CRDTs, E2EE, permissions and Jazz!

garden computing

jazz

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Local-first software

You own your data, in spite of the cloud

Ink & Switch

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Cloud apps like Google Docs and Trello are popular because they enable real-time collaboration with colleagues, and they make it easy for us to access our work from all of our devices. However, by centralizing data storage on servers, cloud apps also take away ownership and agency from users. If a service shuts down, the software stops functioning, and data created with that software is lost.

In this article we propose "local-first software": a set of principles for software that enables both collaboration *and* ownership for users. Local-first ideals include the ability to work offline and collaborate across multiple devices, while also improving the security, privacy, long-term preservation, and user control of data.

We survey existing approaches to data storage and sharing, ranging from email attachments to web apps to Firebase-backed mobile apps, and we examine the trade-offs of each. We look at Conflict-free Replicated Data Types (CRDTs): data structures that are multi-user from the ground up while also being fundamentally local and private. CRDTs have the potential to be a foundational technology for realizing local-first software.

We share some of our findings from developing local-first software prototypes at Ink & Switch over the course of several years. These experiments test the viability of CRDTs in practice, and explore the user interface challenges for this new data model. Lastly, we suggest some next steps for moving towards local-first software: for researchers, for app developers, and a startup opportunity for entrepreneurs.

https://www.inkandswitch.com/essay/local-first/

What if

What if

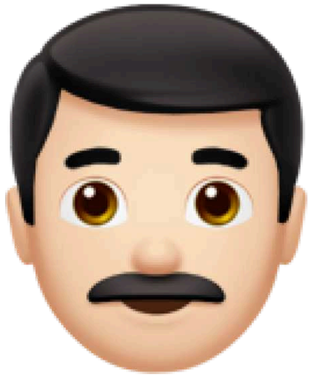
Your app worked offline by default

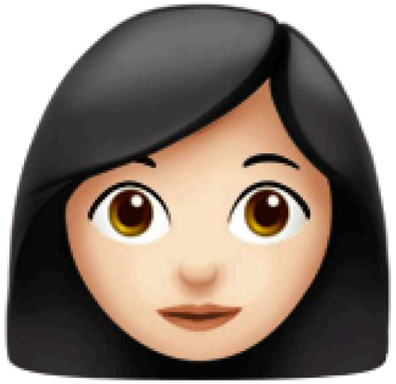
Synced “magically” when connected

And you retained control of your data?


LIVE
breakyourownnews.com
BREAKING NEWS
MAJOR POWER OUTAGE IN EUROPE
12:15
MANAGERS IN SPAIN AND PORTUGAL ARE UNABLE TO USE TO-DO LIST APPS.

The collaboration challenge





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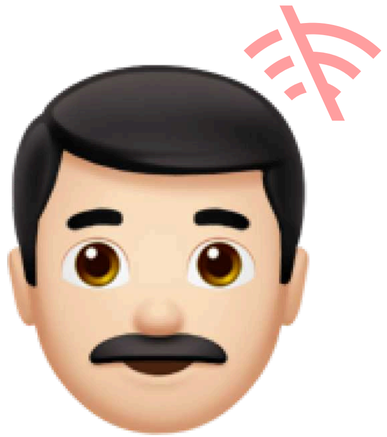
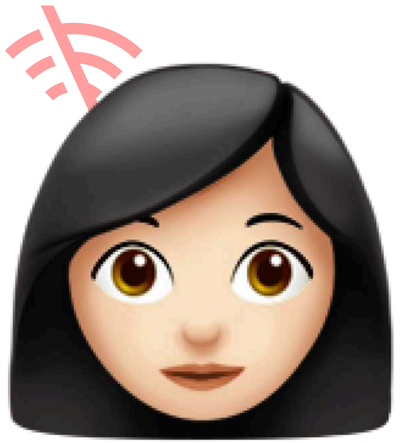
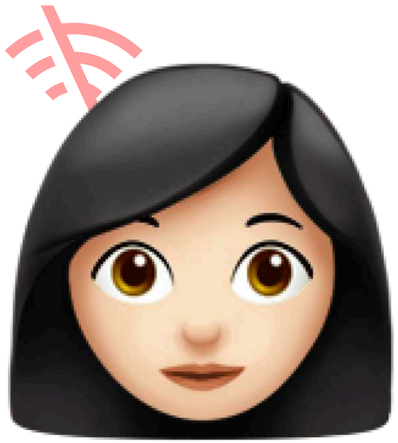




