Distributed Systems

Spring Semester 2020

Lecture 15: PNUTS

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Why this paper

- Massive Global scale system
- Performance + Flexible Consistency
- Still explicitly designed but less complicated than Google Spanner (also less powerful)

DATABASE FEATURES not KV store based
but uses a Pub Sub communications layer

The Big Picture

Multiple Datacenters in Regions

—

Entire Database replicated

Region 1

Region 2

Region 3

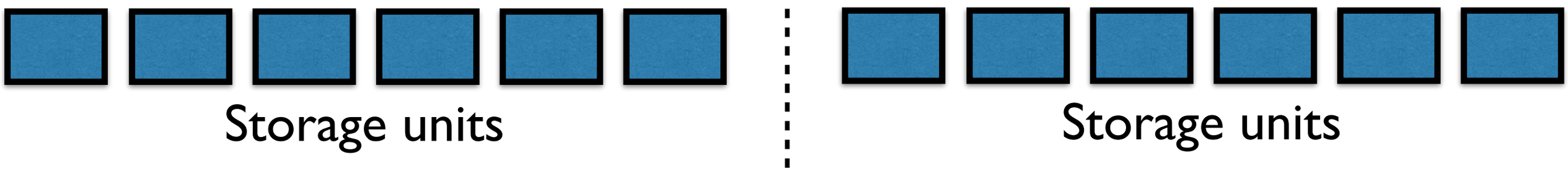
Replication

- GOAL: Make the reads fast!
  - Clients connect to local data center
    - Web app in that data center can do the reads fast — no remote communication
  - BUT reads possible stale
- TRADEOFF: Writes slow!

PNUTS

REGION 1

REGION 2

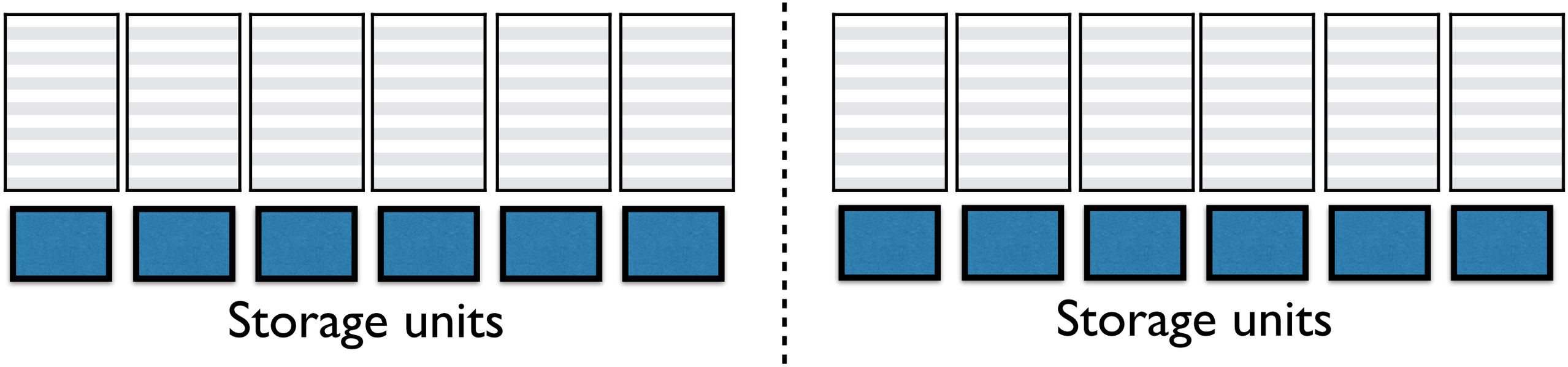


get(), set(), scan()

