Viewstamped replication

10/20/17

A note on assignment 2

Your tests need to pass *deterministically*

Use SyncMap, err on using too many (correctness > performance here)

You don’t need maps of maps (bad design in general)

Due tonight!!

MIDTERM

Next Friday 10/27 at 10am or 11am, you choose (90 minutes)

Covers all material up to and including today’s class

Viewstamped replication

A way to implement replicated state machines

Goal: strong consistency across replicas

Similar to Paxos and RAFT, but less popular

Viewstamped replication

Normal operation

2f + 1 = 3 nodes

Can tolerate f = 1 node failing at once

A

status	normal
replica	0
view	0
op	0
commit	-1

<empty>

B

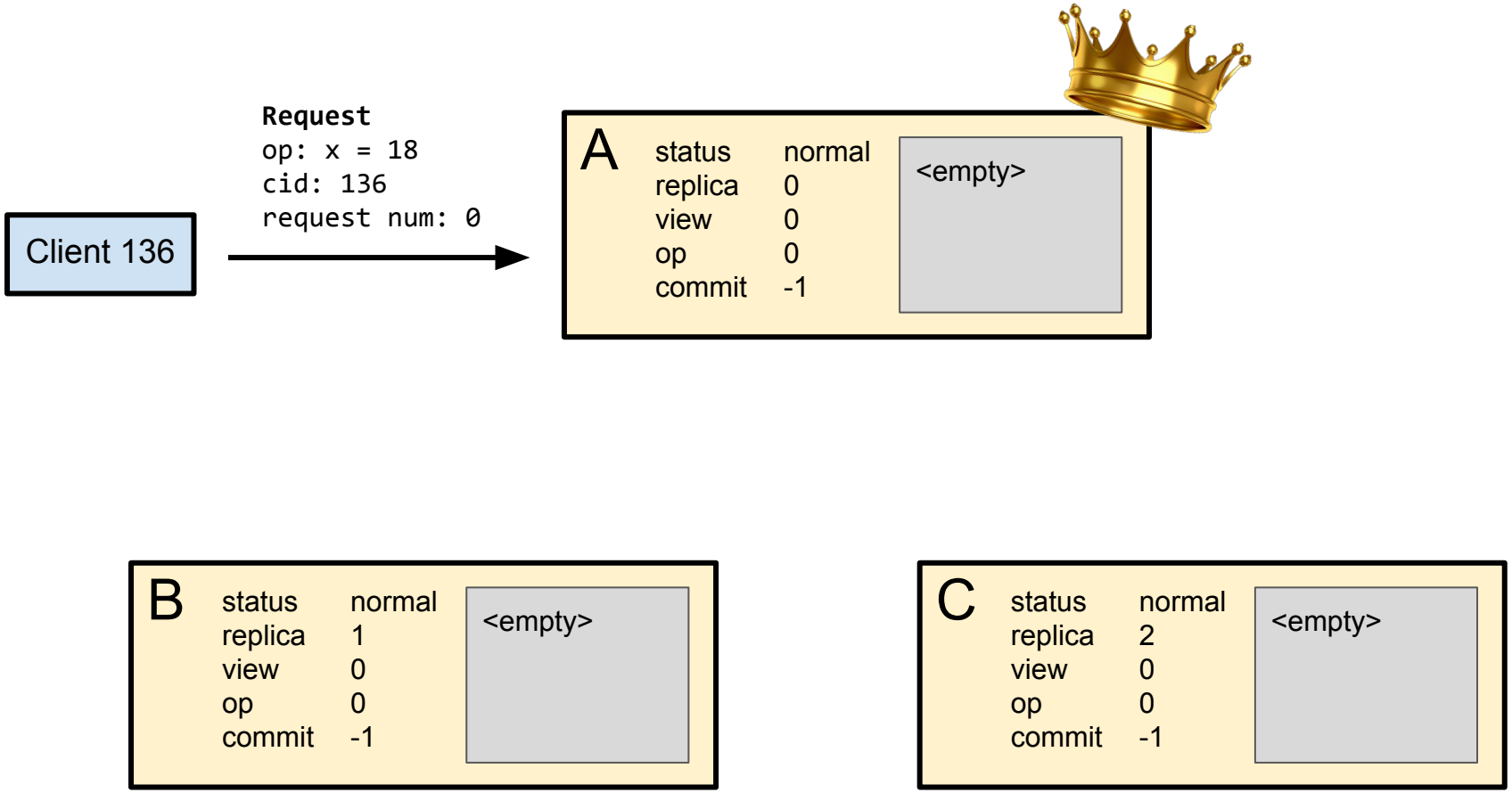
status	normal
replica	1
view	0
op	0
commit	-1

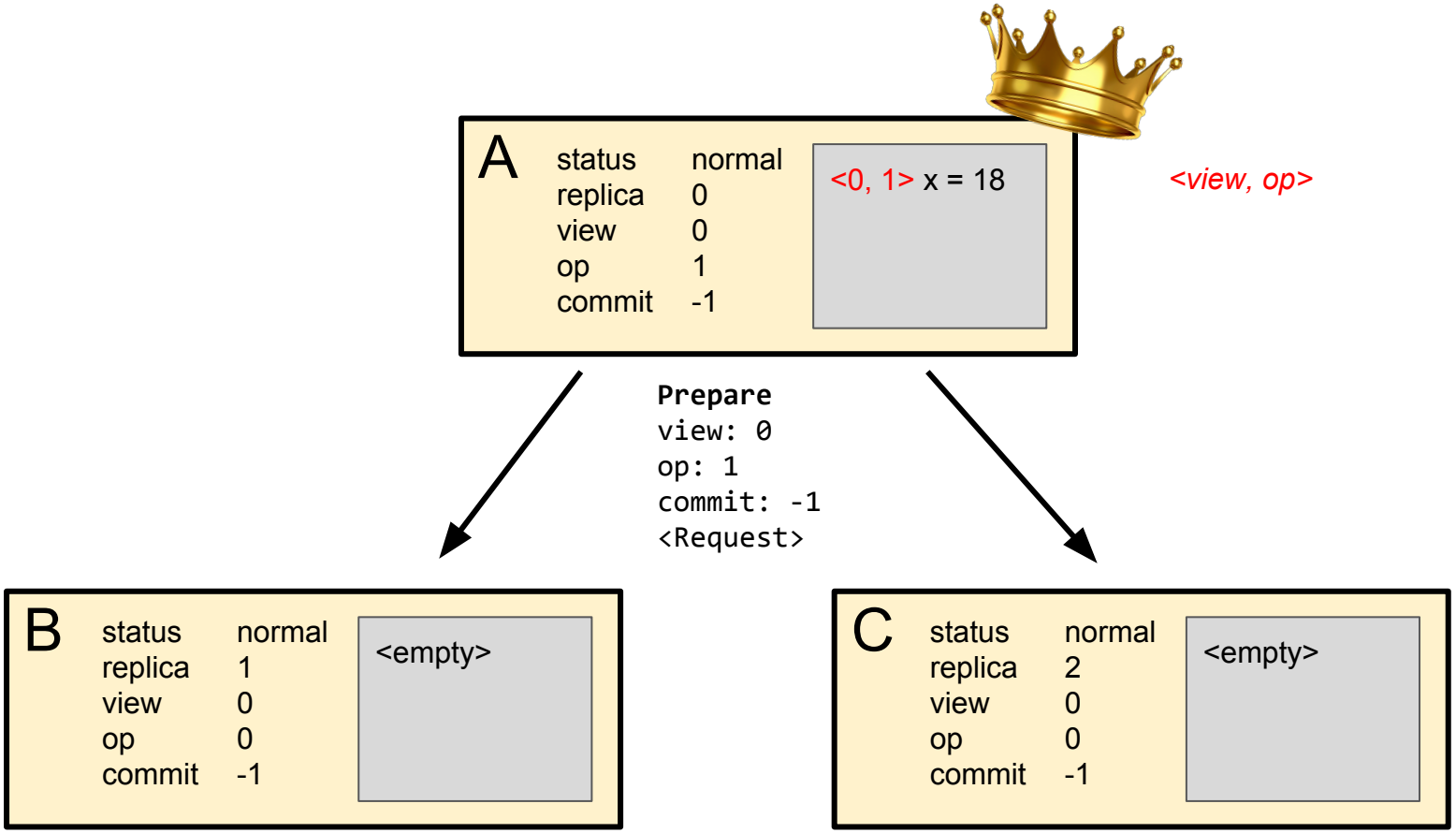
<empty>

C

status	normal
replica	2
view	0
op	0
commit	-1

<empty>


Request
op: x = 18
cid: 136
request num: 0
Client 136
A
status normal
replica 0
view 0
op 0
commit -1
<empty>
B
status normal
replica 1
view 0
op 0
commit -1
<empty>
C
status normal
replica 2
view 0
op 0
commit -1
<empty>


A
status normal
replica 0
view 0
op 1
commit -1
<0, 1> x = 18
<view, op>
Prepare
view: 0
op: 1
commit: -1
<Request>
B
status normal
replica 1
view 0
op 0
commit -1
<empty>
C
status normal
replica 2
view 0
op 0
commit -1
<empty>