The collaboration challenge

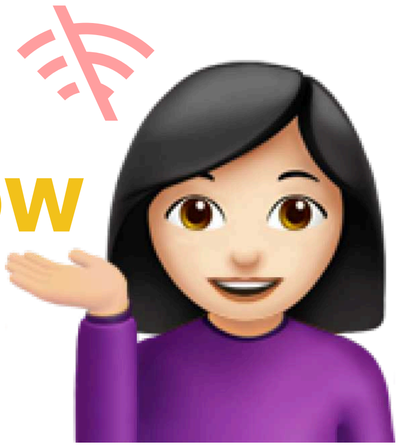
The 🐈 is Blue



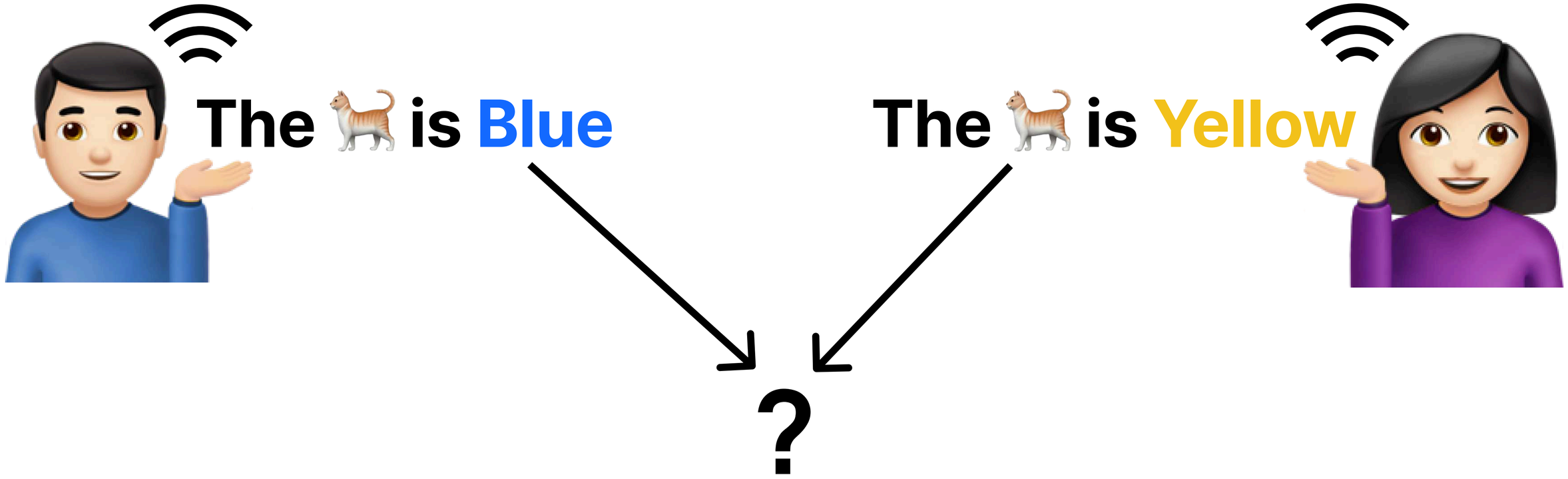
The collaboration challenge

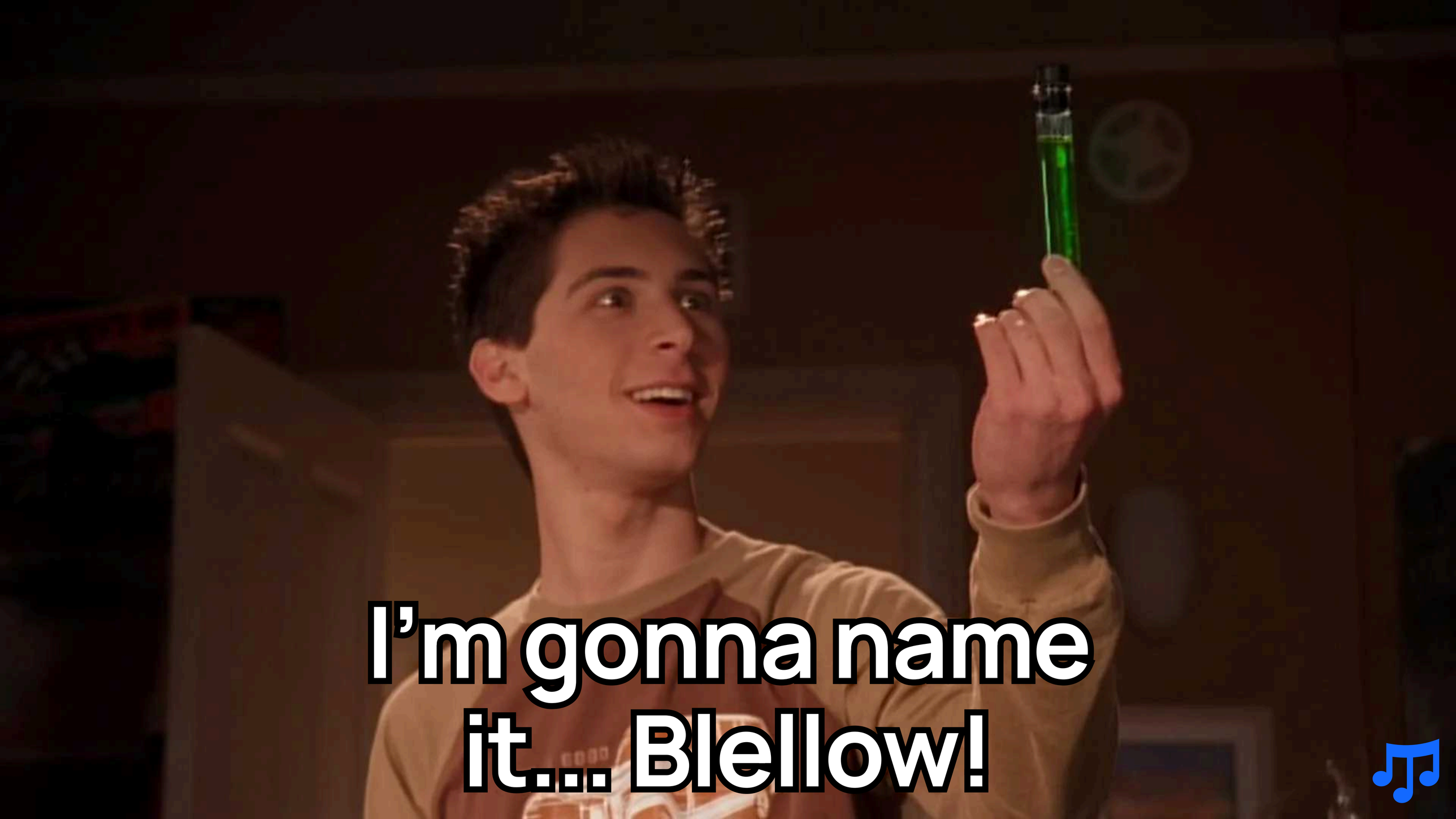
The 🐈 is Blue

The 🐈 is Yellow



The collaboration challenge




I’m gonna name
it... Blellow!

