

Syncing data across user devices for

distributed collaboration

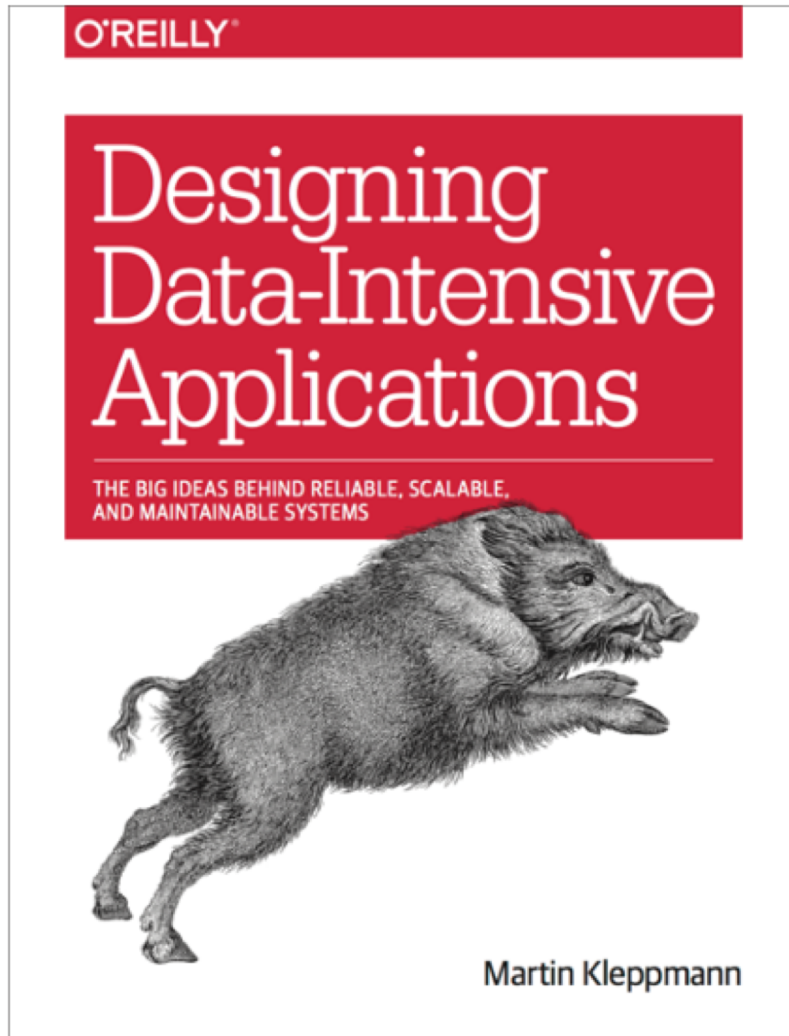
---

Martin Kleppmann <mk428@cl.cam.ac.uk>

<https://martin.kleppmann.com> • @martinkl

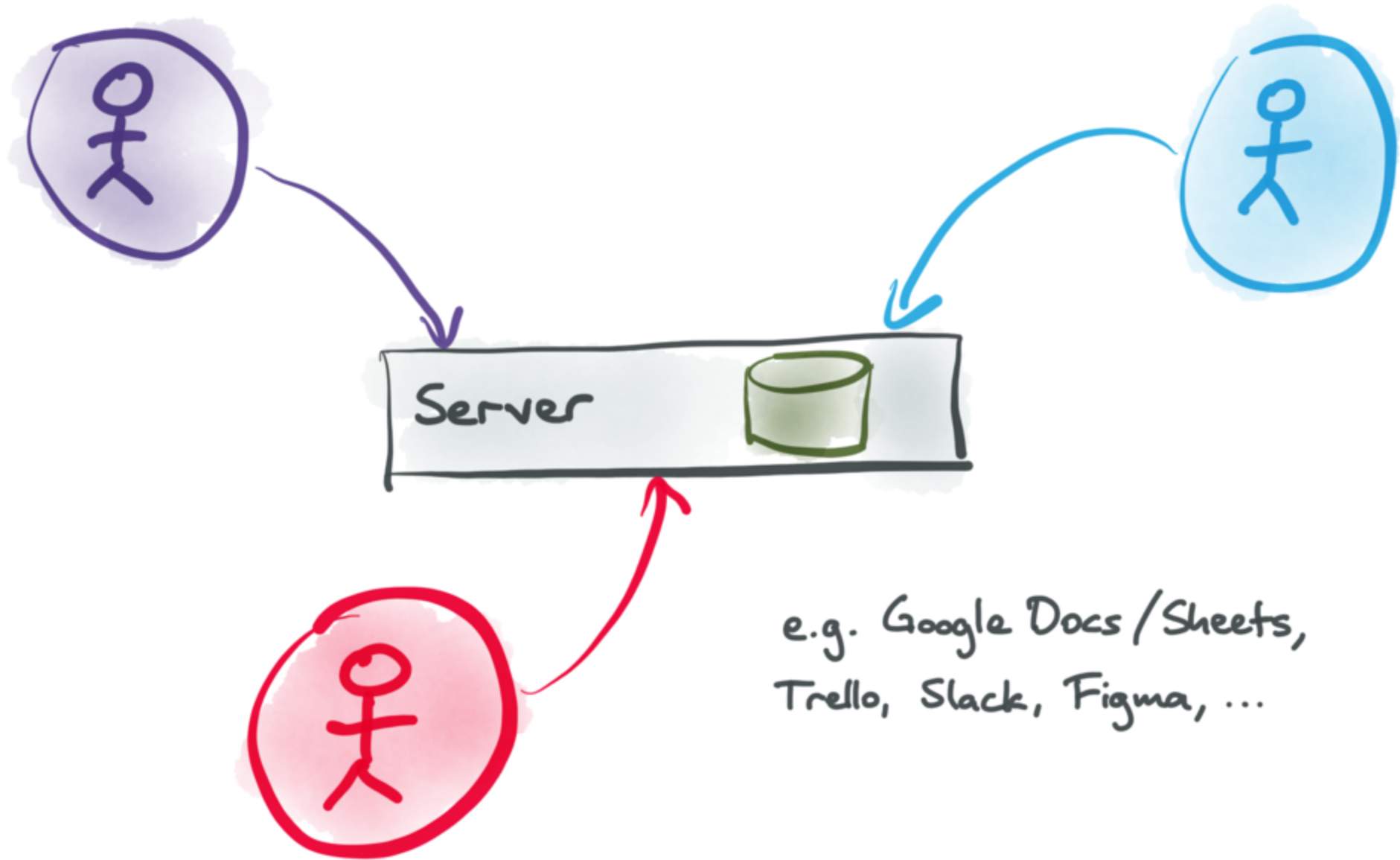
University of Cambridge

dataintensive.net



# CLOUD APPS / WEB APPS / SAAS

---

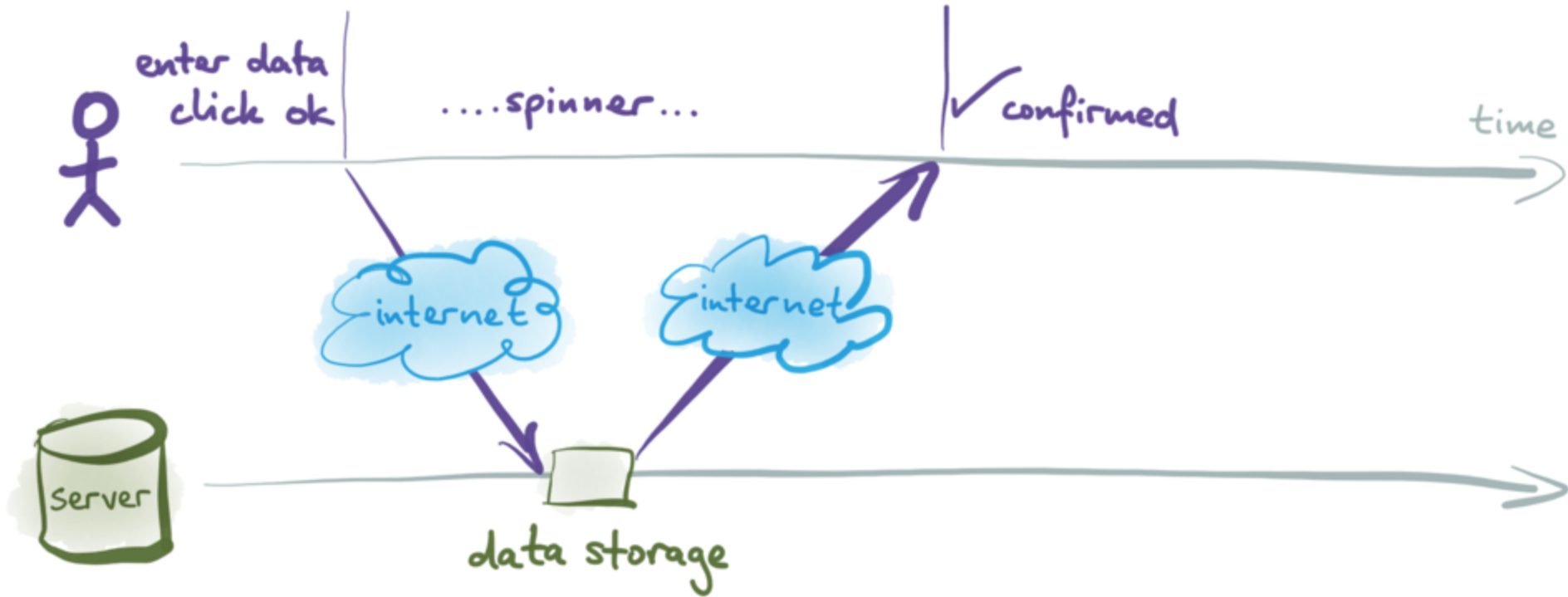


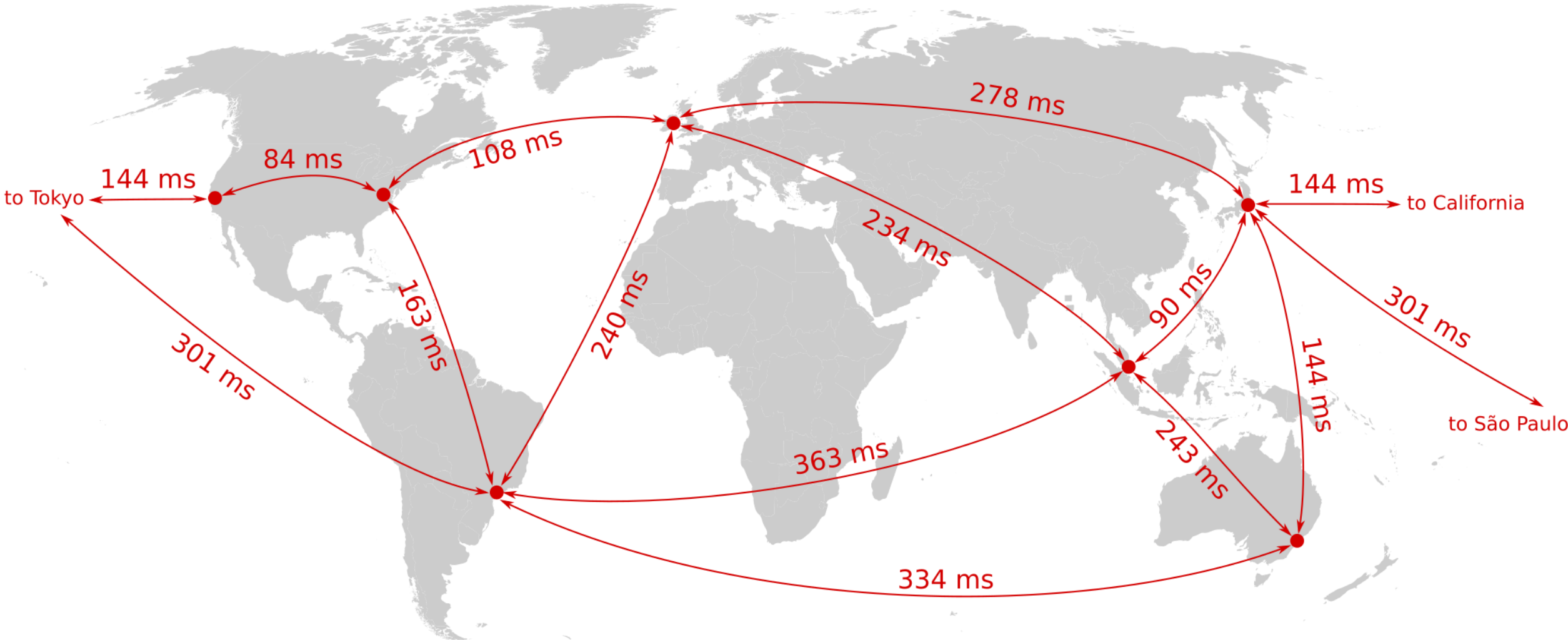
You own your data, in spite of the cloud

# Local - first SOFTWARE

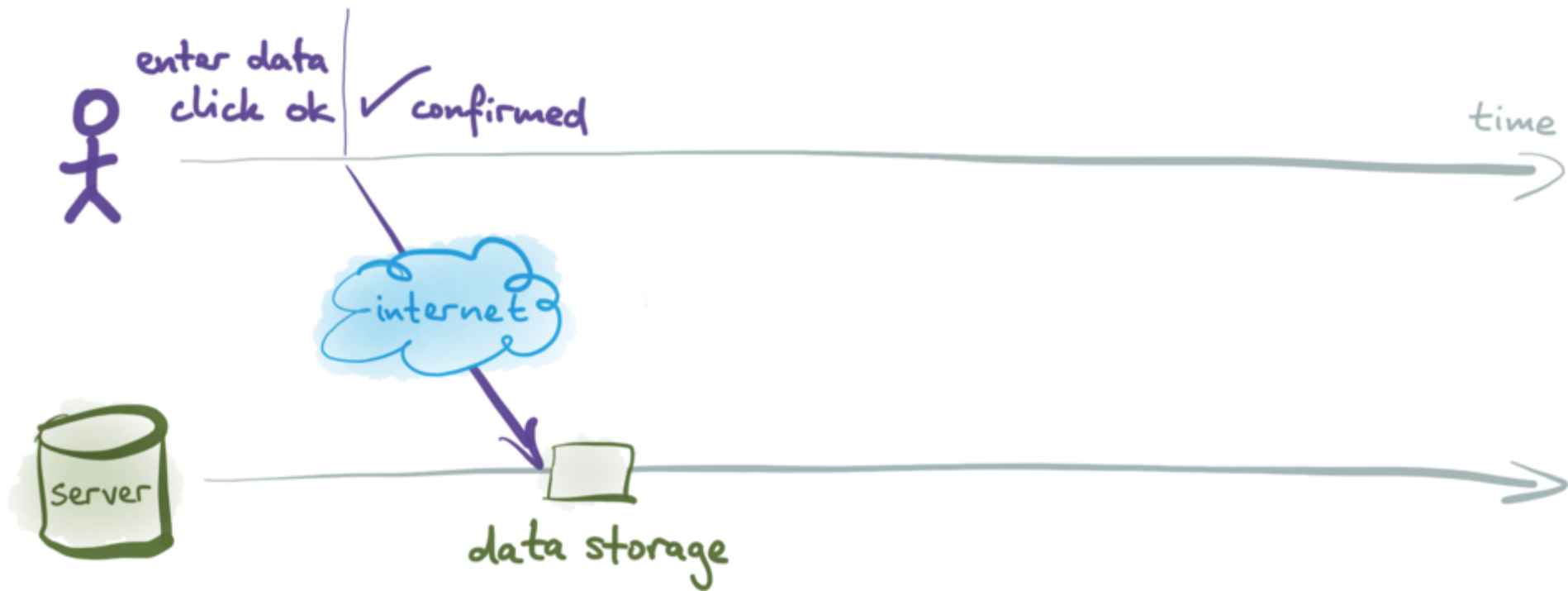
[https://inkandswitch.com  
/local-first.html](https://inkandswitch.com/local-first.html)

