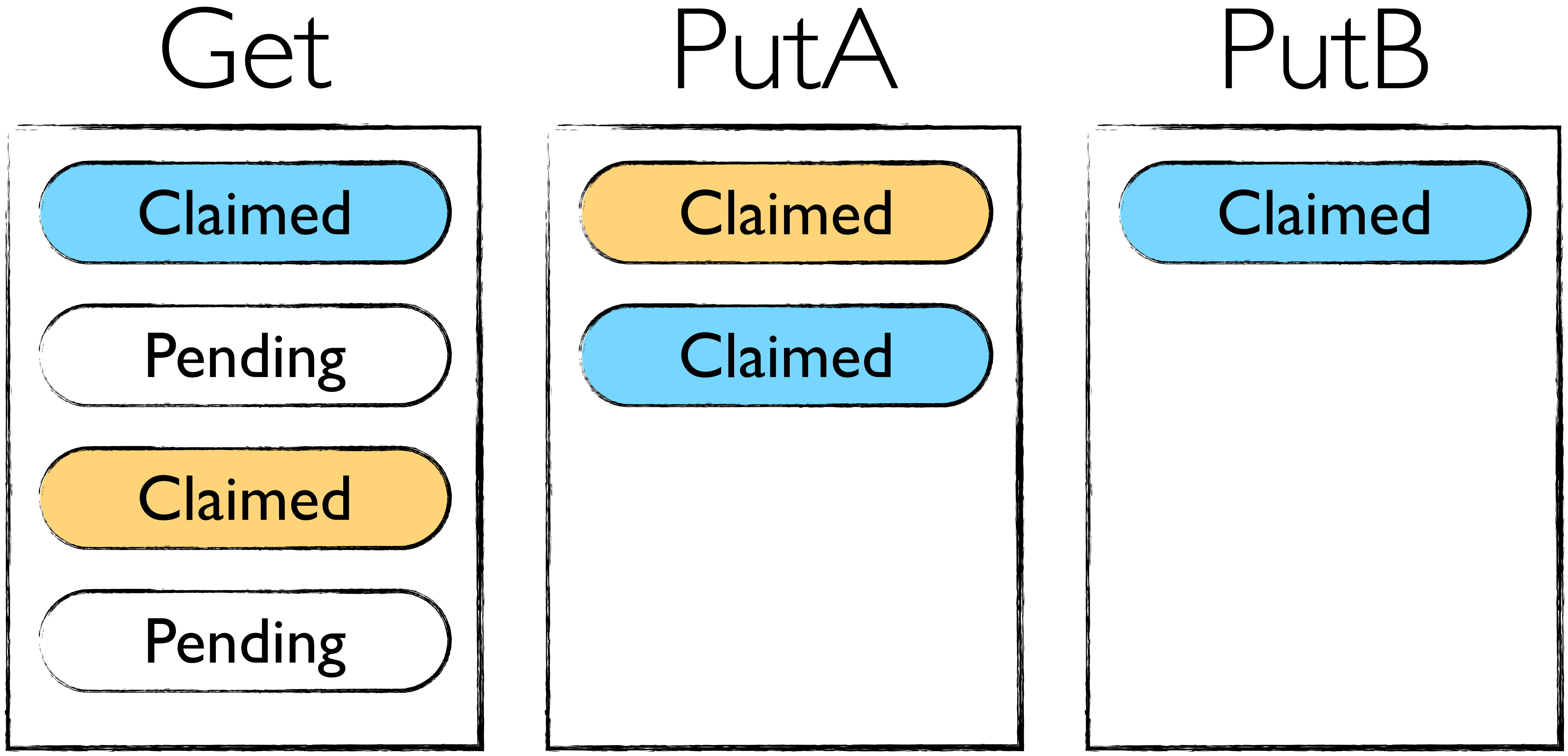

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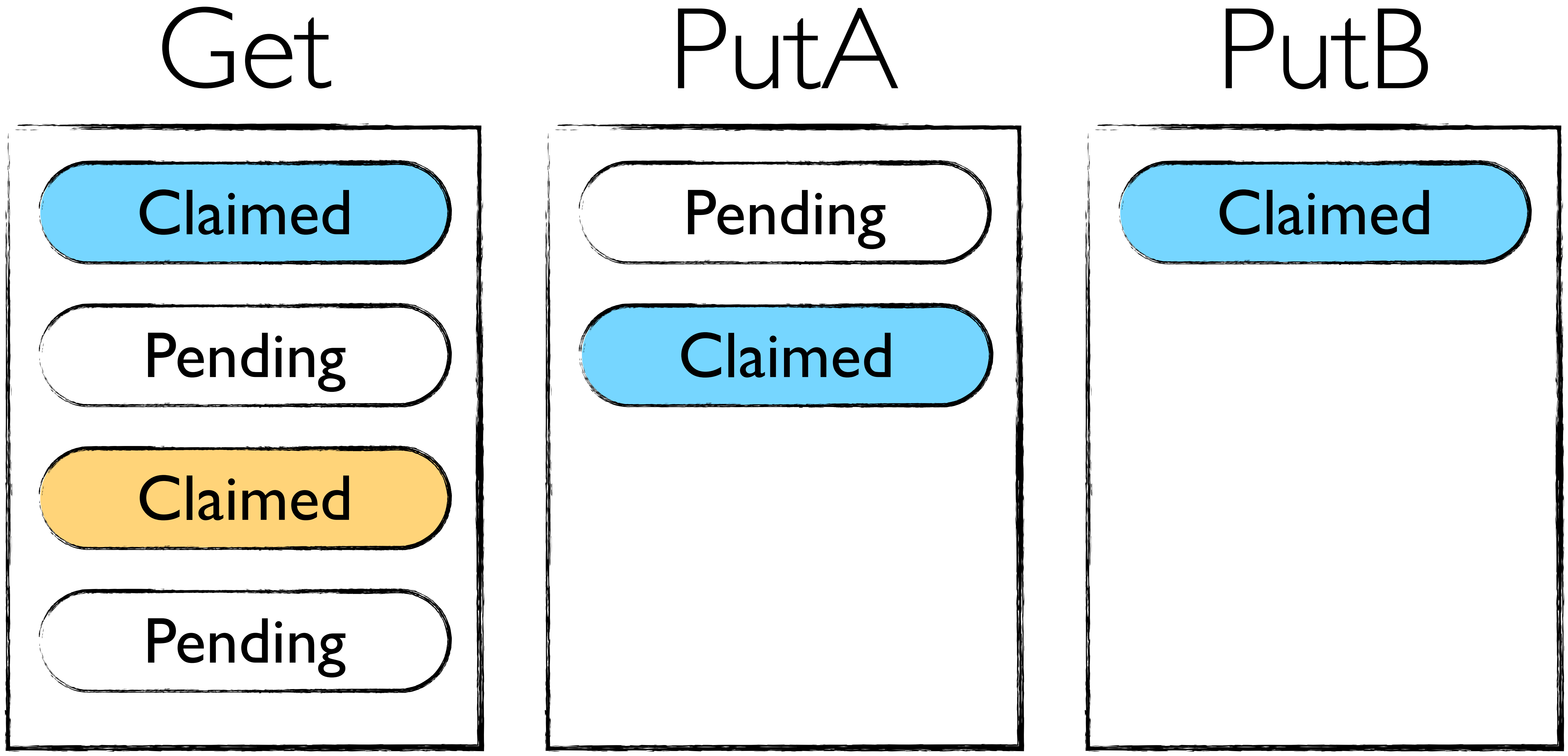