Traditional Approaches

Last Writer Wins

Traditional Approaches

Last Writer Wins

Data Loss

Traditional Approaches

Last Writer Wins

Manual Conflict Resolution

Traditional Approaches

Last Writer Wins

Manual Conflict Resolution

UX Sucks

Traditional Approaches

Last Writer Wins

Manual Conflict Resolution

Resource Locking

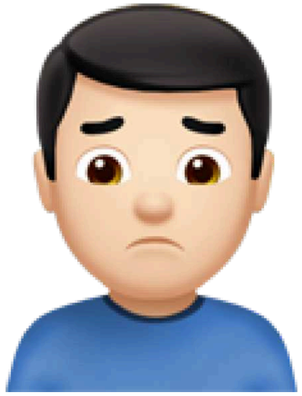
Traditional Approaches

Last Writer Wins

Manual Conflict Resolution

Resource Locking

Kills Collaboration!



The 🐈 is ☠️.

A primer on CRDTs

What is a CRDT anyway?

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Conflict-free **R**eplicated **D**ata **T**ypes

What is a CRDT anyway?

Conflict-free **R**eplicated **D**ata **T**ypes

Data structures mathematically designed to merge **without conflicts**

A Counter

counter.ts

```
class GCounter {
  constructor(private nodeId) {
    this.counts = {
      [nodeId]: 0,
    };
  }

  increment(amount = 1) {
    this.counts[this.nodeId] += amount;
  }

  value() {
    return Object.values(this.counts)
      .reduce((sum, count) => sum + count, 0);
  }

  merge(other) {
    for (let [nodeId, count] of Object.entries(other.counts)) {
      this.counts[nodeId] = Math.max(this.counts[nodeId] || 0, count);
    }
  }
}

```

> We're not resolving conflicts, we’re designing them away

The 🐈 is Green!

Reframing CRDTs

useState(...)

useCoState(...)

Architecture Comparison

Traditional

Client

↓

Server (logic)

↓

Storage

Local-first

Client (logic+state)