# 1. Web apps: Waiting for server round-trip



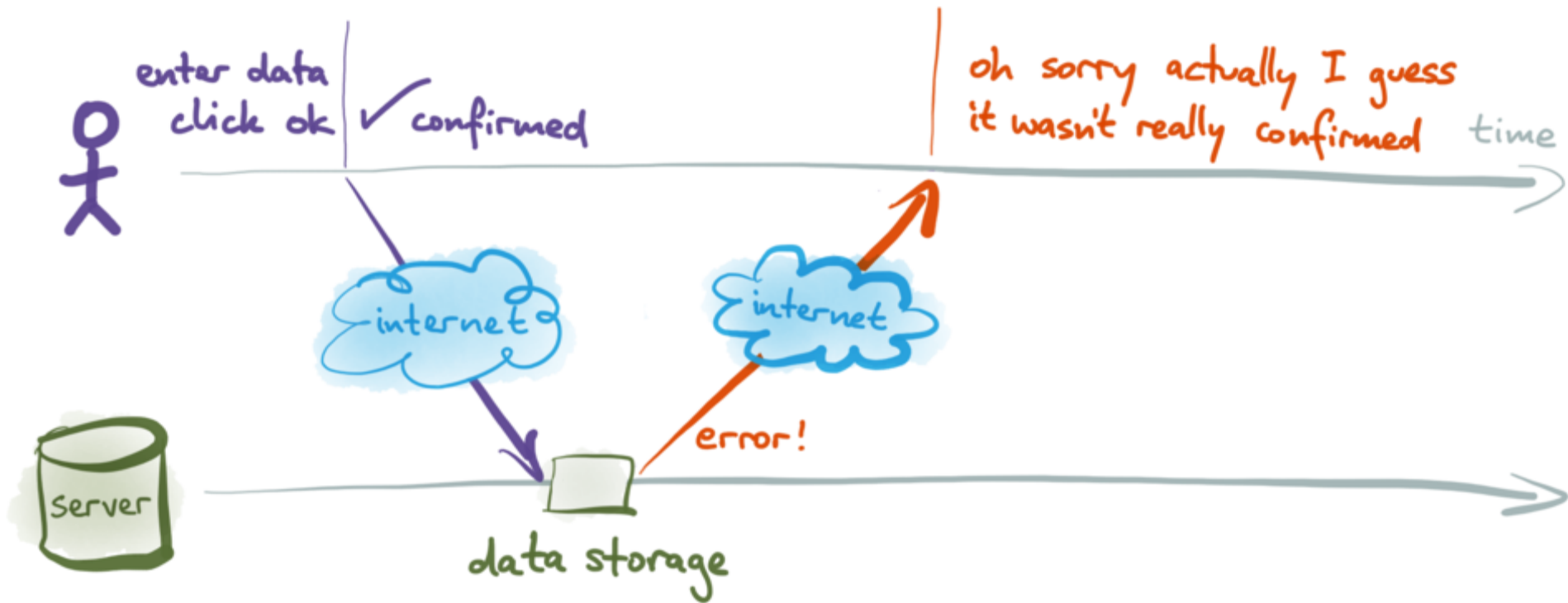


# 1. Web apps: Waiting for server round-trip



"Optimistic UI"

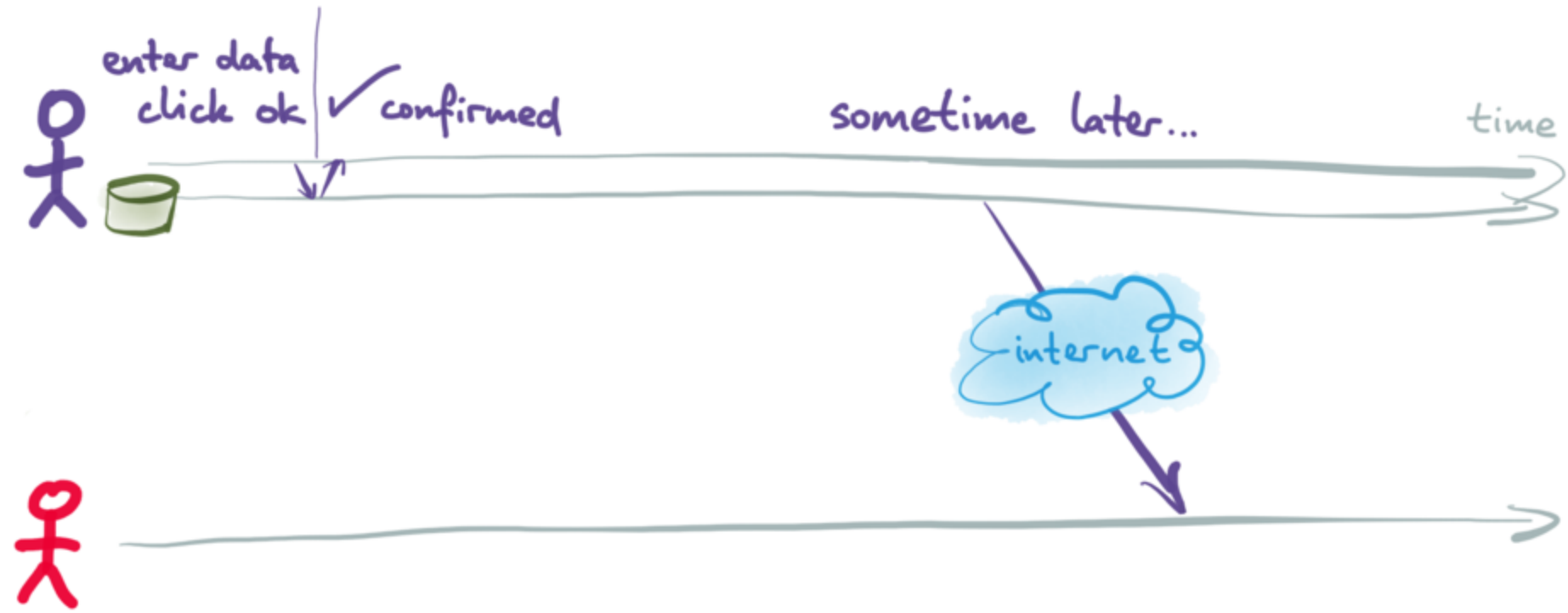
# 1. Web apps: Waiting for server round-trip



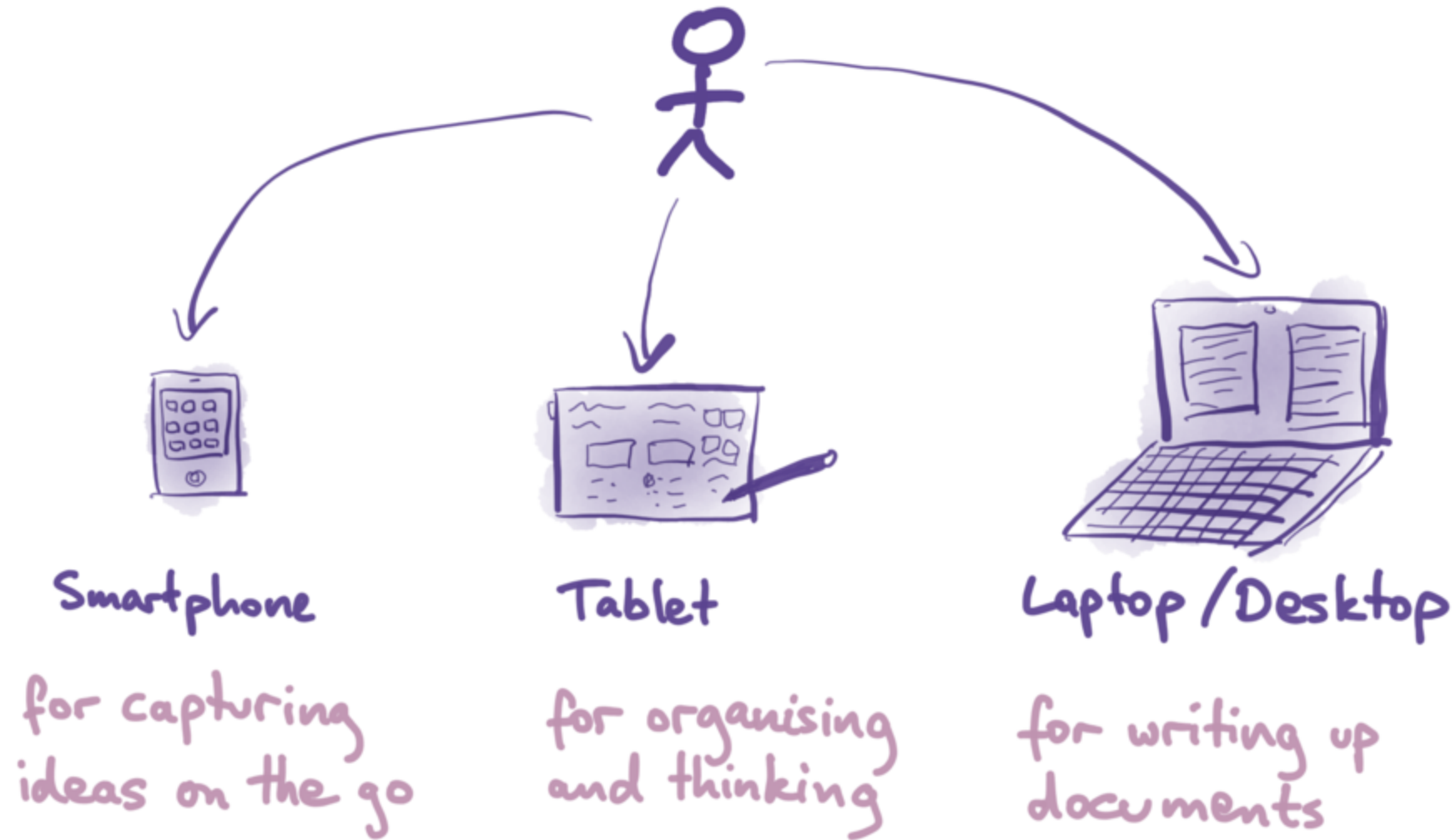
"Optimistic UI"



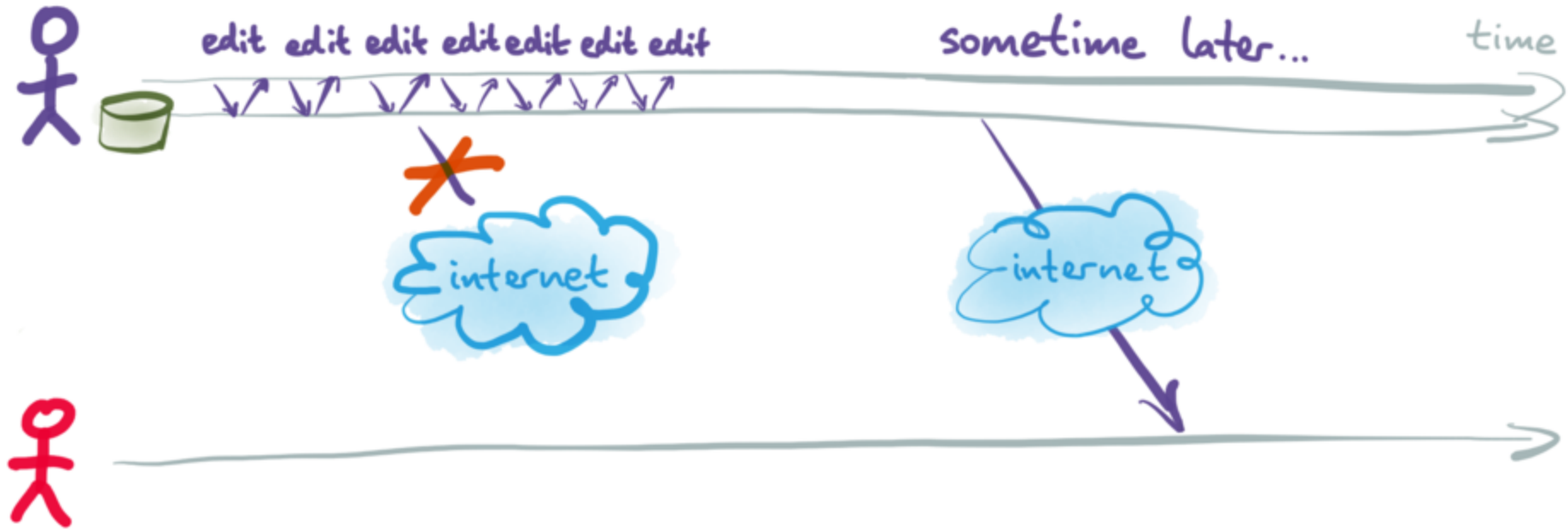
# Local storage & sync



## 2. Multi-device work



# 3. Working offline



When you're mobile, you'll be  
offline at some point.



Will your app still work?



## Connection error

Your computer may be offline or the Figma server may be experiencing problems.

Figma will automatically try to reconnect.

Try again

For help, visit [help.figma.com](https://help.figma.com) or contact [support@figma.com](mailto:support@figma.com).

Error code: ERR\_INTERNET\_DISCONNECTED



## Local-first software: You own your data in spite of the cloud



File Edit View Insert Form

Trying to connect. To edit offline, turn on offline sync when you reconnect.

Undo Redo Print Checkmark Eraser | 100% | Add

tools are even more important. Ten users on a team video call can bring up the same Trello board and each make edits on their own computer while simultaneously seeing what other users are doing.

The flipside to this is the total loss of ownership and control.

If your network hiccups for even a moment, you are locked out of your

## 4. Seamless collaboration

- Google Docs style (real-time collaborative editing, if online)

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- Google Docs style (real-time collaborative editing, if online)
- Git pull request / GDocs suggestions  
(asynchronous collaboration, review + accept/reject)





Rich text editor toolbar with icons for undo, redo, print, bold, italic, underline, text color, link, insert, list, and zoom.

Is it possible? Challenges and opportunities

Technology

CRDTs

Peer-to-peer technologies: ~~Dat~~, ~~and~~ IPFS, BitTorrent and WebRTC

End-to-end encryption

~~WebRTC and videochat~~

~~Bittorrent~~

Design

Role of servers

Permissions

Version control

Business model (Subscriptions work great for cloud services, but that model seems at odds with software that outlives the company that created it. For example, Adobe's software is locally installed, but it uses a subscription model, and hence it has to perform a license check when you start the application. **If Adobe was to go bust, would you still be able to use Photoshop?** And if a non-subscription business model is used, e.g. like old-fashioned software where you pay one-off for a license of unlimited duration, will that still be commercially viable for the software authors?)

Conclusion



Martin Kleppmann

10:55 AM Jan 28



Add: "Peer-to-peer technologies:"



Martin Kleppmann

10:54 AM Jan 28



Replace: "and" with ","



Martin Kleppmann

10:54 AM Jan 28



Add: ", BitTorrent and WebRTC"



Martin Kleppmann

10:54 AM Jan 28



Delete: "WebRTC and videochat Bittorrent"



Adam Wiggins

5:02 PM Jan 25

Resolve



btw there was a similar thing with old-fashioned software and dongles  
[https://en.wikipedia.org/wiki/Software\\_protection\\_dongle](https://en.wikipedia.org/wiki/Software_protection_dongle)



Search or jump to...

