

THE PITFALLS OF ACHIEVING TAGGED CAUSAL DELIVERY

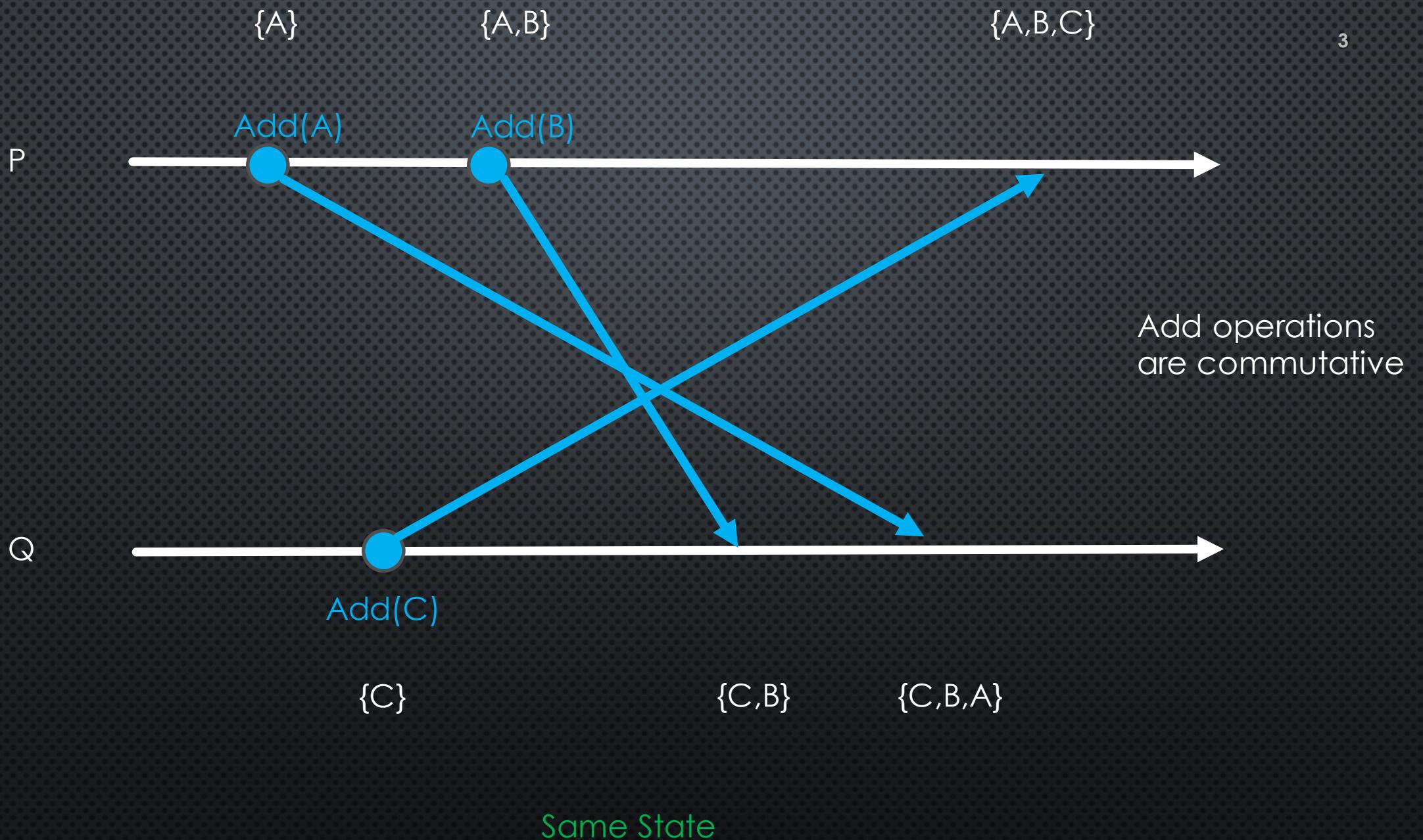
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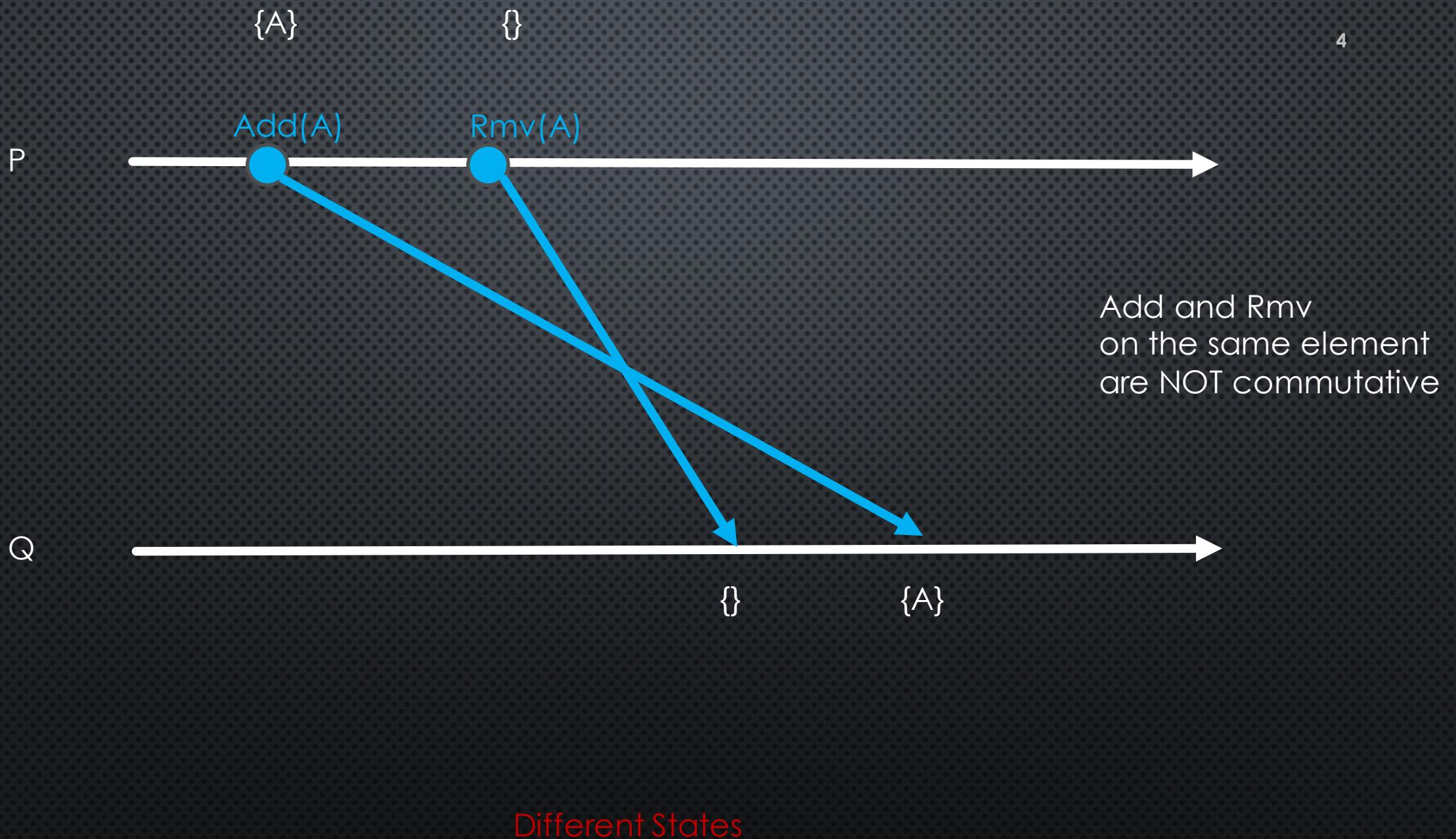
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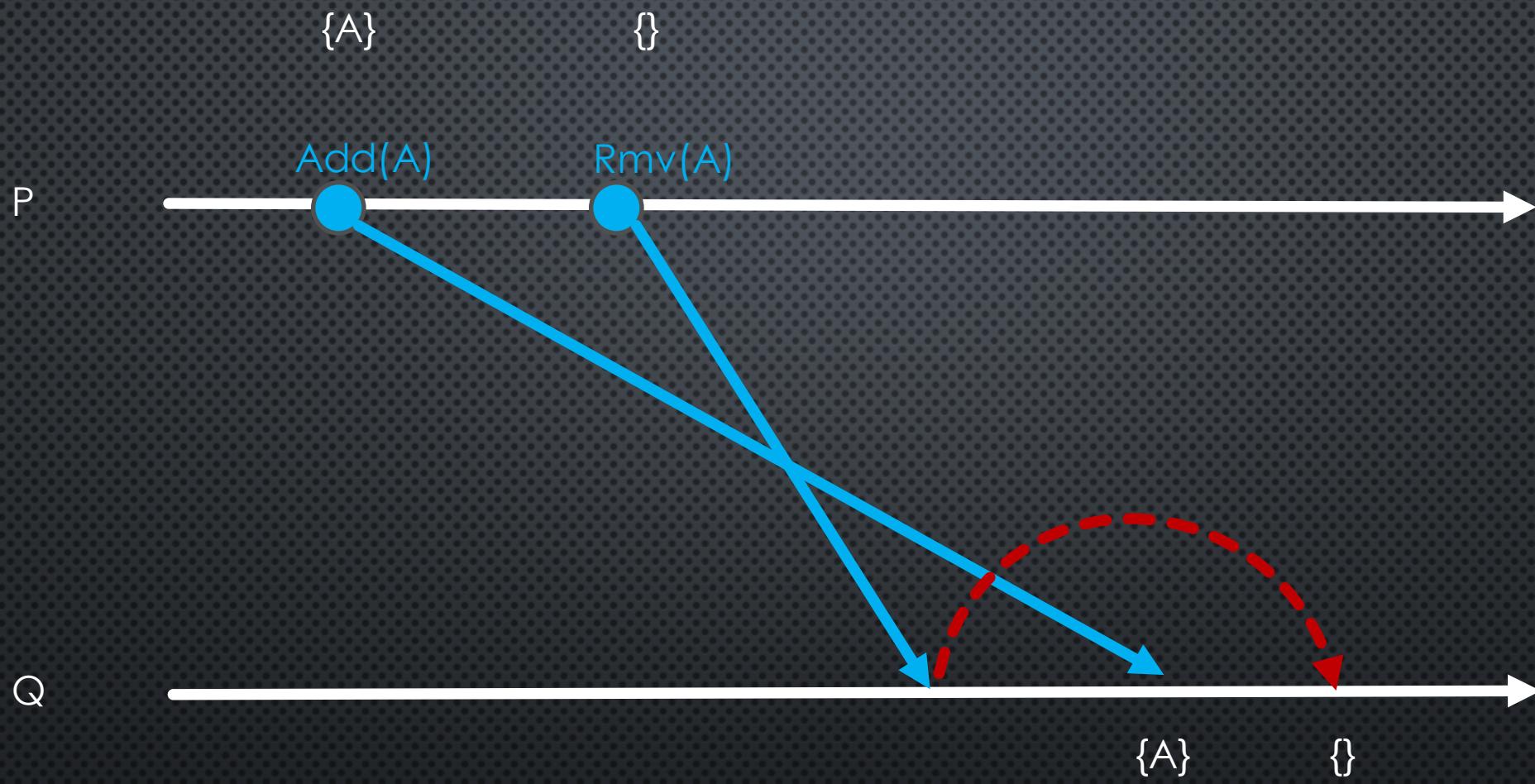
APRIL 23, 2018

USE CASE: REPLICATED SET

- API:
 - ADD(ELEMENT): ADDS THE ELEMENT TO THE SET
 - RMV(ELEMENT): REMOVES THE ELEMENT FROM THE SET
 - QUERY(): RETURNS ALL THE ELEMENTS IN THE SET