PNUTS

REGION 1

REGION 2

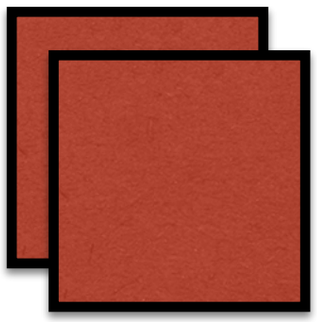


PNUTS

REGION 1

REGION 2

Tablet controller



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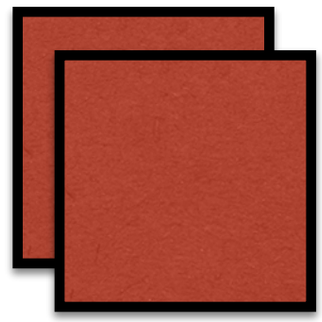
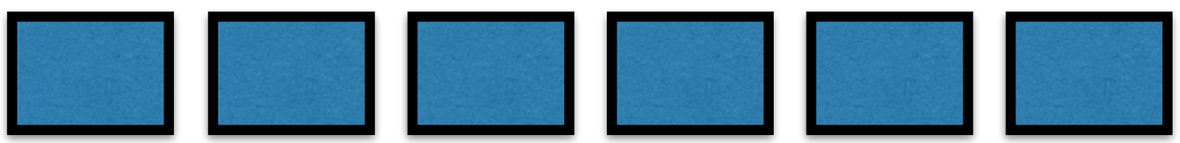
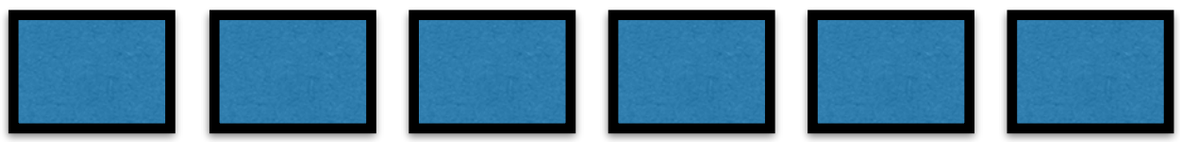