Pull requests Issues Marketplace Explore



automerger / automerger

Unwatch 168

Unstar 6,430

Fork 3,766

Code

Issues 20

Pull requests 2

Projects 0

Wiki

Insights

Settings

# Upgrade to webpack 4 #101

Edit

Merged ept merged 1 commit into automerger:master from salzhrani:webpack4 on 22 Jun 2018

Conversation 3

Commits 1

Checks 0

Files changed 3

+626 -348



salzhrani commented on 18 Jun 2018

The bundle is a few KB smaller

Upgrade to webpack 4

bfd3878



ept reviewed on 21 Jun 2018

View changes

webpack.config.js

```

9      - path: path.resolve(__dirname, 'dist')
10     + path: path.resolve(__dirname, 'dist'),
11     + // https://github.com/webpack/webpack/issues/6525
12     + globalObject: 'this'

```



ept on 21 Jun 2018 Member

@salzhrani Just to understand what's going on, could you explain what this globalObject declaration means? Is the intention that we change it when webpack/webpack#6525 is implemented?

Reviewers



ept

Assignees

No one—assign yourself

Labels

None yet

Projects

None yet

Milestone

No milestone

Notifications

Unsubscribe

## 4. Seamless collaboration

- Google Docs style (real-time collaborative editing, if online)
- Git pull request / GDocs suggestions (asynchronous collaboration, review + accept/reject)
- No conflicts: automatic merging (when several users edit concurrently)



...martin/dev/cl/automerger/test/backend_test_LOCAL_3486.js	...rtin/dev/cl/automerger/test/backend_test_BASE_3486.js	...martin/dev/cl/automerger/test/backend_test_REMOTE_3486.js
5 const ROOT_ID = '00000000-0000-0000-0000-00000000'	6* const ROOT_ID = '00000000-0000-0000-0000-00000000'	6 const ROOT_ID = '00000000-0000-0000-0000-00000000'
6	7	7
7 describe('Backend', () => {	8* describe('Automerger.Backend', () => {	8 describe('Automerger.Backend', () => {
8 describe('incremental diffs', () => {	9* describe('incremental diffs', () => {	9 describe('incremental diffs', () => {
9 it('should assign to a key in a map', () => {	10 it('should assign to a key in a map', () => {	10 it('should assign to a key in a map', () => {
10 const actor = uuid()	11 const actor = uuid()	11 const actor = uuid()
11 const changel = {actor, seq: 1, deps: {},	12* const changel: Change = {	12 const changel: Change = {
12	13* actor,	13 actor,
13	14* seq: 1,	14 seq: 1,
14	15* deps: {},	15 deps: {},
15	16* ops: [	16 ops: [
16	17* {	17 {
17	18* action: 'set',	18 action: 'set',
18 {action: 'set', obj: ROOT_ID, key: 'bird'	19* obj: ROOT_ID,	19 obj: ROOT_ID,
19	20* key: 'bird',	20 key: 'bird',
20	21* value: 'magpie',	21 value: 'magpie',
21	22* } as Op,	22 } as Op,
22	23* ]	23 ],
23	24* }	24 }
24	25* const s0 = Backend.init()	25 const s0 = Backend.init()
25 const [s1, patch1] = Backend.applyChanges(s	26 const [s1, patch1] = Backend.applyChanges(s	26 const [s1, patch1] = Backend.applyChanges(s
26 assert.deepEqual(patch1, {	27 assert.deepEqual(patch1, {	27 assert.deepEqual(patch1, {
27 canUndo: false, canRedo: false, clock: {	28 canUndo: false, canRedo: false, clock: {	28 canUndo: false,
28	29	29 canRedo: false,
29	30	30 clock: { [actor]: 1 },
30	31	31 deps: { [actor]: 1 },
31	32	32 diffs: [
32	33	33 {
33	34	34 action: 'set',
34	35	35 obj: ROOT_ID,
35	36	36 path: [],
36	37	37 type: 'map',
37	38	38 key: 'bird',
38	39	39 value: 'magpie',
39	40	40 } as Diff,
40	41	41 ],
41	42	42 })
42	43	43 })
43	44	44
44	45	45 it('should increment a key in a map', () => {
45	46	46 const actor = uuid()
46	47	47 const changel: Change = {
47	48	48 actor,
48	49	49 seq: 1,
49		

Changes: 17; Conflicts: 35

Reference View (Files as Loaded) Edit View (Merge Result)

Ruleset: \_Default\_ default

2019-04 you own your data

Search

**Favourites**

- AirDrop
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- martin
- Desktop
- Documents
- Downloads
- Dropbox

**iCloud**

- iCloud Drive

**Locations**

- Remote Di...

**Tags**

- Orange

Name	Date Modified
cuneiform.jpg	16 Jan 2019 at 13:57
evernote-conflict.png	Today at 15:53
images	Today at 15:58
local-first (chardonneret.local's conflicted copy 2019-04-12).html	Today at 16:04
local-first.html	Today at 16:04
there-is-no-cloud.png	14 Jan 2019 at 17:06
world-ping-times.png	Yesterday at 10:38
world-ping-times.svg	Yesterday at 12:02

2 of 8 selected, 659.63 GB available



# Conflicting Changes (2019-04-12 14:48:57 +...)

1 note



**Notes from Security Protocols Worksho...**

Steven Murdoch (with Alexander Hicks): If you devise rules for reasoning about the confidence or likelihood of things, such that the rules are intuitiv...

12/04/2019

Created: 11 Apr 2019 Updated: 12 Apr 2019

## Notes from Security Protocols Workshop (SPW) 2019

Steven Murdoch (with Alexander Hicks):

- If you devise rules for reasoning about the confidence or likelihood of things, such that the rules are intuitively sensible and internally consistent, you inevitably end up with something looking very much like the standard laws of probability, including Bayes' rule. Reference: first chapter of E.T. Jaynes, "Probability theory: the logic of science". Cambridge University Press, 2003.
- Criminal cases are different from civil cases: in civil cases, the judge must make their decision based on the law, regardless of whether they think the law is reasonable or not. In criminal cases, the jury is allowed to disregard a law if they think the law is stupid.
- When a court case requires certainty "beyond reasonable doubt" for a conviction, you might think that you want  $P(\text{guilty} | \text{evidence}) > 0.99$  or something like that. But that is problematic, partly because computing that probability requires a prior

## 5. Long-term preservation

- Internet Archive can preserve 1980s Amiga software, but not 2010s web apps (unless the server is open source)



# Software Library

The Internet Archive Software Library is the ultimate software crate-digger's dream: Tens of thousands of playable software titles from multiple computer platforms, allowing instant access to decades of computer history in your browser through the JSMESS [MORE](#)

- Share
- Favorite
- Play All

ABOUT

COLLECTION

109,826 RESULTS

SORT BY **VIEWS** — TITLE — DATE ARCHIVED — CREATOR

Search this Collection

- Metadata
- Text contents

Media Type

- collections 95
- software 108,332
- movies 1,281
- texts 88
- data 23
- images 5

[More](#)

Year

- 2019 366
- 2018 851
- 2017 1,417
- 2016 587
- 2015 452
- 2014 205

[More](#)

Topics & Subjects

- msdos 4,136

The Software Library: MS-DOS

16,487 ITEMS

Software Library: MS-DOS Games

4,334 ITEMS

Historical Software Collection

69 ITEMS

Oregon Trail, The

by MECC

5.8M 0 287

The Software Library: ZX Spectrum

12,259 ITEMS

ZX Spectrum Library: Games

9,623 ITEMS

The Software Library: Apple Computer

25,466 ITEMS

Software Library: Windows 3.x

1,999 ITEMS

Prince of Persia

by Jul 29, 2014

1.5M 0 45

4:00

Oregon Trail Deluxe, The

1.1M 0 123





October  
2019

## Google Hangouts

Sentenced to death in 6 months, Google Hangouts was a communication platform which included messages, video chat, and VOIP features. Execution date is tentative. It was over 6 years old.



August  
2019

## Works with Nest API

"Off with their heads!" in 4 months, Works with Nest was an API that allowed external services to access and control Nest devices. This enabled the devices to be used with third-party home automation platforms and devices. It was about 5 years old.



May  
2019

## Google Cloud Messaging (GCM)

Sentenced to death in 14 days, Google Cloud Messaging (GCM) was a notification service that enabled developers to send messages between servers and client apps running on Android or Chrome. It was almost 7 years old.



2015 - 2019

## Inbox by Gmail

Killed about 1 month ago, Inbox by Gmail aimed to improve email through several key features. It was almost 4 years old.



2011 - 2019

## Google+

Killed about 1 month ago, Google+ was an Internet-based social network. It was almost 8 years old.



2009 - 2019

## Google URL Shortener

Killed about 2 months ago, Google URL Shortener, also known as goo.gl, was a URL shortening service. It was over 9 years old.



2016 - 2019

## Google Allo

Killed 2 months ago, Google Allo was an instant messaging mobile app for Android, iOS, and Web with special features like a virtual assistant and encrypted mode. It was rebranded as Google Chat. It was over 2 years old.



2015 - 2019

## Google Notification Widget (Mr. Jingles)

Killed 2 months ago, Mr. Jingles (aka Google Notification Widget) displayed alerts and notifications from across multiple Google services. It was almost 4 years old.



2008 - 2019

## YouTube Video Annotations

Killed 4 months ago, YouTube Video Annotations allowed video creators to add interactive commentary to their videos containing background information, branching ("choose your own adventure" style) stories, or links to any YouTube video, channel, or search results page. It was over 10 years old.

<https://killedbygoogle.com>

# Myspace loses 'over 50 million songs' from website after server migration project goes wrong

Once-popular social network was used by millions of bands and singers to share their music

**Roisin O'Connor** Music Correspondent | @Roisin\_OConnor | Monday 18 March 2019 10:43 | |



Click to follow  
The Independent Culture

**Myspace** has reportedly lost more than 50 million songs after a server migration project went awry.

The once-popular **social networking site** was used as a platform for bands to share their music, and was behind the discovery and success of artists like **Arctic Monkeys**, Lily Allen, Kate Nash, **Adele** and **Bring Me the Horizon**.

However, last year fans noticed the music links on the site had stopped working. Despite an initial promise to solve the issue, Myspace has now issued a statement on its website saying a backlog of files has been lost.



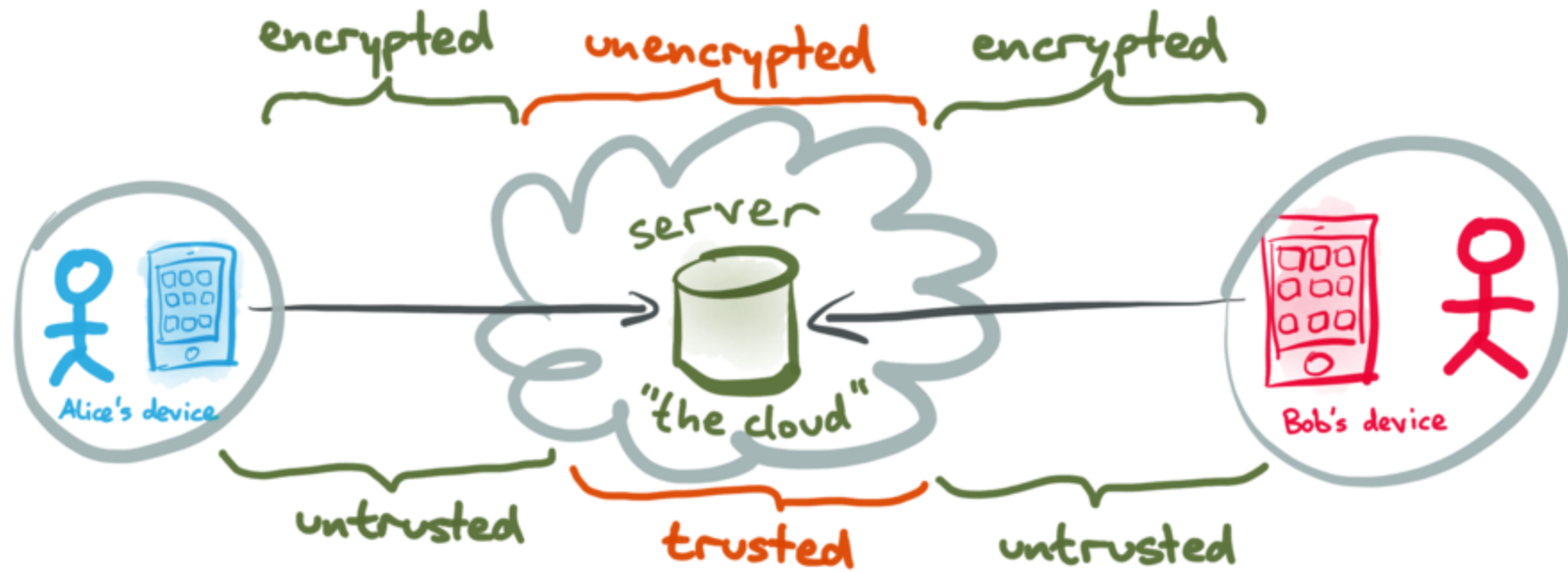
Cuneiform script on clay tablet, ca. 3000 BCE (image from Wikimedia Commons)

## 5. Long-term preservation

- Internet Archive can preserve 1980s Amiga software, but not 2010s web apps (unless the server is open source)
- "Our Incredible Journey" (Tumblr)
- Will we still be able to access our data in 10/20/50/200 years?
- "Digital Dark Age" (Vint Cerf)

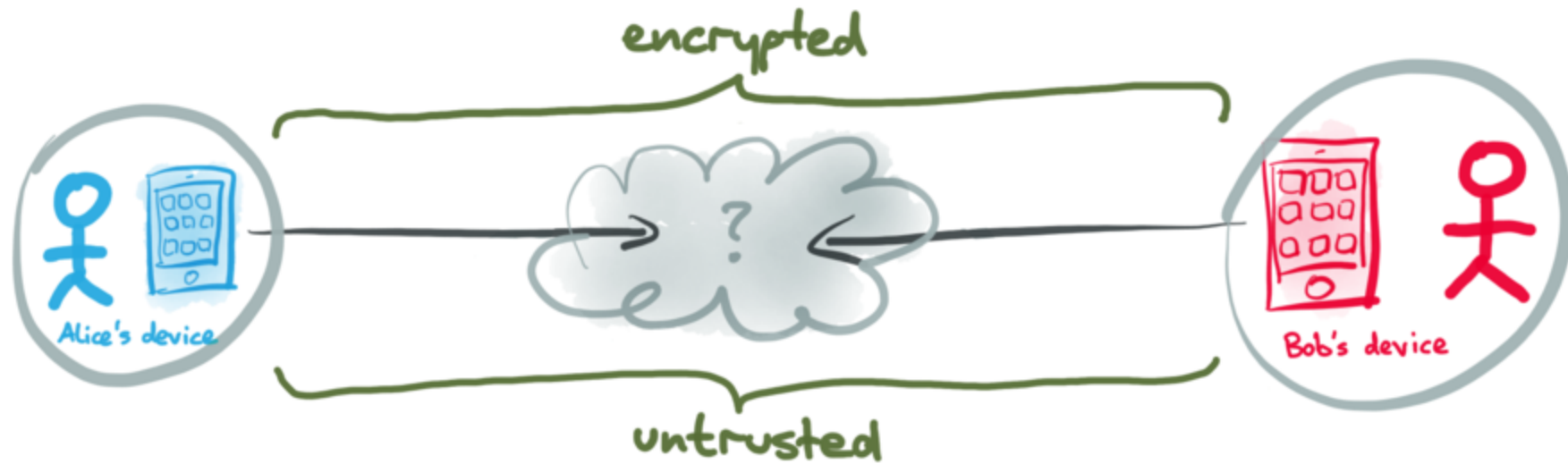
# 6. Security and privacy

https://... (TLS/SSL)



## 6. Security and privacy

### End-to-end encryption



# 7 IDEALS OF LOCAL-FIRST

1. Fast - no spinners

2. Multi-device

3. Works offline

4. Seamless collaboration

5. Long-term preservation

6. Security & privacy

7. User control

	1. Fast	2. Multi-device	3. Offline	4. Collaboration	5. Longevity	6. Security	7. User control
Email attachments	✓	—	✓	✗	✓	—	✓
Google Docs	—	✓	—	✓	—	✗	—
Dropbox	✓	—	—	✗	✓	—	✓
Git + GitHub	✓	—	✓	—	✓	—	✓
Web app (thin client)	✗	✓	✗	✓	✗	✗	✗
Firebase/Realm	—	✓	✓	—	✗	✗	✗
CouchDB	—	—	✓	✗	—	—	—



Example: Text editing



"Hello!"