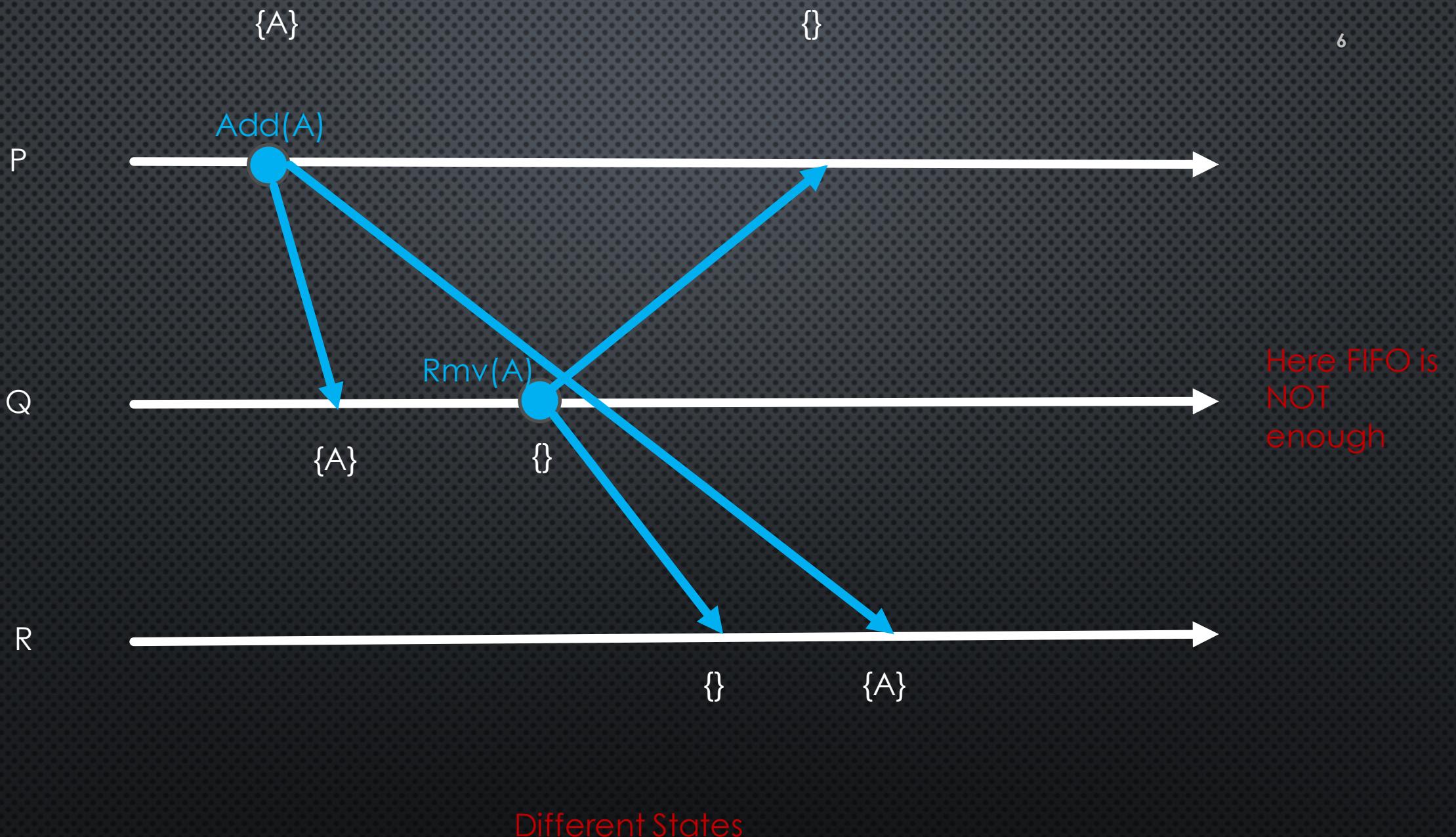


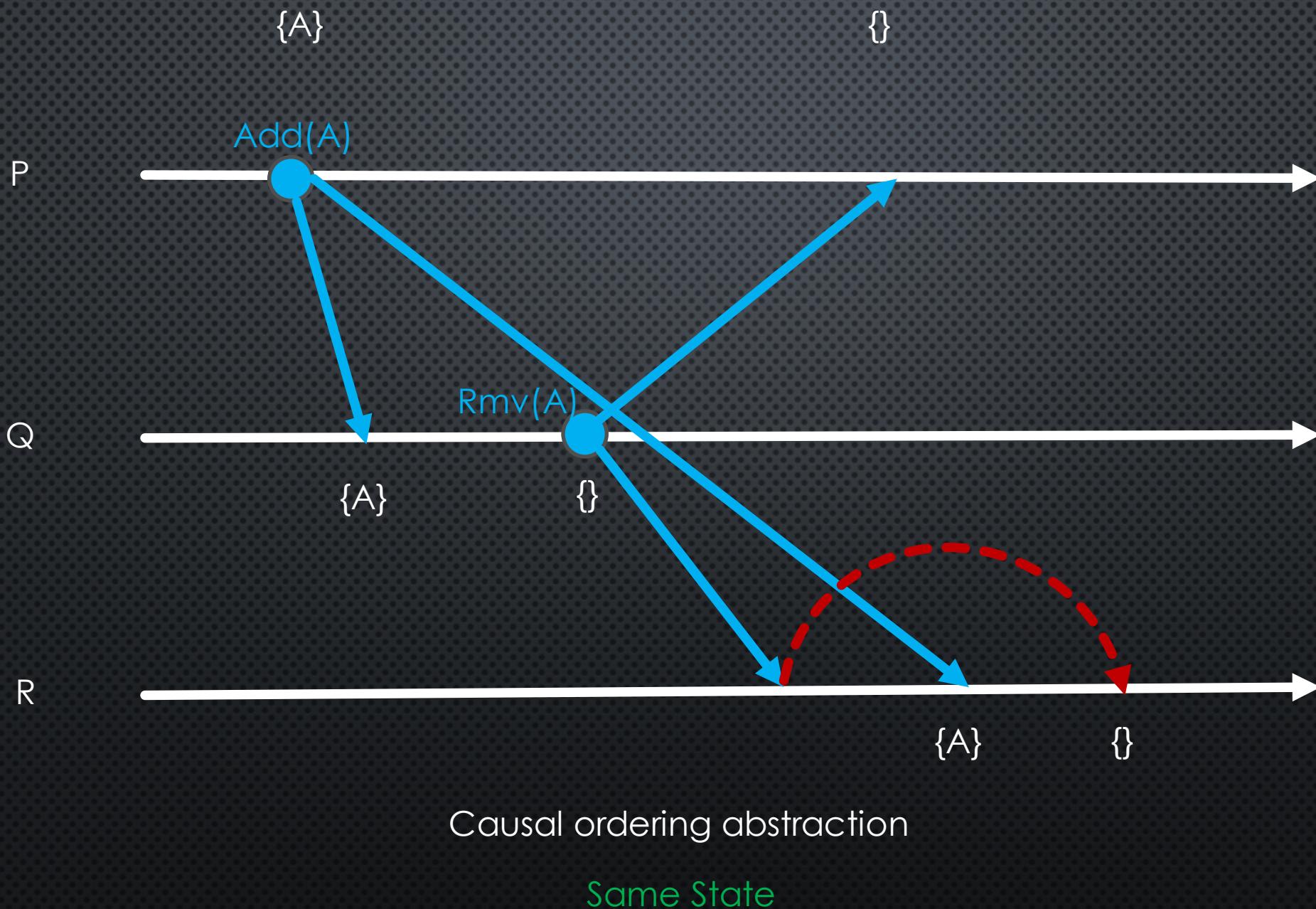


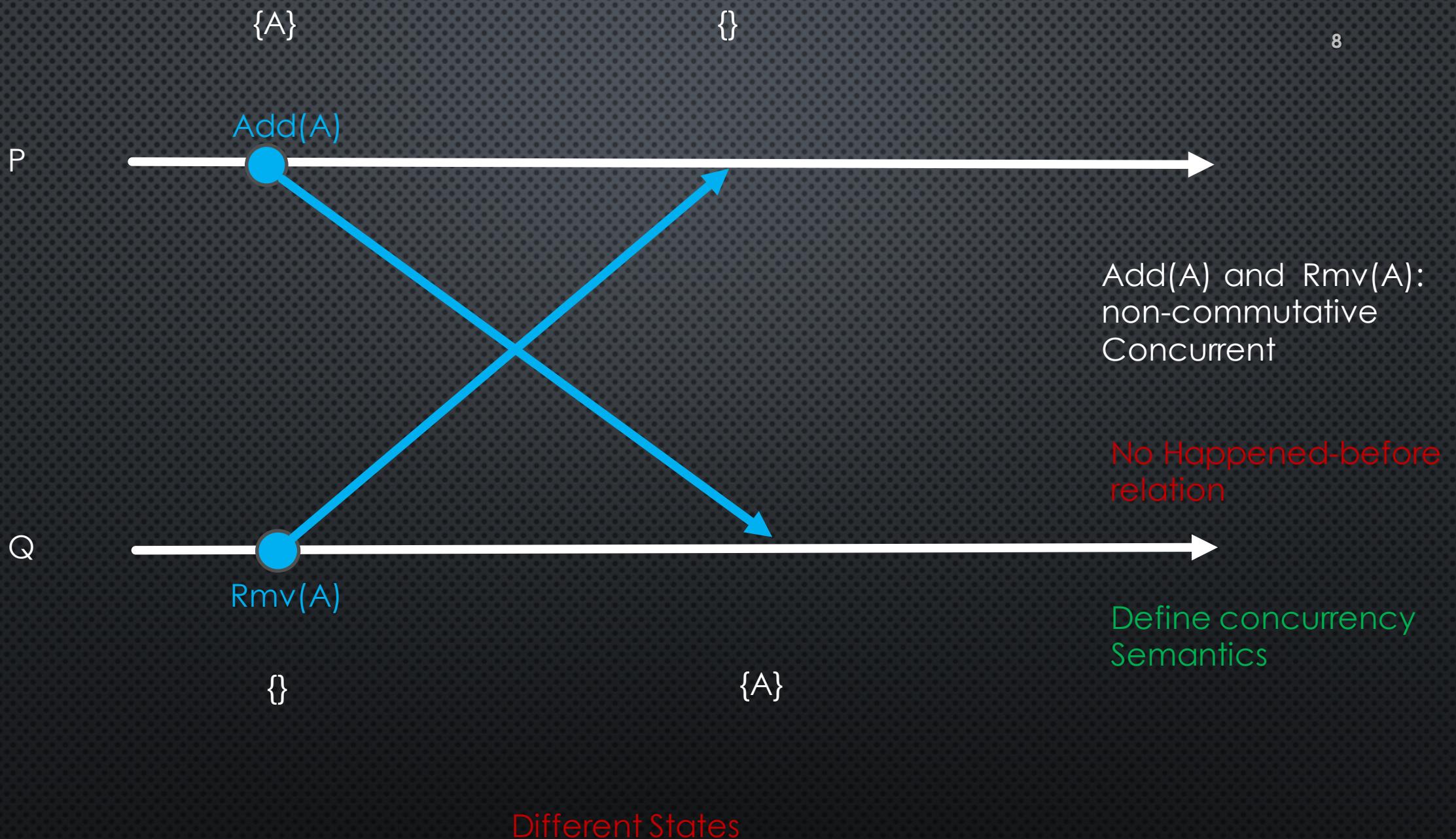


FIFO ordering abstraction

Same State







SOLUTION 1

- WHAT YOU NEED:

- CAUSAL ORDER



Off-the-shelf middleware

- CONCURRENCY SEMANTICS



The “happened-before”
relation between ops

SOLUTION 1

- WHAT YOU NEED:

- CAUSAL ORDER



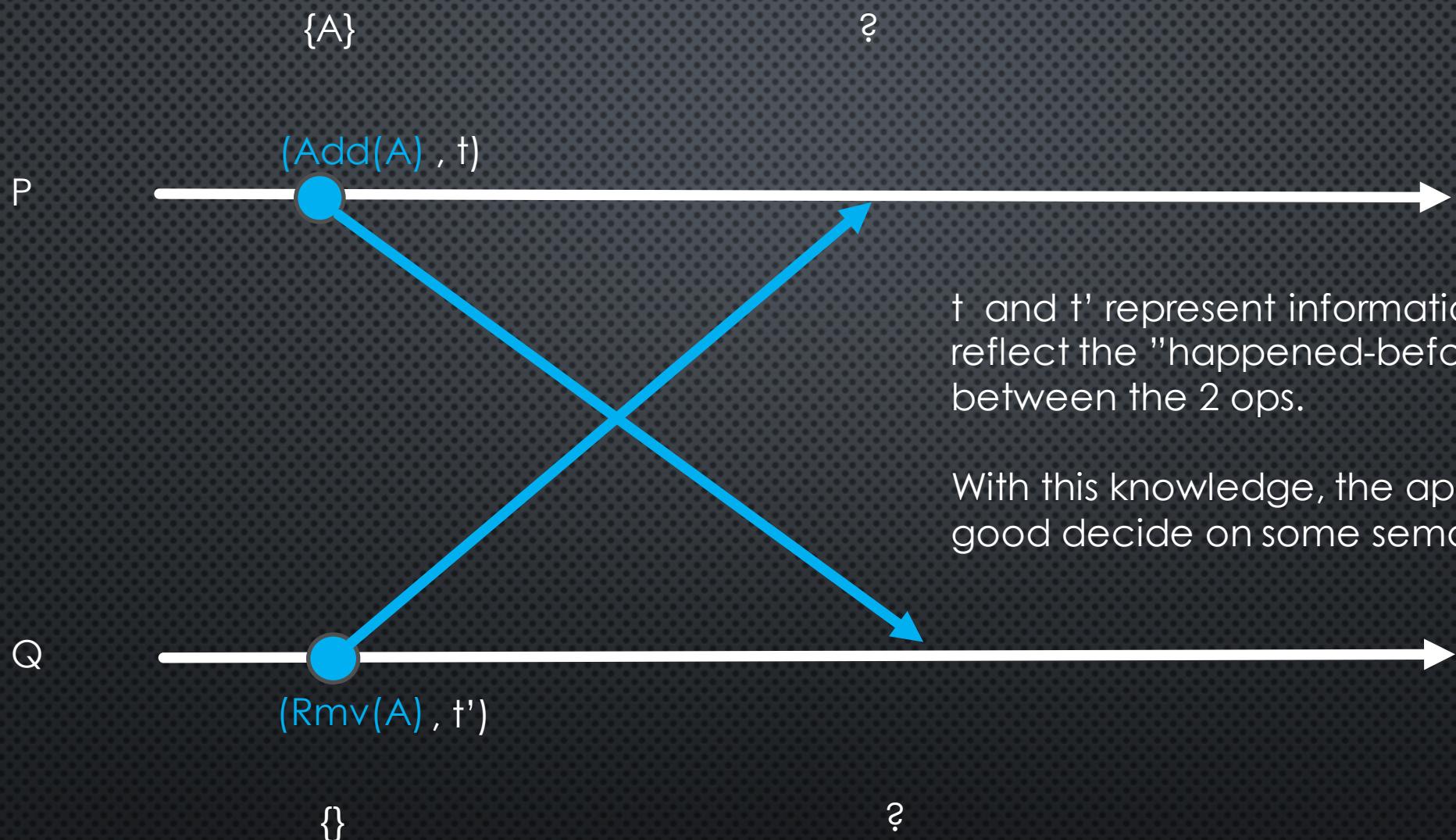
Off-the-shelf middleware

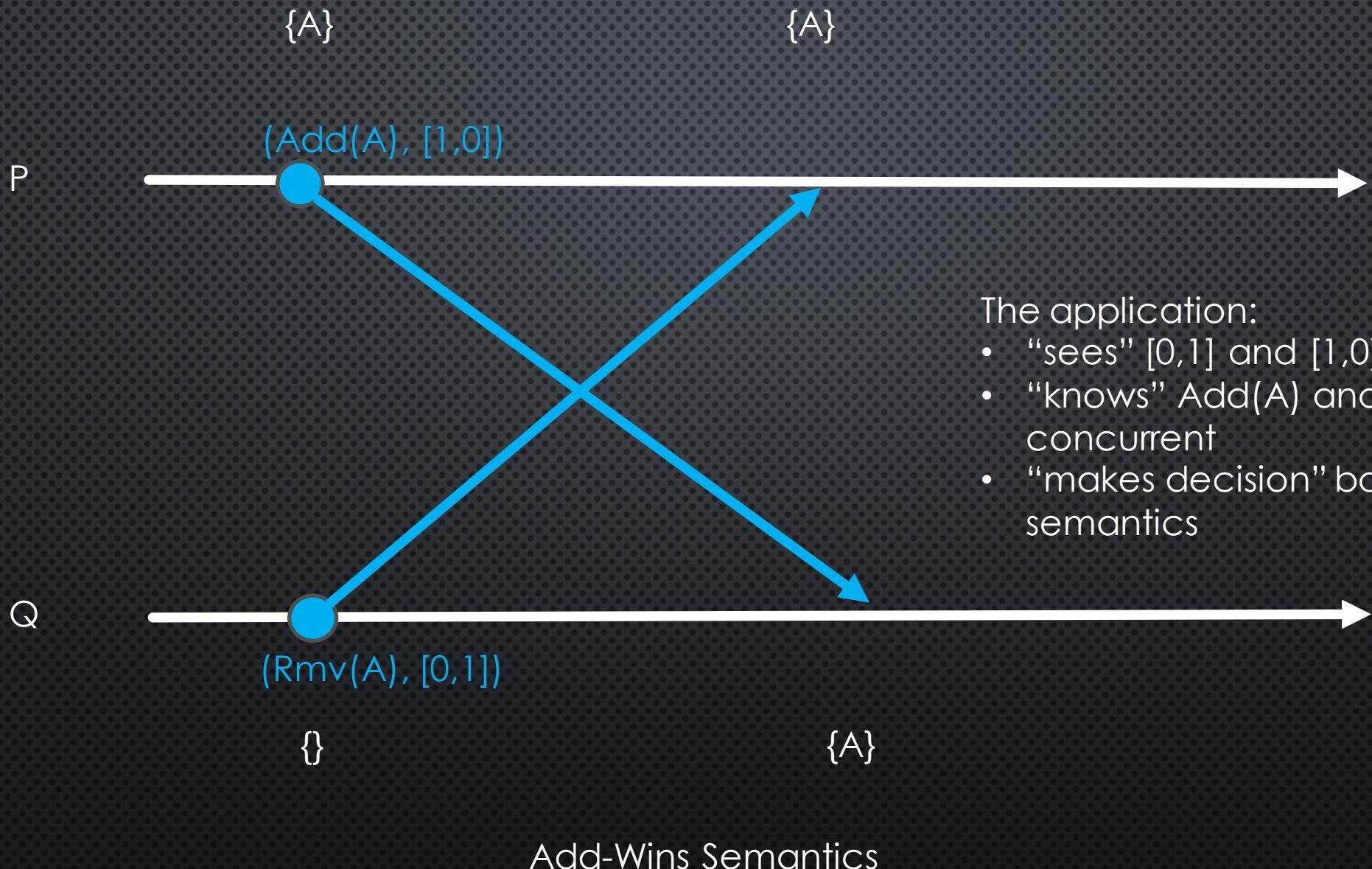
- CONCURRENCY SEMANTICS



The “happened-before”
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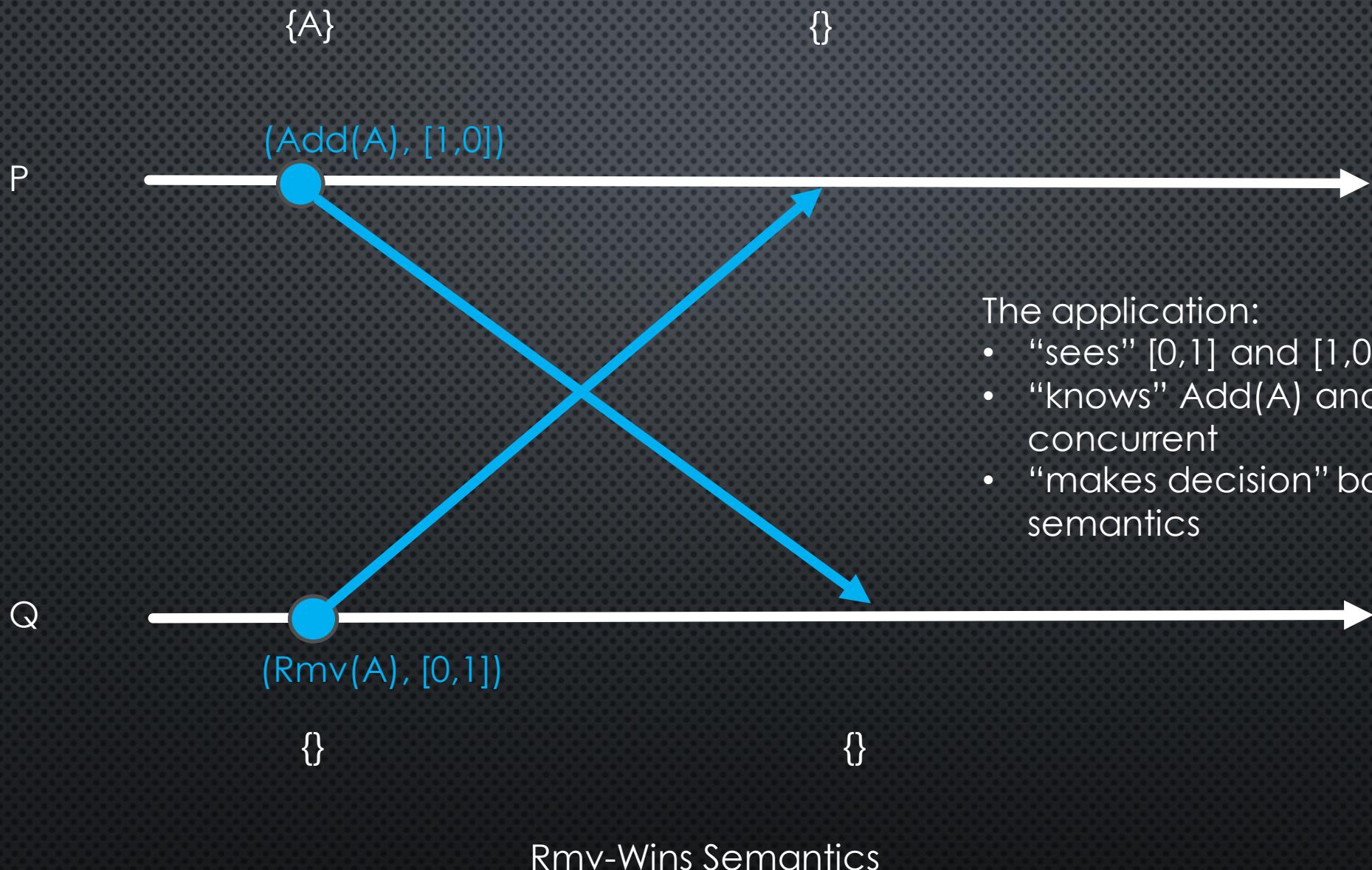
Requires explicit
tagging of operations





The application:

- “sees” $[0,1]$ and $[1,0]$
- “knows” $\text{Add}(A)$ and $\text{Rmv}(A)$ concurrent
- “makes decision” based on semantics



SOLUTION 1

- WHAT YOU NEED:

- CAUSAL ORDER



Off-the-shelf middleware

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The “happened-before”
relation between ops

Requires explicit
tagging of operations

Solves the problem

SOLUTION 1

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The “happened-before”
relation between ops

Requires explicit
tagging of operations

Solves the problem

But

SOLUTION 1

- WHAT YOU NEED:

- CAUSAL ORDER



Off-the-shelf middleware

Already tags for causal delivery

- CONCURRENCY SEMANTICS



The “happened-before” relation between ops

Requires explicit tagging of operations

Solves the problem

But

SOLUTION 1

- WHAT YOU NEED:

- CAUSAL ORDER



Off-the-shelf middleware

Already tags for causal delivery

- CONCURRENCY SEMANTICS



The “happened-before” relation between ops

Tags for concurrency semantics

Requires explicit tagging of operations

Solves the problem

But

SOLUTION 1

- WHAT YOU NEED:

- CAUSAL ORDER



Off-the-shelf middleware

Already tags for causal delivery

- CONCURRENCY SEMANTICS



The “happened-before” relation between ops

Requires explicit tagging of operations

Tags for concurrency semantics

Solves the problem

But

Duplicates effort
More meta-data

SOLUTION 2

- WHAT YOU NEED:

- CAUSAL ORDER



Off-the-shelf middleware

- CONCURRENCY SEMANTICS



The “happened-before”
relation between ops

SOLUTION 2

- WHAT YOU NEED:

- CAUSAL ORDER



Off-the-shelf middleware



Do Not
expose

- CONCURRENCY SEMANTICS



The “happened-before”
relation between ops



SOLUTION 2

- WHAT YOU NEED:

- CAUSAL ORDER

- CONCURRENCY SEMANTICS



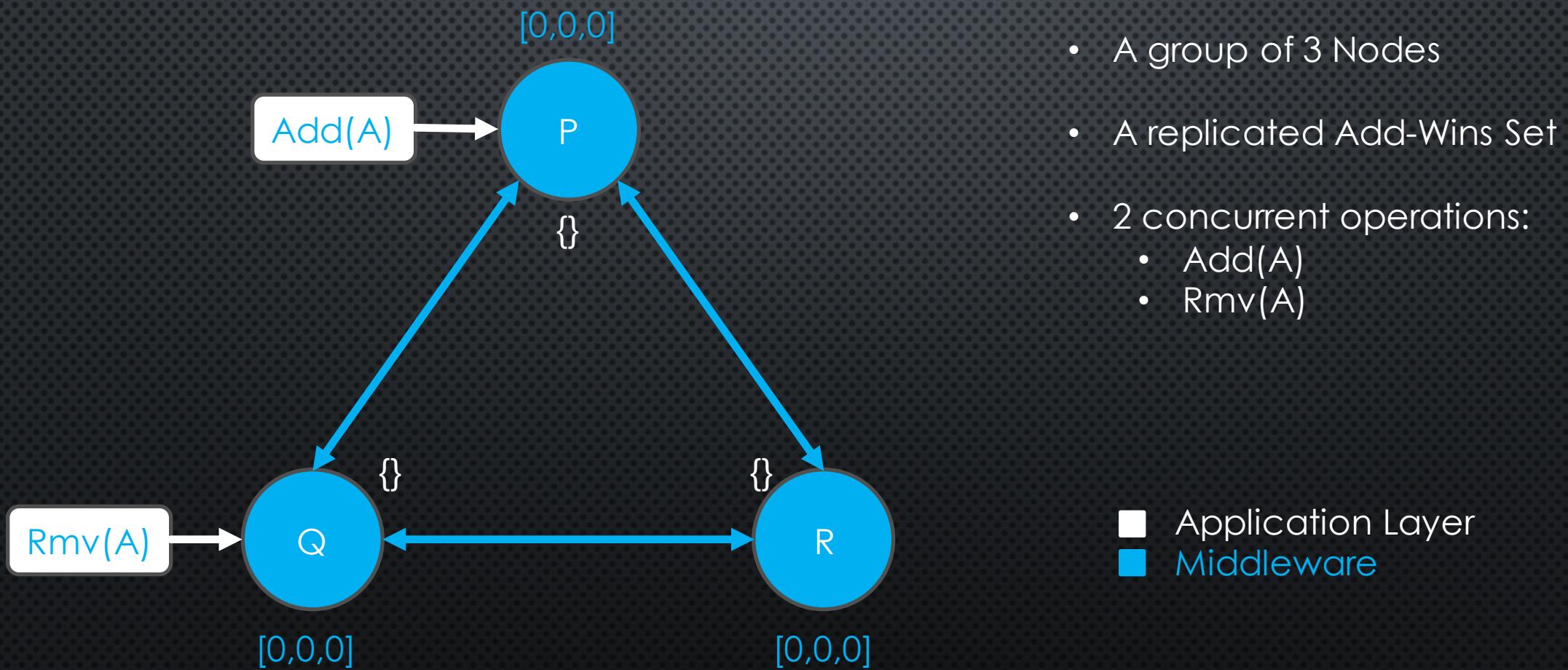
Off-the-shelf middleware

The “happened-before”
relation between ops

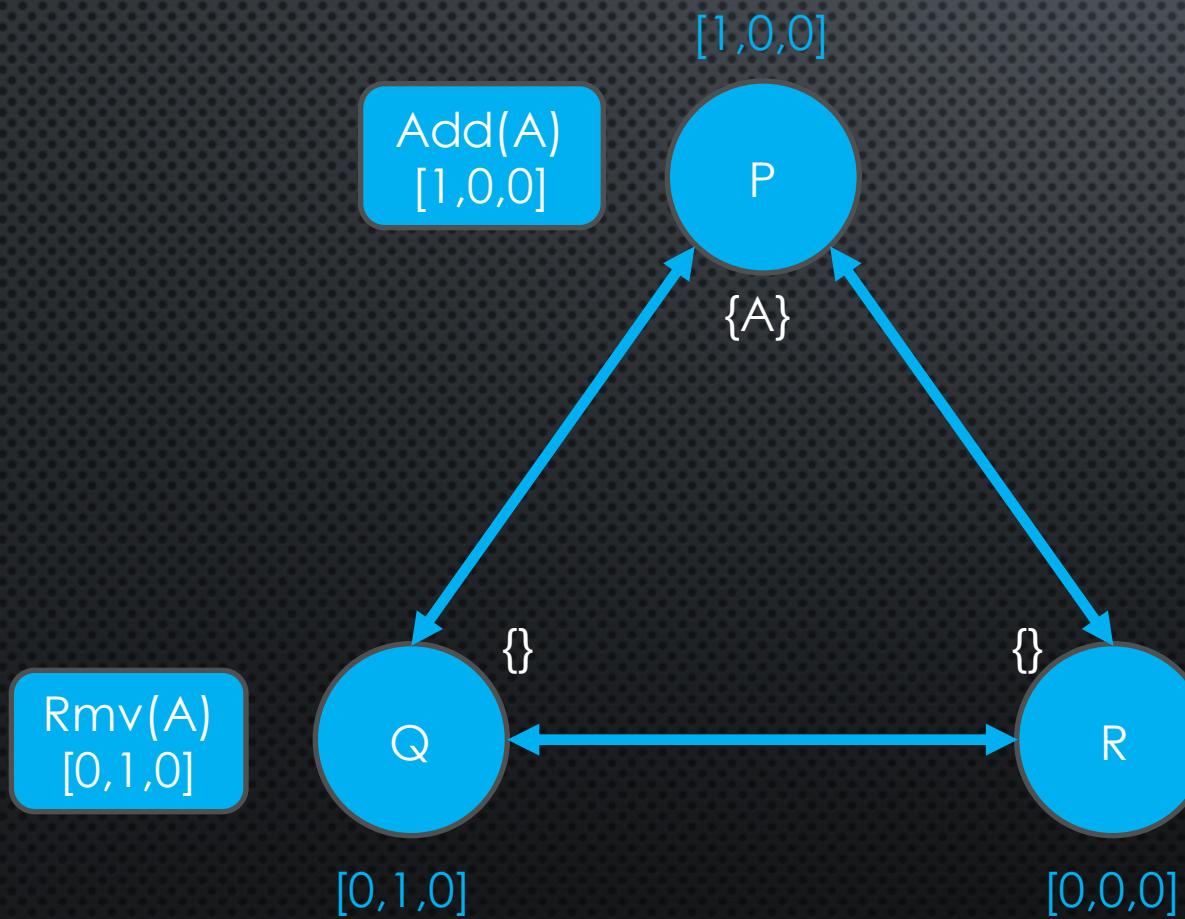
Modify middleware to
expose

Do Not
expose

SOLUTION 2



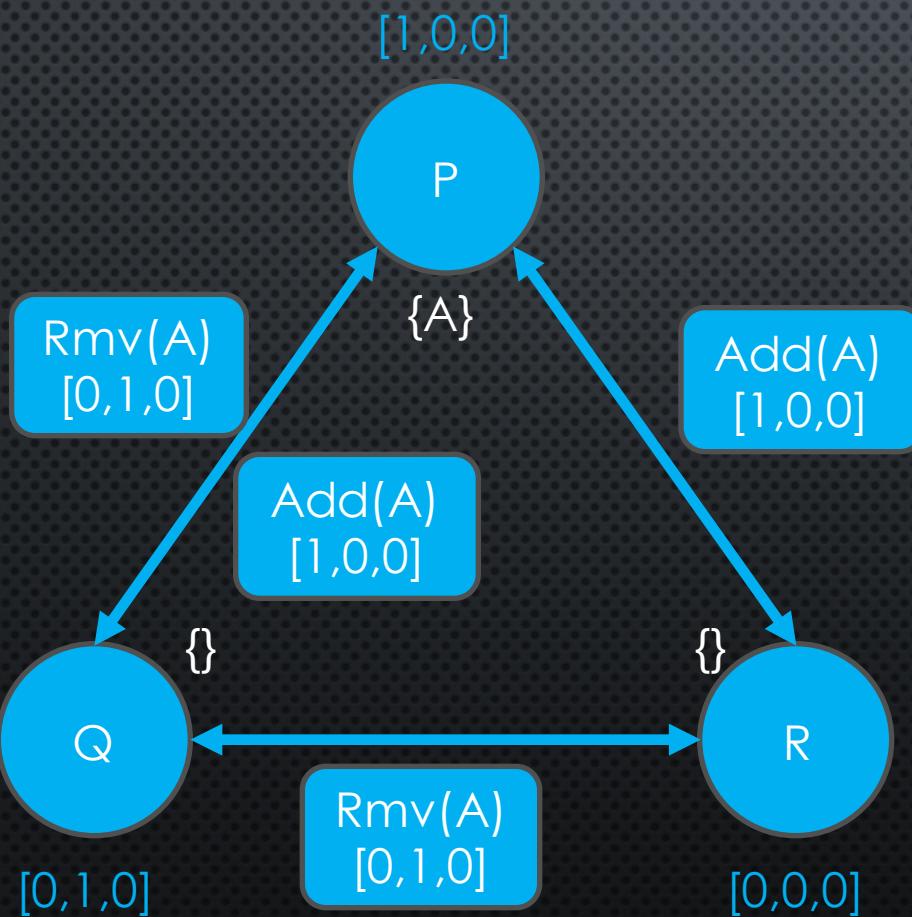
SOLUTION 2



Scenario 1:

- P tags the op $\text{Add}(A)$
- Q tags the op $\text{Rmv}(A)$

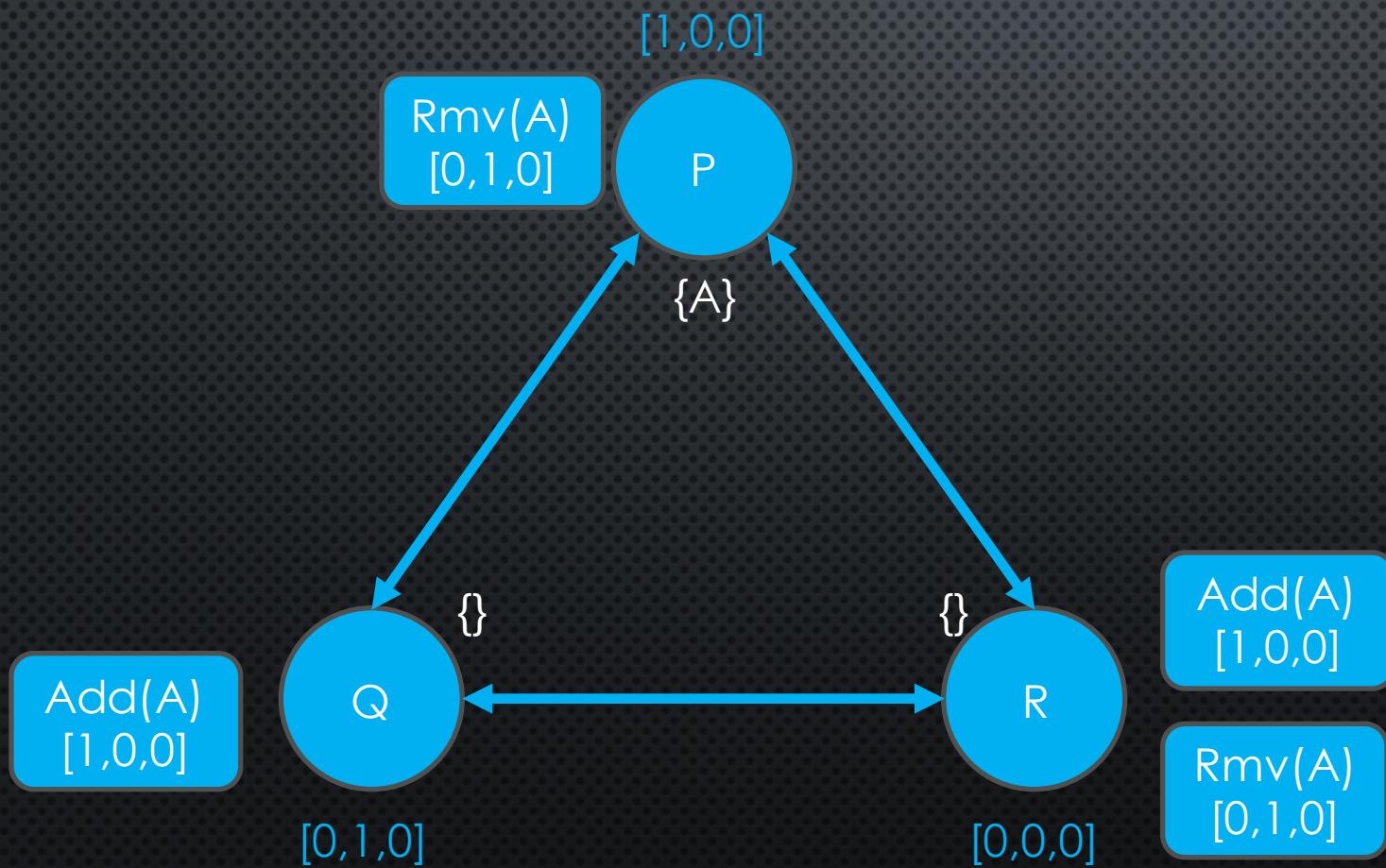
SOLUTION 2



Scenario 1:

- P tags the op Add(A)
- Q tags the op Rmv(A)
- P and Q bcast their tagged ops

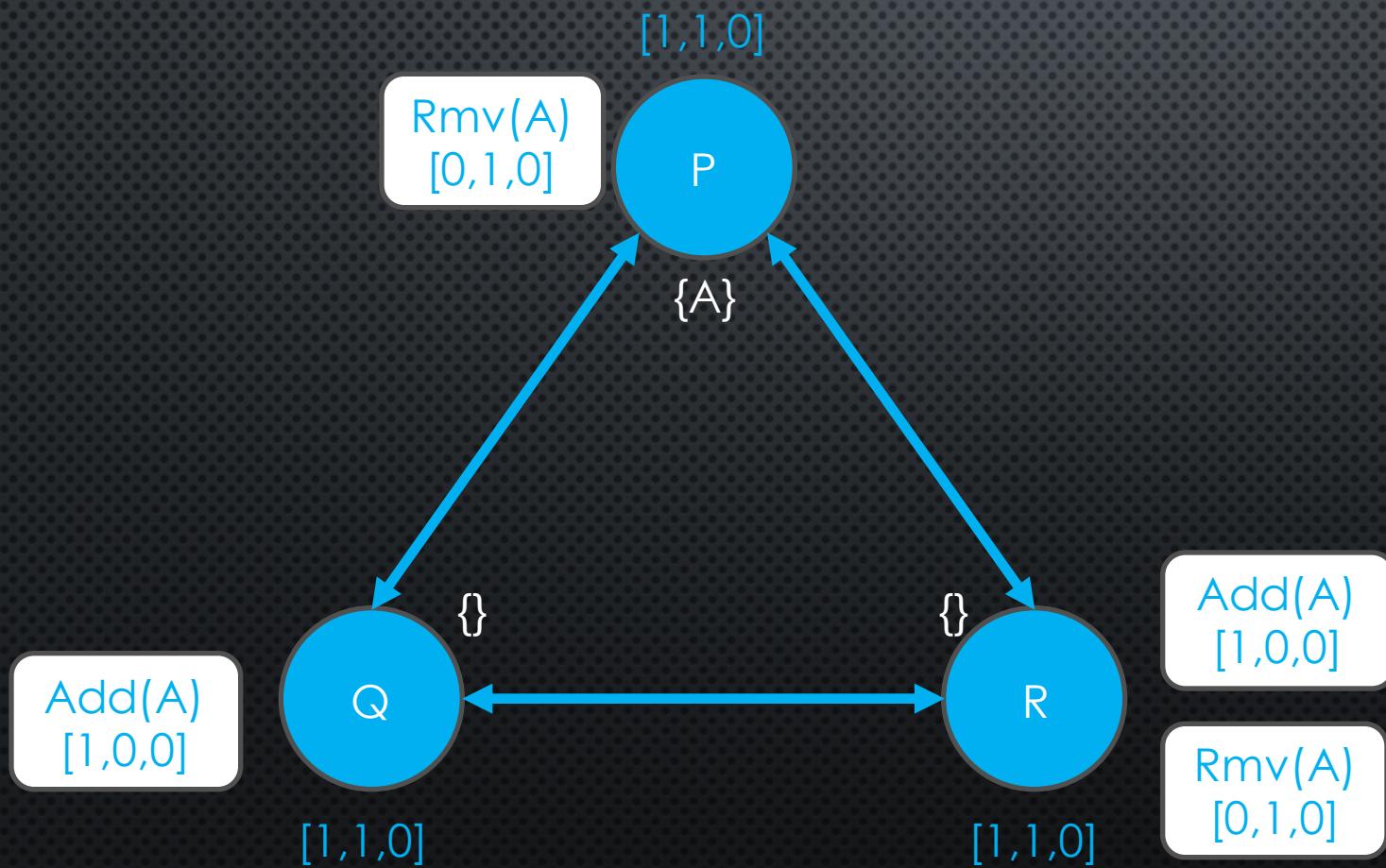
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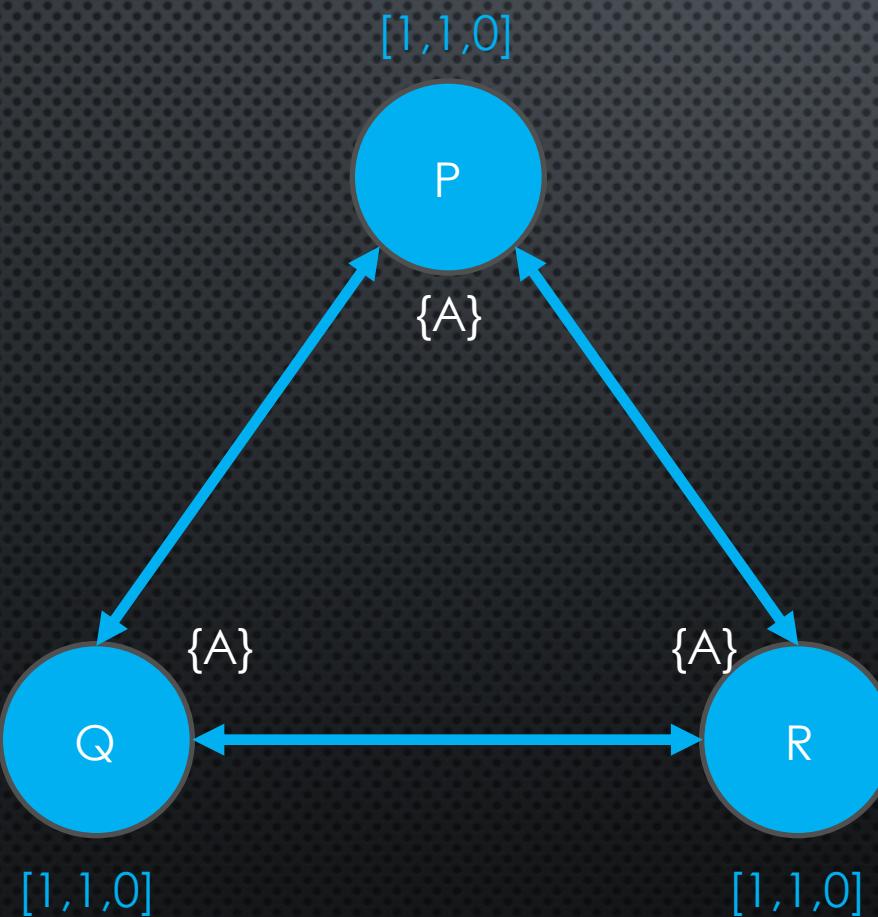
SOLUTION 2