↓

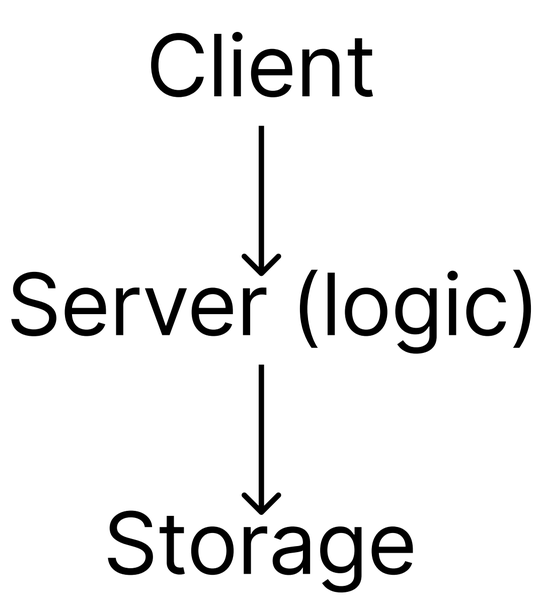
Sync & Storage

↓

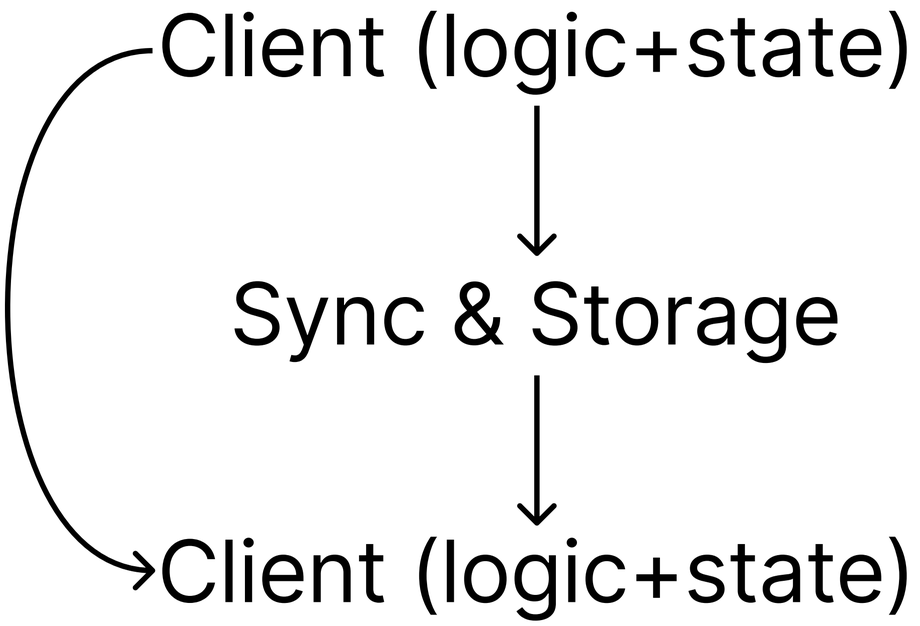
Client

Architecture Comparison

Traditional



Local-first



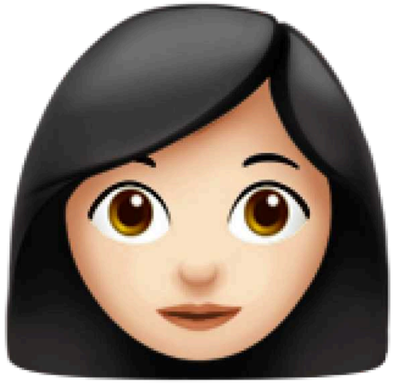
Benefits of Local-First

Benefits of Local-First

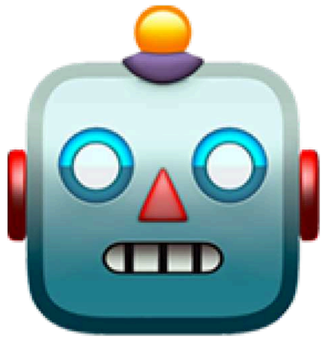
BUUUUUUT...😈

How do we stop users from reading or writing data they shouldn't?

Traditional Model: Server as Gatekeeper



I want to update this record!



Let me check if you're allowed...
OK, done

Naive Approaches Don't Work

Just check on the client

Naive Approaches Don't Work

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Clients can be modified

Naive Approaches Don't Work

Just check on the client

Server validation

Naive Approaches Don't Work

Just check on the client

Server validation

We need a smart server again

Naive Approaches Don't Work

Just check on the client

Server validation

Don't sync everything

Naive Approaches Don't Work

Just check on the client

Server validation

Don't sync everything

We lose the magic of CRDTs

Jazz’s Take on Permissions

CoMap co_z09dDT3×9my

HEADER

```
type: "comap"                                  owner: "co_zCCymDTETFr2rv9U"
createdAt: "30/01/2026 3:00:00 PM"             uniqueness: "fc89fjwo3"
```