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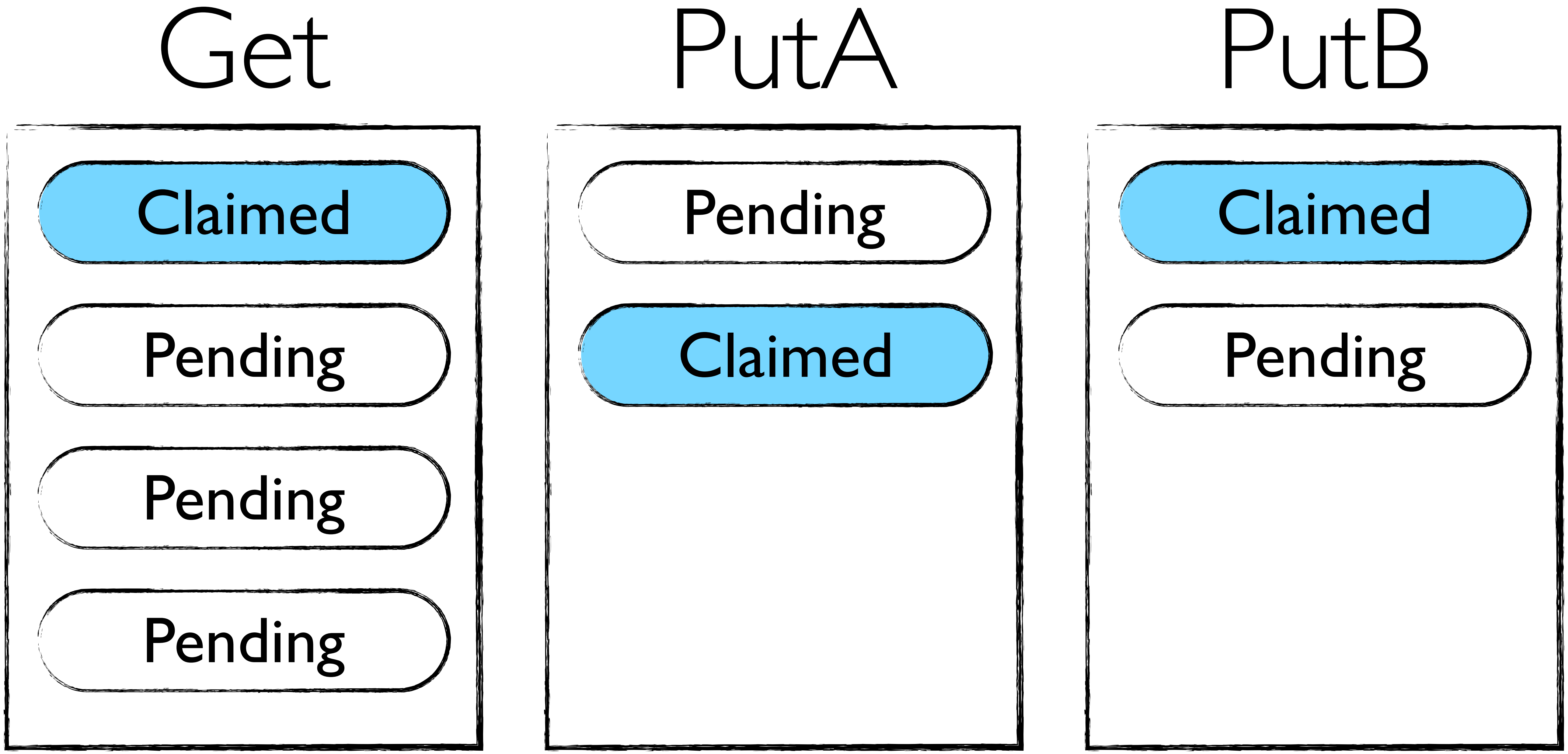
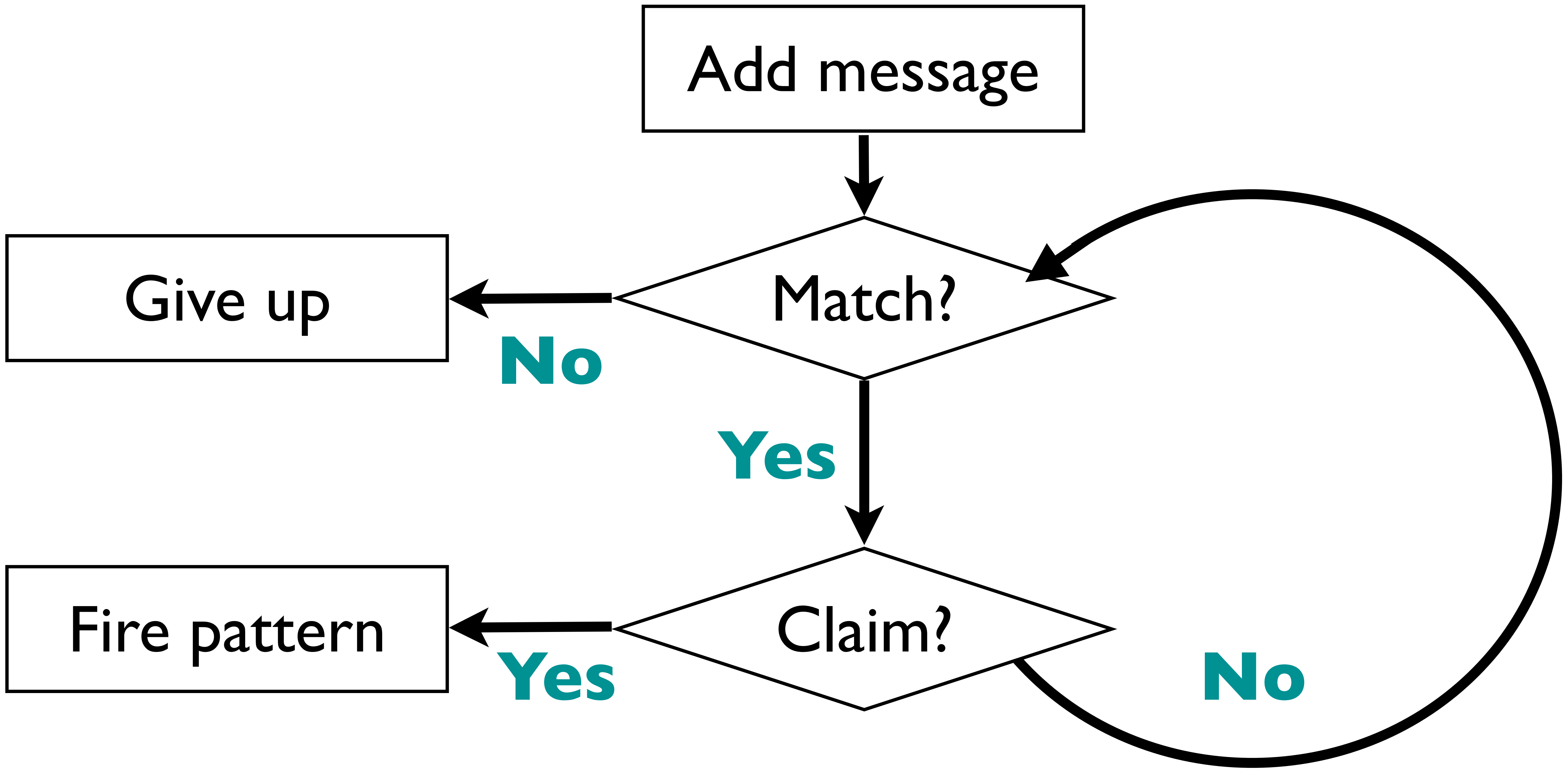