Primary only needs to wait for f = 1 replies before committing

A

status	normal
replica	0
view	0
op	1
commit	-1

<0, 1> x = 18

<view, op>

PrepareOK
`view: 0`
`op: 1`
`replica: 1`

PrepareOK
`view: 0`
`op: 1`
`replica: 2`

B

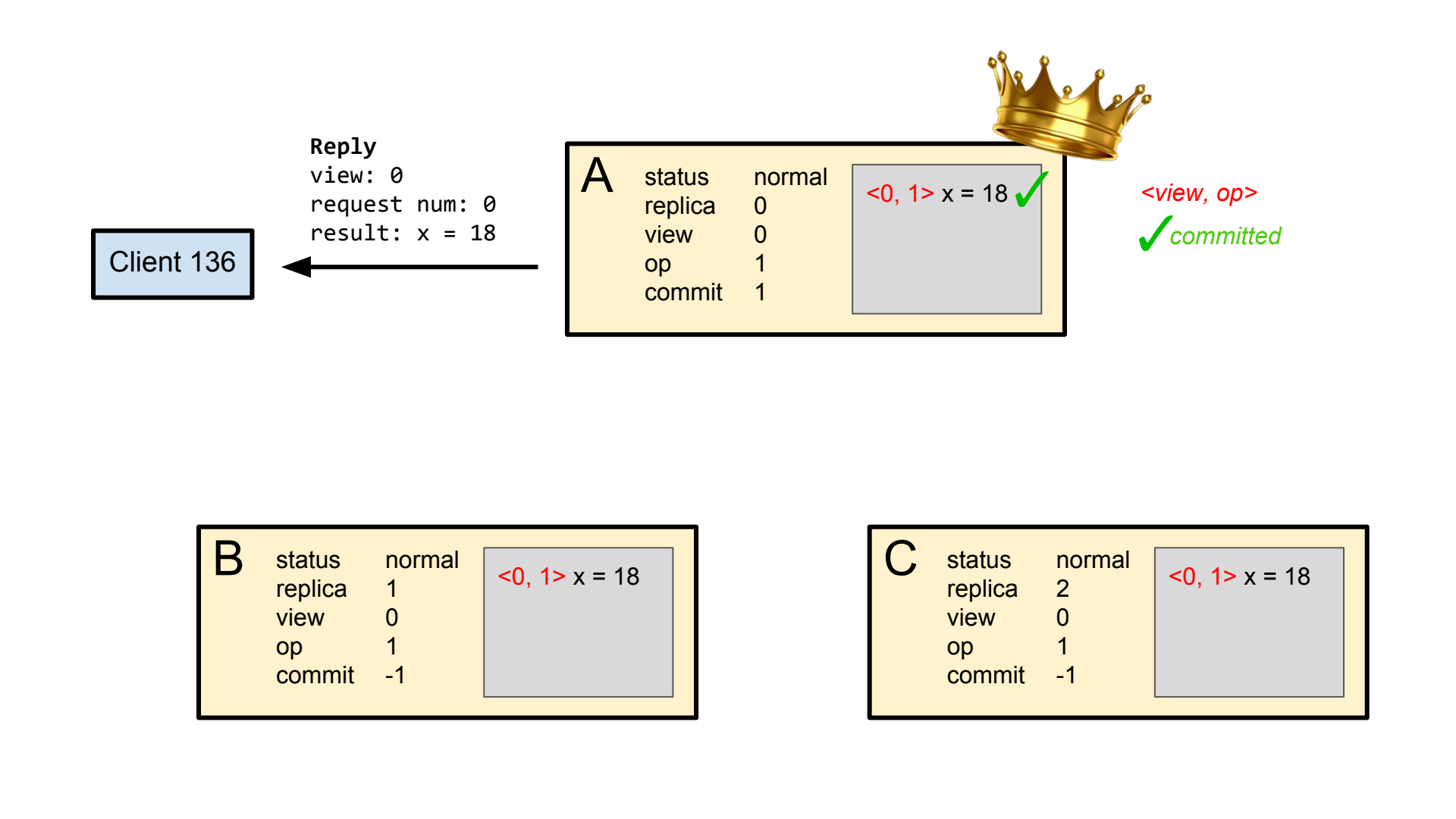
status	normal
replica	1
view	0
op	1
commit	-1

<0, 1> x = 18

C

status	normal
replica	2
view	0
op	1
commit	-1

<0, 1> x = 18


Reply
view: 0
request num: 0
result: x = 18
Client 136
A
status normal
replica 0
view 0
op 1
commit 1
<0, 1> x = 18
<view, op>
committed
B
status normal
replica 1
view 0
op 1
commit -1
<0, 1> x = 18
C
status normal
replica 2
view 0
op 1
commit -1
<0, 1> x = 18

Primary informs backups that op 1 is committed during the next `Prepare`

A

status	normal
replica	0
view	0
op	1
commit	1

<0, 1> x = 18 ✓

<view, op>

✓ *committed*

B

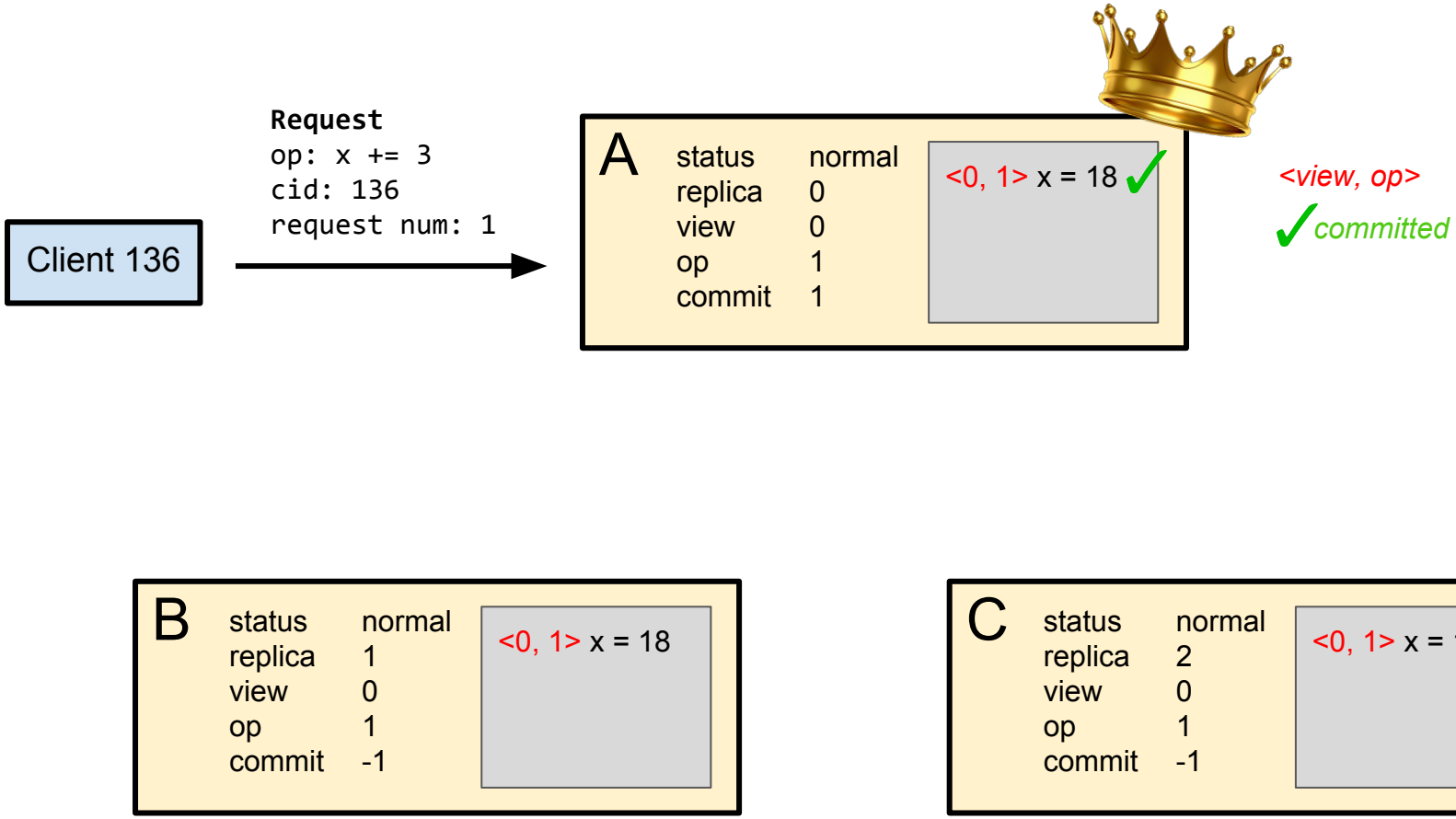
status	normal
replica	1
view	0
op	1
commit	-1