HISTORY

Linda device 1

color: red	3:01 PM
height: 16	3:01 PM
height: 17	**3:05 PM**

Bob device 1

color: amber	3:02 PM
color: grey	3:03 PM
color: green	**3:06 PM**

Bob device 2

height: 18	3:04 PM

STATE

```
{
  color: "green",
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blake3

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01 10 hash_zjF6y1pGT8AP

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blake3

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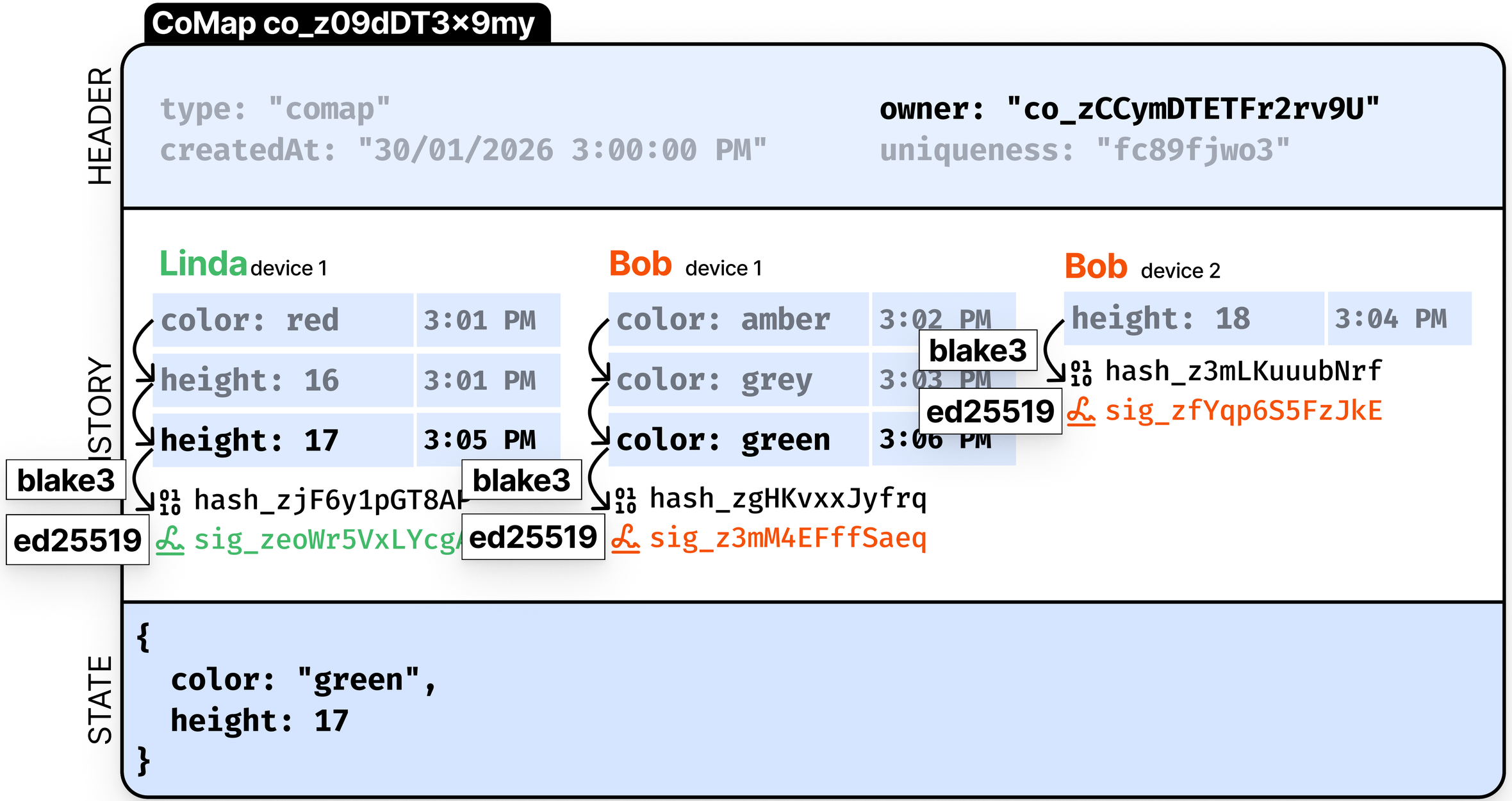
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Linda device 1

en_U2iMcpm9f…	3:01 PM
en_U38Zu3JZX…	3:01 PM
en_U38Zu3JZX…	3:05 PM

blake3 hash_z4DTFLEbdCJe

ed25519 sig_z3srJjcroFGY

Bob device 1

en_U2iL8B63w…	3:02 PM
en_U2iQ7gjDp…	3:03 PM
en_U2iL8Hf35…	3:06 PM

blake3 hash_z3zP4ZBy8M8W

ed25519 sig_zDCjXFVjefuXz

Bob device 2

en_U38Zu3JZX…	3:04 PM

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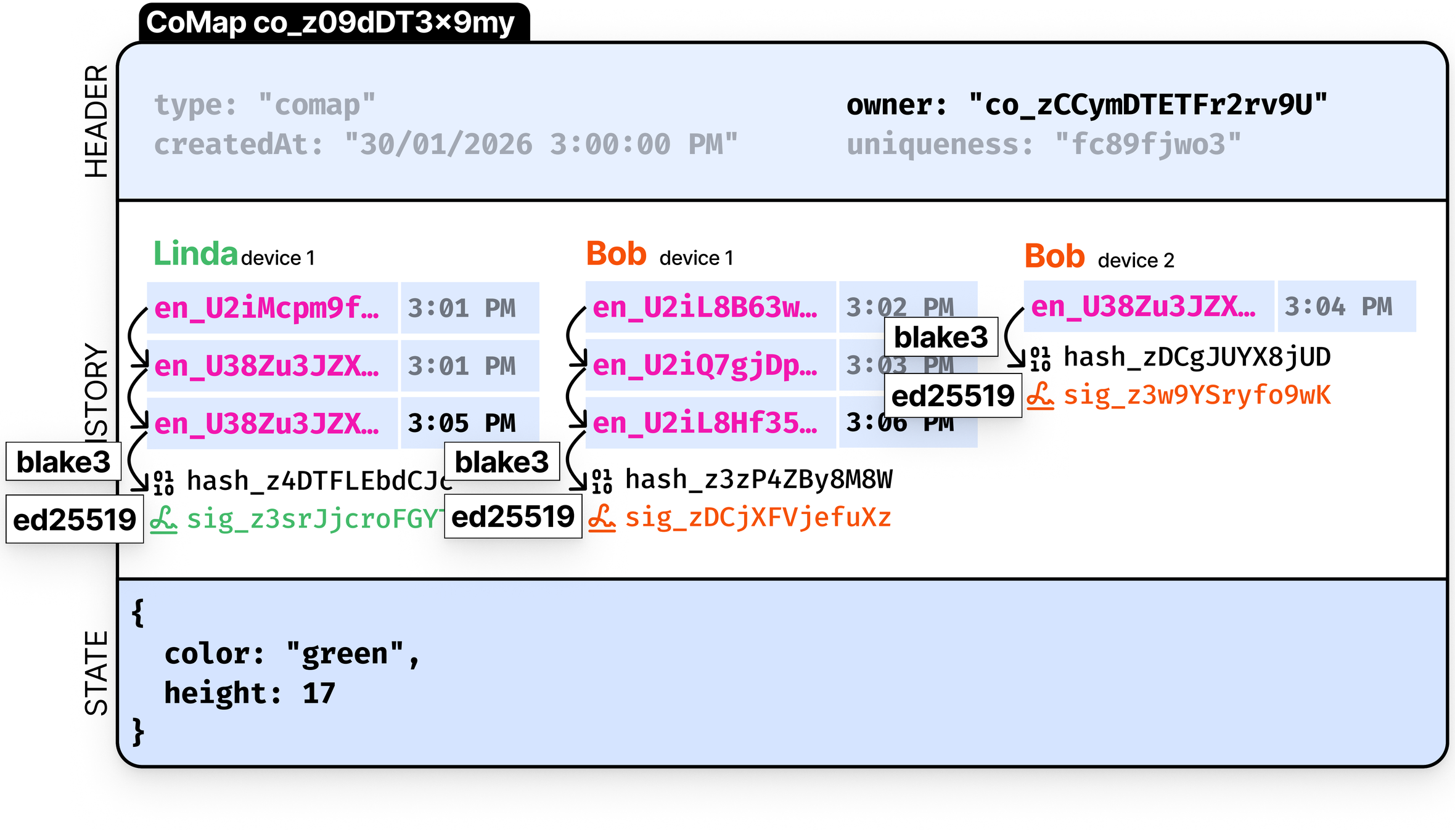
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Linda device 1

en_U2iMcpm9f…	3:01 PM
en_U38Zu3JZX…	3:01 PM
en_U38Zu3JZX…	3:05 PM

blake3 hash_z4DTFLEbdCJe

ed25519 sig_z3srJjcroFGY

Bob device 1

en_U2iL8B63w…	3:02 PM
en_U2iQ7gjDp…	3:03 PM
en_U2iL8Hf35…	3:06 PM

blake3 hash_z3zP4ZBy8M8W

ed25519 sig_zDCjXFVjefuXz

Bob device 2

en_U38Zu3JZX…	3:04 PM

blake3 hash_zDCgJUYX8jUD

ed25519 sig_z3w9YSryfo9wK

STATE