Scenario 1:

- P tags the op $\text{Add}(A)$
- Q tags the op $\text{Rmv}(A)$
- P and Q bcast their tagged ops
- All nodes deliver both ops

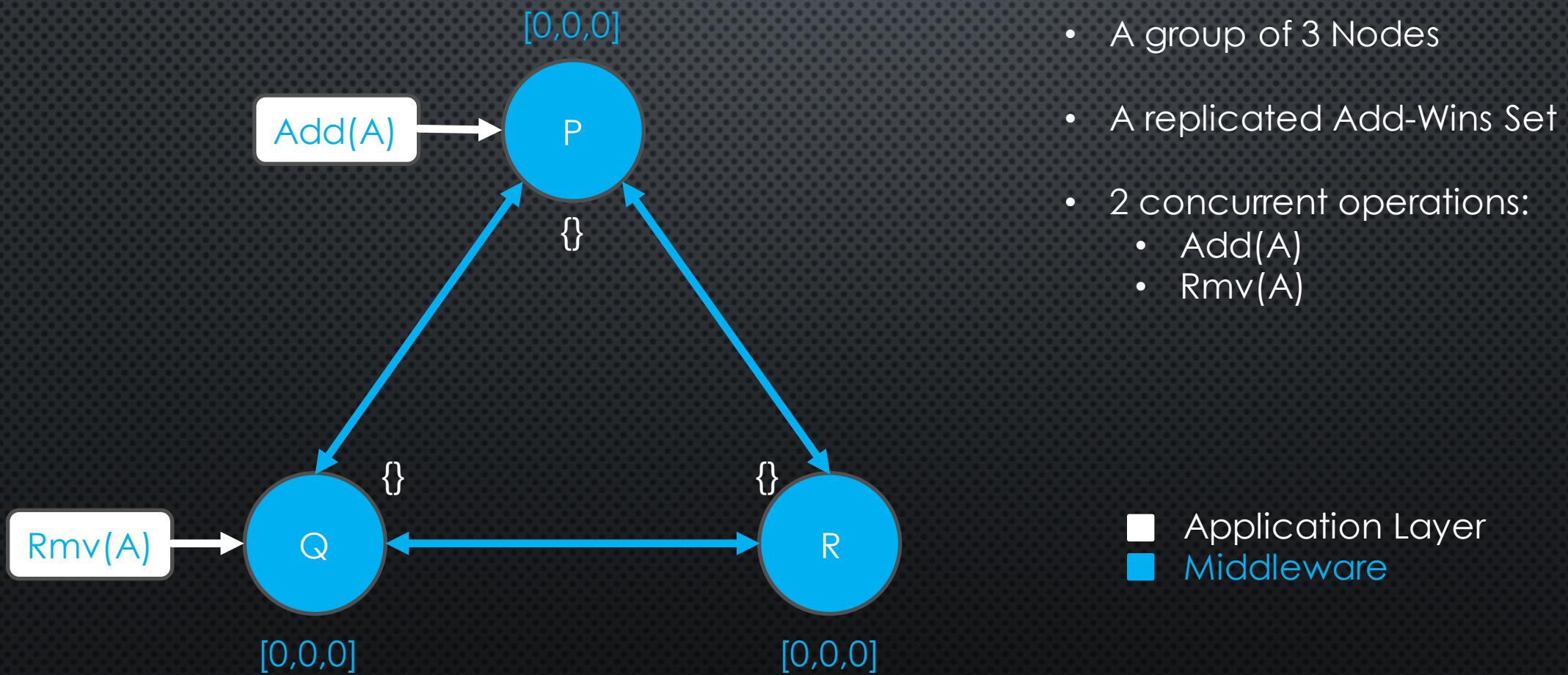
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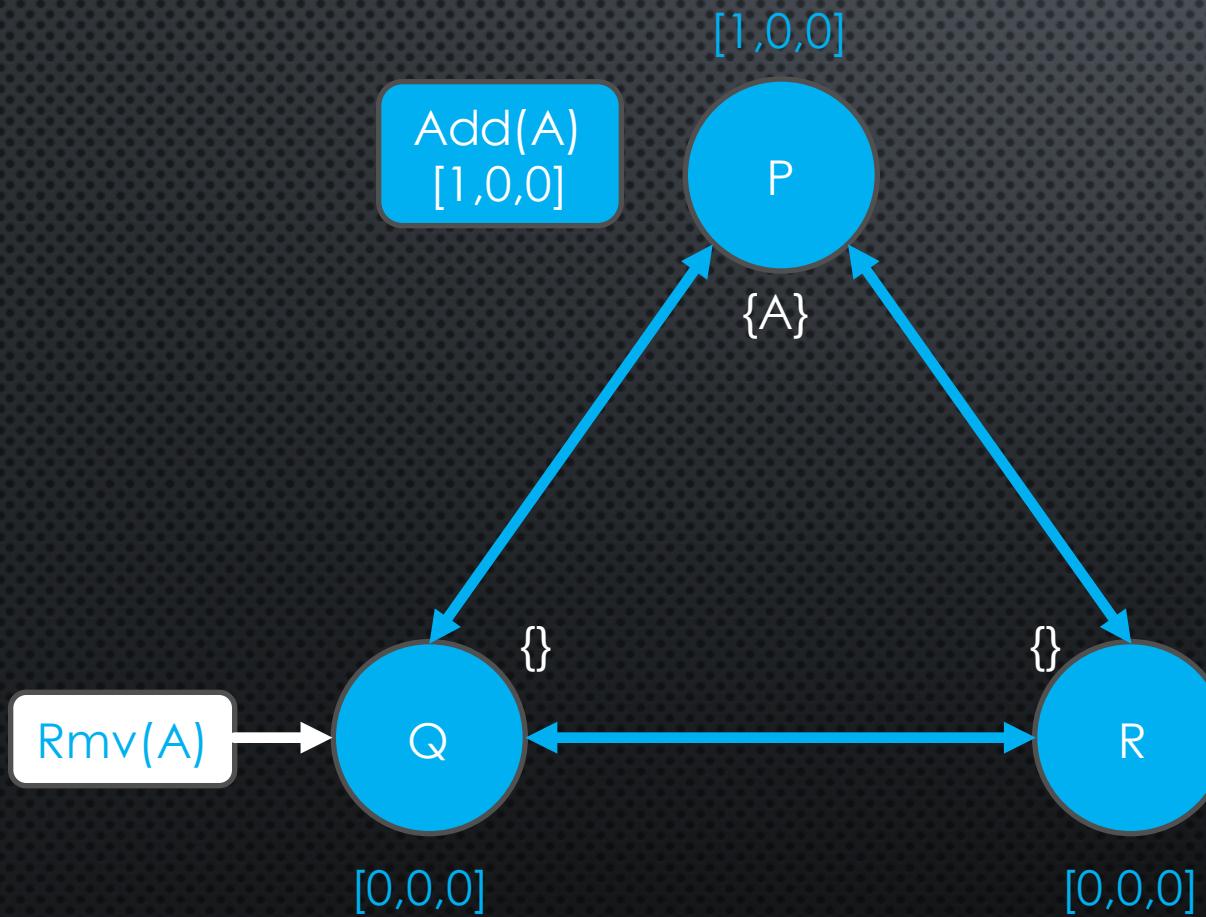
Scenario 1:

- P tags the op Add(A)
- Q tags the op Rmv(A)
- P and Q bcast their tagged ops
- All nodes deliver both ops
- [1,0,0] and [0,1,0] are concurrent
 - Add-Wins Semantics
 - A is there

SOLUTION 2



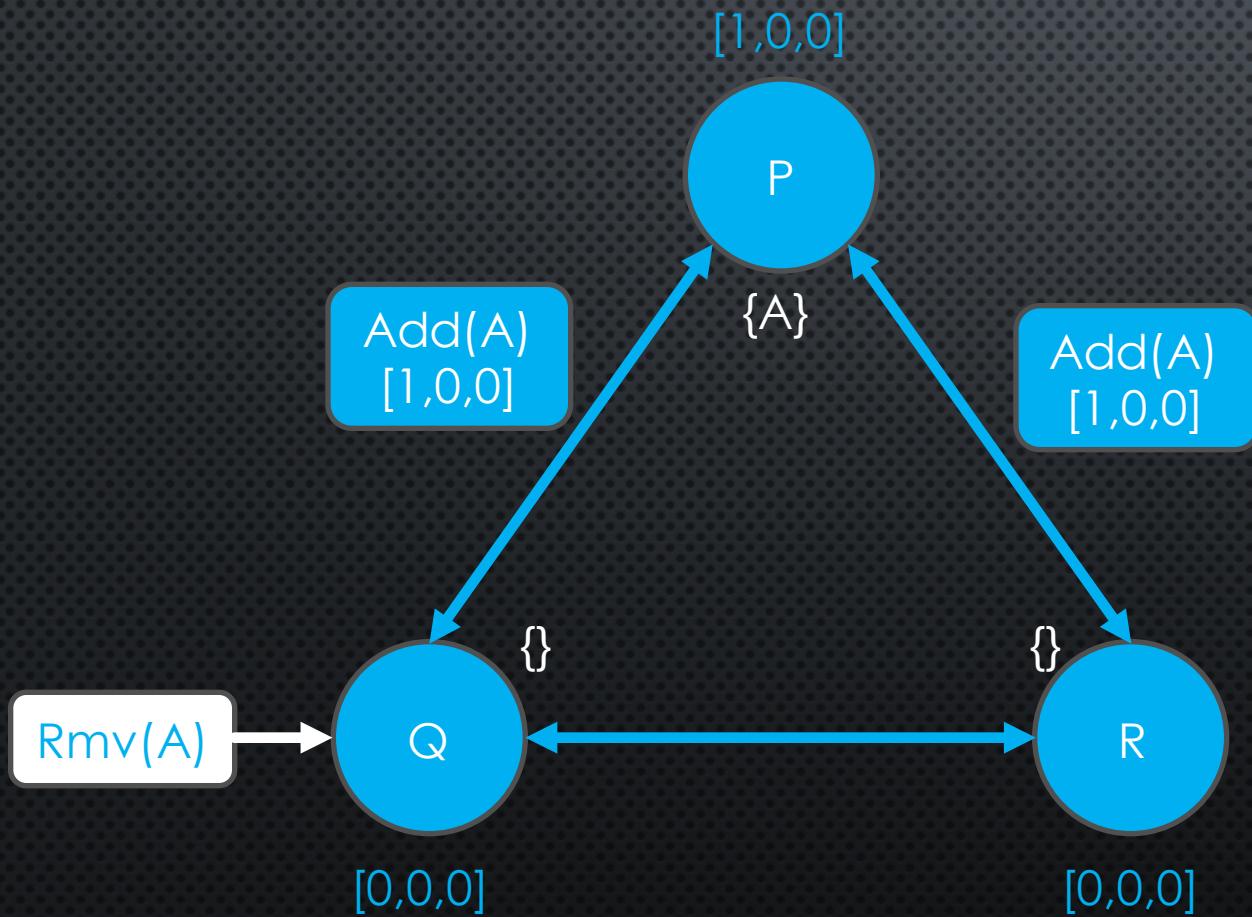
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Scenario 2:

- P tags the op Add(A)
- Rmv(A) is still in the queue waiting to be processed by Q