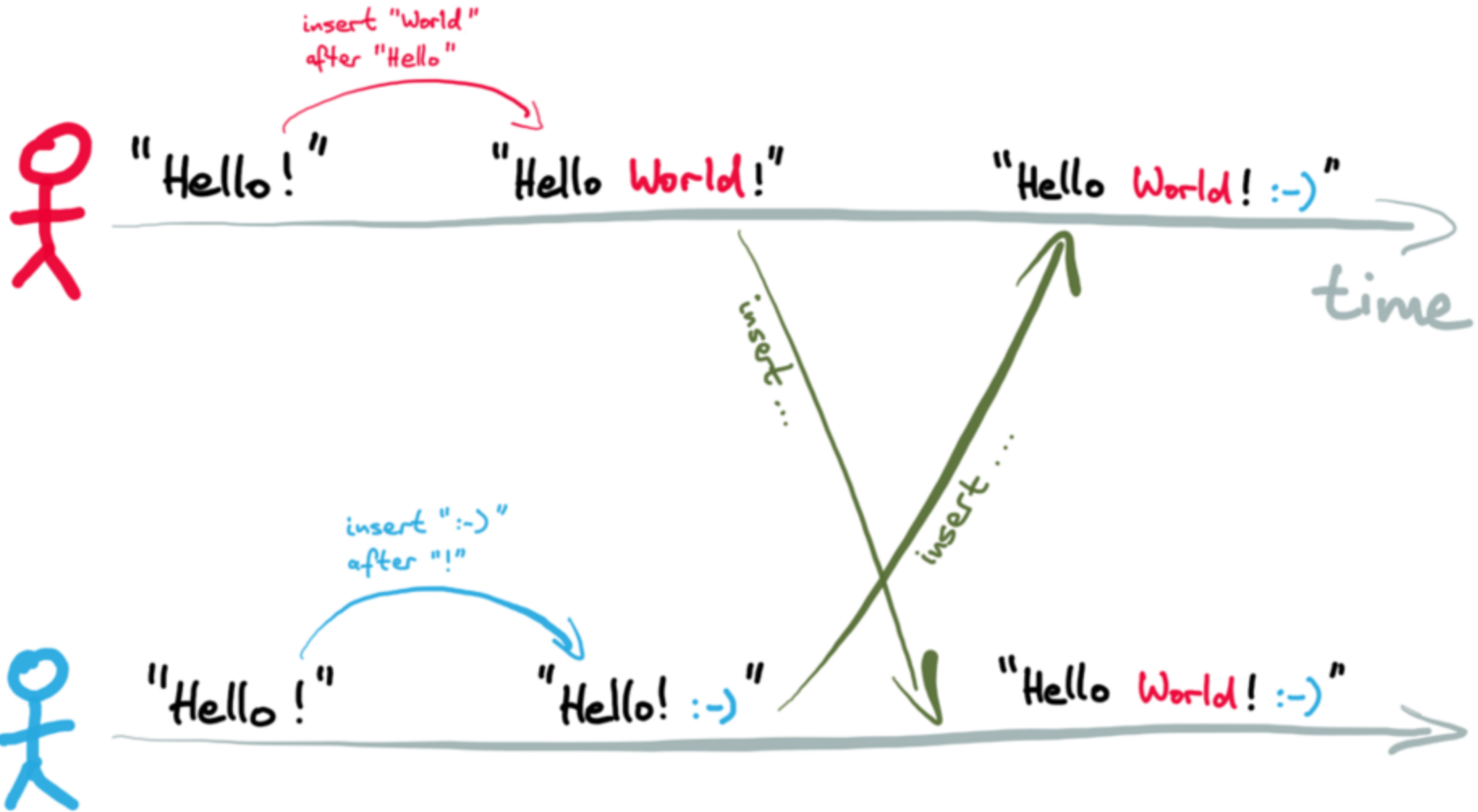
"Hello!"



## Example: Text editing



# Example: Text editing



"EVENTUAL CONSISTENCY" ?

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- eventual delivery

(eventually, every op seen by every node)

asynchronous: may deliver in any order

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## - eventual delivery

(eventually, every op seen by every node)

asynchronous: may deliver in any order

## - convergence

(seen same ops  $\Rightarrow$  have same state)

# "EVENTUAL CONSISTENCY" ?

## - eventual delivery

(eventually, every op seen by every node)

asynchronous: may deliver in any order

## - convergence

(seen same ops  $\Rightarrow$  have same state)

## - don't lose data

(otherwise it's easy 😊)

# Algorithms for convergence

---

## OPERATIONAL TRANSFORMATION (OT)

- e.g. Google Docs,  
MS Office Online

1989-2006

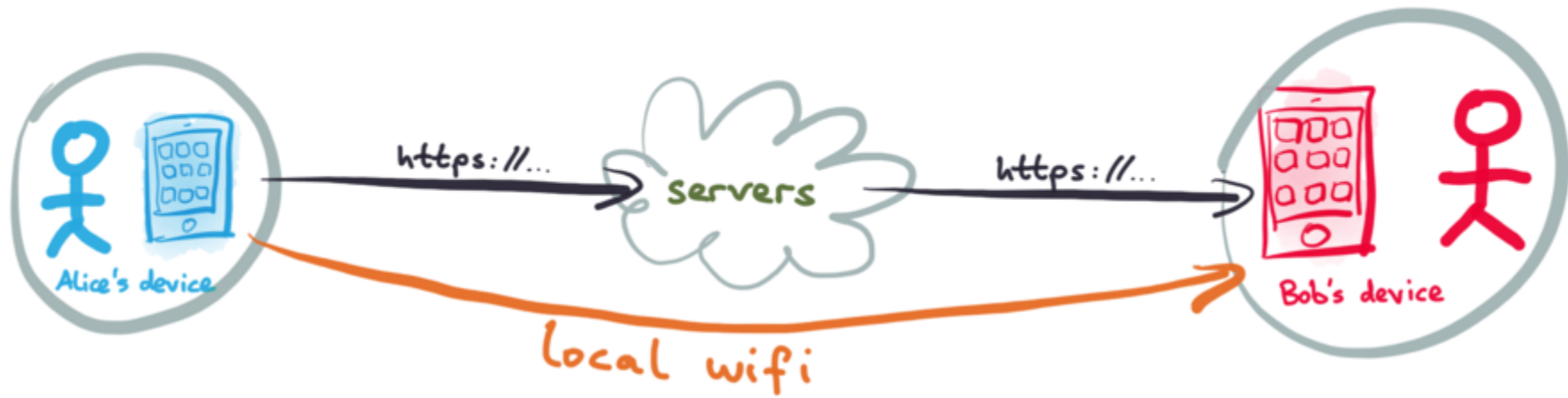
## CONFLICT-FREE REPLICATED DATA TYPES (CRDTs)

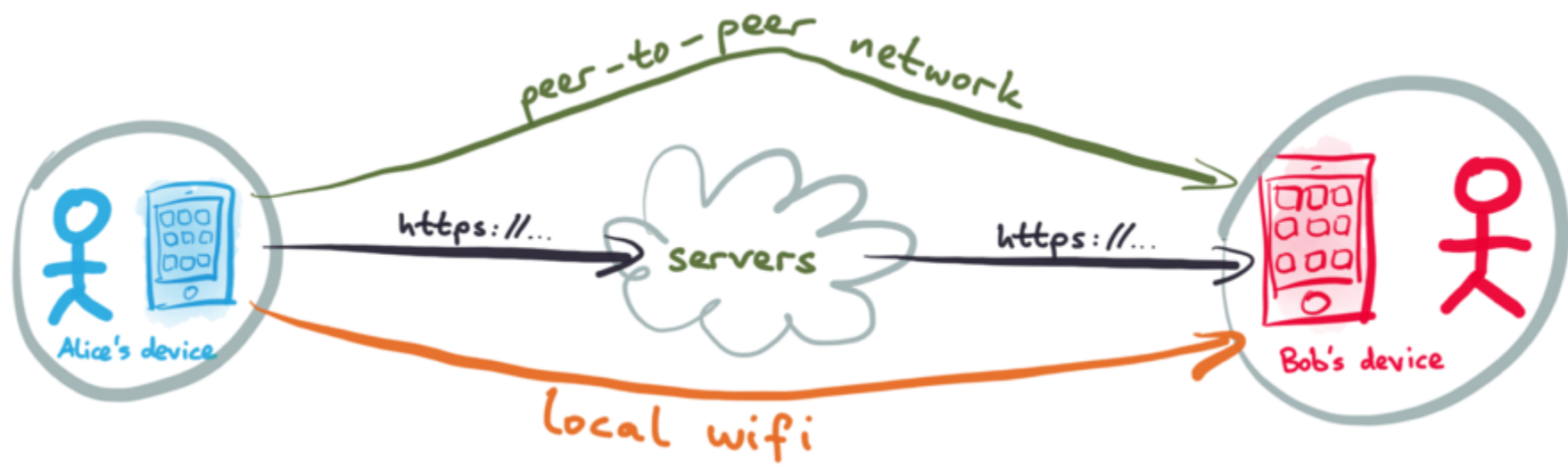
- e.g. Riak, TomTom GPS,  
Teletype for Atom, ...