```
{
  color: "green",
  height: 17
}
```

Sync & Storage Server

CoMap co_z09dDT3×9my

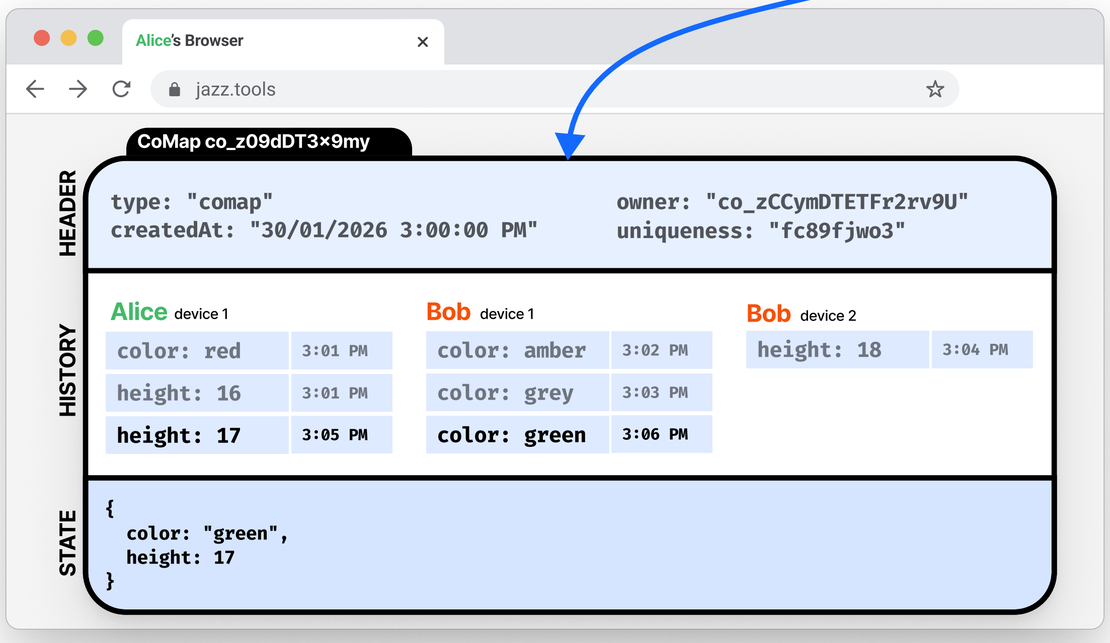
HEADER

```
type: "comap"                          owner: "co_zCCymDTETFr2rv9U"
createdAt: "30/01/2026 3:00:00 PM"     uniqueness: "fc89fjwo3"
```

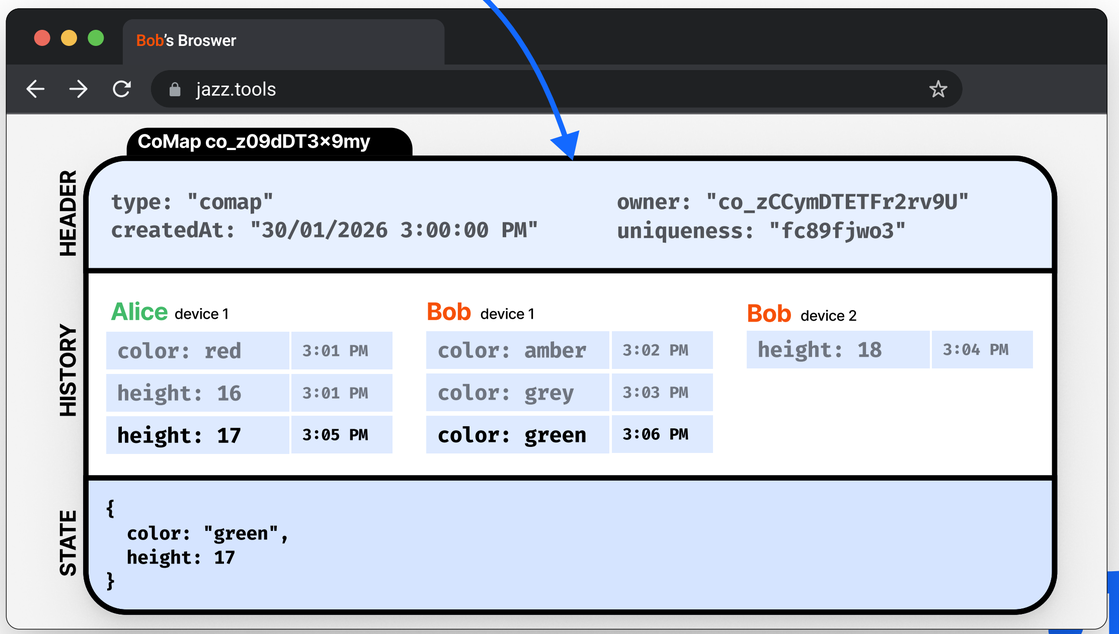
HISTORY

Linda device 1		Bob device 1		Bob device 2	
color: red	3:01 PM	color: amber	3:02 PM	height: 18	3:04 PM
height: 16	3:01 PM	color: grey	3:03 PM		
height: 17	3:05 PM	color: green	3:06 PM		

Linda's Browser



Bob's Browser



Sync & Storage Server

CoMap co_z09dDT3×9my

HEADER