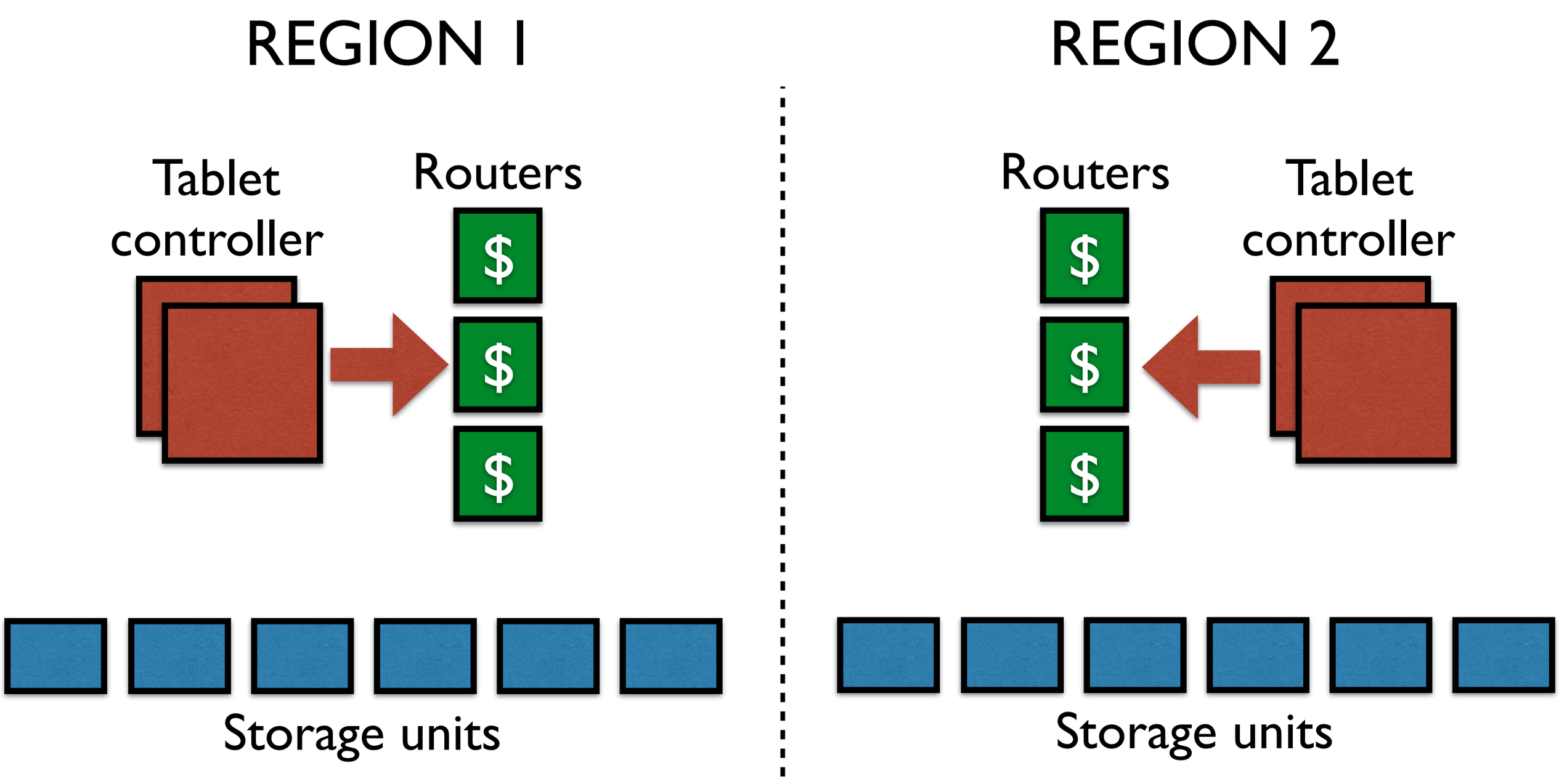


Storage units



Storage units

PNUTS


REGION 1
REGION 2
Tablet controller
Routers
Routers
Tablet controller
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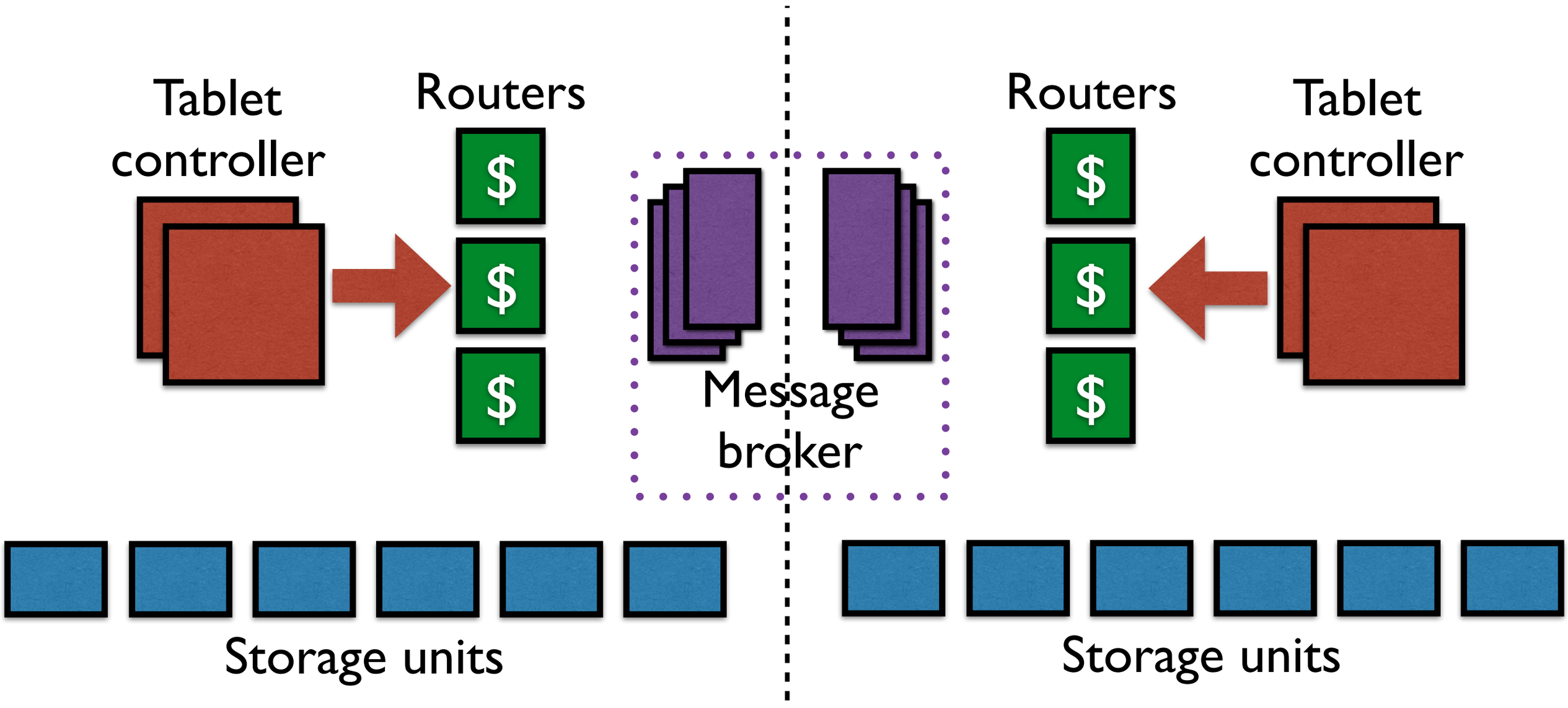
Storage units
Storage units