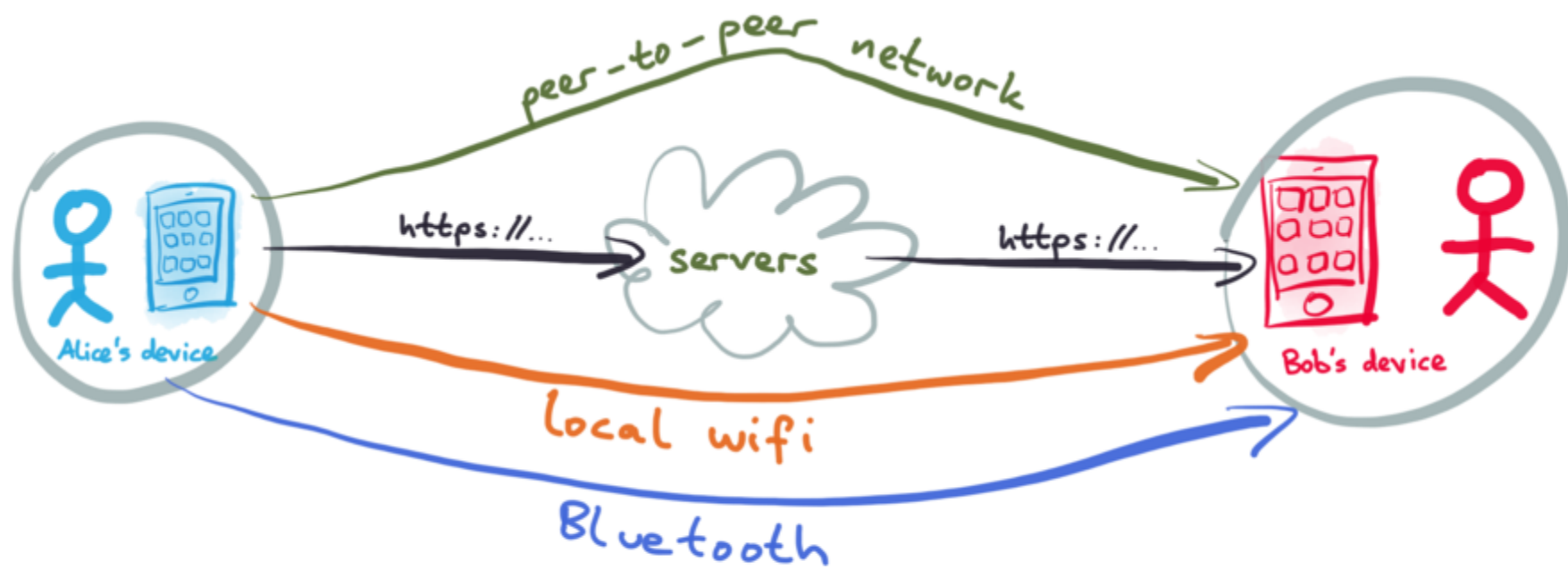
2006 - present

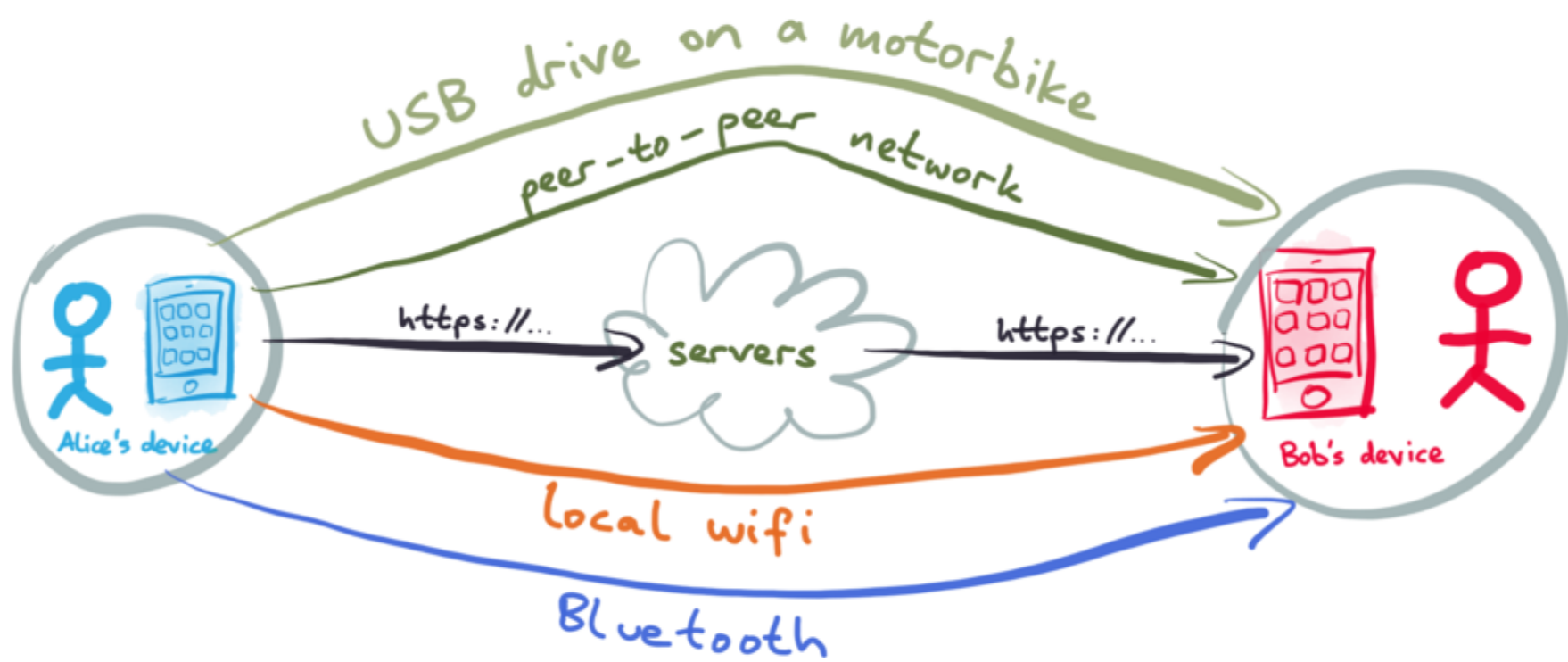


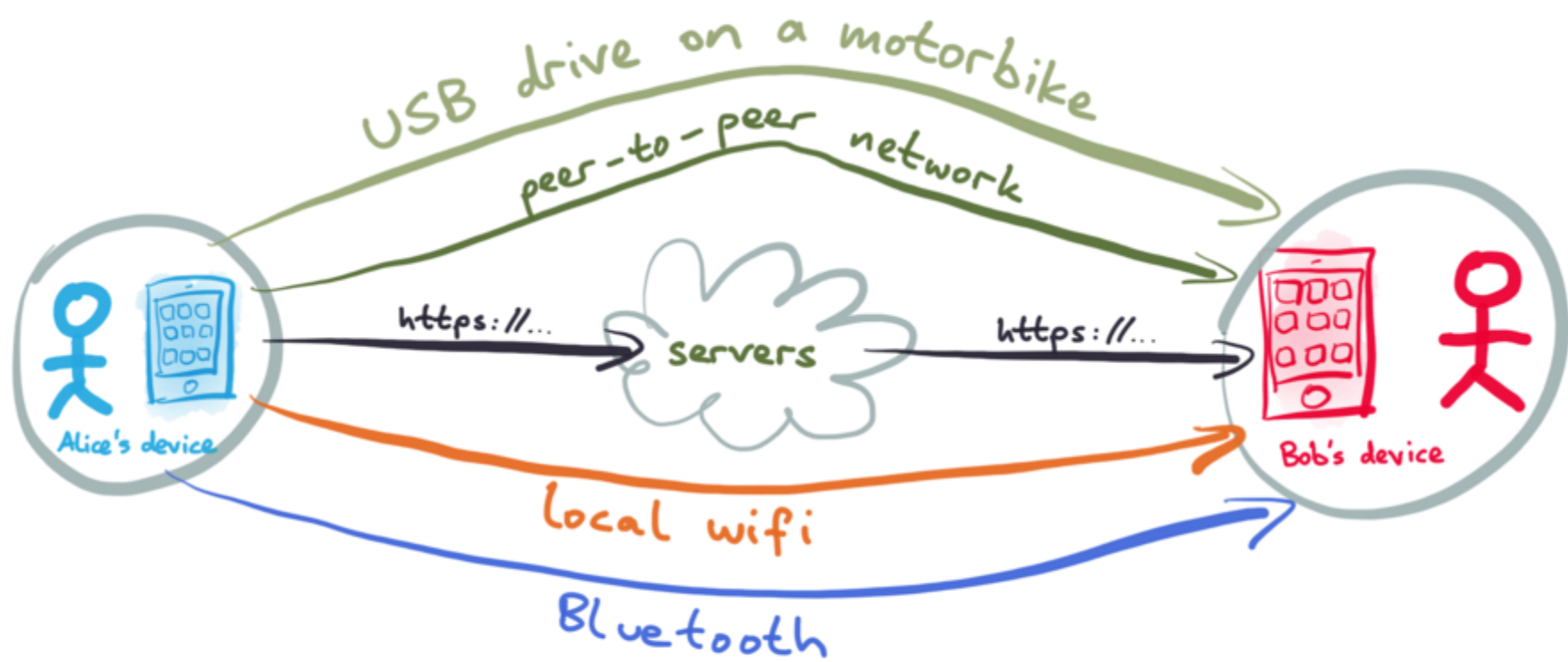












Reducing dependence on trusted servers:

1. End-to-end encryption
2. Collaboration entirely without servers

# PROVING CRDTs CORRECT

RGA

ORSet

Counter

...

STRONG EVENTUAL CONSISTENCY (SEC)

NETWORK MODEL



# PROVING CRDTs CORRECT



assumptions

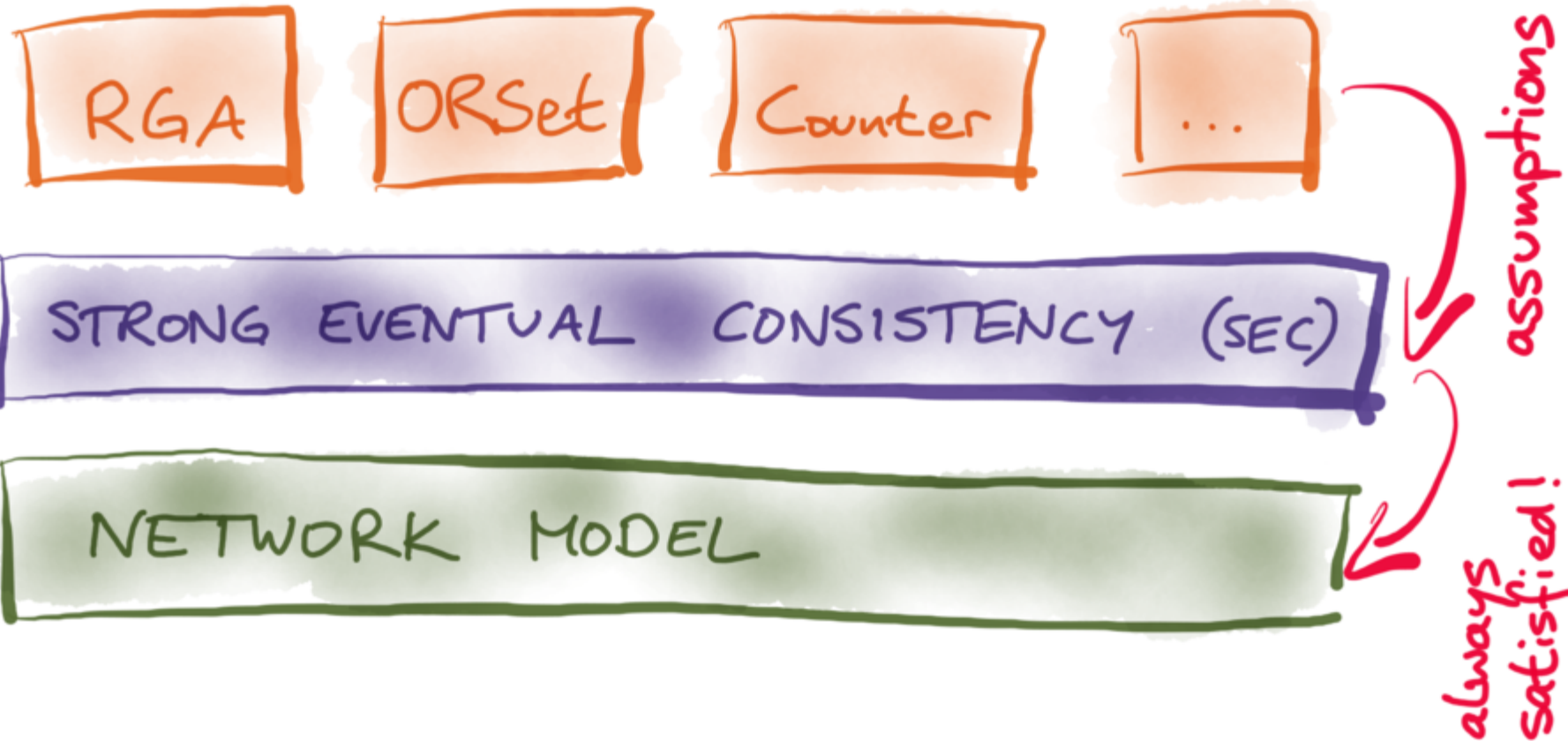
STRONG EVENTUAL CONSISTENCY (SEC)

NETWORK MODEL





# PROVING CRDTs CORRECT



For details, see our paper at <https://doi.org/10.1145/3133933>

Victor B. F. Gomes, Martin Kleppmann, Dominic P. Mulligan, and Alastair R. Beresford:  
Verifying Strong Eventual Consistency in Distributed Systems. PACMPL 1(OOPSLA), 2017.



# — CONCURRENT CHANGES —

```
{ todos: [  
  { title: "Water plants",  
    done: false }  
]}
```

```
{ todos: [  
  { title: "Water plants",  
    done: false }  
]}
```

# CONCURRENT CHANGES

```
{ todos: [  
  { title: "Water plants",  
    done: false }  
]}
```



```
doc.todos.push ({  
  title: "Buy milk",  
  done: false  
})
```

```
{ todos: [  
  { title: "Water plants",  
    done: false }  
]}
```



```
doc.todos[0].done = true
```

# — CONCURRENT CHANGES —

```
doc.todos.push ({  
  title: "Buy milk",  
  done: false  
})
```

```
doc.todos[0].done = true
```

# — CONCURRENT CHANGES —

```
doc.todos.push ({  
  title: "Buy milk",  
  done: false  
})
```

↓

```
{ todos: [  
  { title: "Water plants",  
    done: false },  
  { title: "Buy milk",  
    done: false }  
]}
```

```
doc.todos[0].done = true
```

↓

```
{ todos: [  
  { title: "Water plants",  
    done: true }  
]}
```

# — CONCURRENT CHANGES —

```
doc.todos.push ({
  title: "Buy milk",
  done: false
})
```

```
doc.todos[0].done = true
```

network communication

```
{ todos: [
  { title: "Water plants",
    done: true },
  { title: "Buy milk",
    done: false }
]}
```

```
{ todos: [
  { title: "Water plants",
    done: true },
  { title: "Buy milk",
    done: false }
]}
```

# — CONCURRENT CHANGES —

doc.contents =  
Text("Hello!")

doc.contents =  
Text("Hello!")

# — CONCURRENT CHANGES —

doc.contents =  
Text("Hello!")



doc.contents  
.insertAt(5, "World")

doc.contents =  
Text("Hello!")



doc.contents  
.insertAt(6, " :-)")



# — CONCURRENT CHANGES —

doc.contents =  
Text("Hello!")



doc.contents  
.insertAt(5, "world")



"Hello world!"

doc.contents =  
Text("Hello!")



doc.contents  
.insertAt(6, " :-)")



"Hello! :-)"

# CONCURRENT CHANGES

doc.contents =  
Text("Hello!")

doc.contents =  
Text("Hello!")

doc.contents  
.insertAt(5, "world")

doc.contents  
.insertAt(6, " :-)")

"Hello world!"

"Hello! :-)"

"Hello world! :-)"

"Hello world! :-)"



# — CONCURRENT CHANGES —

doc.todos[0].deadline  
= "2019-07-10"

doc.todos[0].deadline  
= "2019-07-14"

# — CONCURRENT CHANGES —

```
doc.todos[0].deadline  
= "2019-07-10"
```



```
{todos: [  
  {title: "Water plants",  
    done: false,  
    deadline: "2019-07-10"  
  }  
]}
```

```
doc.todos[0].deadline  
= "2019-07-14"
```



```
{todos: [  
  {title: "Water plants",  
    done: false,  
    deadline: "2019-07-14"  
  }  
]}
```

# CONCURRENT CHANGES

`doc.todos[0].deadline`  
`= "2019-07-10"`

`doc.todos[0].deadline`  
`= "2019-07-14"`

network communication

{ todos: [  
 { title: "Water plants",  
 done: false,  
 deadline: "2019-07-10",  
 \_conflicts: { deadline:  
 { 1234: "2019-07-14" }  
 }  
 }  
]}

{ todos: [  
 { title: "Water plants",  
 done: false,  
 deadline: "2019-07-10",  
 \_conflicts: { deadline:  
 { 1234: "2019-07-14" }  
 }  
 }  
]}

{title: "Water plants", done: false}

---

{op: "makeMap", id: "1a"}

{op: "assign", id: "2a", obj: "1a", key: "title", value: "Water plants", overwrites: []}

{op: "assign", id: "3a", obj: "1a", key: "done", value: false, overwrites: []}

{title: "Water plants", done: false}

---

{op: "makeMap", id: "1a"}  
{op: "assign", id: "2a", obj: "1a", key: "title", value: "Water plants", overwrites: []}  
{op: "assign", id: "3a", obj: "1a", key: "done", value: false, overwrites: []}

{title: "Water plants", done: false}

---

{op: "makeMap", id: "1a"}

{op: "assign", id: "2a", obj: "1a", key: "title", value: "Water plants", overwrites: []}

{op: "assign", id: "3a", obj: "1a", key: "done", value: false, overwrites: []}

---

doc.todos[0].done = true

---

{op: "assign", id: "4a", obj: "1a", key: "done", value: true, overwrites: ["3a"]}



{title: "Water plants", done: false}

---

{op: "makeMap", id: "1a"}

{op: "assign", id: "2a", obj: "1a", key: "title", value: "Water plants", overwrites: []}

{op: "assign", id: "3a", obj: "1a", key: "done", value: false, overwrites: []}

---

doc.todos[0].done = true

---

{op: "assign", id: "4a", obj: "1a", key: "done", value: true, overwrites: ["3a"]}

`doc.todos[0].deadline = "2019-07-10"`

---

`{op: "assign", id: "5a", obj: "1a", key: "deadline", value: "2019-07-10",  
overwrites: []}`

---

`doc.todos[0].deadline = "2019-07-14"`

---

`{op: "assign", id: "5b", obj: "1a", key: "deadline", value: "2019-07-14",  
overwrites: []}`

doc.todos[0].deadline = "2019-07-10"

---

{op: "assign", id: "5a", obj: "1a", key: "deadline", value: "2019-07-10",  
overwrites: []}

---

doc.todos[0].deadline = "2019-07-14"

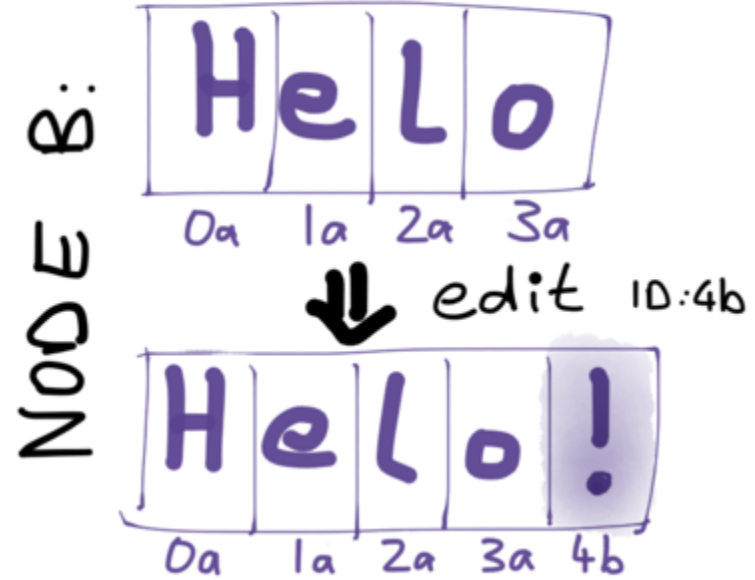
---

{op: "assign", id: "5b", obj: "1a", key: "deadline", value: "2019-07-14",  
overwrites: []}

# ORDERED LIST CRPT (NUTSHELL)



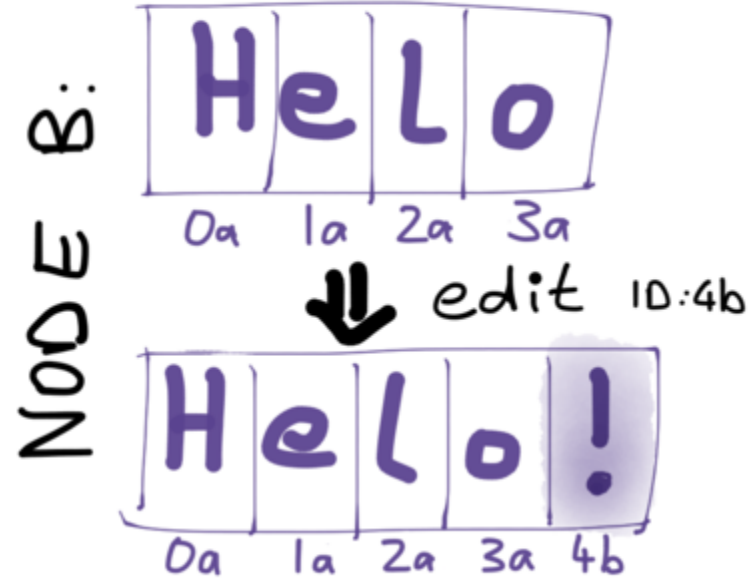
# ORDERED LIST CRDT (NUTSHELL)