```
type: "comap"                          owner: "co_zCCymDTETFr2rv9U"
createdAt: "30/01/2026 3:00:00 PM"     uniqueness: "fc89fjwo3"
```

HISTORY

Linda device 1		Bob device 1		Bob device 2	
en_U2iMcpm9…	3:01 PM	en_U2iL8B63…	3:02 PM	en_U38Zu3JZ…	3:04 PM
en_U38Zu3JZ…	3:01 PM	en_U2iQ7gjD…	3:03 PM		
en_U2iL8B63…	3:05 PM	en_U2iL8Hf3…	3:06 PM		

Linda's Browser

Alice's Browser

jazz.tools

CoMap co_z09dDT3×9my

HEADER

```
type: "comap"                          owner: "co_zCCymDTETFr2rv9U"
createdAt: "30/01/2026 3:00:00 PM"     uniqueness: "fc89fjwo3"
```

HISTORY

Alice device 1		Bob device 1		Bob device 2	
color: red	3:01 PM	color: amber	3:02 PM	height: 18	3:04 PM
height: 16	3:01 PM	color: grey	3:03 PM		
height: 17	**3:05 PM**	**color: green**	**3:06 PM**		

STATE

```
{
  color: "green",
  height: 17
}
```

Bob's Browser

Bob's Broswer

jazz.tools

CoMap co_z09dDT3×9my

HEADER