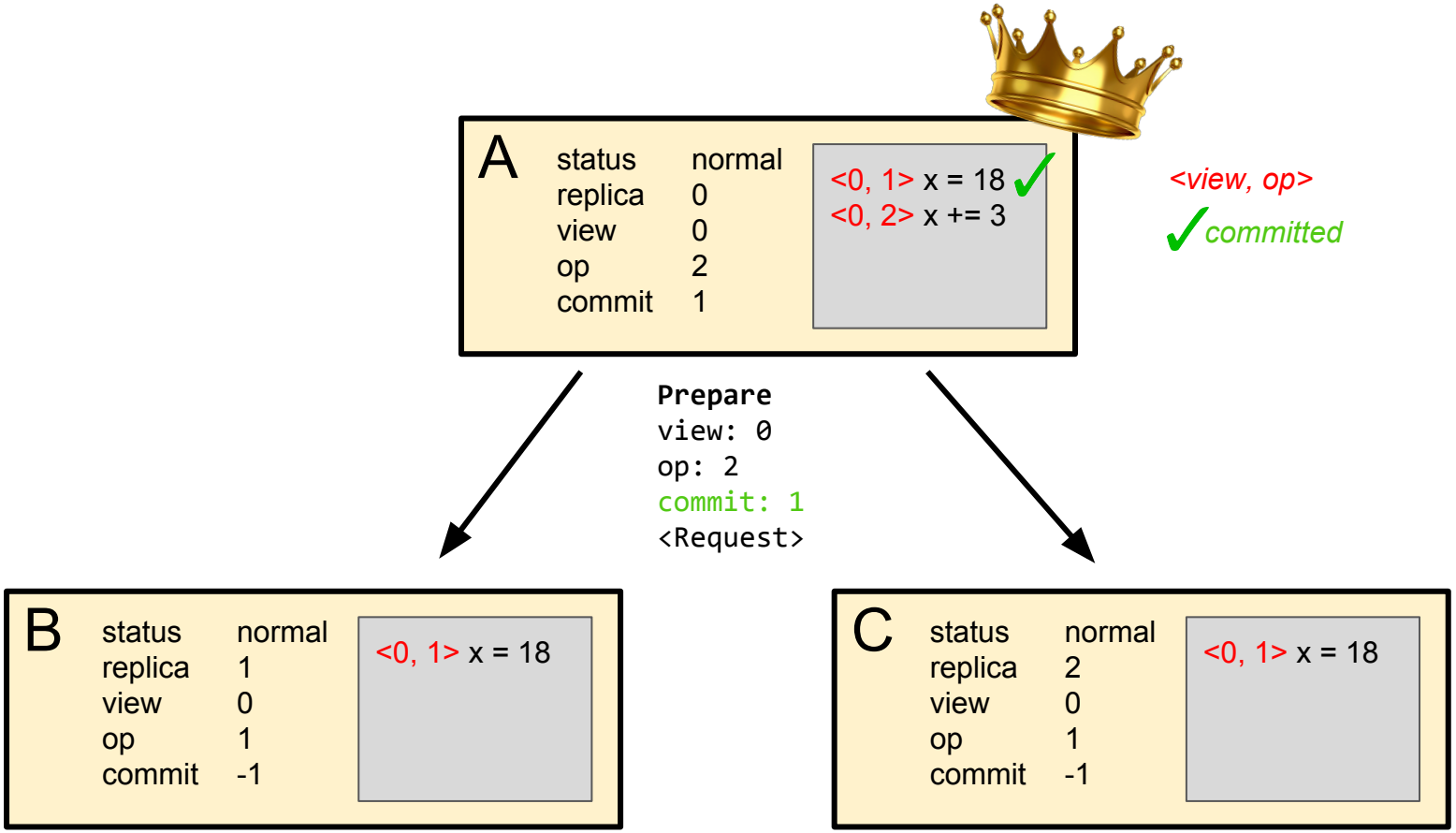
<0, 1> x = 18

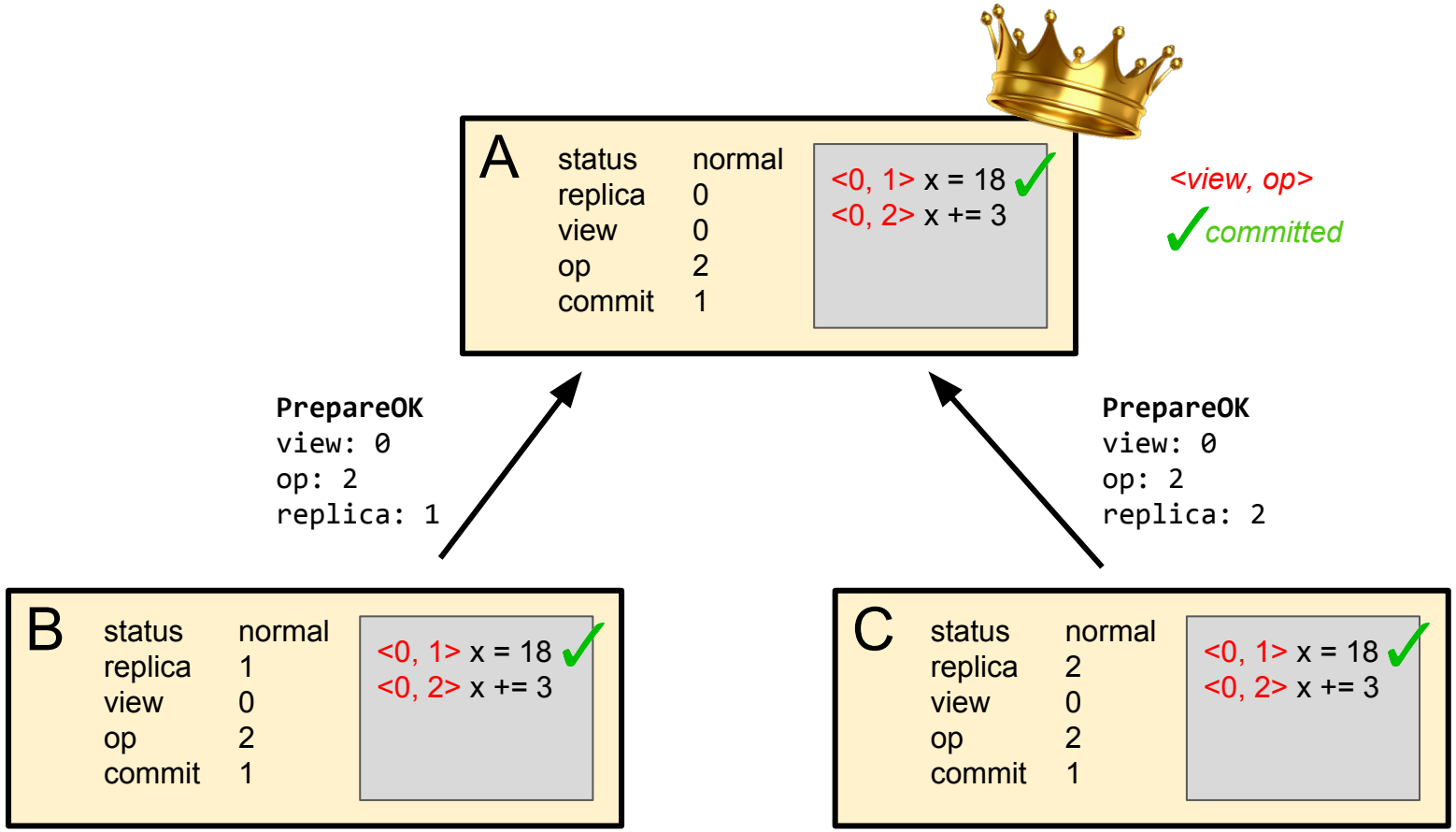
C

status	normal
replica	2
view	0
op	1
commit	-1

<0, 1> x = 18


Request
op: x += 3
cid: 136
request num: 1
Client 136
A
status normal
replica 0
view 0
op 1
commit 1
<0, 1> x = 18
<view, op>
committed
B
status normal
replica 1
view 0
op 1
commit -1
<0, 1> x = 18
C
status normal
replica 2
view 0
op 1
commit -1
<0, 1> x = 18


A
status normal
replica 0
view 0
op 2
commit 1
<0, 1> x = 18
<0, 2> x += 3
<view, op>
committed
Prepare
view: 0
op: 2
commit: 1
<Request>
B
status normal
replica 1
view 0
op 1
commit -1
<0, 1> x = 18
C
status normal
replica 2
view 0
op 1
commit -1
<0, 1> x = 18


A
status normal
replica 0
view 0
op 2
commit 1
<0, 1> x = 18
<0, 2> x += 3
<view, op>
committed
PrepareOK
view: 0
op: 2
replica: 1
PrepareOK
view: 0
op: 2
replica: 2
B
status normal
replica 1
view 0
op 2
commit 1
<0, 1> x = 18
<0, 2> x += 3
C
status normal
replica 2
view 0
op 2
commit 1
<0, 1> x = 18
<0, 2> x += 3

Reply
`view: 0`
`request num: 1`
`result: x = 21`

Client 136

A

status	normal
replica	0
view	0
op	2
commit	2

<0, 1> x = 18 ✓
<0, 2> x += 3 ✓

<view, op>
✓ *committed*

B

status	normal
replica	1
view	0
op	2
commit	1

<0, 1> x = 18 ✓
<0, 2> x += 3

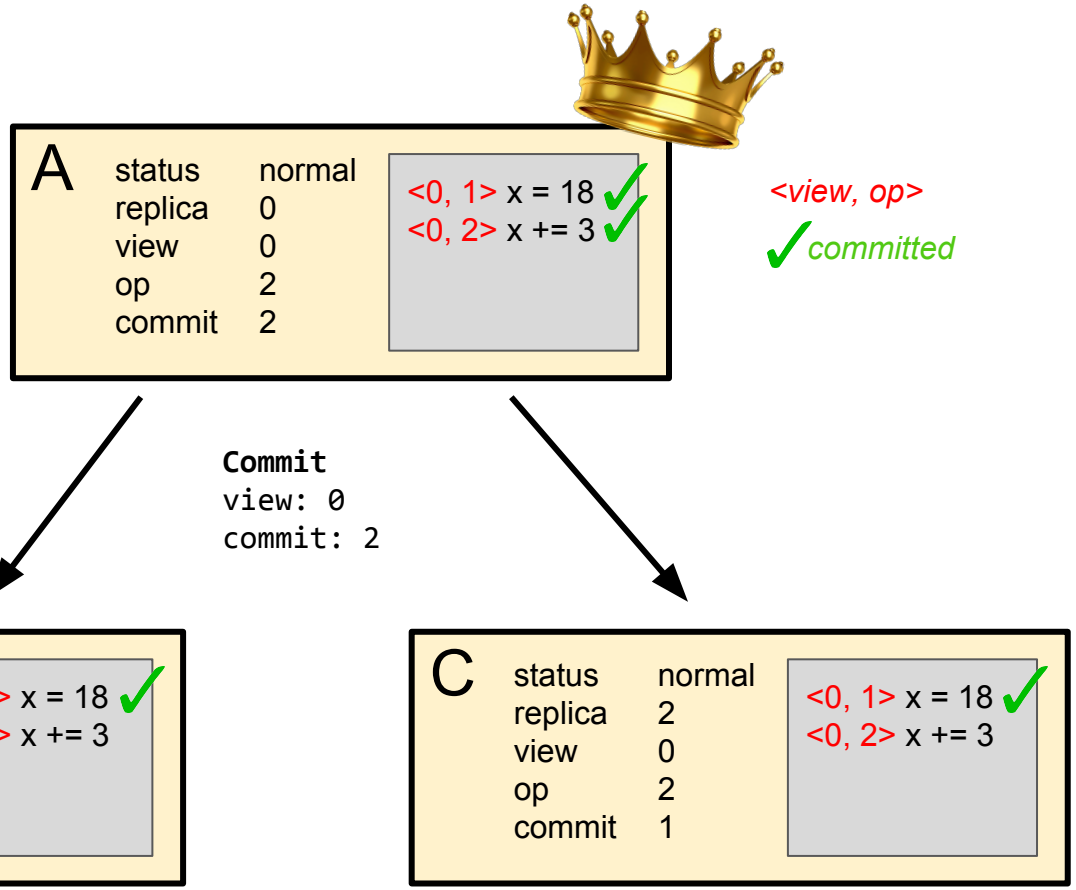
C

status	normal
replica	2
view	0
op	2
commit	1

<0, 1> x = 18 ✓
<0, 2> x += 3

What if the next `Prepare` *never comes?*

Primary times out and sends a `Commit` *message to each backup*



A

status	normal
replica	0
view	0
op	2
commit	2

<0, 1> x = 18 ✓
<0, 2> x += 3 ✓

<view, op>
✓ committed

B

status	normal
replica	1
view	0
op	2
commit	2

<0, 1> x = 18 ✓
<0, 2> x += 3 ✓

C

status	normal
replica	2
view	0
op	2
commit	2

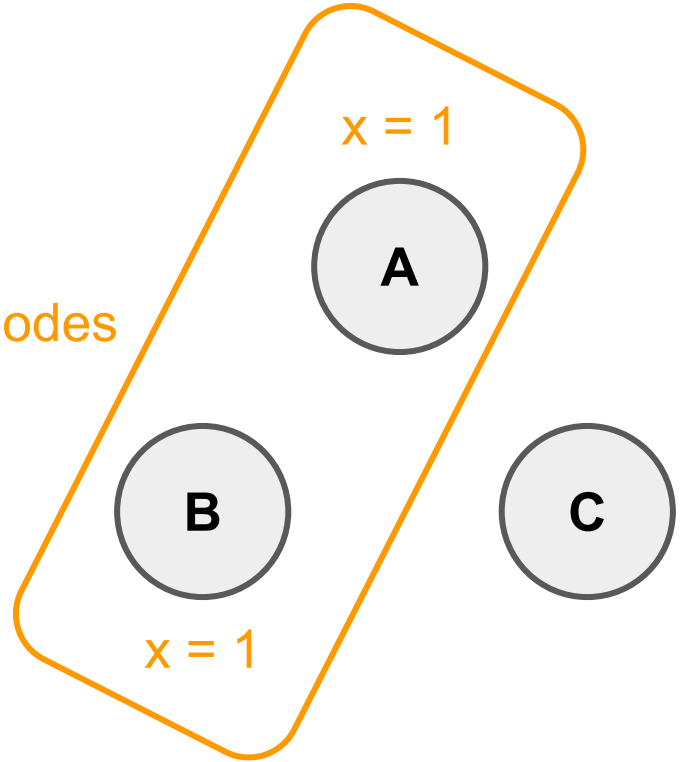
<0, 1> x = 18 ✓
<0, 2> x += 3 ✓

Why is waiting for *f* nodes enough?