# ORDERED LIST CRDT (NUTSHELL)



insert "l"  
with id 4a  
after id 2a

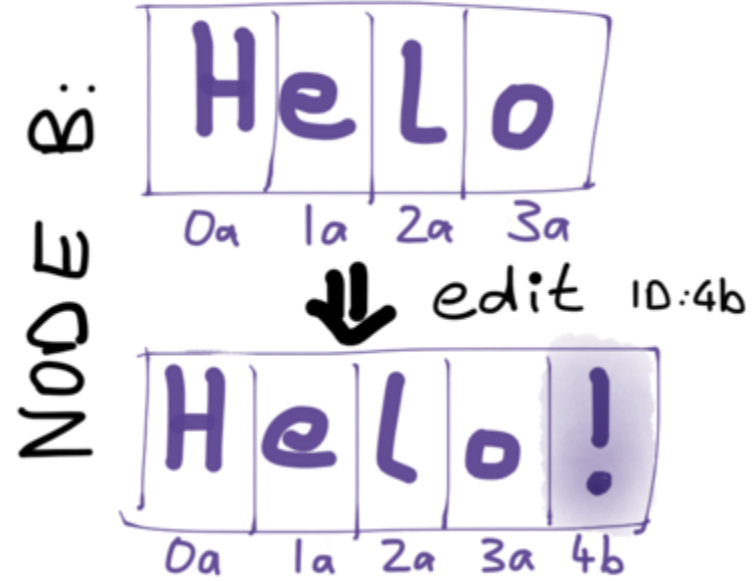


insert "!" with  
id 4b after id 3a

# ORDERED LIST CRDT (NUTSHELL)



insert "L"  
with id 4a  
after id 2a



insert "!" with  
id 4b after id 3a

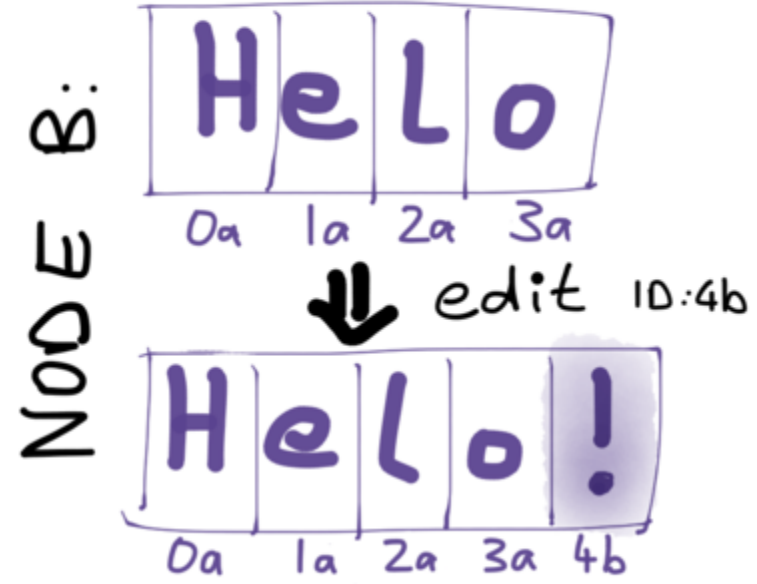
insert "L" with  
id 4a after id 2a



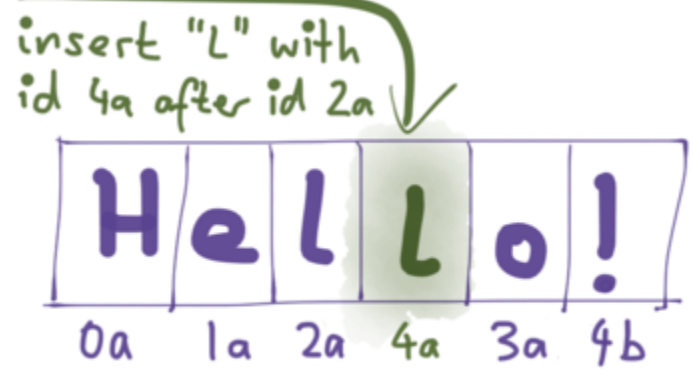
# ORDERED LIST CRDT (NUTSHELL)



insert "L"  
with id 4a  
after id 2a



insert "!" with  
id 4b after id 3a



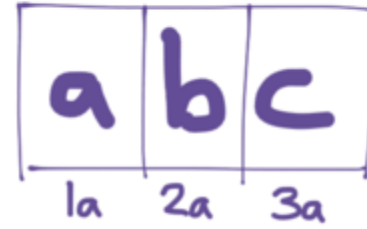
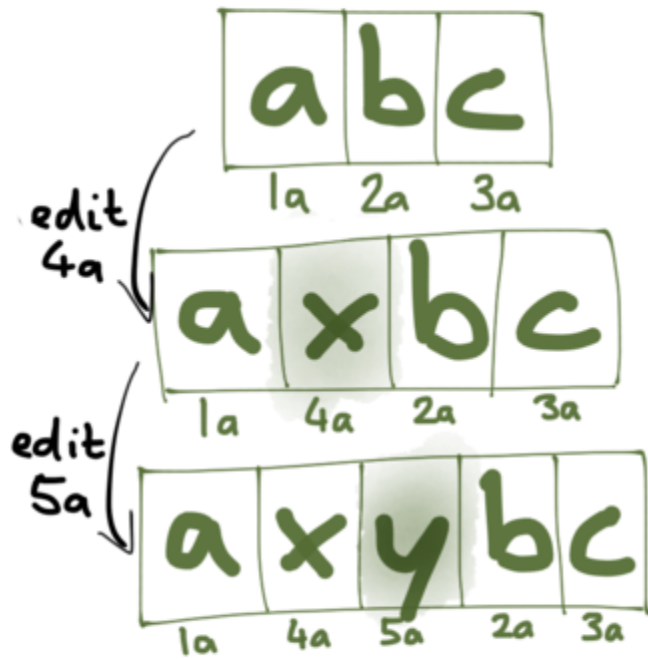


# INSERTING IN THE SAME PLACE

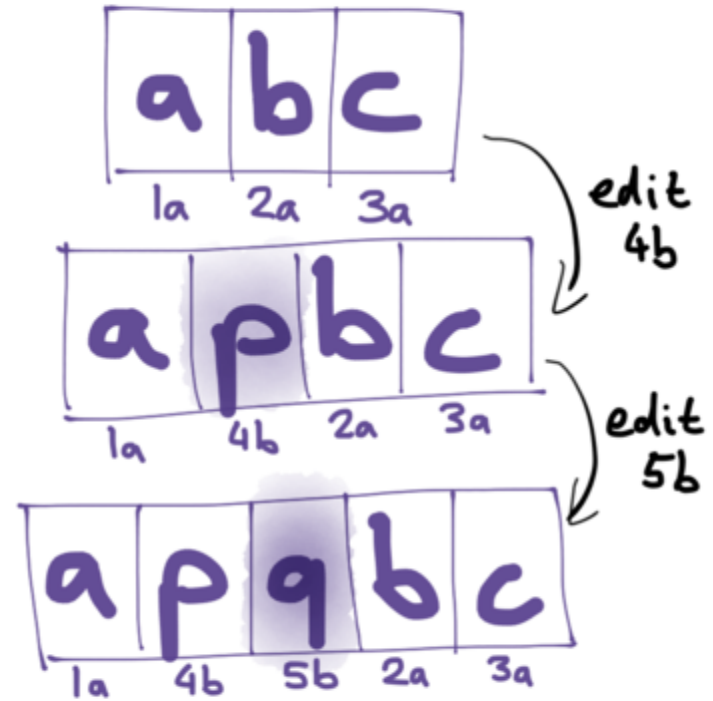
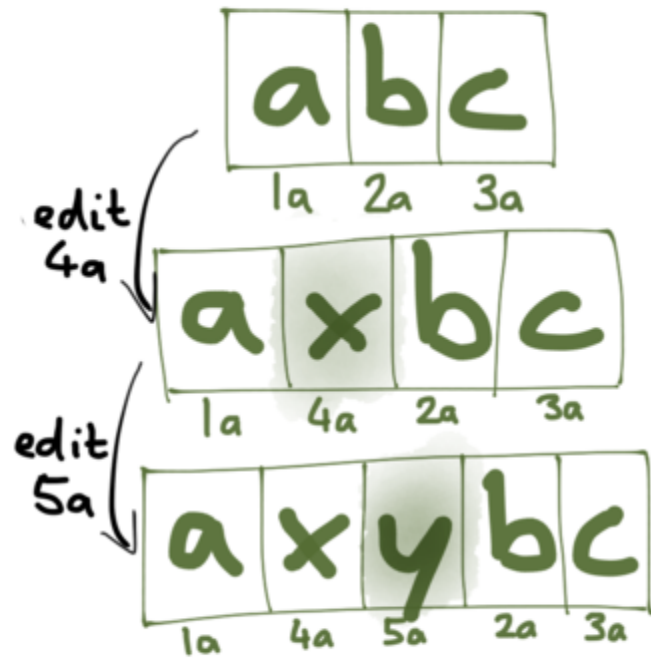
a	b	c
1a	2a	3a

a	b	c
1a	2a	3a

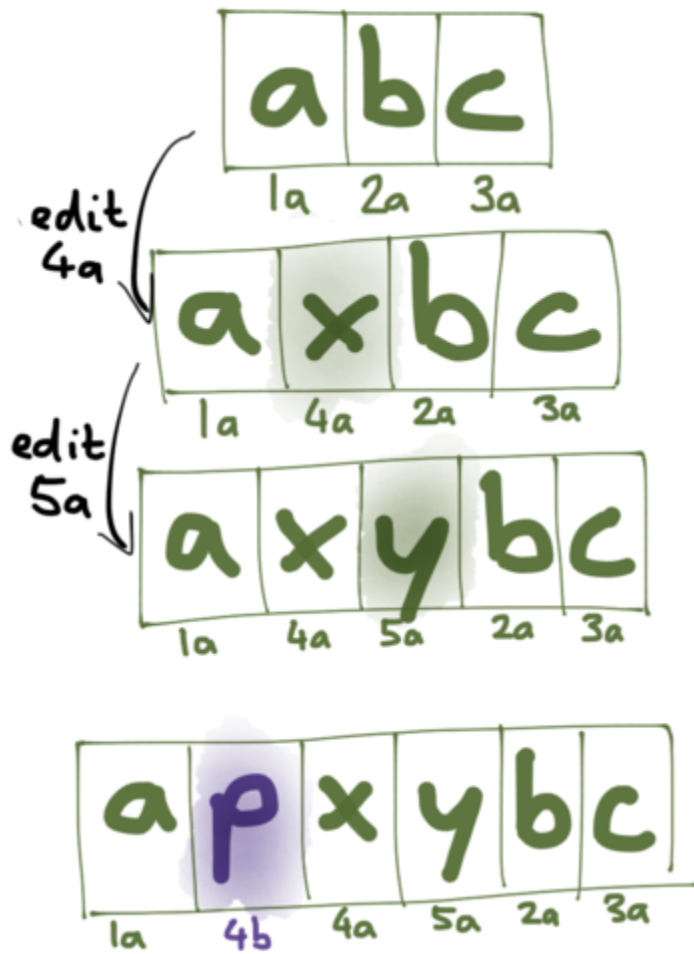
# INSERTING IN THE SAME PLACE



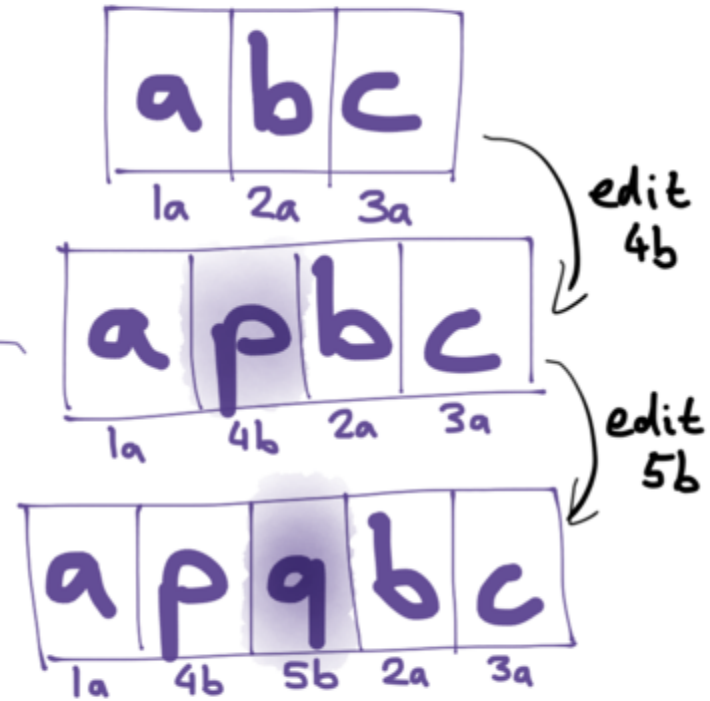
# INSERTING IN THE SAME PLACE



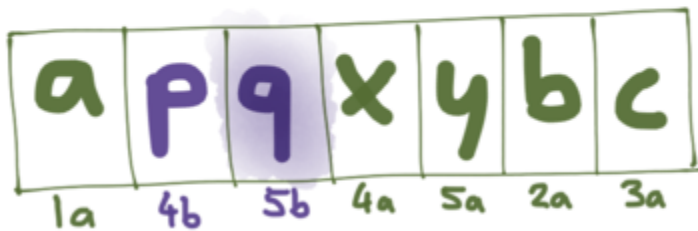
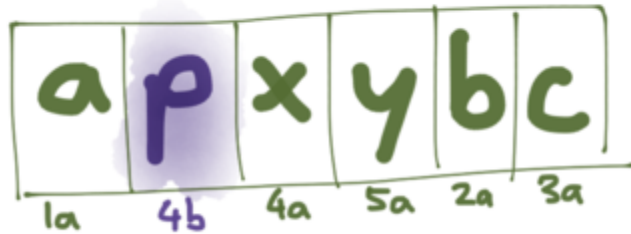
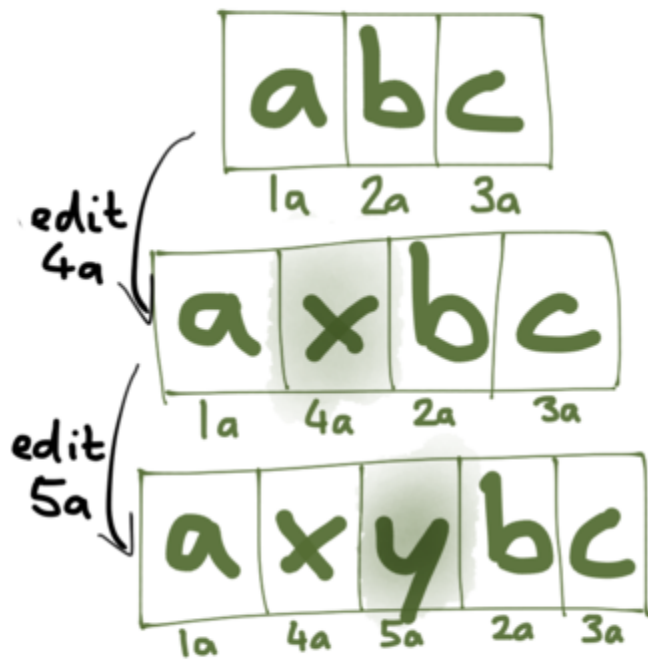
# INSERTING IN THE SAME PLACE