```
type: "comap"                          owner: "co_zCCymDTETFr2rv9U"
createdAt: "30/01/2026 3:00:00 PM"     uniqueness: "fc89fjwo3"
```

HISTORY

Alice device 1		Bob device 1		Bob device 2	
color: red	3:01 PM	color: amber	3:02 PM	height: 18	3:04 PM
height: 16	3:01 PM	color: grey	3:03 PM		
height: 17	**3:05 PM**	**color: green**	**3:06 PM**		

STATE

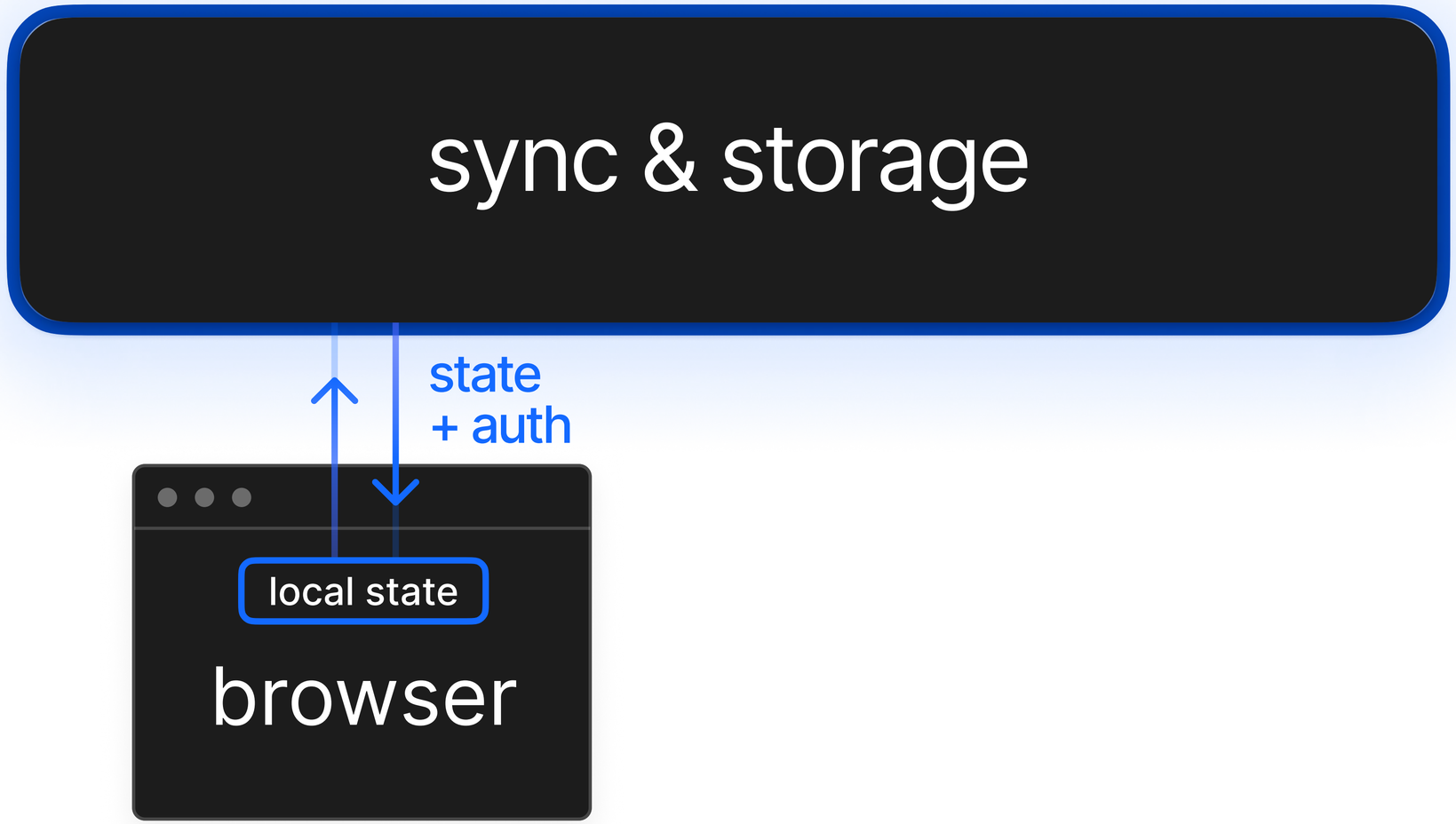
```
{
  color: "green",
  height: 17
}
```

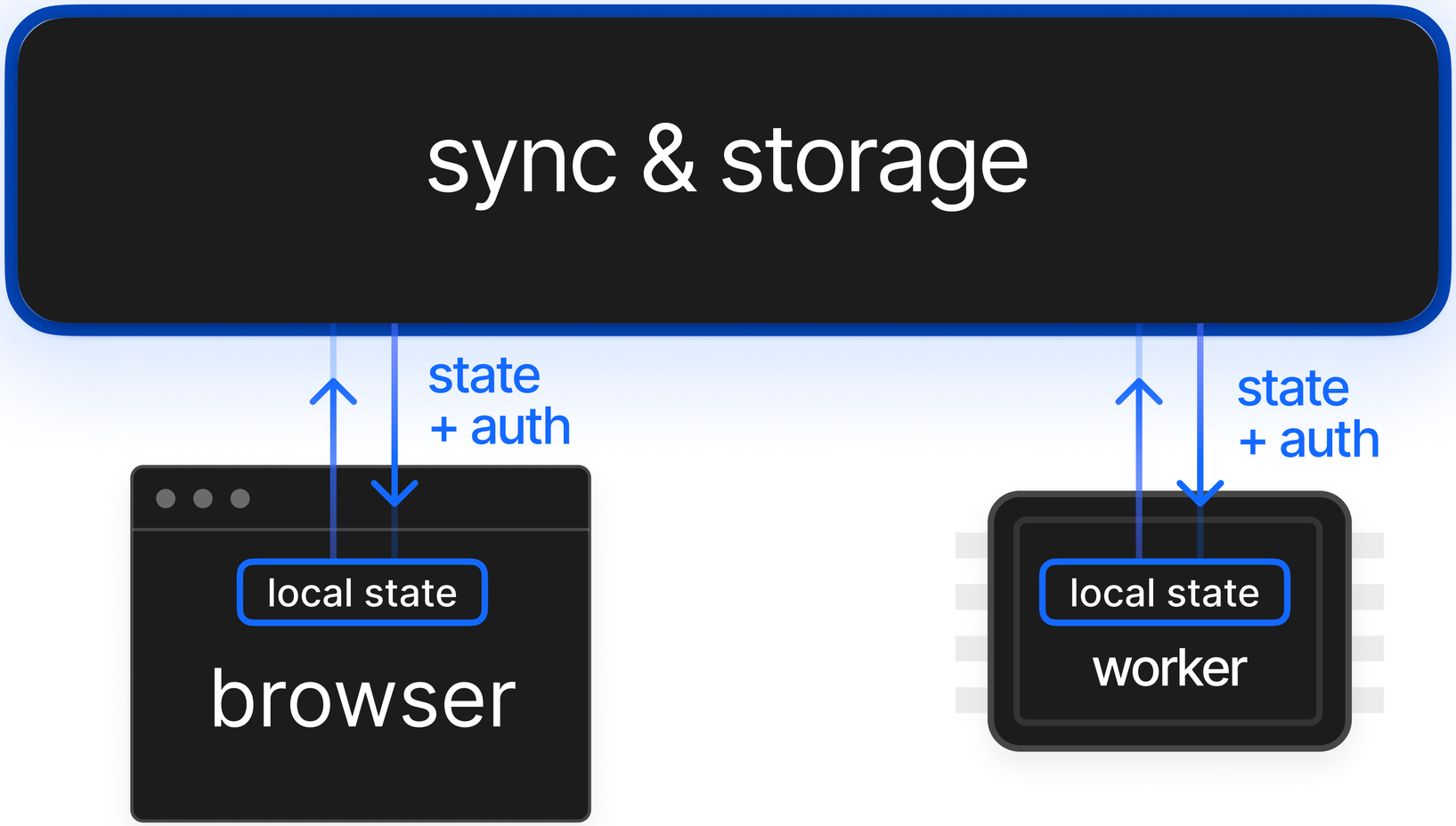
Yeah, sure.
But I need to send emails.

> There is no cloud, it’s just someone else’s computer

There is no server, it’s just another client

local-first ≠ browser-only


sync & storage
state
+ auth
local state
browser


sync & storage
state
+ auth
state
+ auth
local state
browser
local state
worker

Code Example(s)

schema.ts

```ts
import {co, z} from "jazz-tools";

const Cat = co.map({
  name: co.string(),
  color: z.literal(['blue', 'yellow', 'green']),
});
```

Code Example(s)

alice.ts

```ts
import { Group, Account } from "jazz-tools";
import { Cat } from "./schema";

const ownersGroup = Group.create();

const whiskers = Cat.create({
  name: "Whiskers",
  color: "blue",
}, { owner: ownersGroup });

const bob = await Account.load('co_bobId123');
ownersGroup.addMember(bob, "writer");
```

Code Example(s)

bob.ts

```ts
import { Account } from "jazz-tools";
import { Cat } from "./schema";

const me = await Account.getMe();

const cat = await Cat.load('co_whiskersId123');

if(me.canWrite(cat)) {
  cat.$jazz.set('color', 'yellow');
}
```

Ευχαριστώ!
Grazie!
Thank you!
Merci!
Obrigado!
Danke!
고마워!
Dankjewel!
شكرًا!
Dzięki!

garden computing

jazz