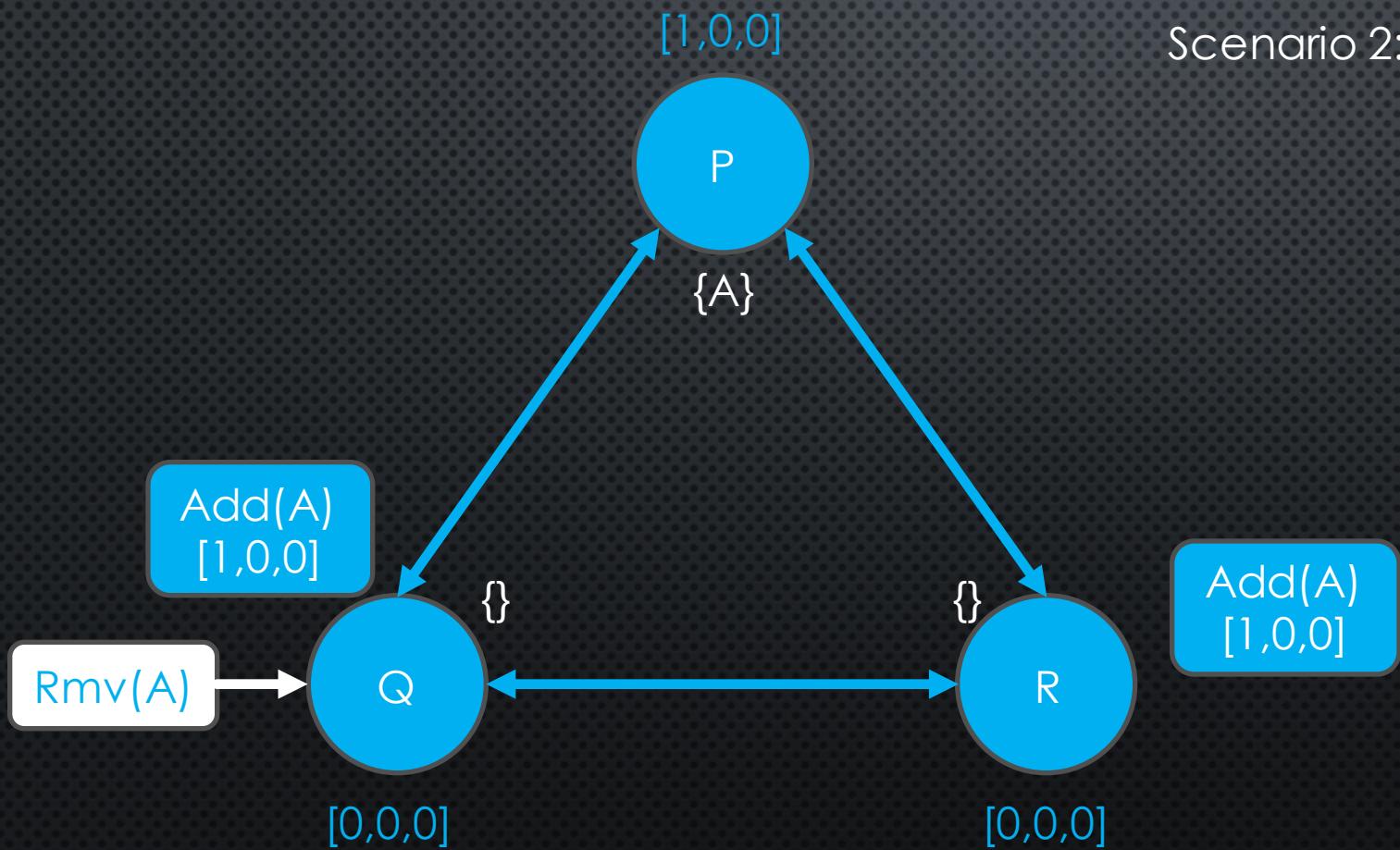
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Scenario 2:

- P tags the op Add(A)
- Rmv(A) is still in the queue waiting to be processed by Q
- P broadcasts their tagged op

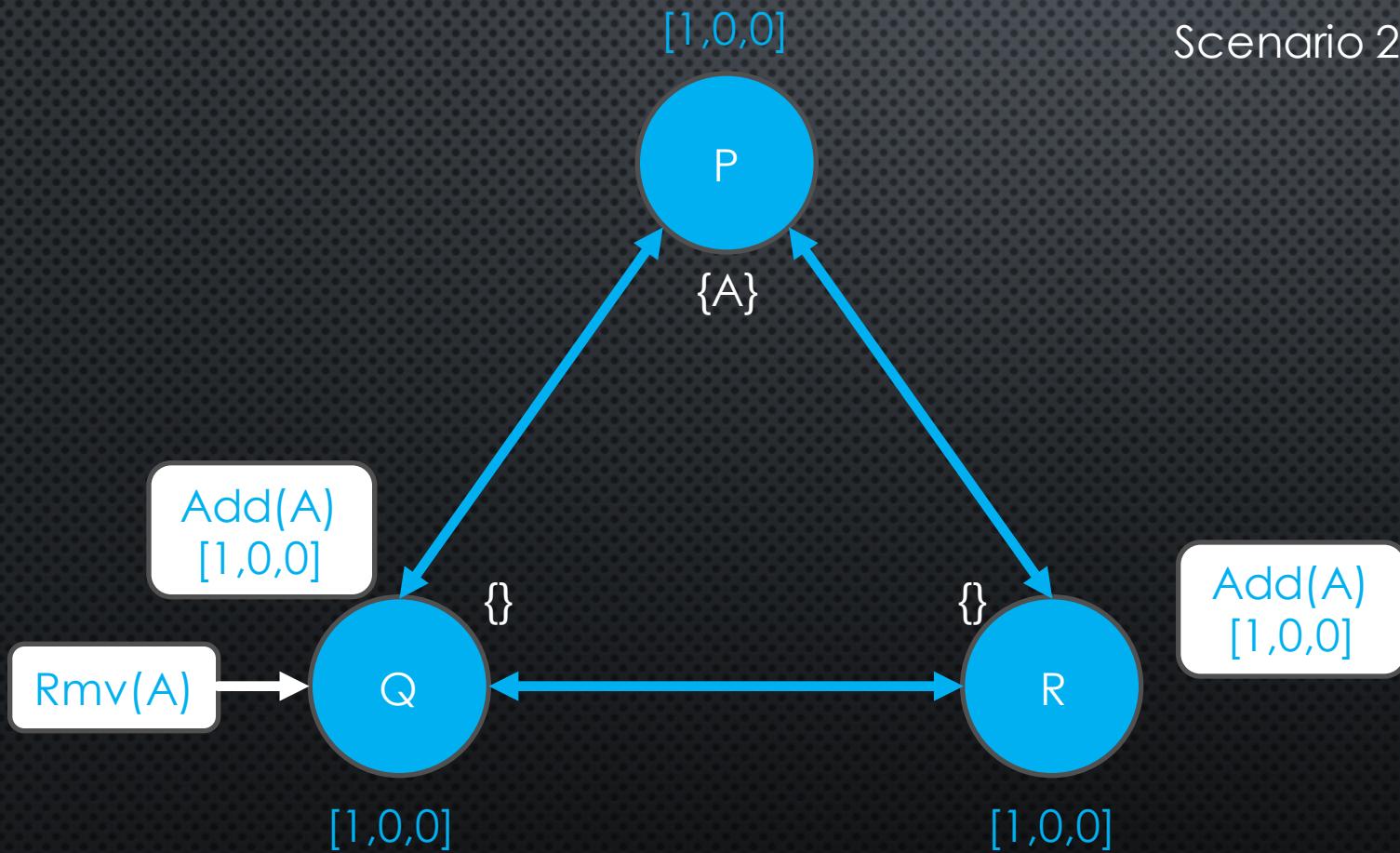
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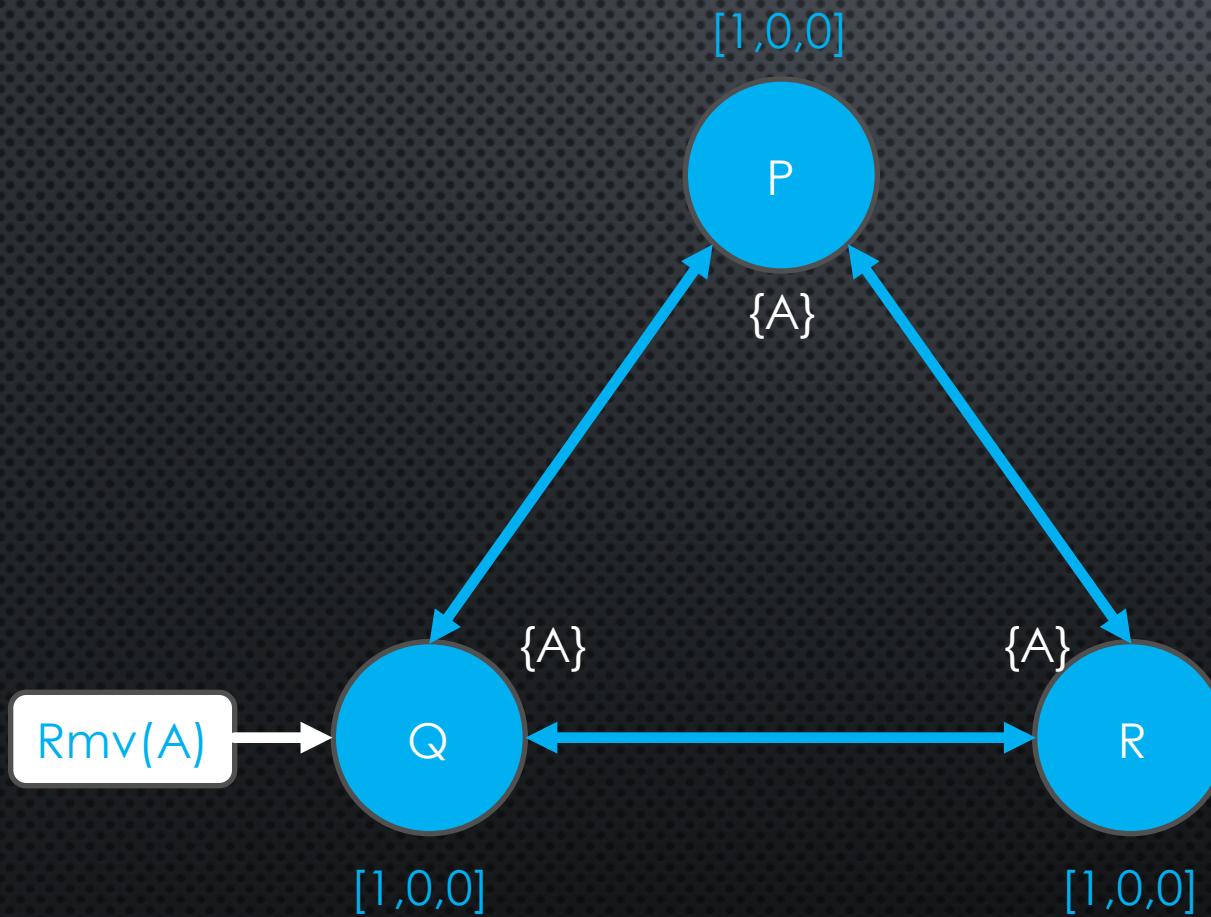
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- P broadcasts their tagged op
- All nodes deliver $\text{Add}(A)$

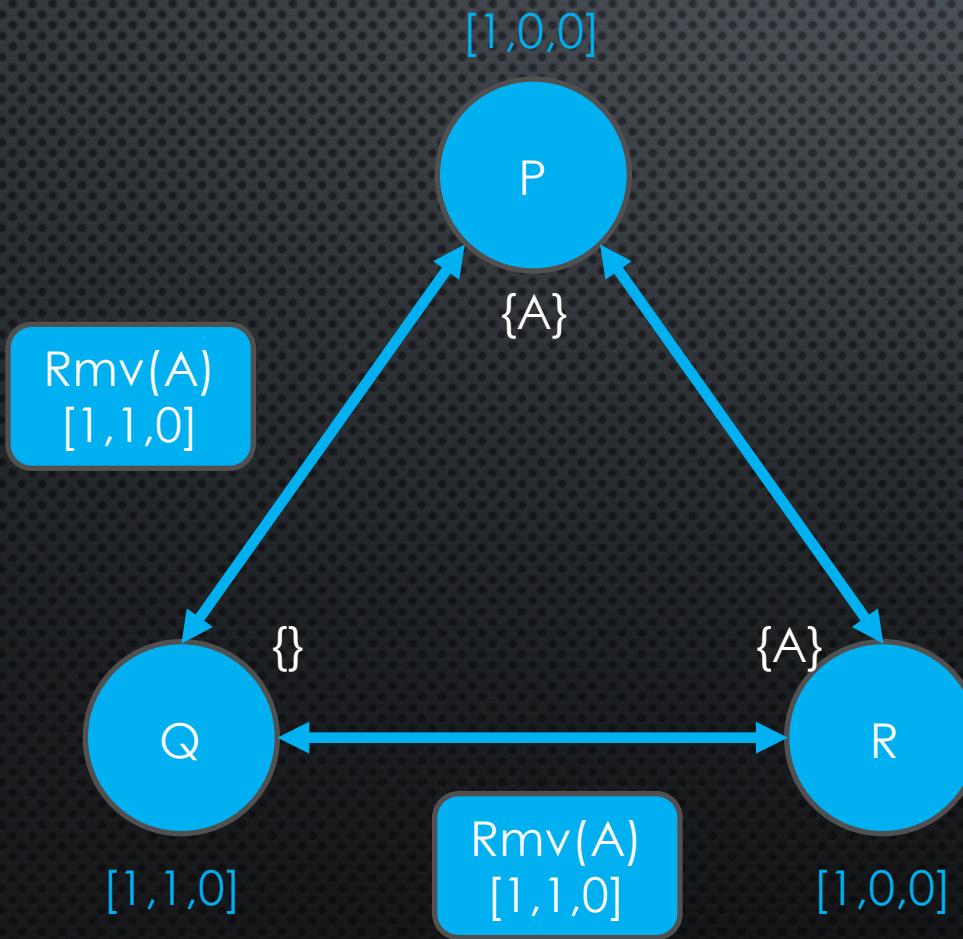
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- P broadcasts their tagged op
- All nodes deliver Add(A)