Op is guaranteed to have been executed on *f* + *1* nodes (majority)

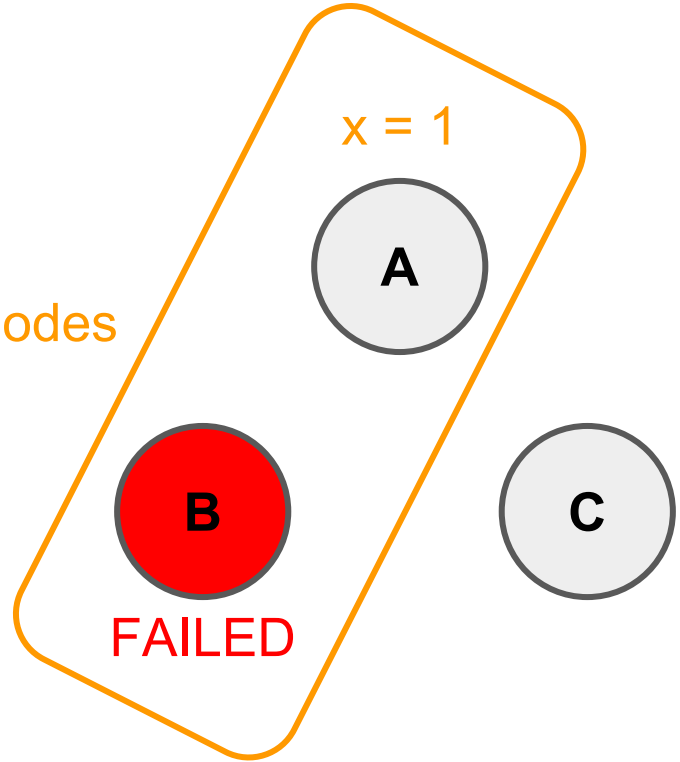
Overlapping quorums

Write quorum
contains *f* + *1* nodes



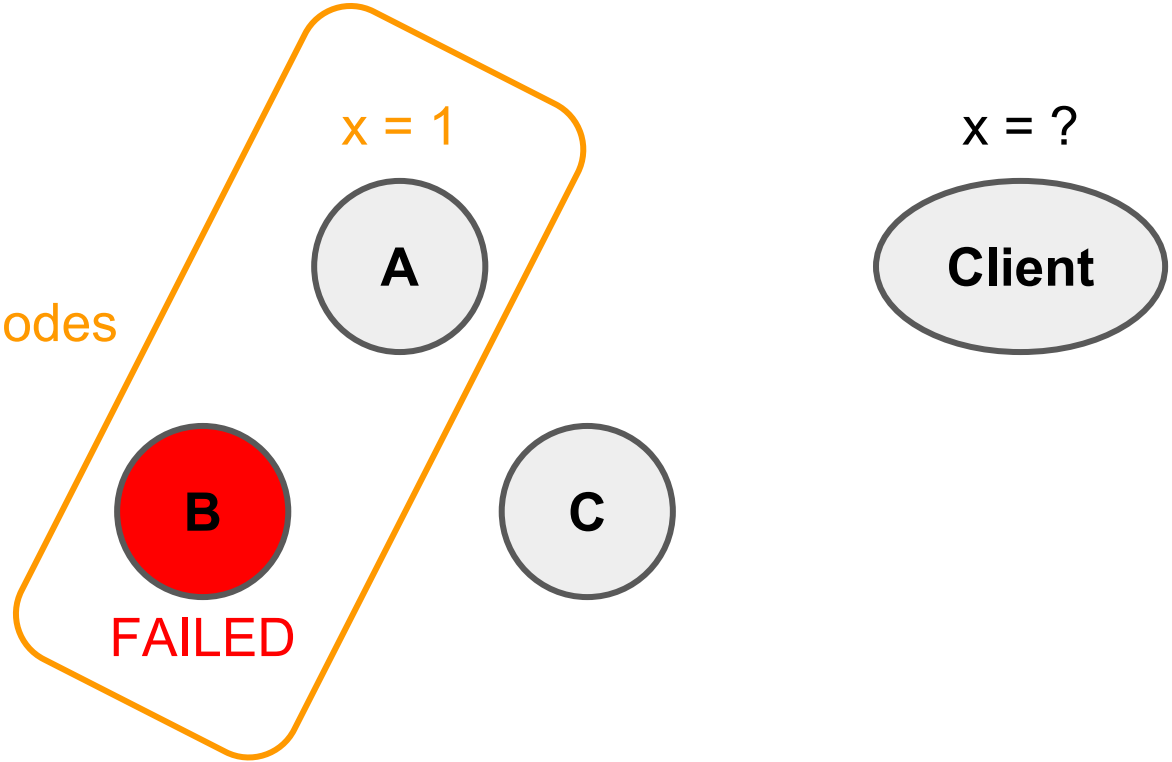
Overlapping quorums

Write quorum
contains *f* + *1* nodes

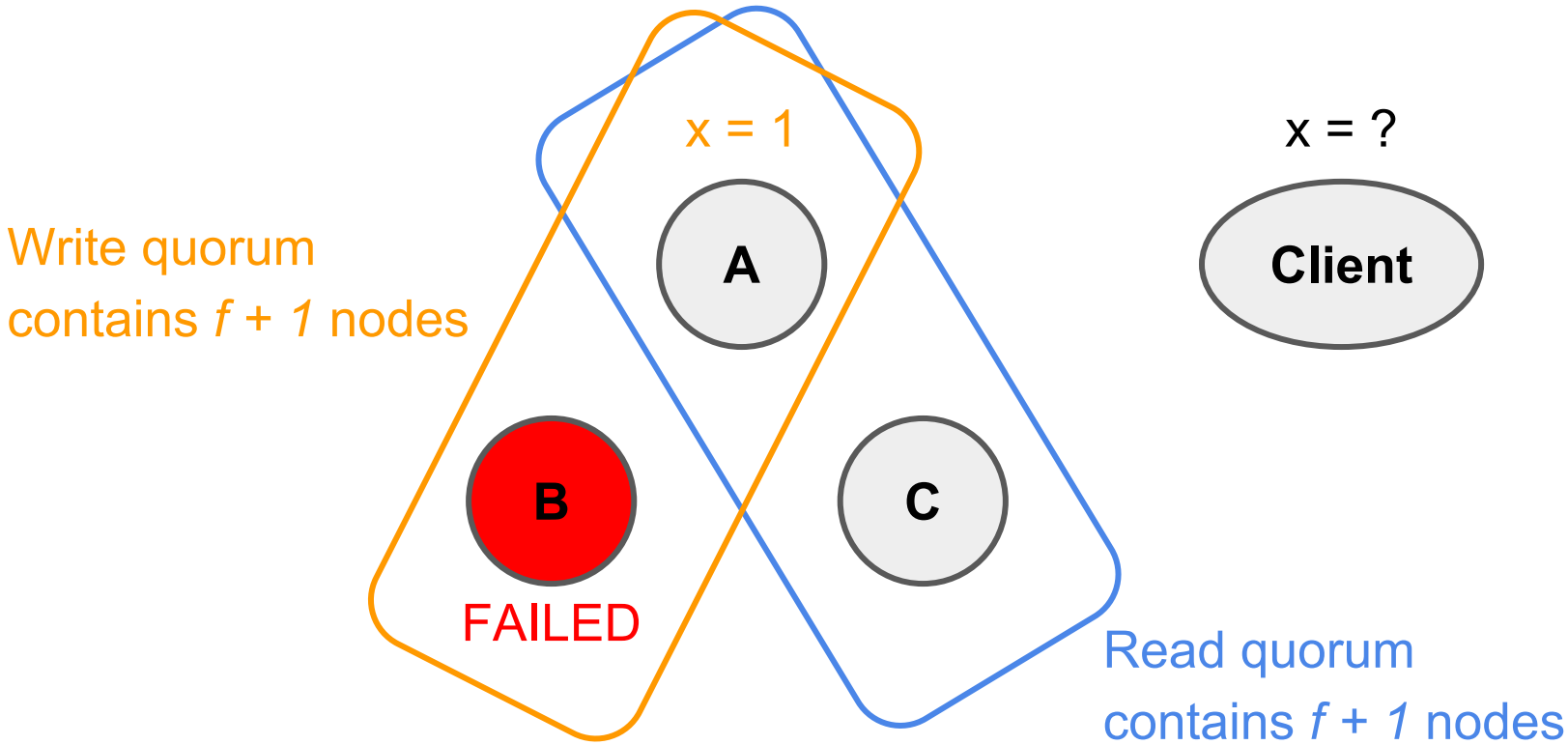