The Protocol



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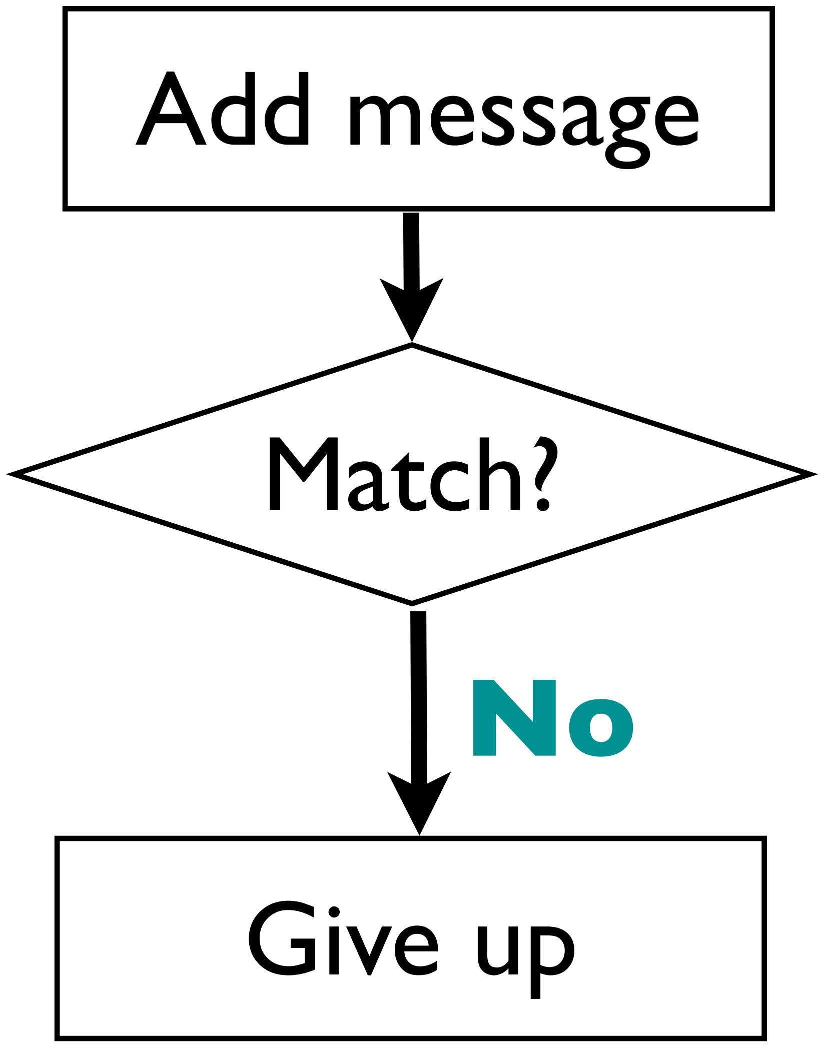

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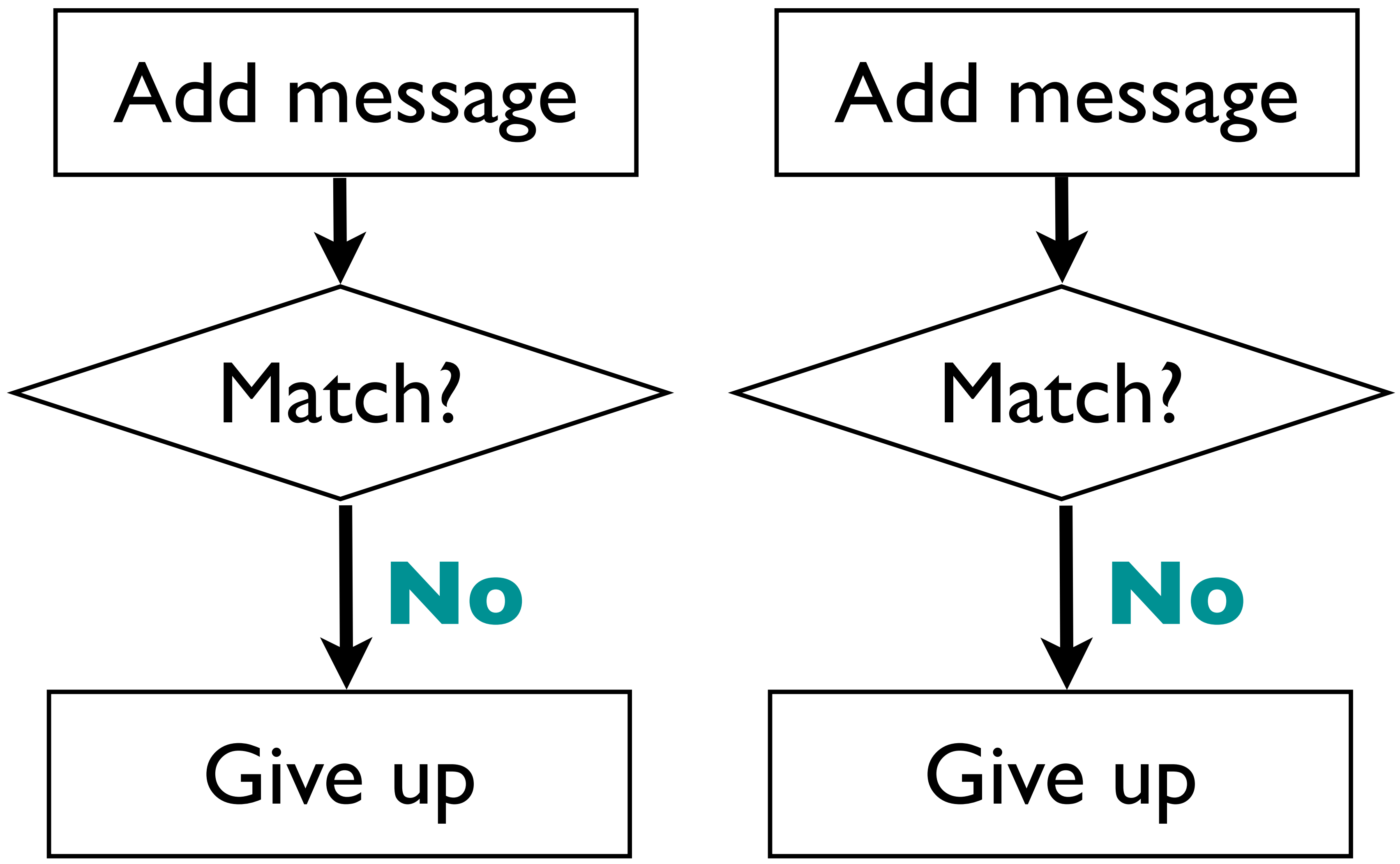