PNUTS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Message broker
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Tablet controller
Storage units
Storage units

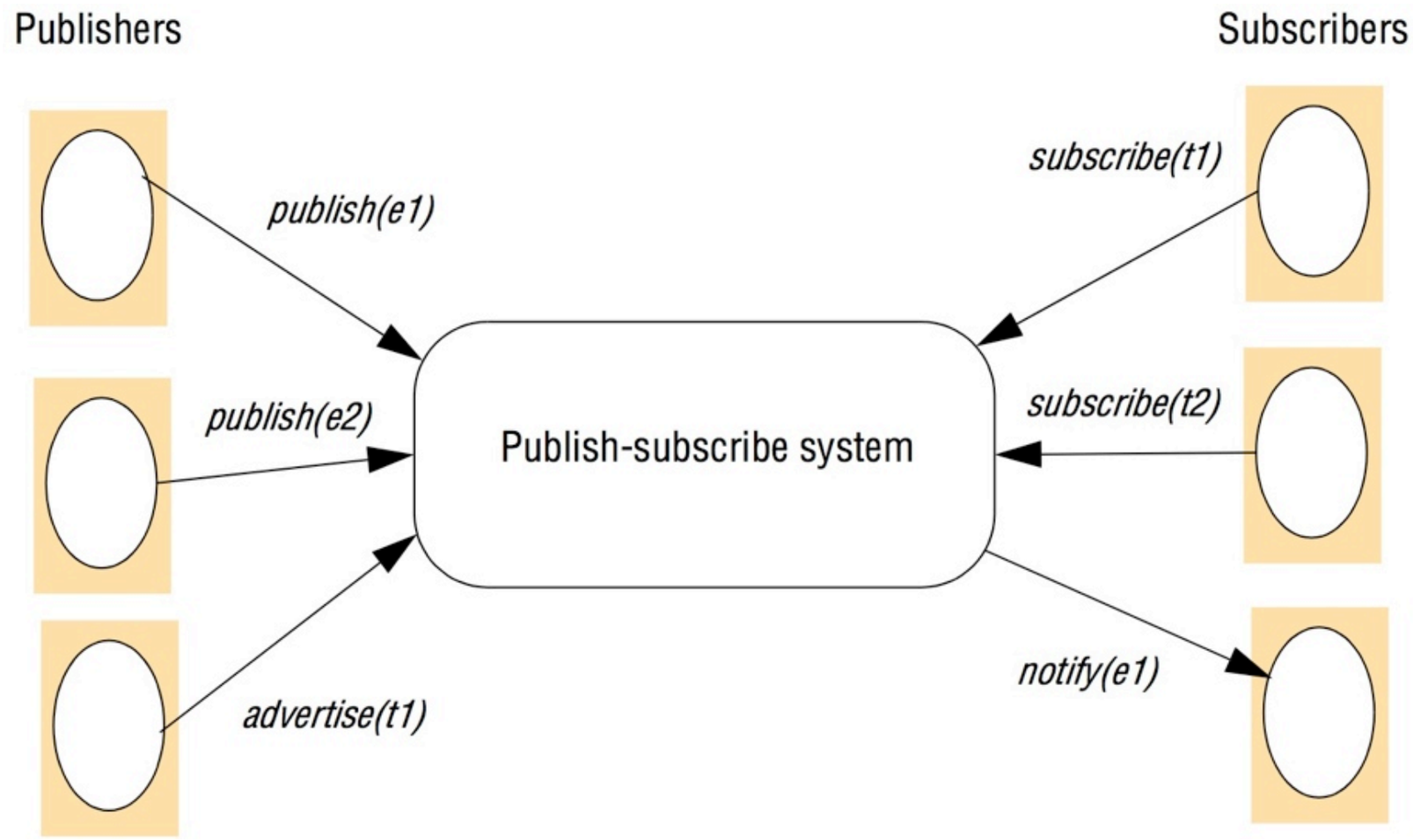
Publish-subscribe

Distributed Event Based Systems

- "Decoupled and reactive style of programming"
- ***Publishers*** publish structured events to an event service
- ***Subscribers*** subscribe to particular events through subscriptions
- System must match subscriptions against published events and ensure the correct delivery of ***event notifications***
- ***one-to-many*** paradigm of communications
- Asynchronous
- ***Delivery guarantees:*** reliability, agreement, latency, etc.