Overlapping quorums

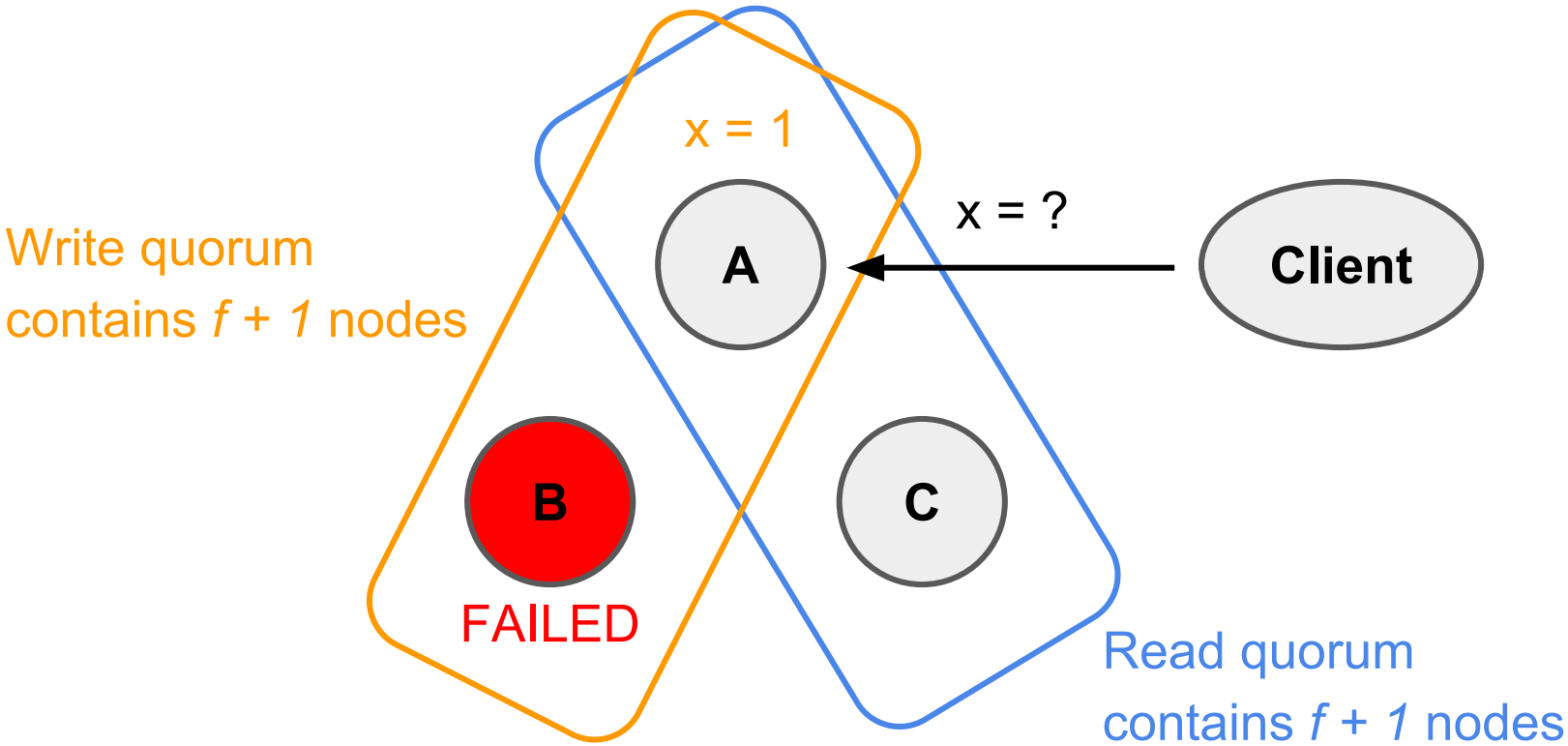
Write quorum
contains *f* + *1* nodes



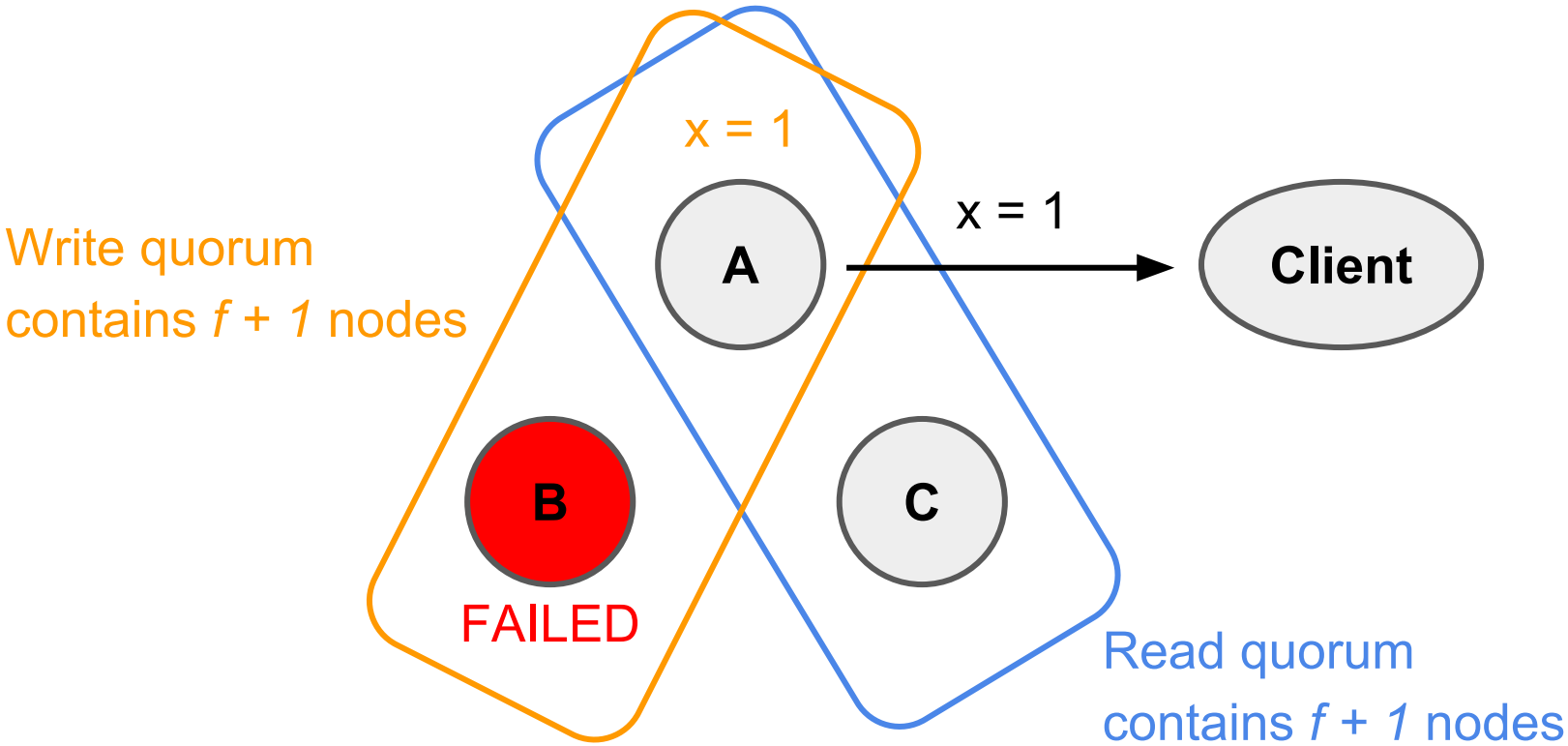
Overlapping quorums



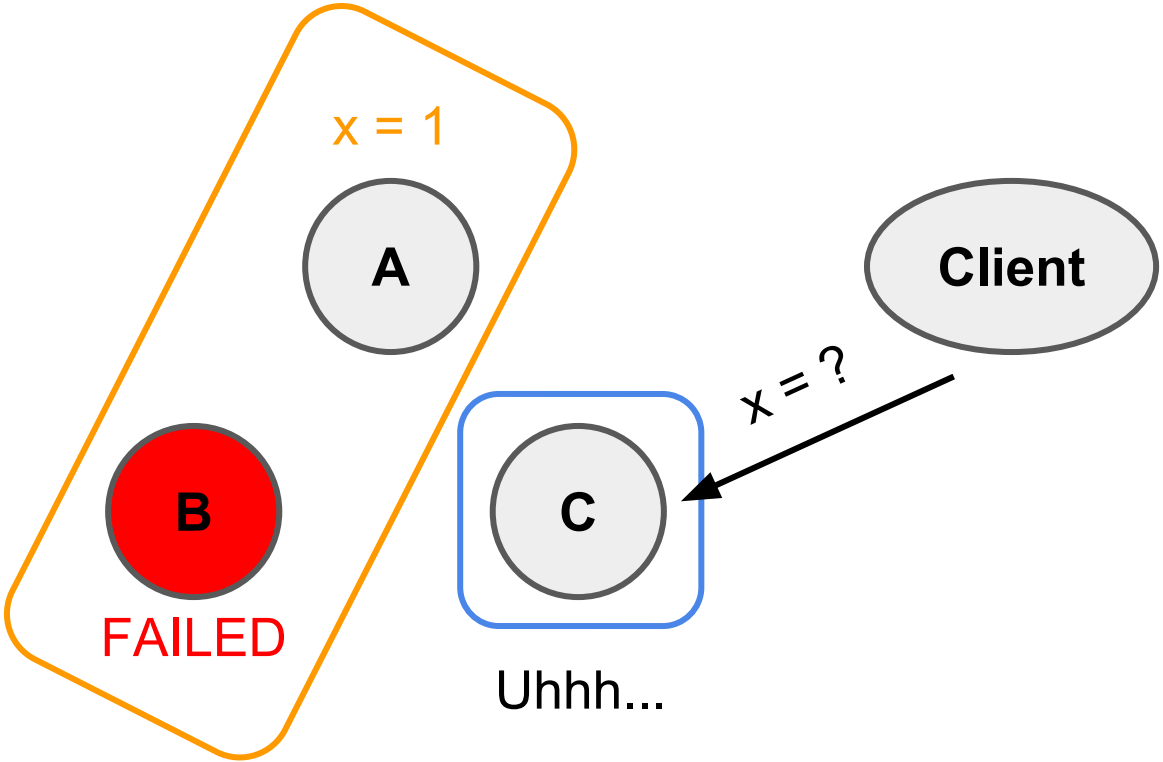
Overlapping quorums



Overlapping quorums

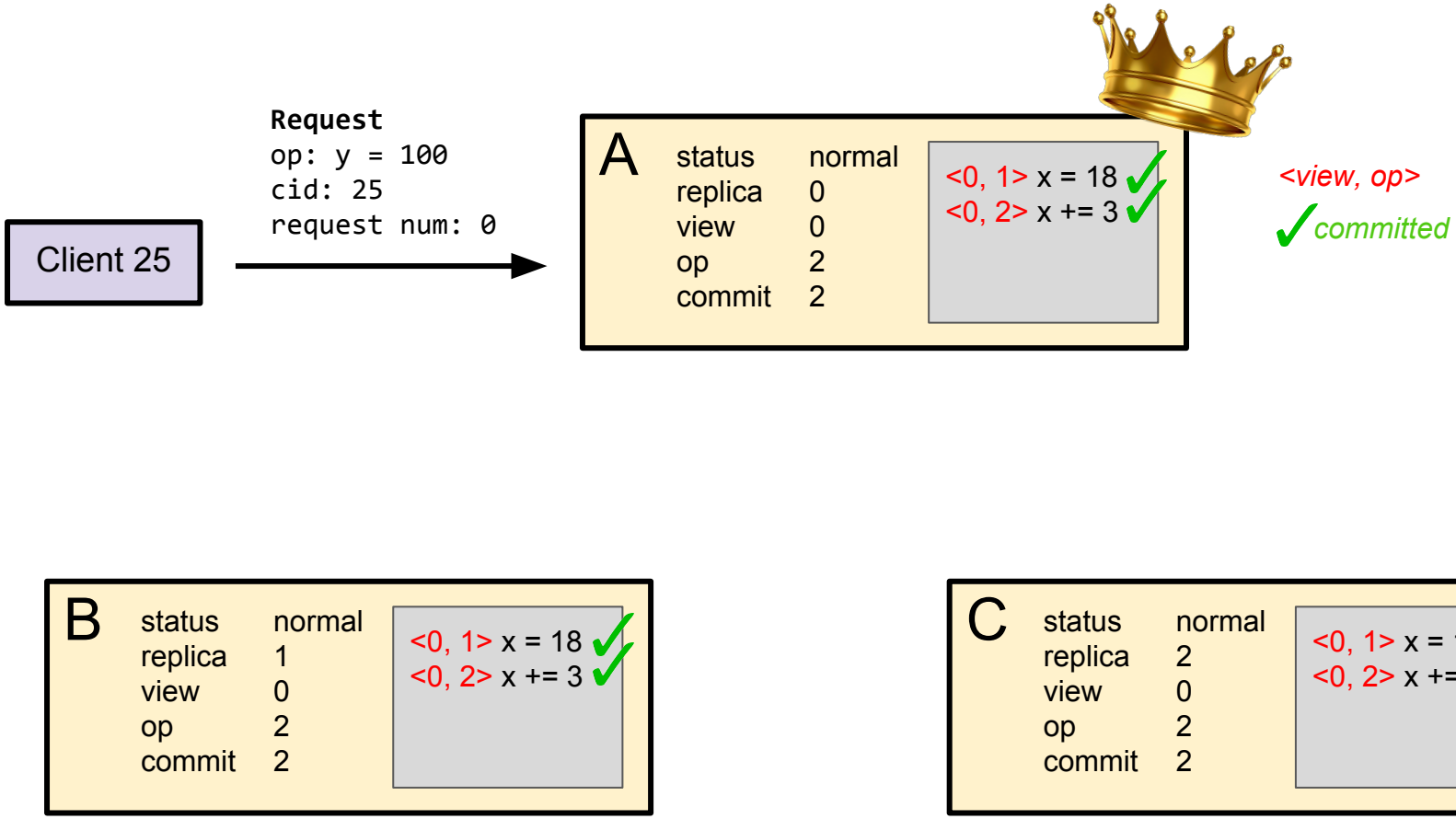


Non-overlapping quorums?