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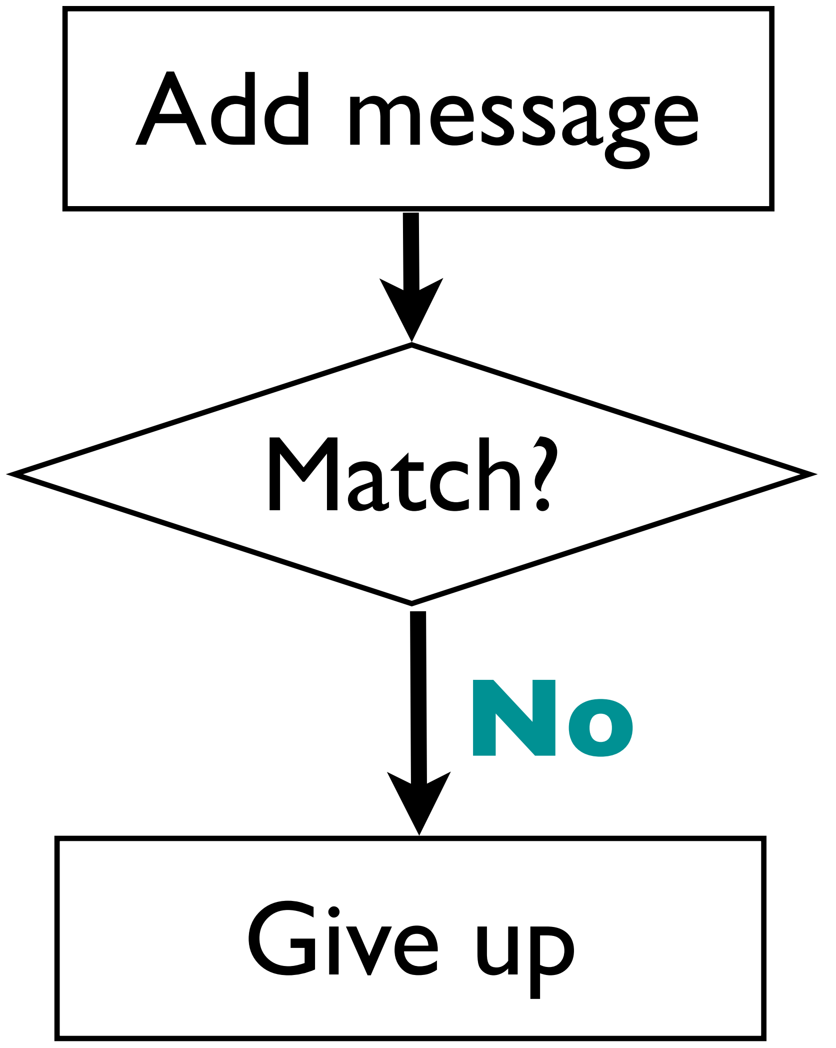
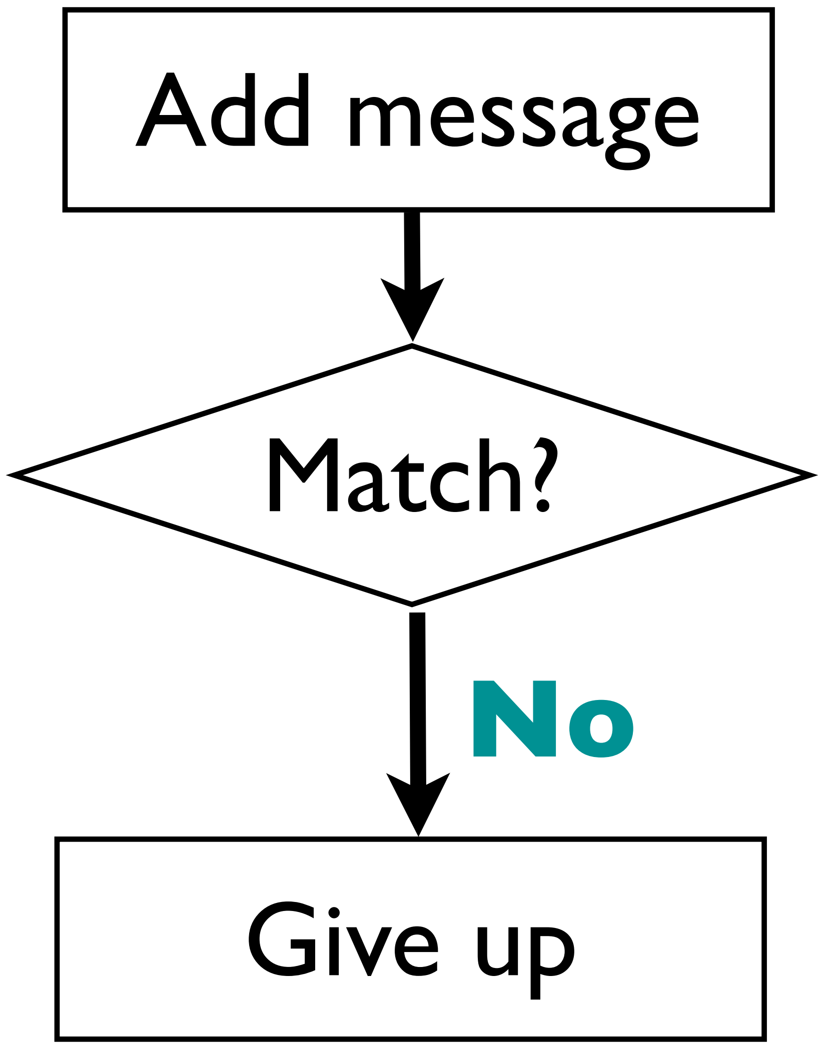