insert "p"  
with id 4b  
after id 1a

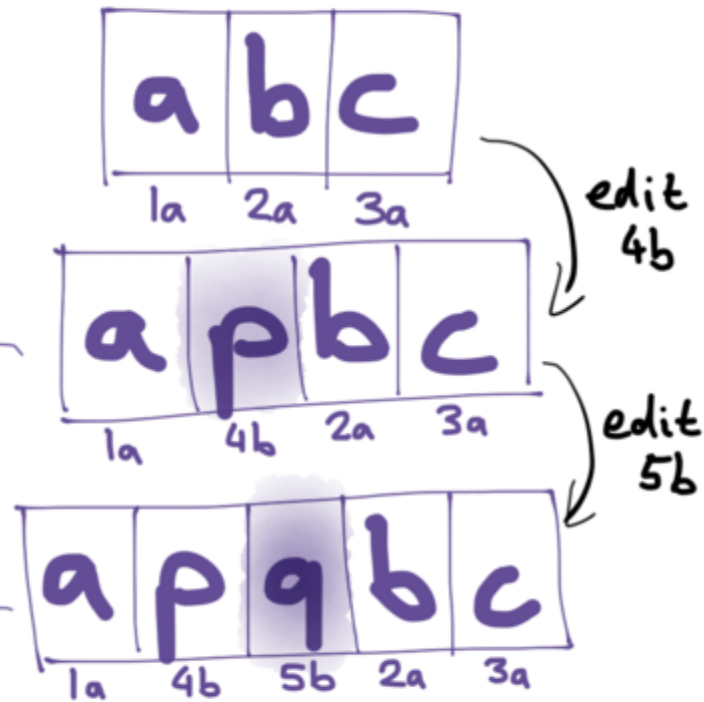


# INSERTING IN THE SAME PLACE

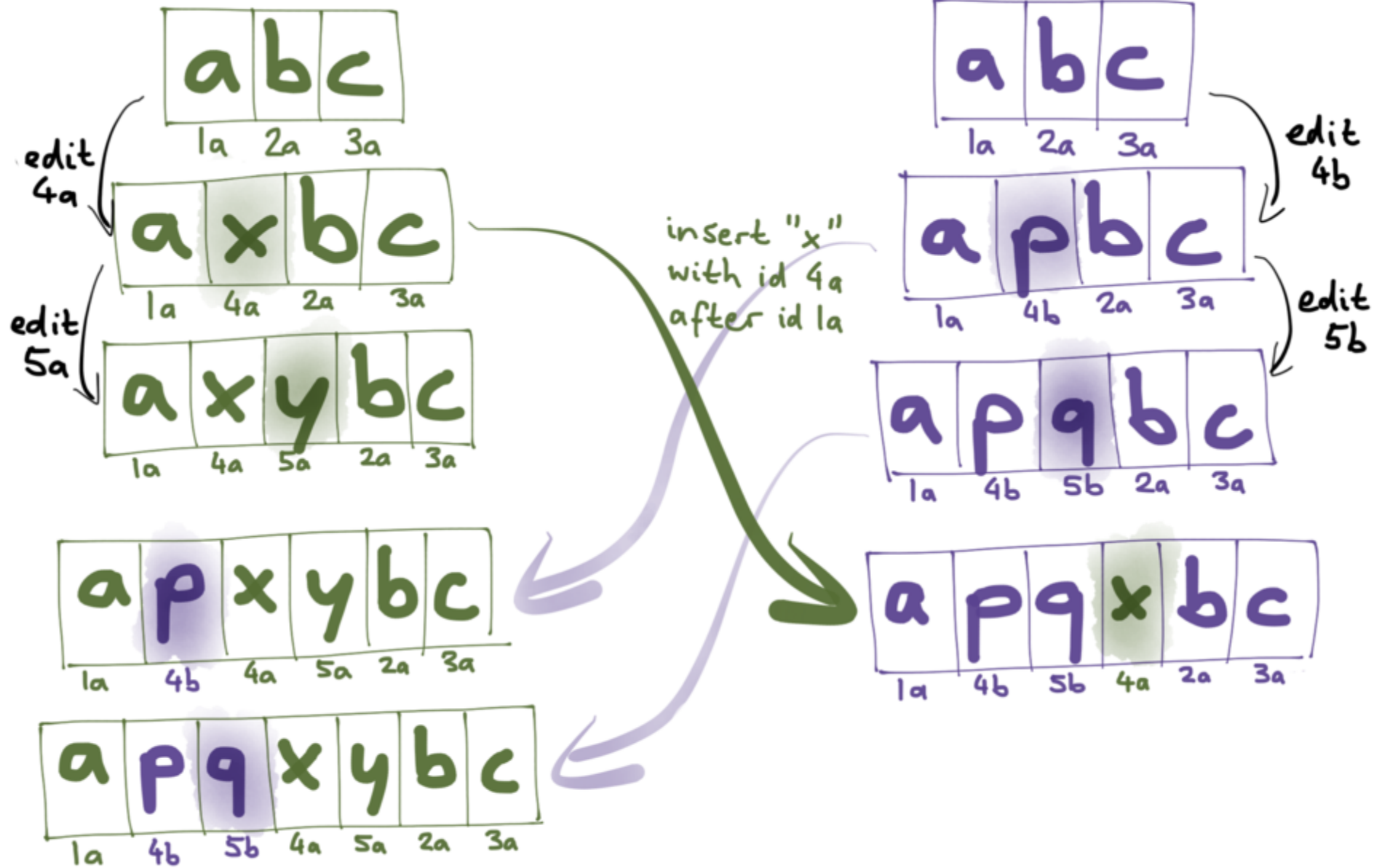


insert "p"  
with id 4b  
after id 1a

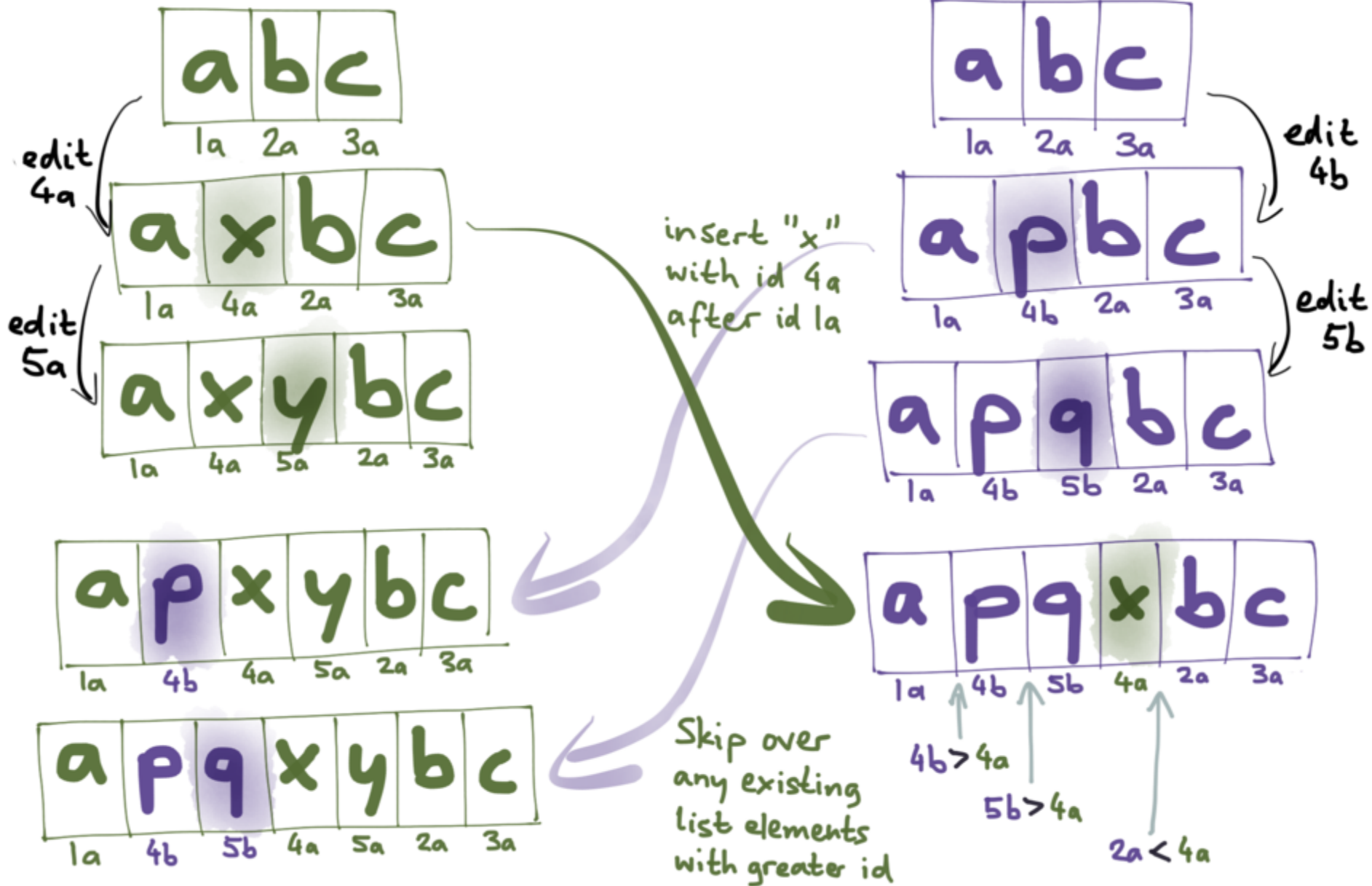
insert "q"  
with id 5b  
after id 4b



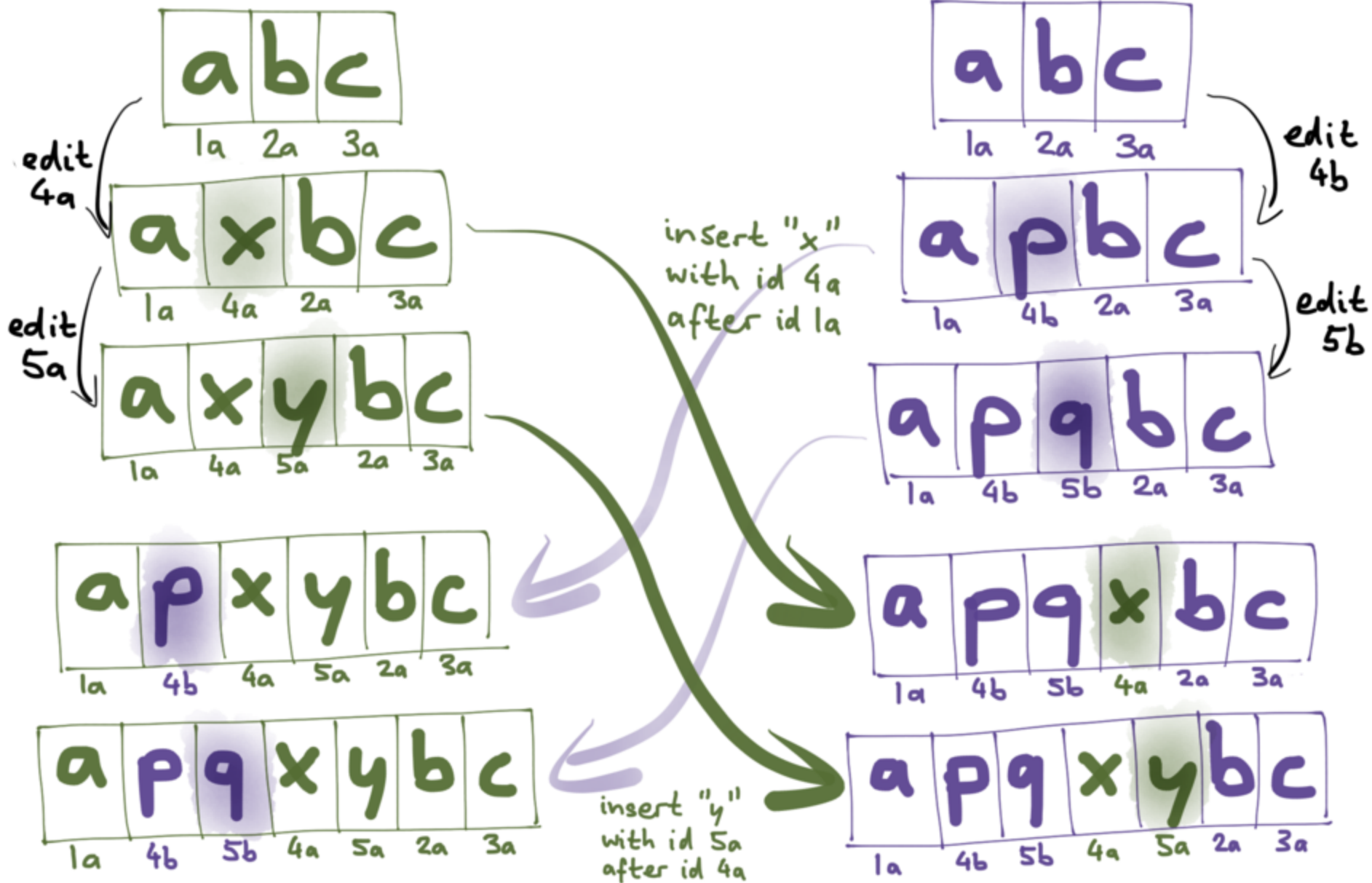
# INSERTING IN THE SAME PLACE



# INSERTING IN THE SAME PLACE



# INSERTING IN THE SAME PLACE





`doc.text.insertAt(4, "!")`

---

`{op: "insert", id: "4b", obj: "0a", after: "3a", value: "!"}`

---

`doc.text.deleteAt(4)`

---

`{op: "remove", id: "5b", obj: "0a", removes: ["4b"]}`

doc.text.insertAt(4, "!")