Viewstamped replication

View change


Request
op: y = 100
cid: 25
request num: 0
Client 25
A
status normal
replica 0
view 0
op 2
commit 2
<0, 1> x = 18
<0, 2> x += 3
<view, op>
committed
B
status normal
replica 1
view 0
op 2
commit 2
<0, 1> x = 18
<0, 2> x += 3
C
status normal
replica 2
view 0
op 2
commit 2
<0, 1> x = 18
<0, 2> x += 3

A

status	normal
replica	0
view	0
op	3
commit	2

<0, 1> x = 18 ✓
<0, 2> x += 3 ✓
<0, 3> y = 100

<view, op>
✓ *committed*

B

status	normal
replica	1
view	0
op	2
commit	2

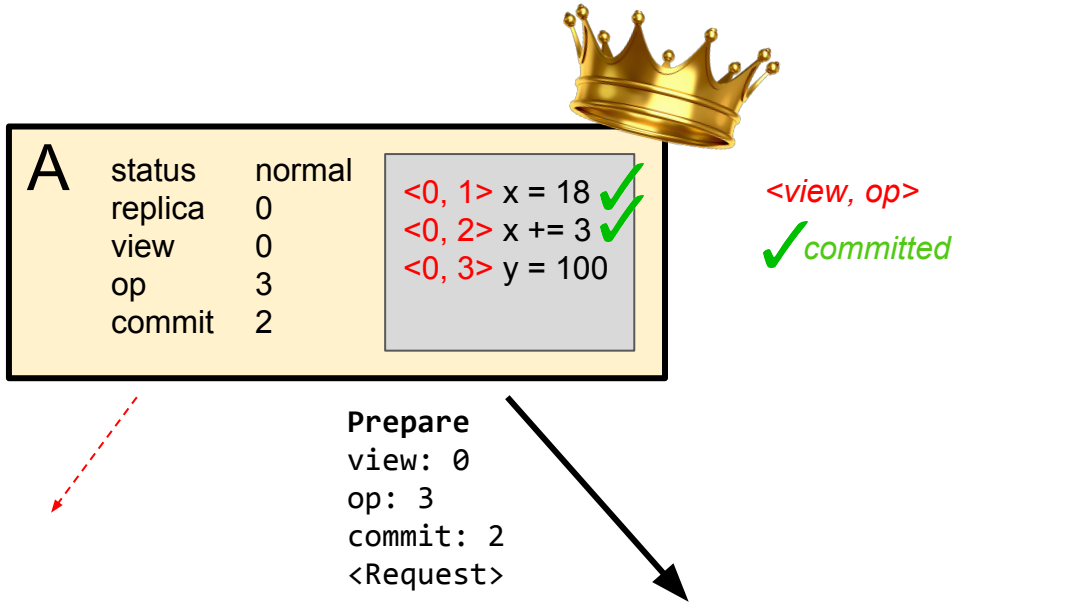
<0, 1> x = 18 ✓
<0, 2> x += 3 ✓

C

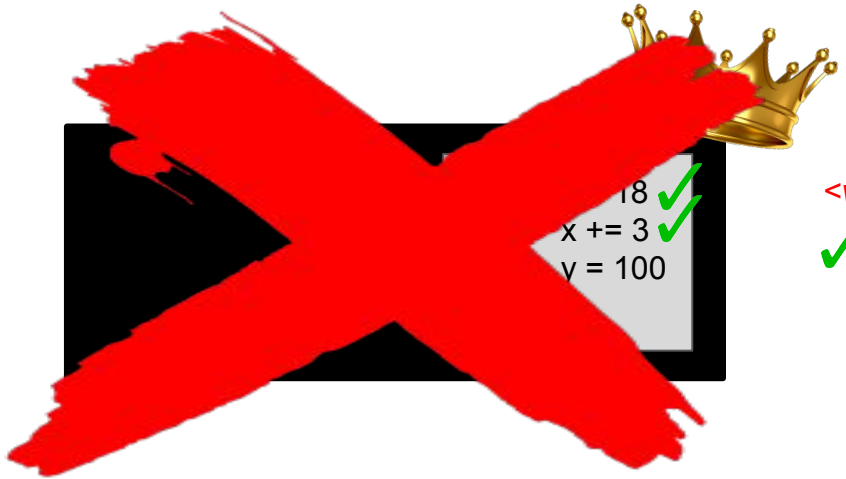
status	normal
replica	2
view	0
op	2
commit	2

<0, 1> x = 18 ✓
<0, 2> x += 3 ✓

Primary fails before sending `Prepare` *to B*



Logs are out of sync



<view, op>
committed

B

status	normal
replica	1
view	0
op	2
commit	2

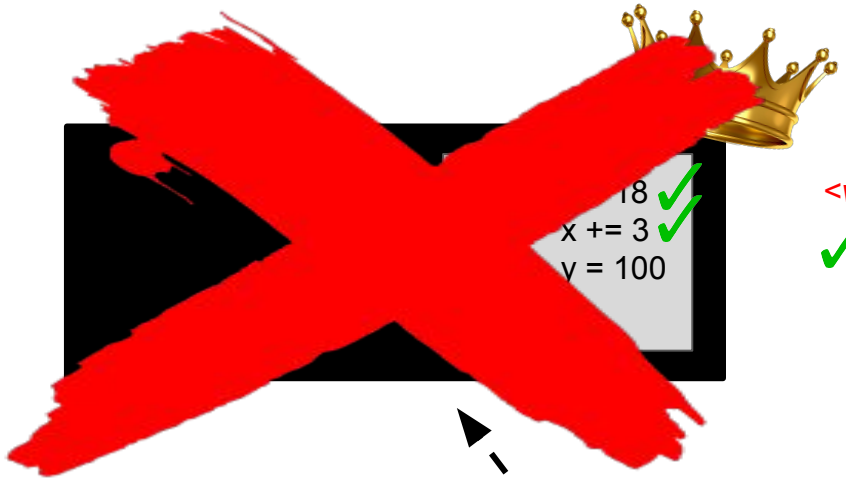
<0, 1> x = 18
<0, 2> x += 3

C

status	normal
replica	2
view	0
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

C times out on hearing from the primary and starts view change



<view, op>
committed

B		
	status	normal
	replica	1
	view	0
	op	2
	commit	2

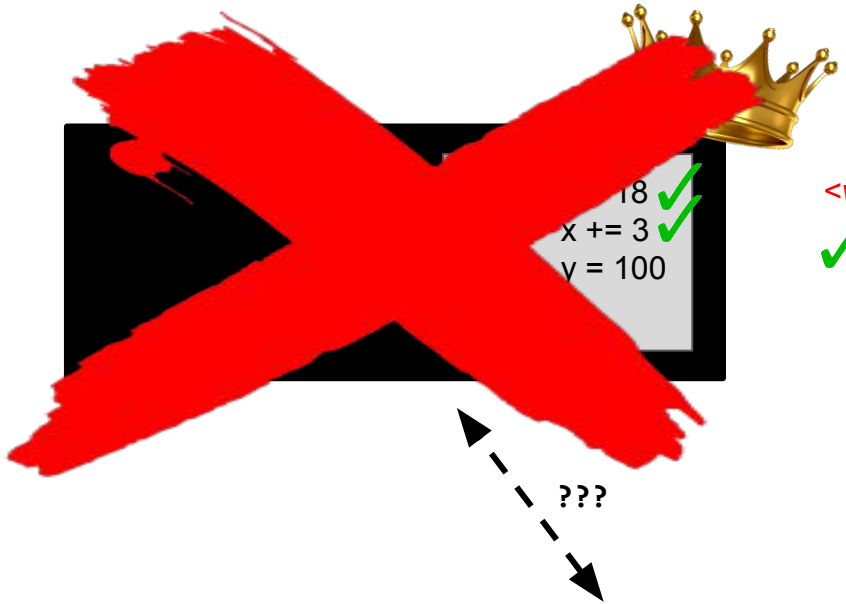
<0, 1> x = 18
<0, 2> x += 3

C		
	status	normal
	replica	2
	view	0
	op	3
	commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Who is the new primary?

Go through the list of sorted IP addresses and find the next one (i.e. B)



<view, op>

✓ *committed*

B

status	normal
replica	1
view	0
op	2
commit	2

<0, 1> x = 18 ✓
<0, 2> x += 3 ✓

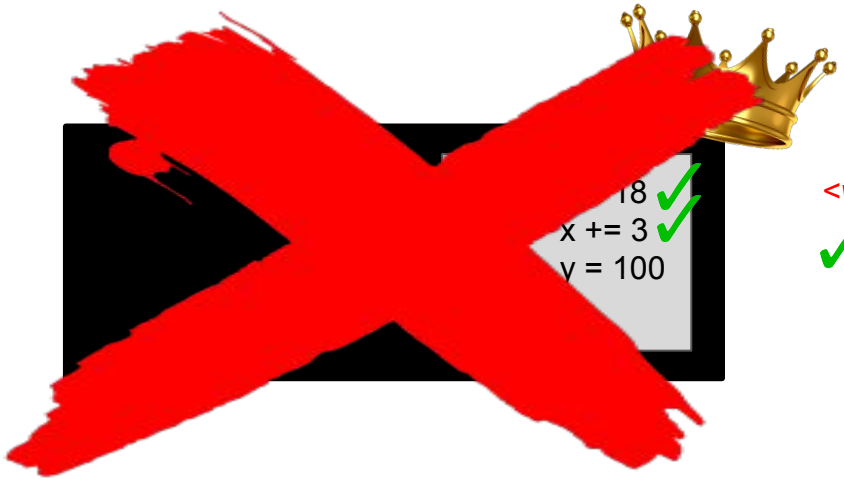
C

status	normal
replica	2
view	0
op	3
commit	2

<0, 1> x = 18 ✓
<0, 2> x += 3 ✓
<0, 3> y = 100

Start view change:

Status = change
Increment local view
Send SVC *to all nodes*



<view, op>
committed

B

status	normal
replica	1
view	0
op	2
commit	2

<0, 1> x = 18
<0, 2> x += 3

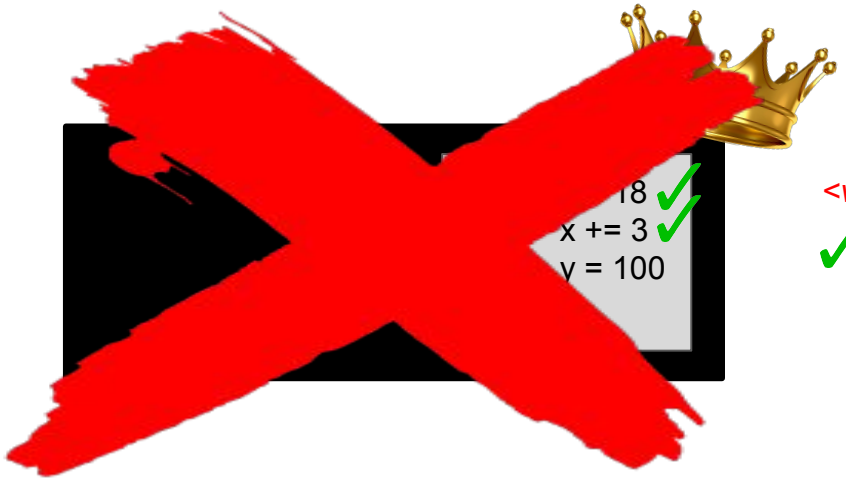
C

status	normal
replica	2
view	0
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Start view change:

Status = change
Increment local view
Send SVC *to all nodes*



<view, op>
committed

B

status	normal
replica	1
view	0
op	2
commit	2

<0, 1> x = 18
<0, 2> x += 3

StartViewChange
view: 1
replica: 2

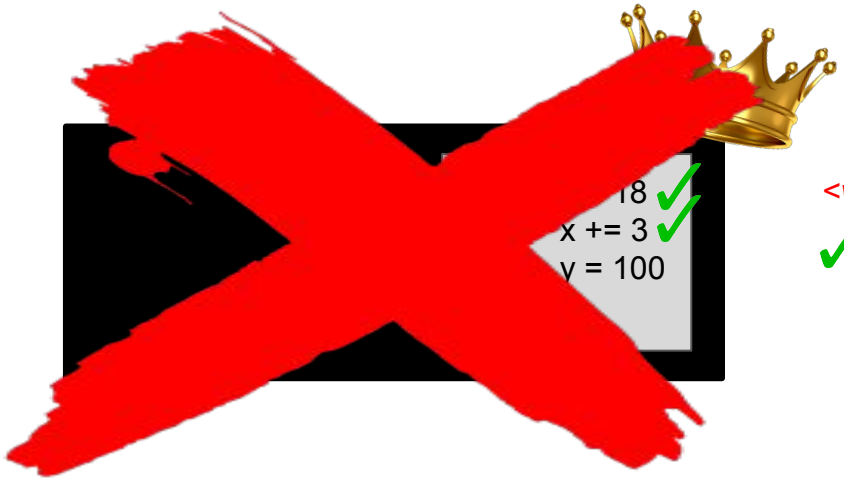
C

status	change
replica	2
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Receive SVC where:

SVC.view > local view {
Status = `view change`
Advance local view
Send SVC *to other nodes*
}



<view, op>
committed

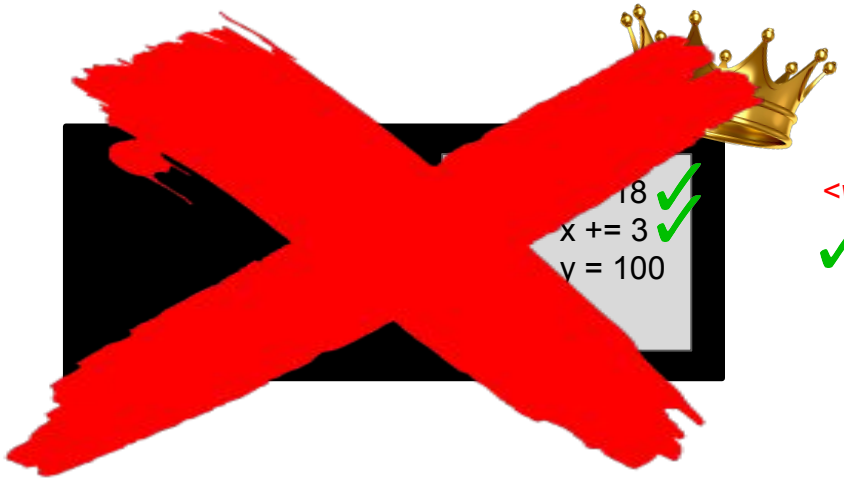
B		
status	normal	<0, 1> x = 18 ✓
replica	1	<0, 2> x += 3 ✓
view	0	
op	2	
commit	2	

StartViewChange
view: 1
replica: 2

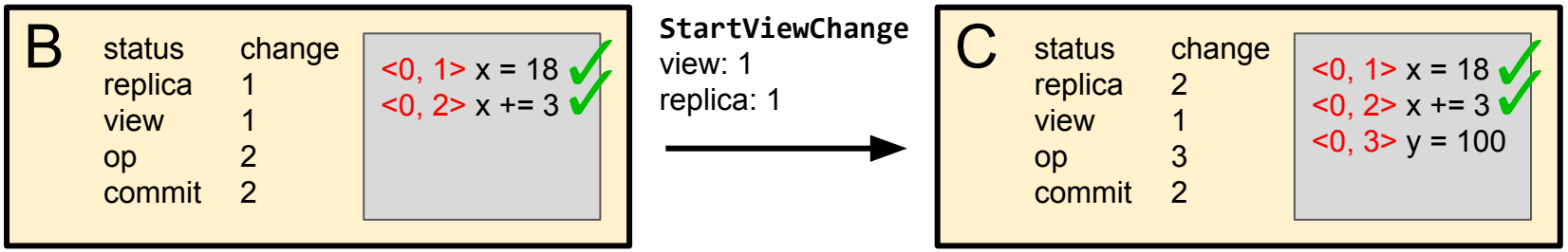
C		
status	change	<0, 1> x = 18 ✓
replica	2	<0, 2> x += 3 ✓
view	1	<0, 3> y = 100
op	3	
commit	2	

Receive SVC where:

SVC.view > local view {
Status = `view change`
Advance local view
Send SVC *to other nodes*
}

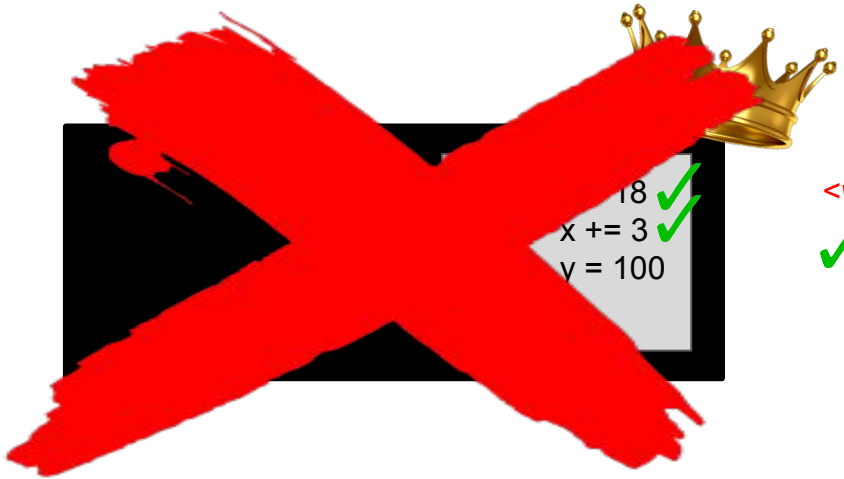


<view, op>
committed



Receive f SVCs where:

SVC.view == local view {
Send DVC to new primary
}



<view, op>
committed

B

status	change
replica	1
view	1
op	2
commit	2

<0, 1> x = 18
<0, 2> x += 3

`StartViewChange`
view: 1
replica: 1

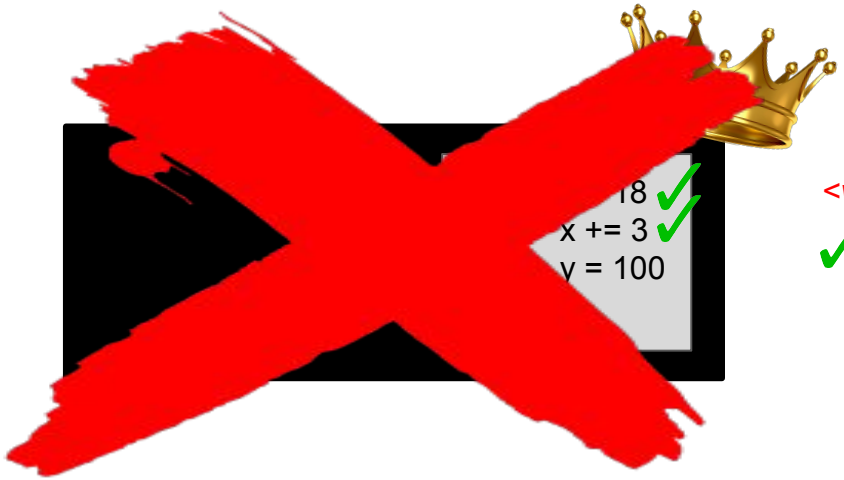
C

status	change
replica	2
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Receive f SVCs where:

SVC.view == local view {
Send DVC to new primary
}



<view, op>
committed

DoViewChange
replica: 2
view: 1
op: 3
commit: 2
<log>

B

status	change
replica	1
view	1
op	2
commit	2

<0, 1> x = 18
<0, 2> x += 3

C

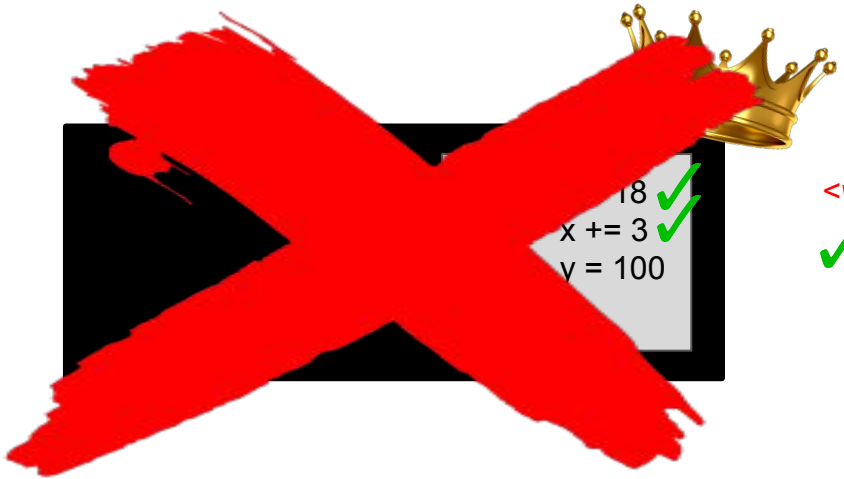
status	change
replica	2
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Logs are no longer out of sync!