The Paper

- “Lazy” message adding
- Stealing
- Counter channels

The Paper

- "Lazy" message adding
- Stealing
- Counter channels

⇨

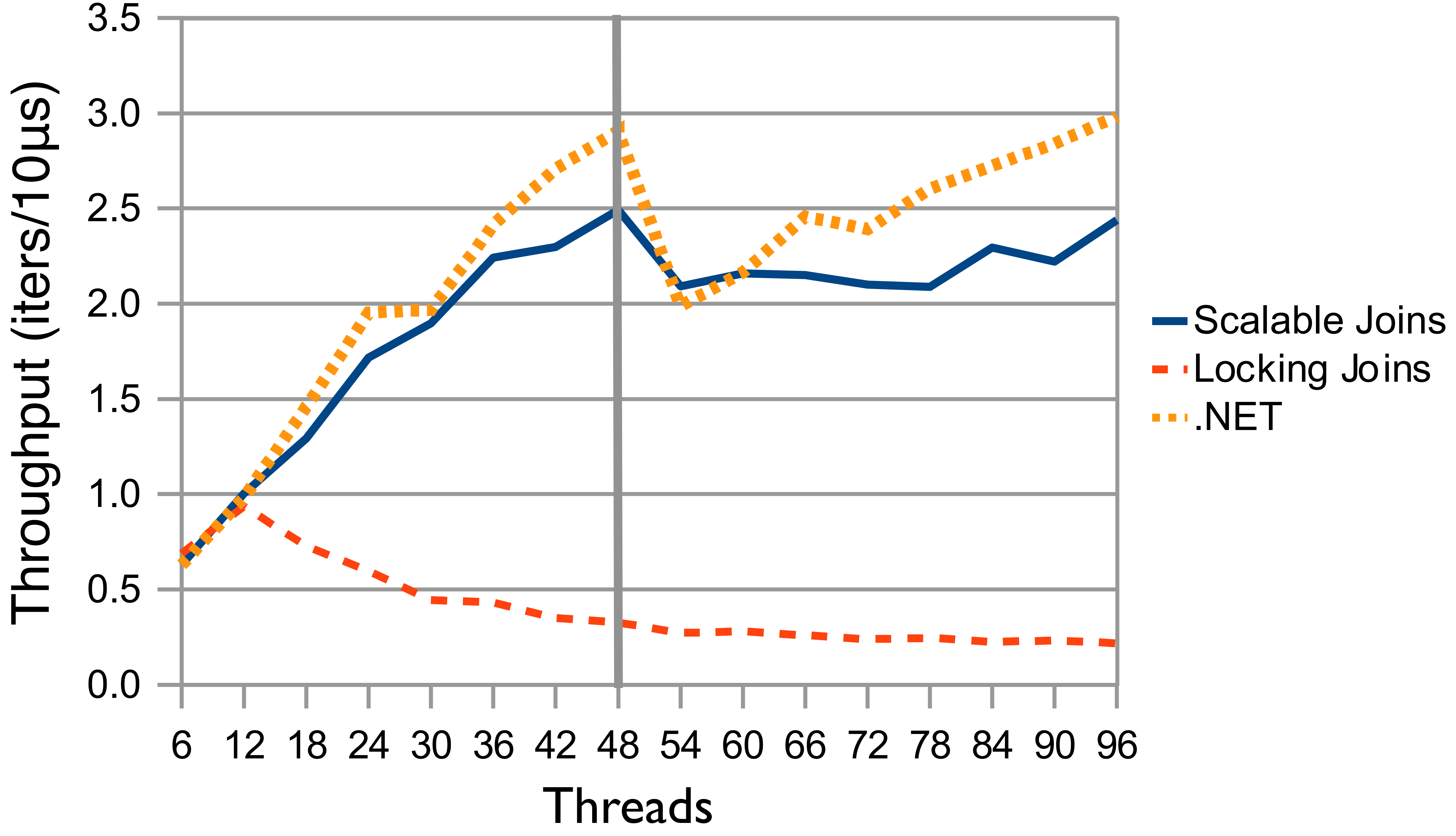
Recover existing algorithms

Benchmarks

48 core AMD machine

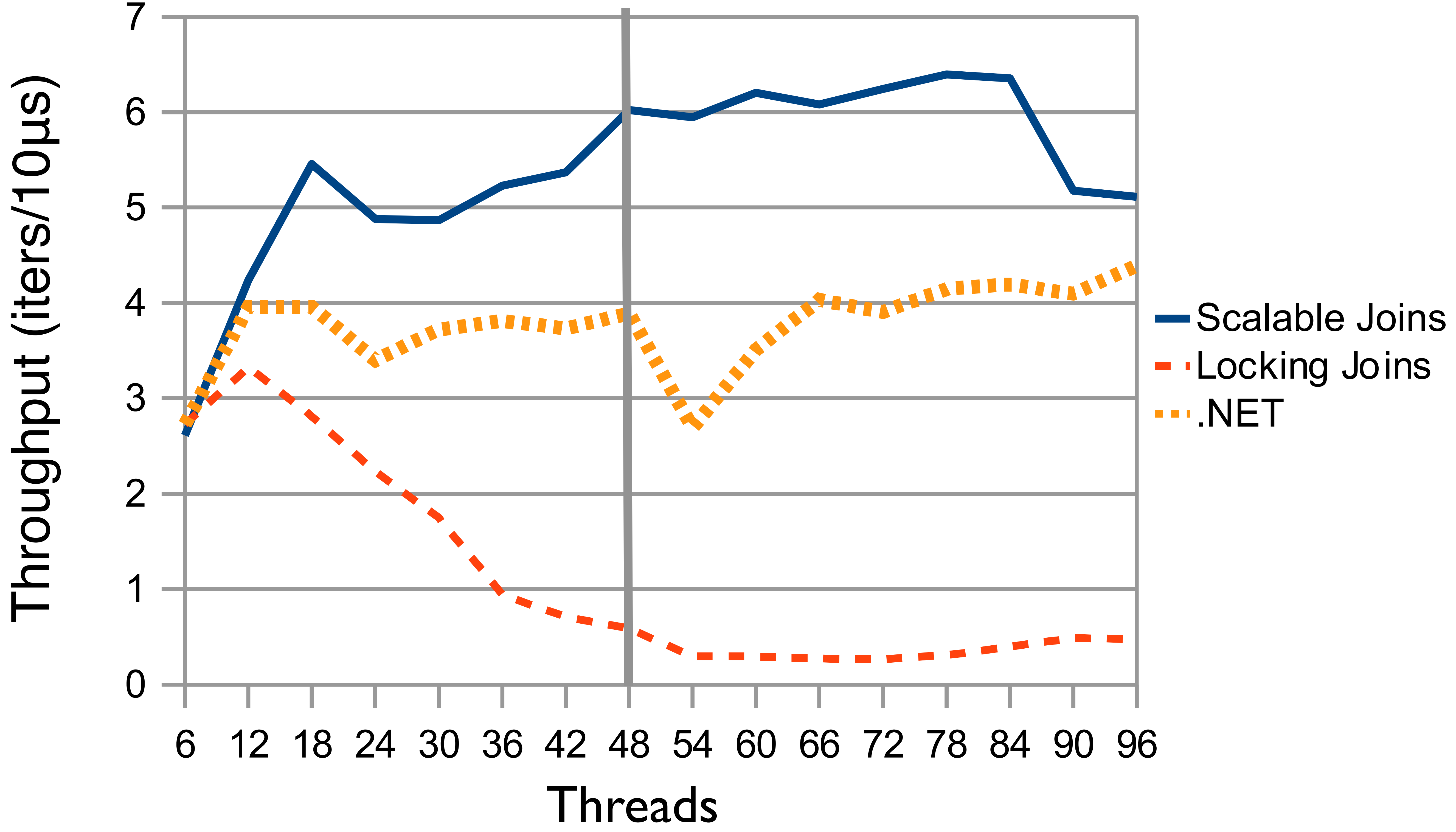
Simulated fine-grained parallel workload

Lock