---

{op: "insert", id: "4b", obj: "0a", after: "3a", value: "!"}

---

doc.text.deleteAt(4)

---

{op: "remove", id: "5b", obj: "0a", removes: ["4b"]}

`doc.todos.unshift("Water plants")`

---

`{op: "insert", id: "4b", obj: "0a", after: "head", value: "Water plants"}`

---

`doc.todos.moveItem(0, 4)`

---

`{op: "insert", id: "5b", obj: "0a", after: "3a", moves: "4b"}`

doc.todos.unshift("Water plants")

---

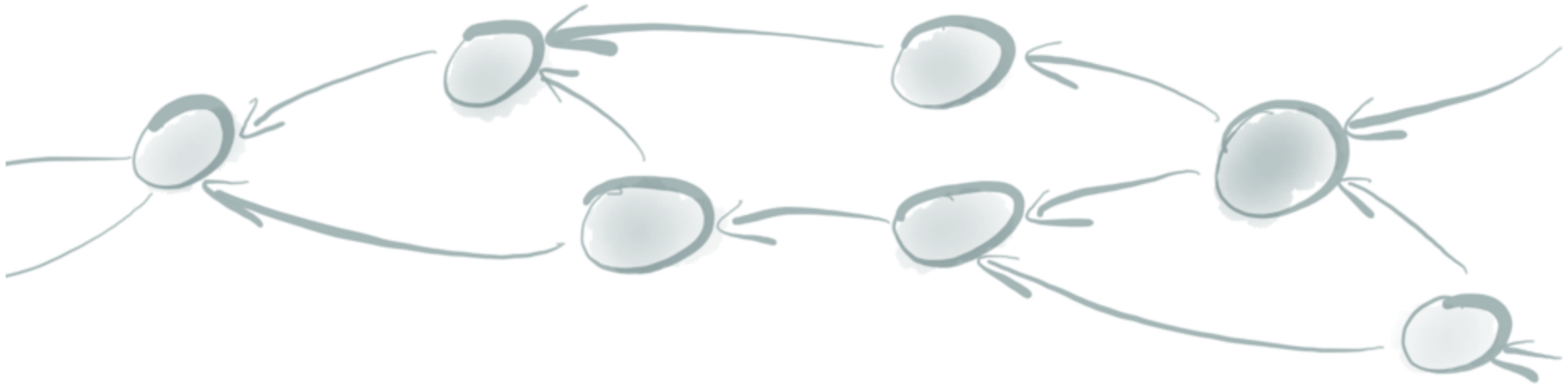
{op: "insert", id: "4b", obj: "0a", after: "head", value: "Water plants"}

---

doc.todos.moveItem(0, 4)

---

{op: "insert", id: "5b", obj: "0a", after: "3a", moves: "4b"}



# Automerge

## **Ink & Switch**

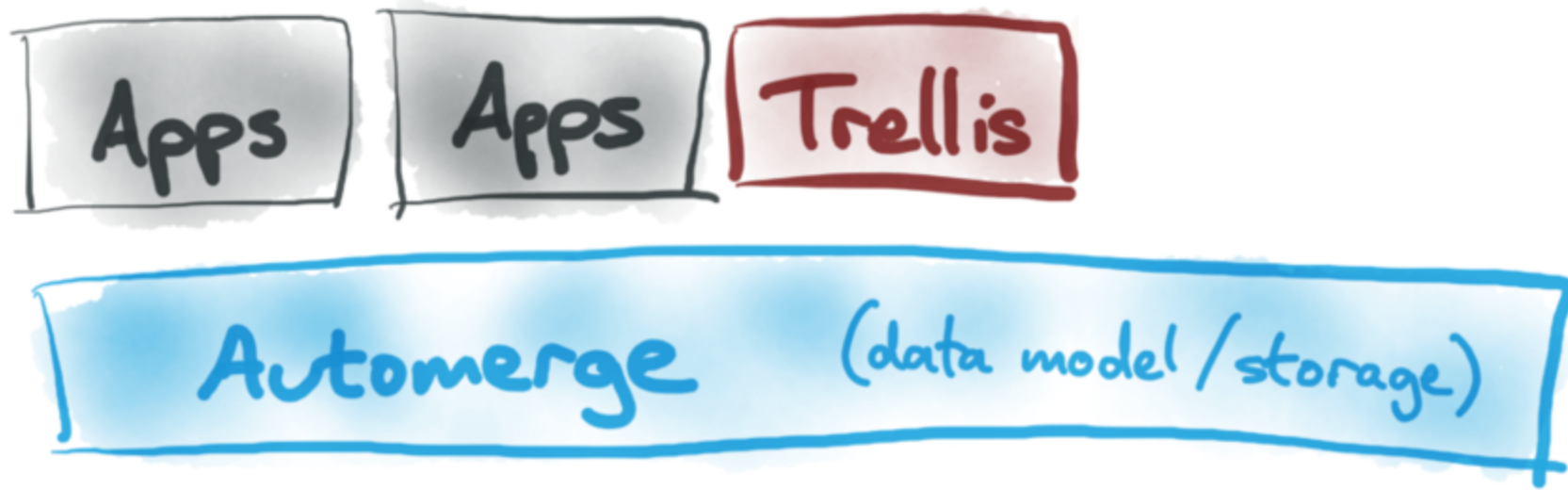
<https://github.com/automerge/automerge>

Automerge

(data model / storage)

Apps Apps

Automerge (data model / storage)



Trellis, a Trello clone based on Automerge: <https://github.com/automerge/trellis>  
Joint work with Orion Henry, Peter van Hardenberg, Roshan Choxi, and Adam Wiggins.



# The Avengers Initiative

## PROSPECTS



## RECRUITING



## JOINED THE TEAM



Spiderman

1

Doctor Strange

Star Lord

Groot


Add a card...

Iron Man



Add a card...

Black Widow



The Hulk

1



Add a card...

## Network



● Introducer localhost:4242

● Bonjour Helicarrier

Peer ID Sent Received

● Nick Fury 60b6

● Natasha dbc0 2 2

## Documents

saffron-cairo-71

**The Avengers Initiative**

Natasha · Nick Fury

silver-istanbul-27

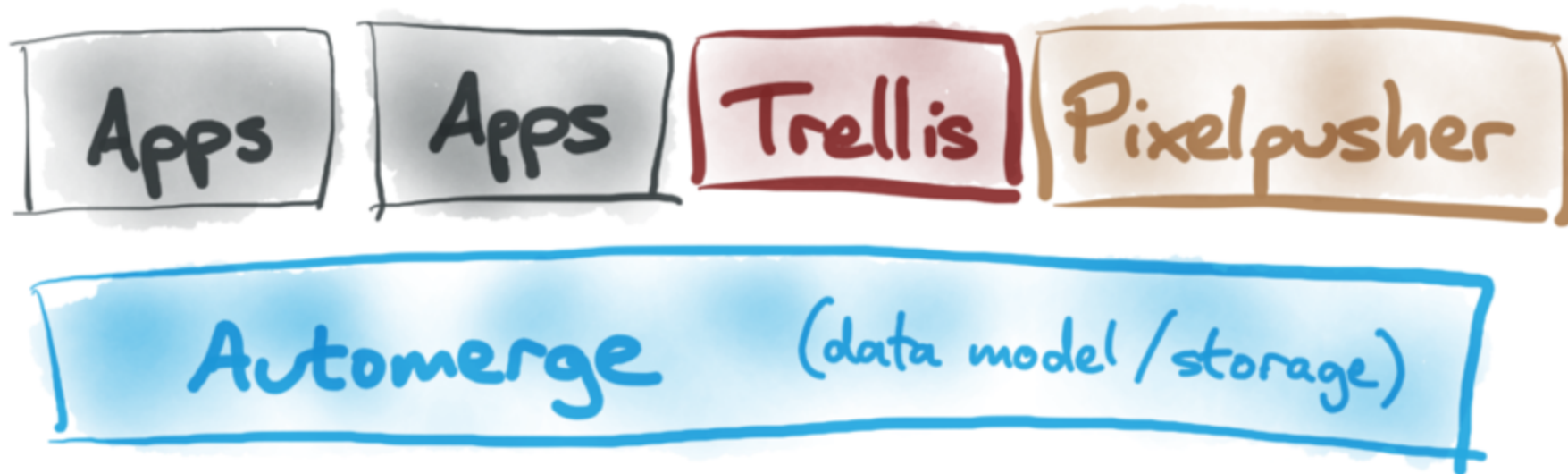
**Brainstorming**

cobalt-moscow-73

**Sprint Planning**

## Changes

- Nick Fury updated board title to **The Avengers Initiative**
- Natasha created card **Groot**
- Natasha created card **Star Lord**
- Nick Fury created card **Doctor Strange**
- Natasha moved **The Hulk** from **Recruiting** → **Joined The Team**
- Natasha added a comment to **The Hulk**
- Nick Fury assigned **The Hulk**



Pixelpusher, a collaborative pixel art editor: <https://github.com/automerge/pixelpusher>  
Created by Javier Valencia, Jeff Peterson, Peter van Hardenberg, and Jim Pick.

# PIXELPUSHER

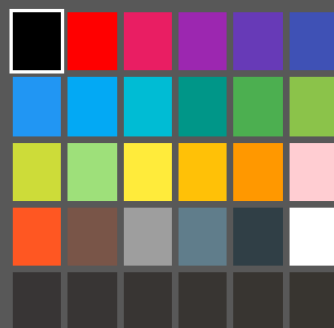
pxlpshr://6ZCp5Yt3YJ5vmFF5hne9Yx4nZJpJpTFWPJoWATa4701X/3JB



Projects

Preview

Reset



Pixel Size

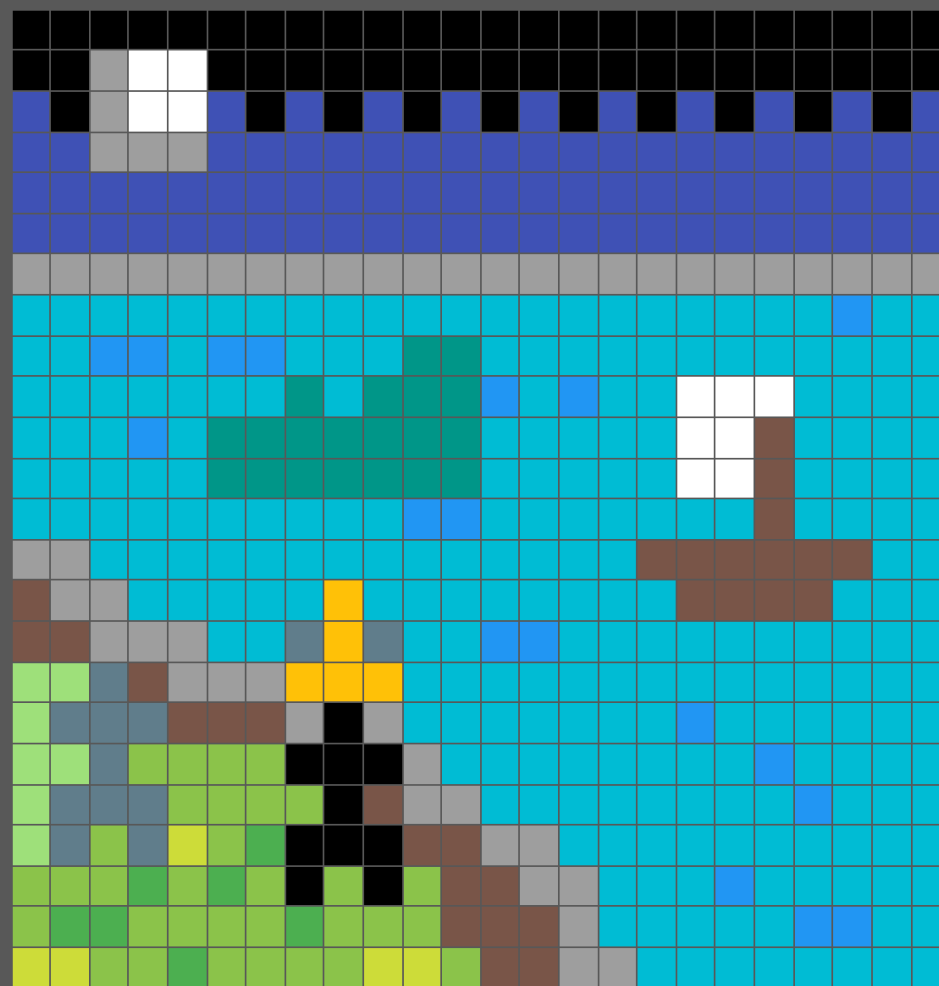
10

Duration

1



## Sailing Midnight

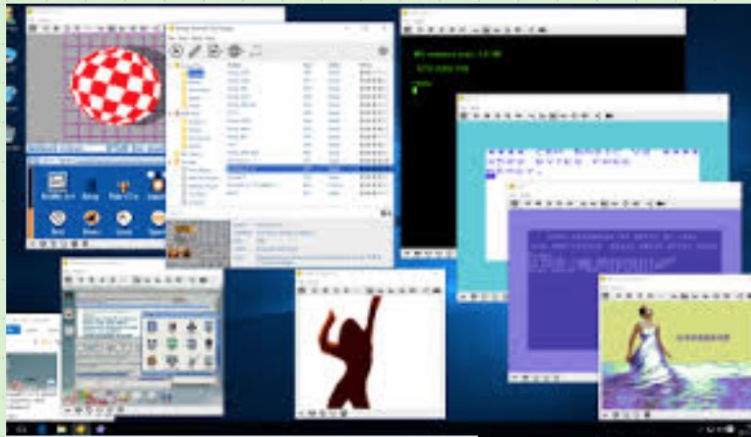


### Versions



### Archivers

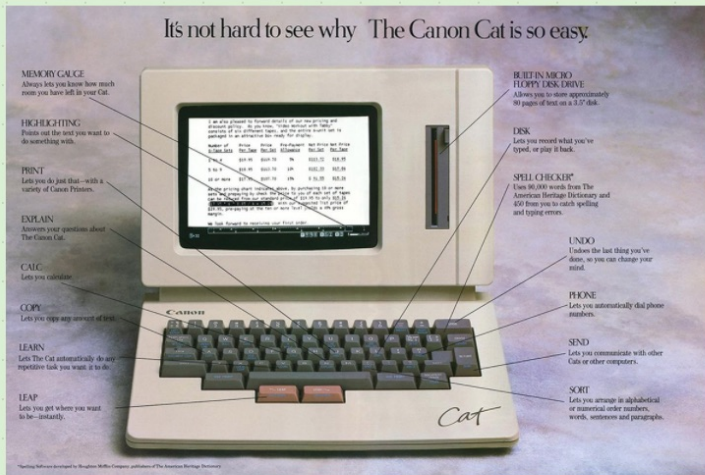




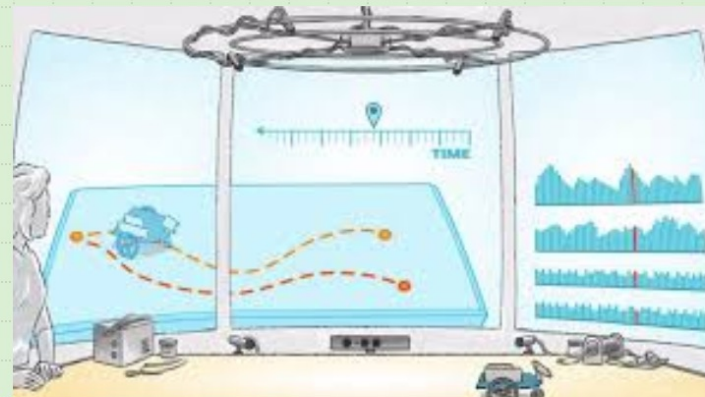
Amiga



BeOS



Canon Cat



Seeing Spaces

Inking

Nested boards

# Berlin Team Summit Venues

1st choice

2nd choice

Hotel Oderburger

7 single rooms for 400 nights  
1000 USD

amenities: high-speed internet, parking, laundry, etc.

location: 15 min to the airport

sweet airplane room

Gerli Apts

cool deck / G

small apartment at Gerli things to do

Small quality apartment, perfect meeting place

Others...

Hotel MANNI

Mon Bijou

SOHO House

Unicorn coworking space

- cool space but smallish
- Obvious room is 1350 + VAT for the week
- not far from mauerpark and that fun stuff but not quite in it, on a somewhat boring / practical street



Ink/erase mode controls

Shelf





MPL, a WebRTC network layer for Automerge: <https://github.com/automerge/mpl>  
Joint work with Orion Henry, Peter van Hardenberg, Roshan Choxi, and Adam Wiggins.



Hypermerge, a peer-to-peer network layer: <https://github.com/automerge/hypermerge>  
Created by Jim Pick, Jeff Peterson, and Peter van Hardenberg.

Apps

Apps

Trellis

Pixelpusher

Automerge (data model / storage)

MPL

Hypermerge

WebSocket  
Client / Server

WebRTC

Hypercore / Dat



# Resources

- Martin's email: [mk428@cl.cam.ac.uk](mailto:mk428@cl.cam.ac.uk)
- Martin on Twitter: [@martinkl](https://twitter.com/martinkl)
- Martin's book: <http://dataintensive.net/>
  
- **Local-first software:** <https://www.inkandswitch.com/local-first.html>
- Automerge: <https://github.com/automerge/automerge>
- Trellis: <https://github.com/automerge/trellis>
- Pixelpusher: <https://github.com/automerge/pixelpusher>
- PushPin: <https://inkandswitch.github.io/pushpin/>
- Capstone: <https://www.inkandswitch.com/capstone-manuscript.html>
- Hypermerge: <https://github.com/automerge/hypermerge>
- Dat / Hypercore: <https://datproject.org/>
- Proving CRDTs correct: <https://doi.org/10.1145/3133933>
- JSON CRDT: <http://arxiv.org/abs/1608.03960>



**Ink & Switch**



dataintensive.net