Publish-subscribe

Distributed Event Based Systems



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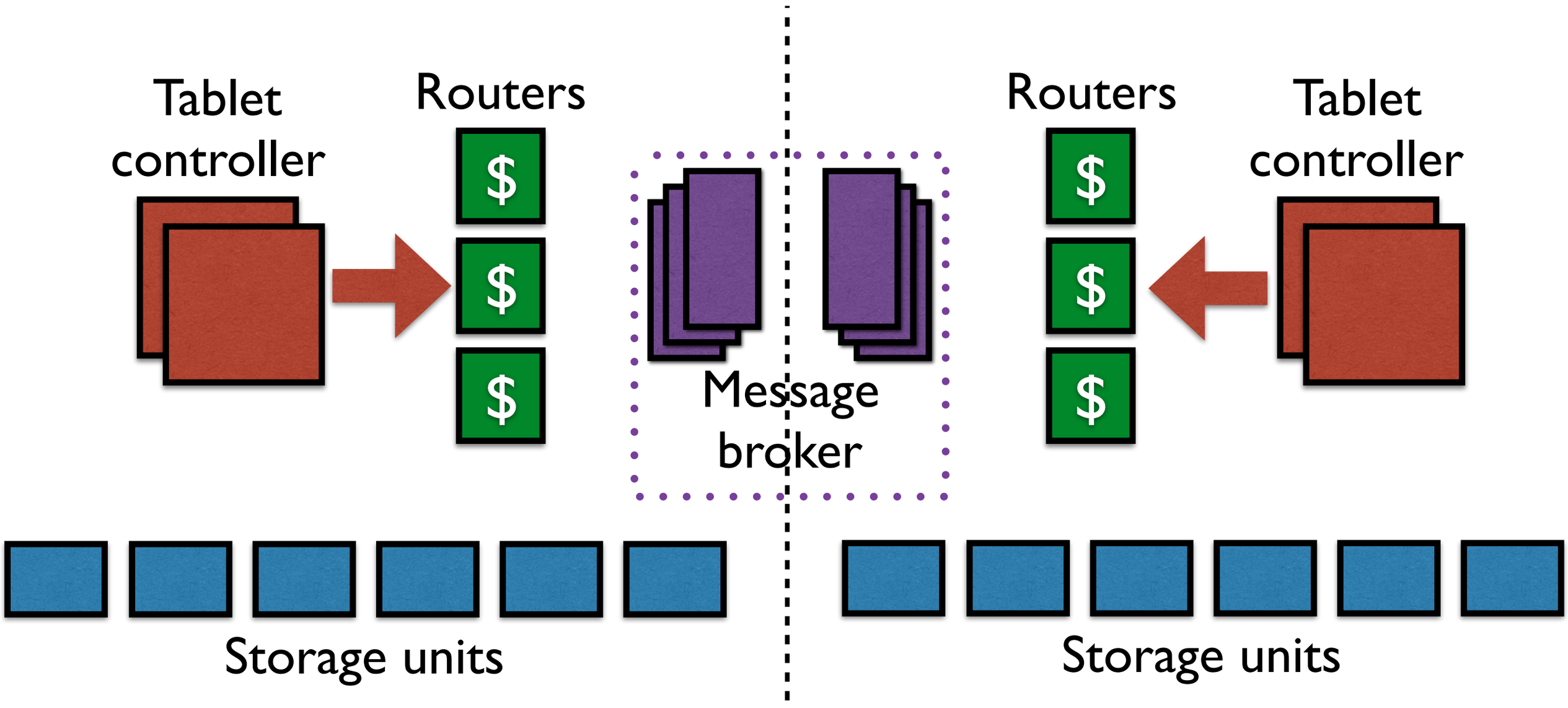
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Tablet controller
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Storage units
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Updates

REGION 1

webserver

App
r/w to PNUTS

Tablet

Routers

controller

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$

$

Message broker

REGION 2

Routers

Tablet

controller

$

$

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Storage units

Storage units

Updates

REGION 1

REGION 2

Why not just have app logic send update to every region?