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Throughput (iters/10μs)
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Threads
Scalable Joins
Locking Joins
.NET

Semaphore



Throughput (iters/10µs)
0
1
2
3
4
5
6
7
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
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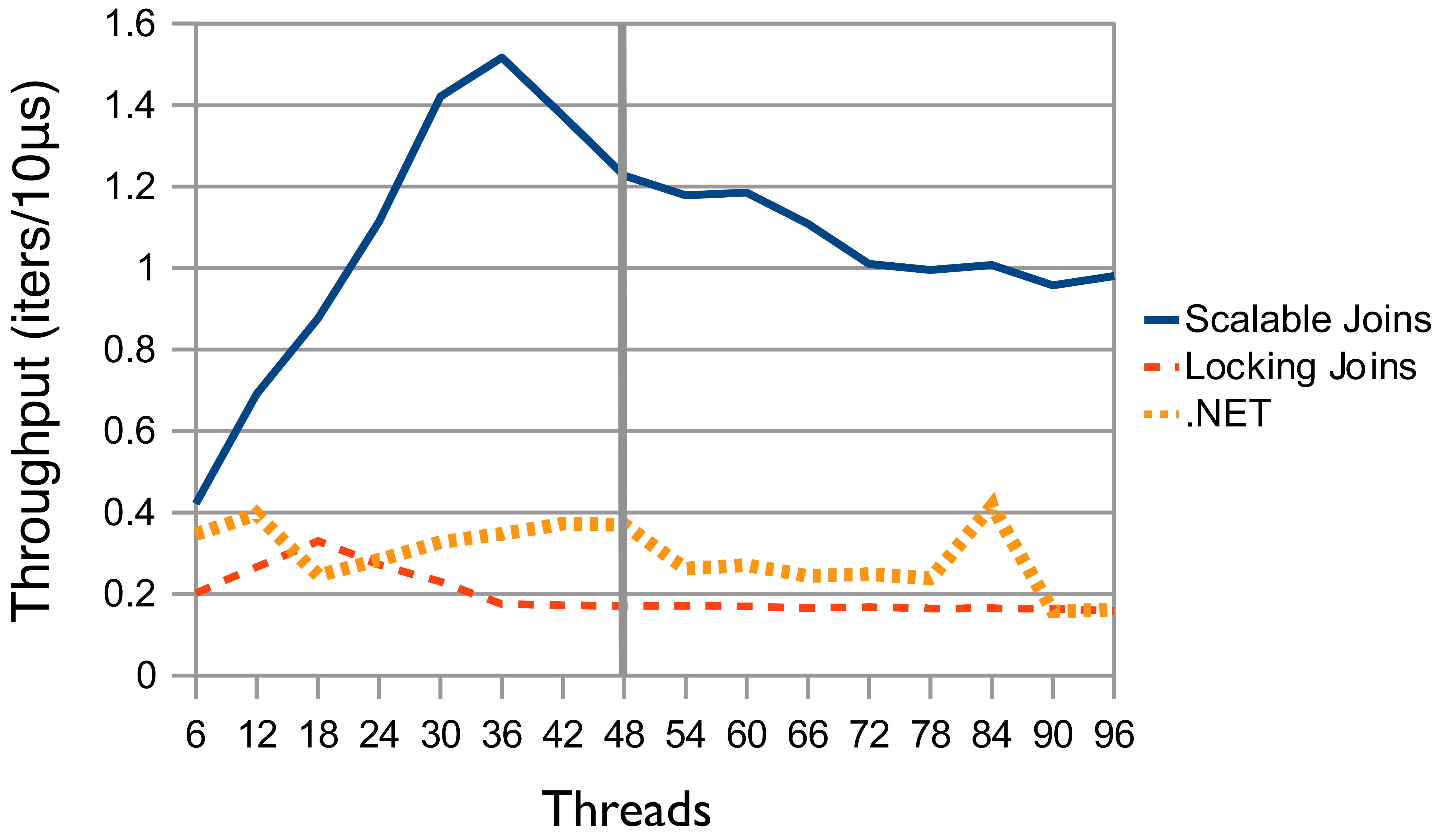
Producer/Consumer