With more nodes, we may receive multiple different logs

Pick the one with highest view and op number



<view, op>
committed

B

status	change
replica	1
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

C

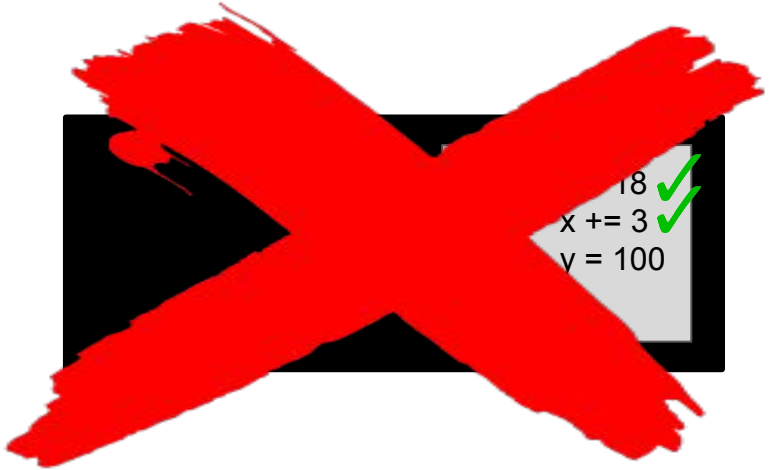
status	change
replica	2
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Receive f DVCs:

Become new primary
Send `StartView` *to others*

Why do we send the log here?



<view, op>
committed

B

status	normal
replica	1
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

`StartView`
view: 1
replica: 1
op: 3
commit: 2
<log>

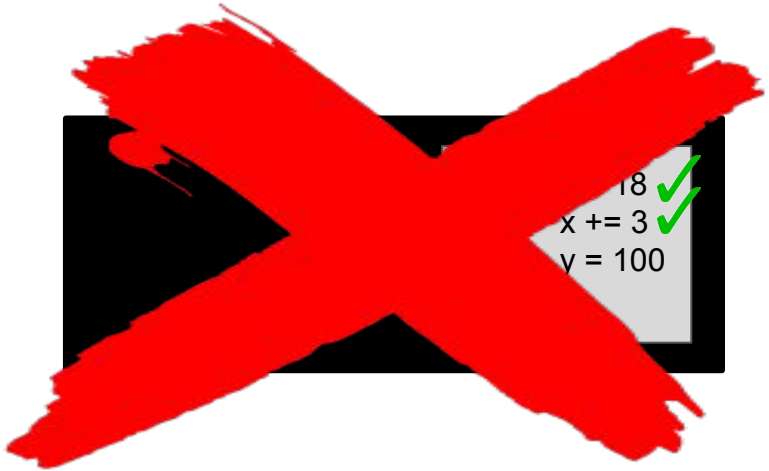
C

status	change
replica	2
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Notice <0, 3> is uncommitted and from an old view...

Do we commit it?



<view, op>
committed

B

status	normal
replica	1
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

PrepareOK
view: 0
op: 3
replica: 2

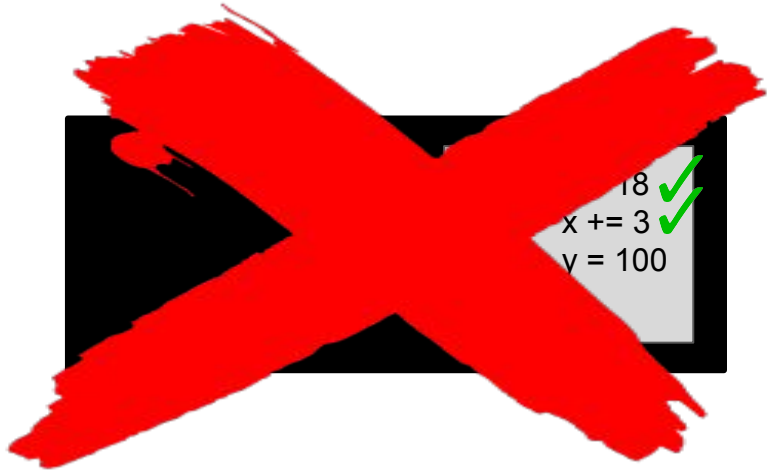
C

status	normal
replica	2
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Are uncommitted ops like <0, 3> guaranteed to survive into the new view?

What about committed ops? (e.g. <0, 1> and <0, 2>)



<view, op>
committed

B

status	normal
replica	1
view	1
op	3
commit	3

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

C

status	normal
replica	2
view	1
op	3
commit	2

<0, 1> x = 18
<0, 2> x += 3
<0, 3> y = 100

Summary: view change in VR

New primary is pre-selected based on IP address (round-robin)

View change triggered by timeout, could be any node

Wait for *f* `SVC` that matches our view number before sending `DVC`

Wait for *f* `DVC` to start new view (primary)

- Why *f* in both cases?
- Provided that at most *f* servers fail, is *liveness* guaranteed?

Failure detection

Two kinds of failures

Server failures

Network partitions

These two are indistinguishable from a single machine!

Failure detection goals

Completeness: Each failure is detected

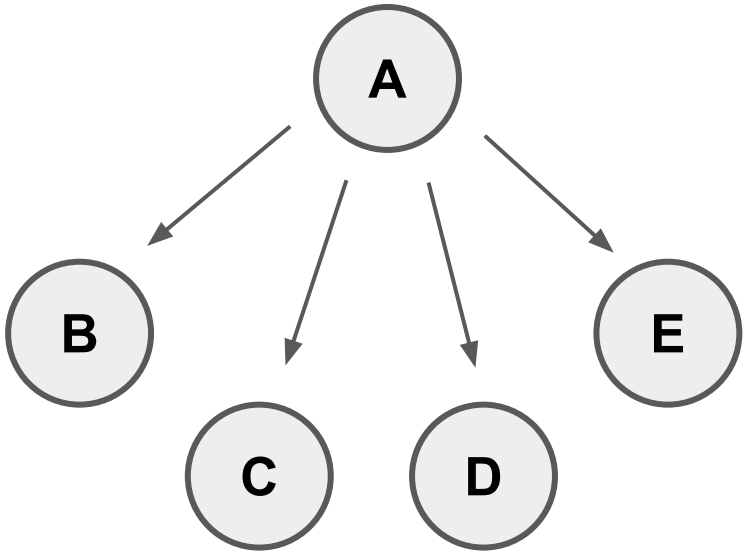
Accuracy: There is no mistaken detection

Speed: Time to first detection of a failure

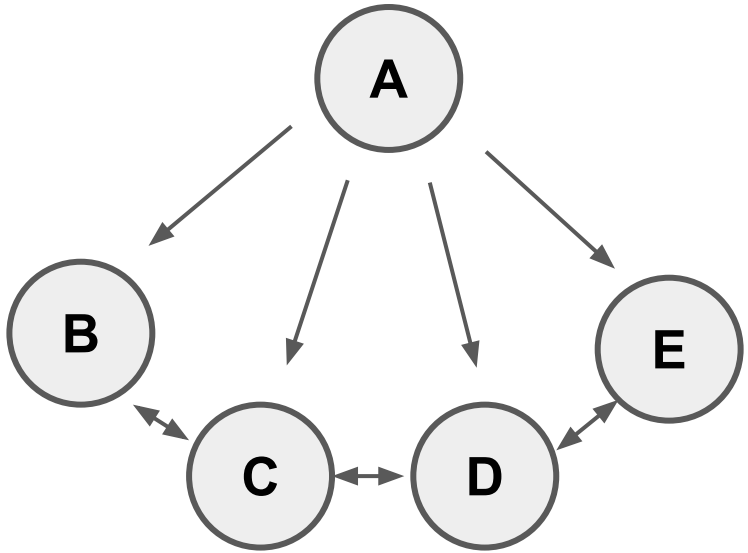
Scale: Equal load on each node

… in terms of CPU and network bandwidth

Centralized detection

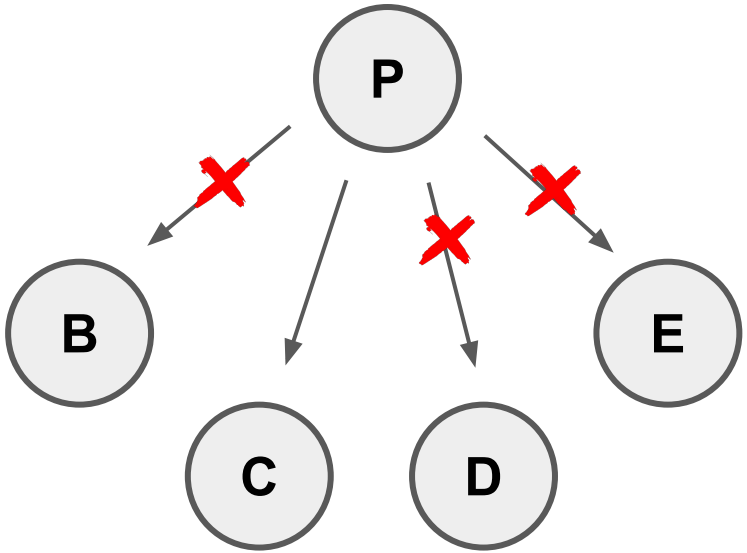


Gossip detection

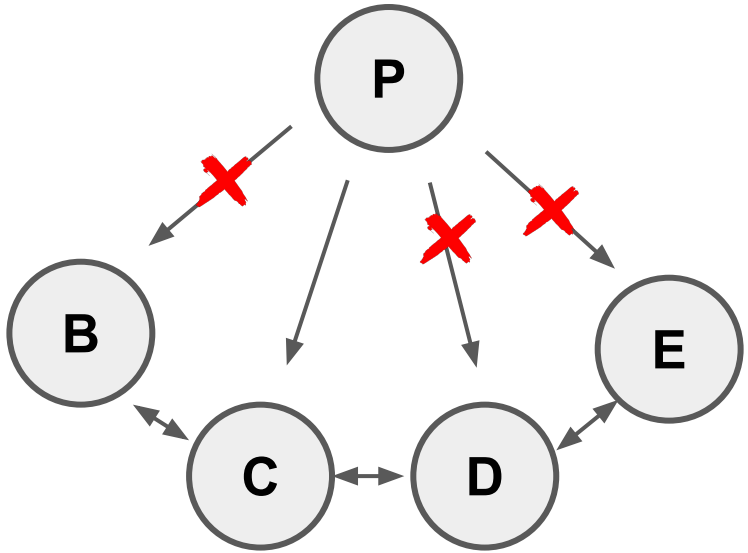


Completeness, accuracy, speed, load?

Centralized detection



Gossip detection



If we're running the view change protocol, what happens in each case?

What is gossip detection good for?

Certainly not viewstamped replication!

- May cause *liveness* issues; primary cannot reach *f* nodes

Dynamo uses gossip for membership and failure detection

- More suitable for completely decentralized environments

Additional reading for viewstamped replication

http://pmg.csail.mit.edu/papers/vr-revisited.pdf

https://blog.acolyer.org/2015/03/06/viewstamped-replication-revisited/

Q & A