Tablet

Routers

Routers

Tablet

controller

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$

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Message broker

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controller

Storage units

Storage units

Updates

REGION 1

REGION 2

What if app crashes after updating only some regions?
What if concurrent updates to same record?

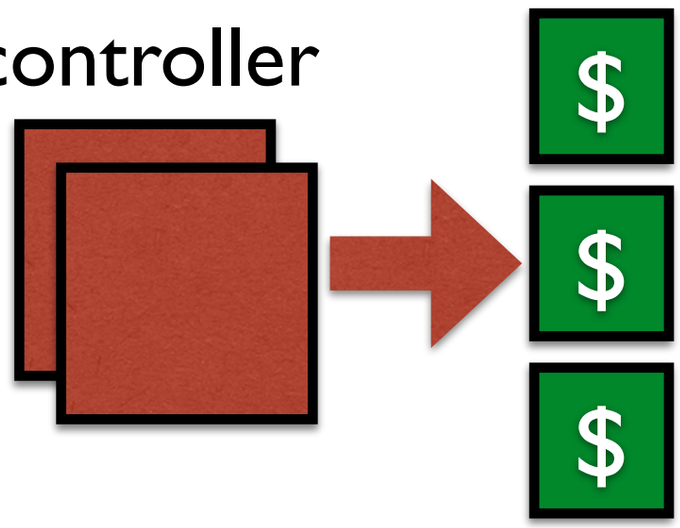
Tablet

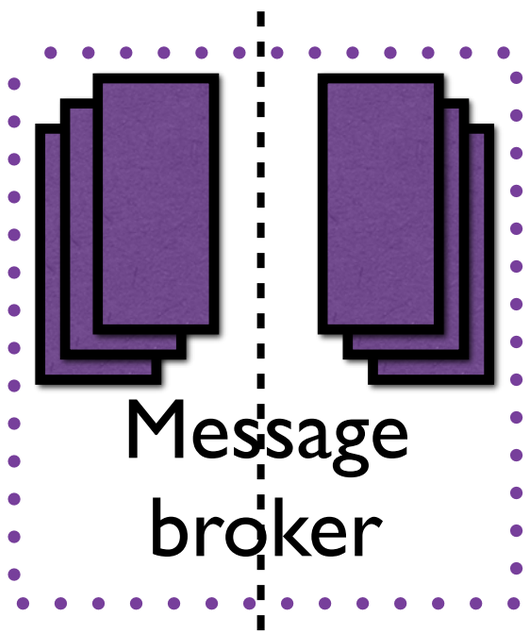
Routers

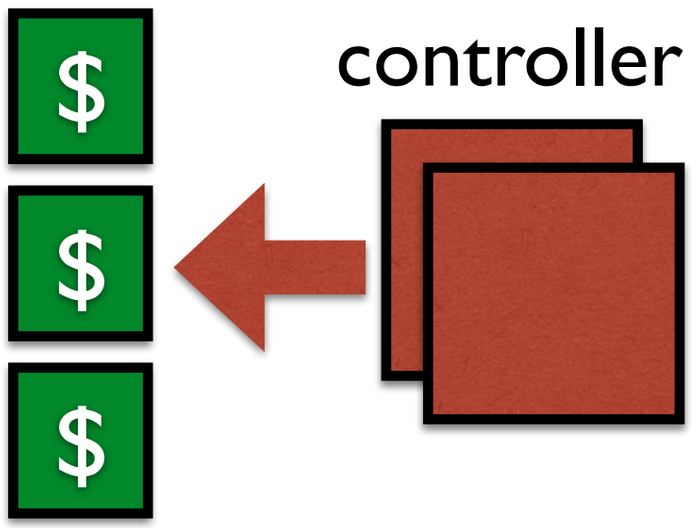
Routers

Tablet

controller







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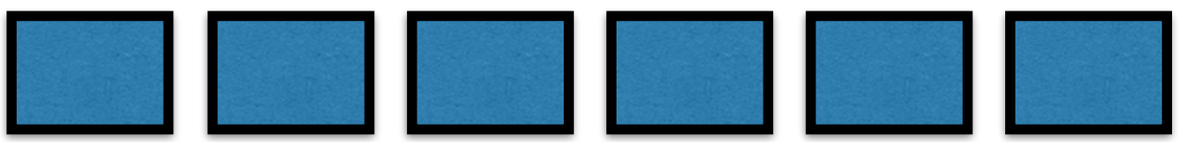