This work

Use ***join patterns*** for synchronization:

[Fournet & Gonthier]

Expressive

Write synchronization primitives declaratively and concisely

Scalable

Competitive with industrial libraries; can recover existing algorithms

The Takeaway

Have your cake and eat it, too

Just one algorithm to implement, endlessly extensible by the user, competitive with custom solutions

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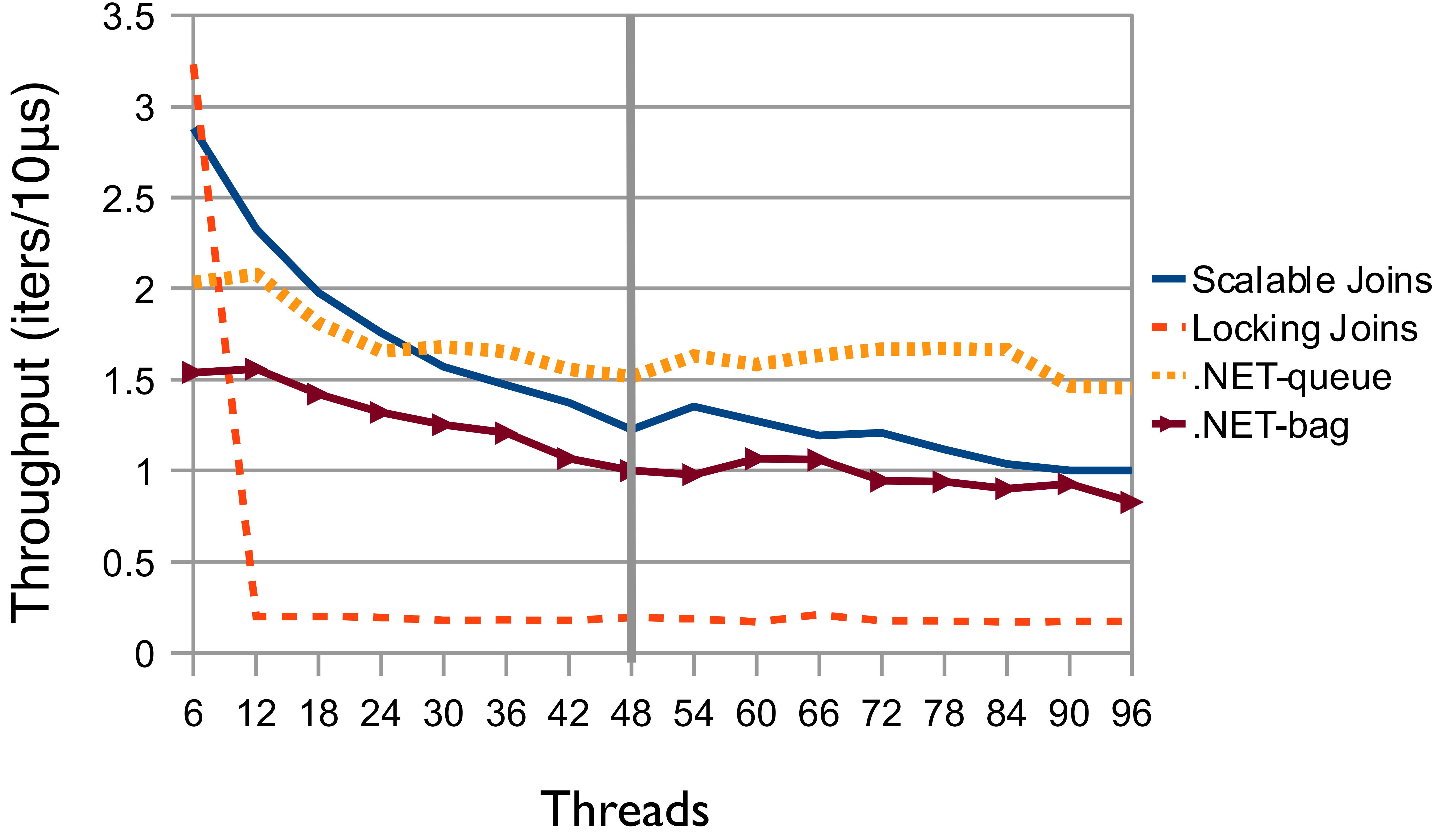
Have your cake and eat it, too

Just one algorithm to implement, endlessly extensible by the user, competitive with custom solutions

Thank you

Producer/Consumer (no work)


Throughput (iters/10µs)
Threads
Scalable Joins
Locking Joins
.NET-queue
.NET-bag