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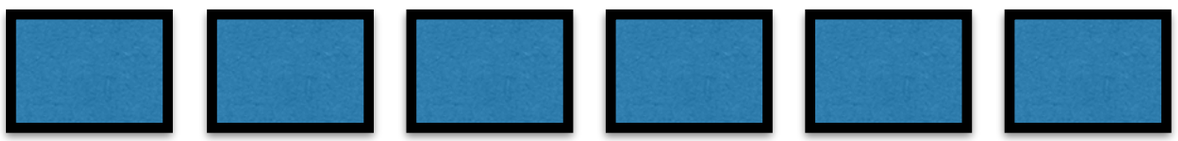

Storage units

Updates

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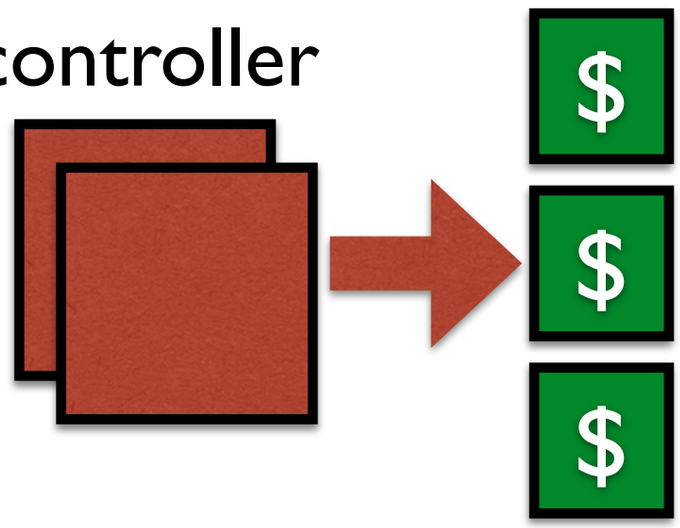
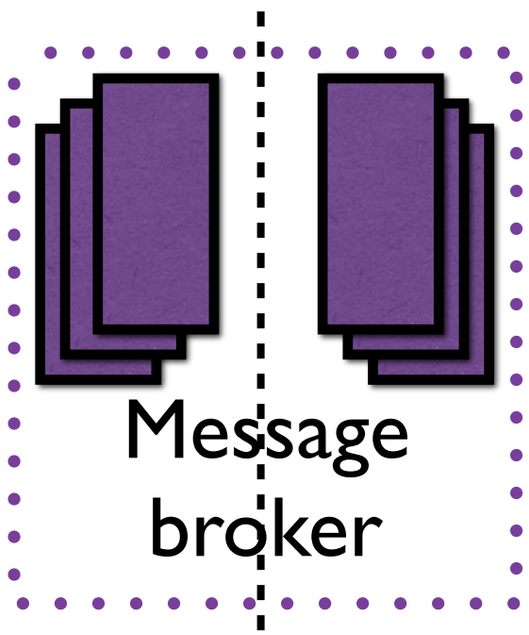
So what does PNUTs do?

Tablet controller

Routers





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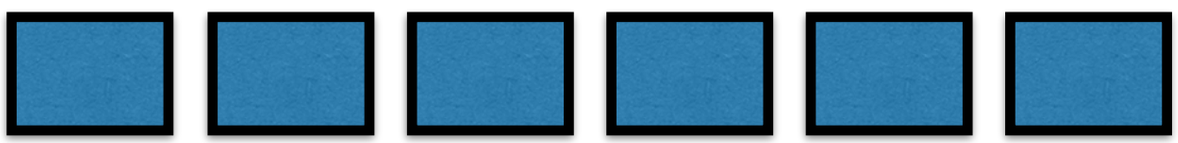

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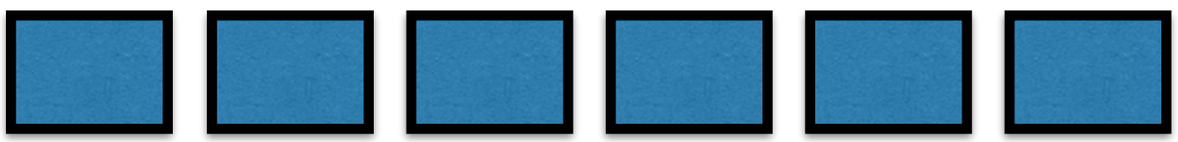

Storage units

Record based Mastering

- PNUTS has a "record master" (region) for each record
  - All updates are directed to master
    - Master imposes order on writes for each record
    - Responsible storage unit executes updates one at a time per record
    - Tells MB to broadcast updates in order to all regions

Two cases:

1. Update occurs at master Region
2. Update occurs at non-master Region

What is the difference?

Two cases:

1. Update occurs at master Region
2. Update occurs at non-master Region

What is the difference?

PERFORMANCE

So what is going on

- Why per-record master? — consider table of shopping carts — updates have locality
- PNUTs master is dynamic each row has hidden column that indicates master region — can migrate
- Hopefully get best of both worlds:
  - Fast reads of local data
  - Fast writes b/c master is often the local region

Update Walk Through

REGION 1

REGION 2

App
w to PNUTS

Tablet

Routers

Routers

Tablet

controller

$

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Message
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But for this to be useful what do we need from the Message Brokers

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Async and Reliable Communication

Message Broker : Cool Idea

- Reliable: logs to disk, keeps trying, to cope with various failures
- Ordered: record's replicas eventually identical even w/ multiple writers
- Async: apps don't wait once write committed at MB

Encapsulates all kinds of the tricky DS stuff — App's and DB don't have to deal with it

Write Order

REGION 1

REGION 2

USER	WHERE	WHAT
Alice	Home	Asleep
Bob	Gym	Running
…		
…		

USER	WHERE	WHAT
Alice	Home	Asleep
Bob	Gym	Running
…		
…		

Write Order

REGION 1

Alice App:

1.write(WHAT=Awake)

2.write(WHERE=Work)

USER	WHERE	WHAT
Alice	Home	Asleep
Bob	Gym	Running
…		
…		

REGION 2

User in another Region following Alice : Local Reads

USER	WHERE	WHAT
Alice	Home	Asleep
Bob	Gym	Running
…		
…		

Write Order

REGION 1

Alice App:

1. write(WHAT=Awake)
2. write(WHERE=Work)

USER	WHERE	WHAT
Alice	Work	Awake
Bob	Gym	Running
…		
…		

REGION 2

might observe:

Home/Asleep

Home/Awake

Work/Awake

~~Work/Asleep~~

USER	WHERE	WHAT
Alice	Home	Awake
Bob	Gym	Running
…		
…		

Only single record ordering of updates and transactions

e.g.

Write(Bob.What, on duty)
Write(Alice.What, off duty)

Why is it OK for writes to take effect slowly?

- fundamental benefit: reads are then very fast, since local and reads usually greatly outnumber writes
- PNUTS mitigates write cost:
  - application waits for MB commit but not propagation (“asynchronous")
  - master likely to be local (they claim 80% of the time)
  - so MB commit will often be quick
- down side: readers at non-master regions may see stale data

How stale might a non-master record be?

- Depends on how quickly MB sends updates to regions
- Guess: less than a second usually
- Longer if network slow/flaky, or MB busy

So can and how do we deal with Stale data?

- Sometimes stale is ok: looking at other people's profiles
- Sometimes stale is not ok: shopping cart after add/delete item

The App is the Boss and needs to decide

So can and how do we deal with Stale data?

Application gets to choose how consistent (section 2.2)

- read-any(k) : read from local SU, fast but maybe stale
- read-critical(k, required_version): fast local read if local SU has vers >= required_version, otherwise slow read from master SU. Why: app knows it just wrote, wants value to reflect write
- read-latest(k): always read from master, slow if master is remote! Why: app needs fresh data

- What if app needs to increment a counter stored in a record?
- Is read-latest(k), increment, then write(k) enough?

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  - Is read-latest(k), increment, then write(k) enough?

Not if there might be concurrent updates!

Atomic Operation

`test-and-set-write(version#, new value)`

Atomic update to one record

master rejects the write if current version # != version#

so if concurrent updates, one will lose and retry

```
while(1):
    (x, ver) = read-latest(k)
    if(t-a-s-w(k, ver, x+1))
        break
```

t-a-s-w is fully general for single-record atomic read-modify-write