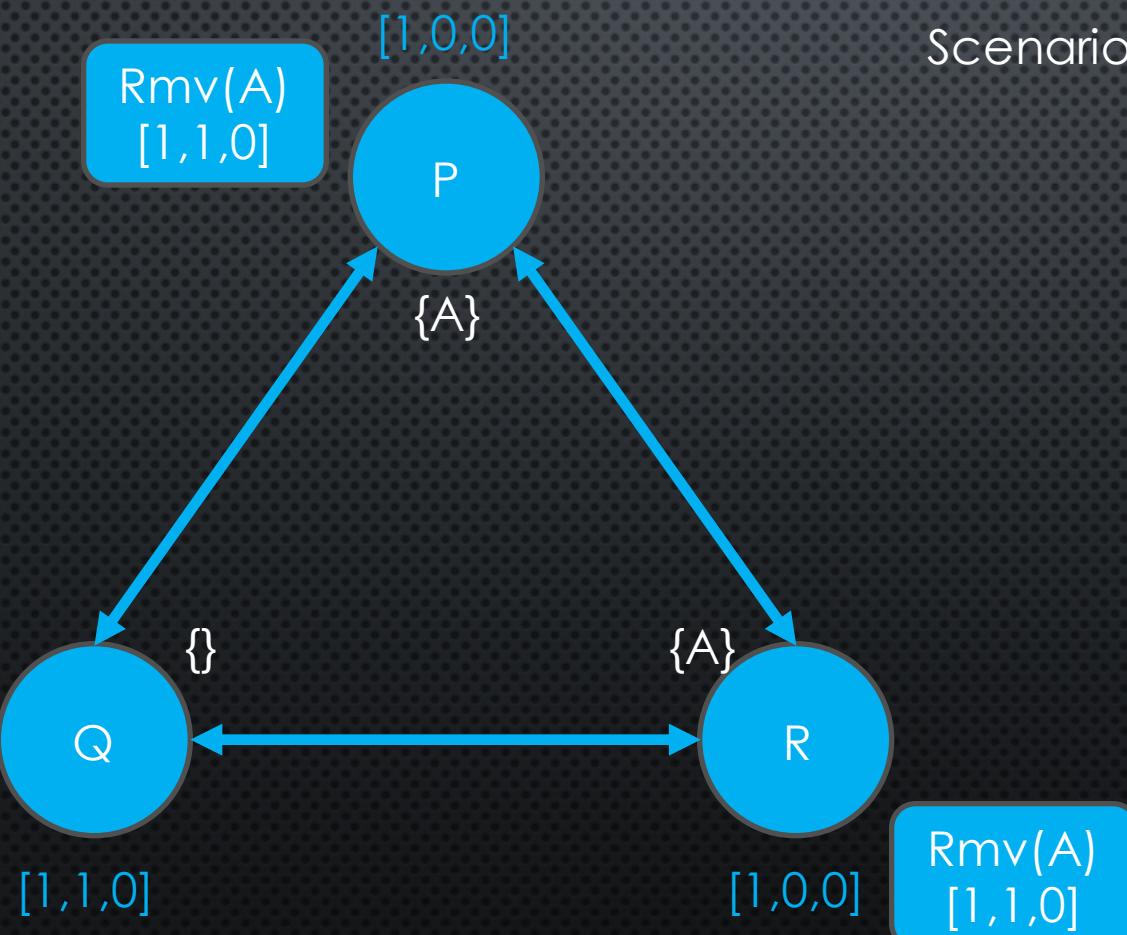
SOLUTION 2



Scenario 2:

- P tags the op $Add(A)$
- $Rmv(A)$ is still in the queue waiting to be processed by Q
- P bcasts their tagged op
- All nodes deliver $Add(A)$
- Q dequeues $Rmv(A)$, tags and bcasts it

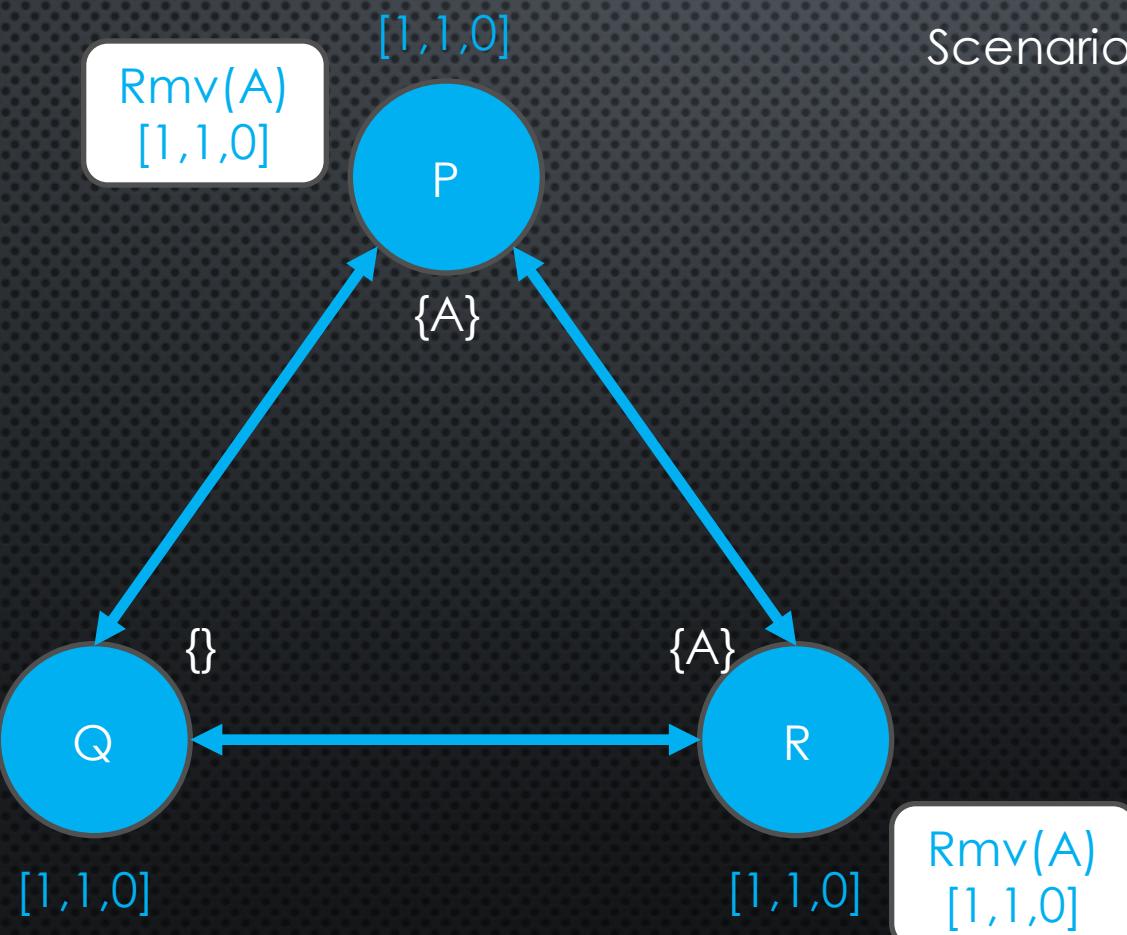
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- P bcasts their tagged op
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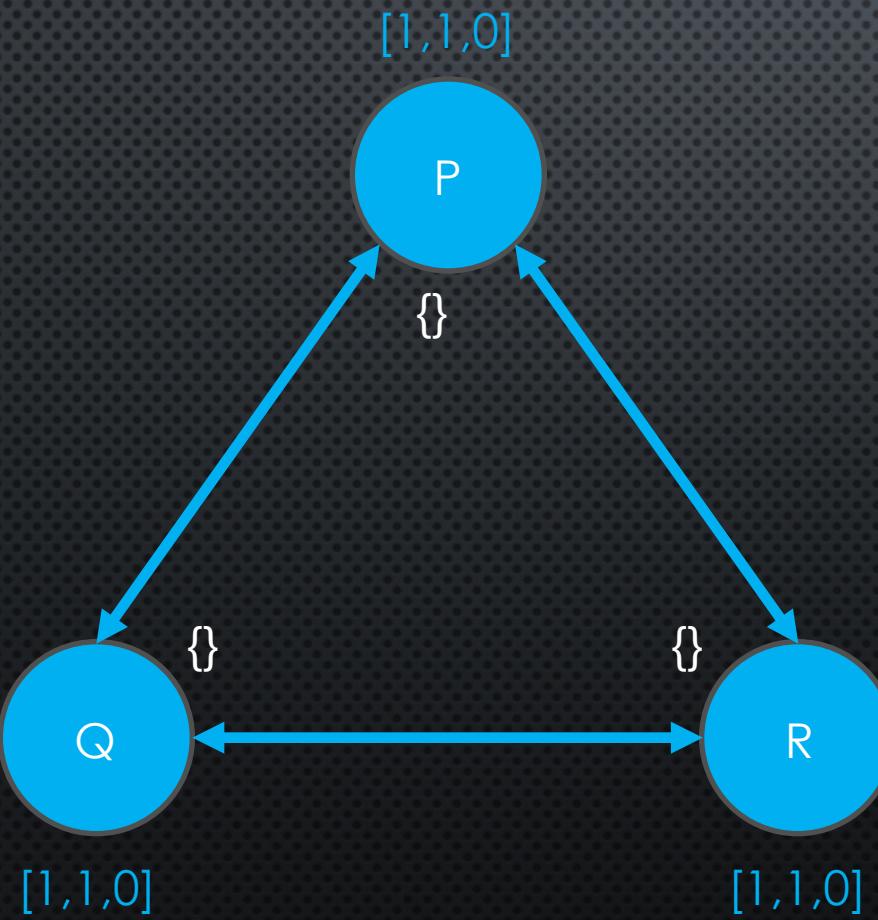
SOLUTION 2



Scenario 2:

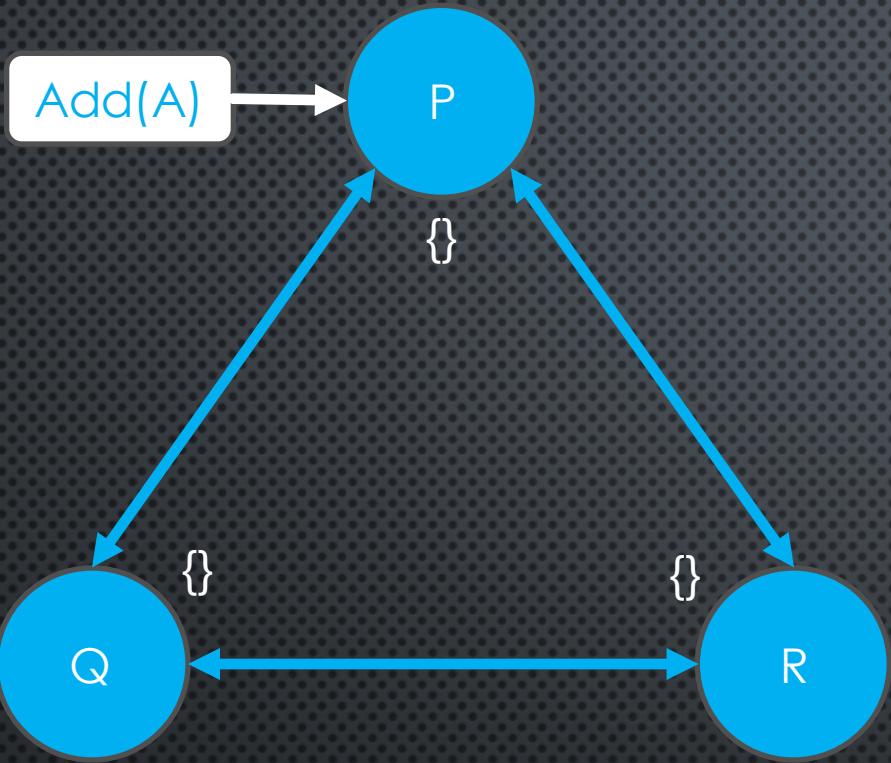
- P tags the op $\text{Add}(A)$
- $\text{Rmv}(A)$ is still in the queue waiting to be processed by Q
- P bcasts their tagged op
- All nodes deliver $\text{Add}(A)$
- Q dequeues $\text{Rmv}(A)$, tags and bcasts it
- $\text{Rmv}(A)$ delivered at P and R

SOLUTION 2



Scenario 2:

- P tags the op Add(A)
- Rmv(A) is still in the queue waiting to be processed by Q
- P bcasts their tagged op
- All nodes deliver Add(A)
- Q dequeues Rmv(A) , tags and bcasts it
- Rmv(A) delivered at P and R
- [1,0,0] happened-before [1,1,0]
 - A is not there (**expected {A}**)



Scenario 1:

- Add(A) and Rmv(A) tagged as concurrent
- Final State: {A}

Solution 2: not a solution

- Does not “care” about concurrent operations
- Orders concurrent ops based on their delivery order
 - Could order concurrent ops as one happening before the other (Scenario 2)

Scenario 2:

- Rmv(A) tagged as in the future of Add(A)
- Final State: {}

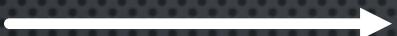
SOLUTION 3

- BETTER CHARACTERIZATION OF THE HAPPENED-BEFORE RELATION BETWEEN OPS
 - TAG BASED ON WHAT WAS DELIVERED AT THE APPLICATION LEVEL
- AS DELIVERY HAPPENS AT THE APPLICATION LEVEL
 - TAG AT THE APPLICATION LEVEL

SOLUTION 3

- WHAT YOU NEED:

- CAUSAL ORDER



- CONCURRENCY SEMANTICS



Tag operations
at app level

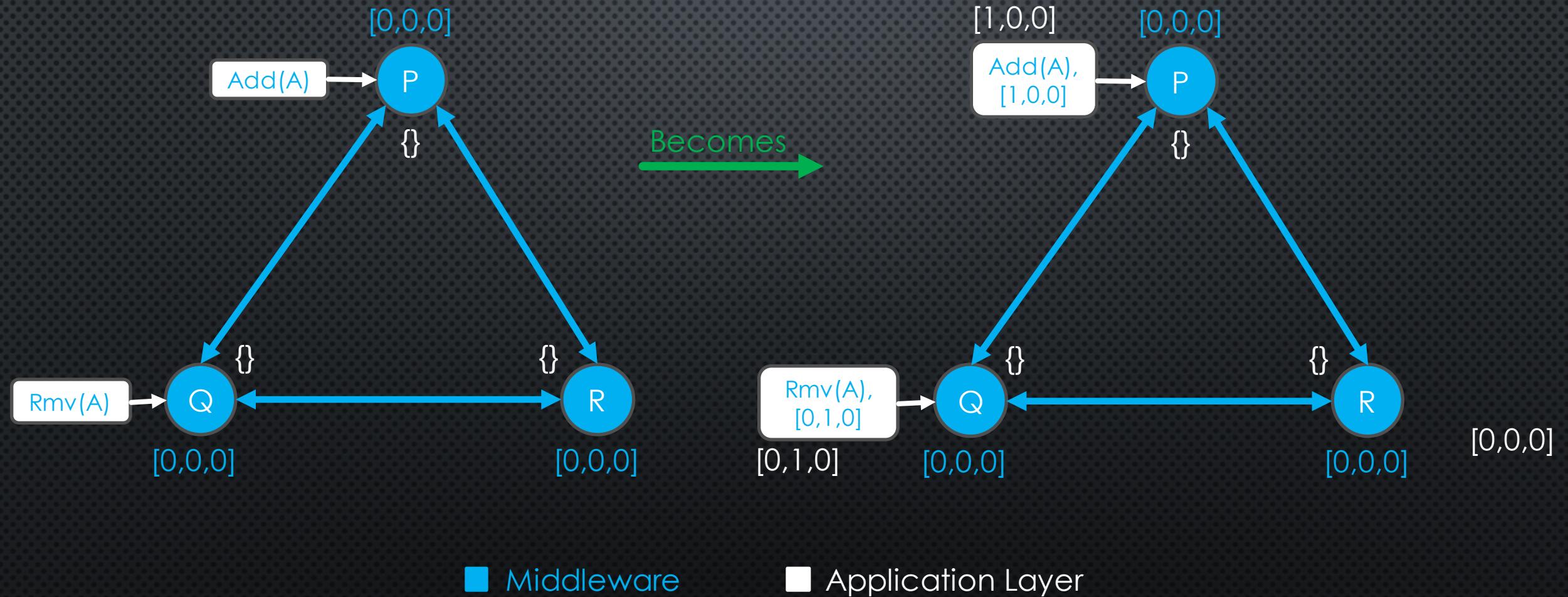
Use those tags
for causal
delivery

Off-the-shelf middleware

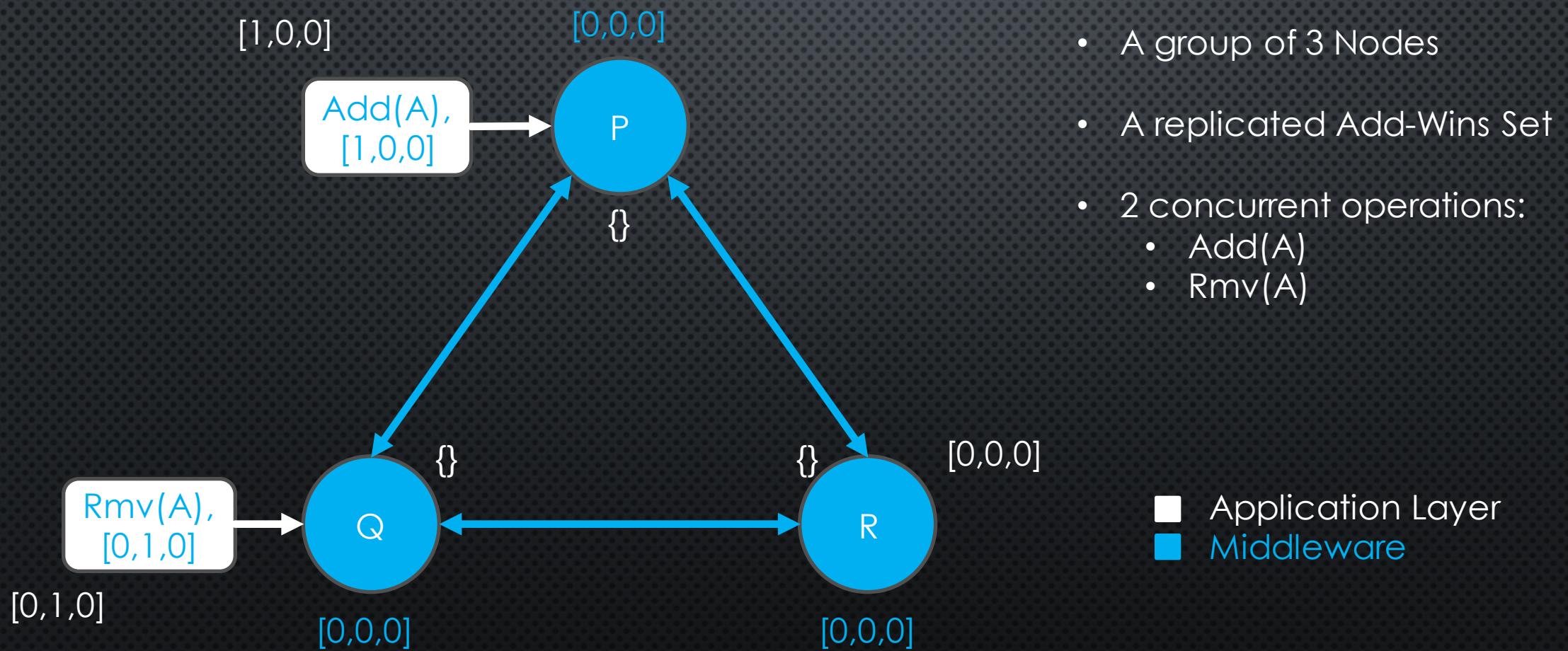
The “happened-before”
relation between ops

Requires tagging
operations

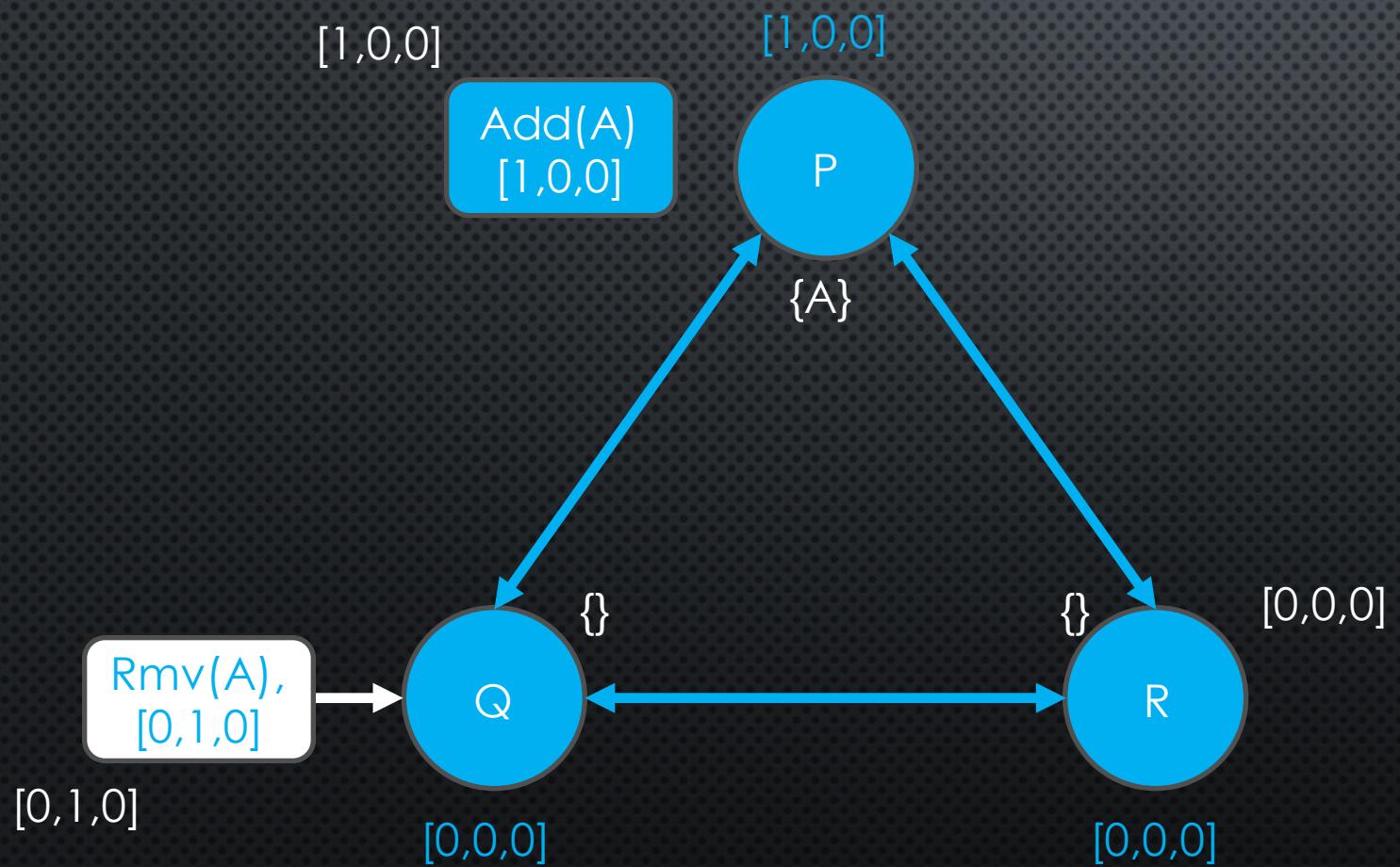
SOLUTION 3



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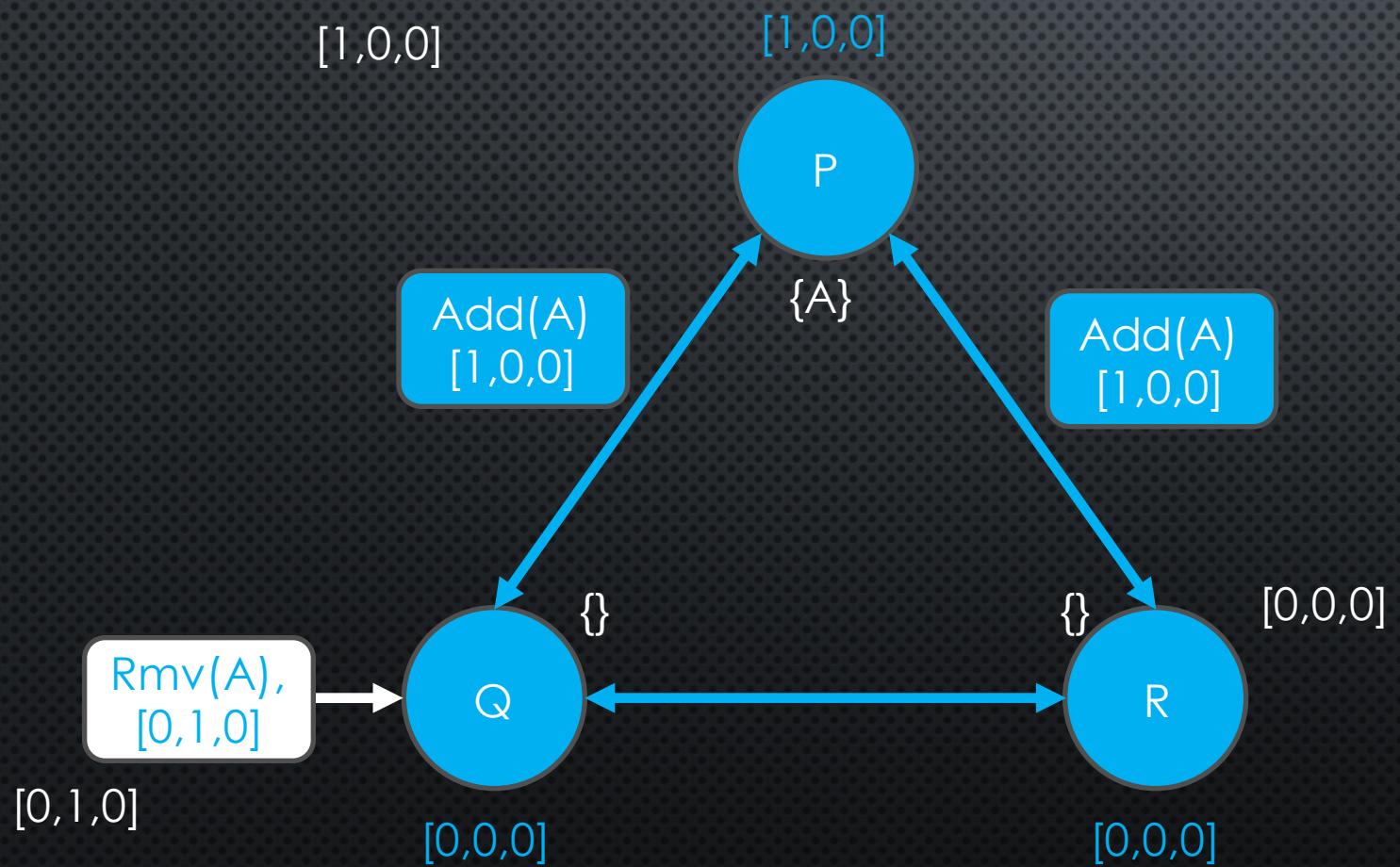
SOLUTION 3



Scenario 2:

- Both ops tagged at App level
- P bcasts Add(A)
- Rmv(A) is still in the queue waiting to be bcast by Q

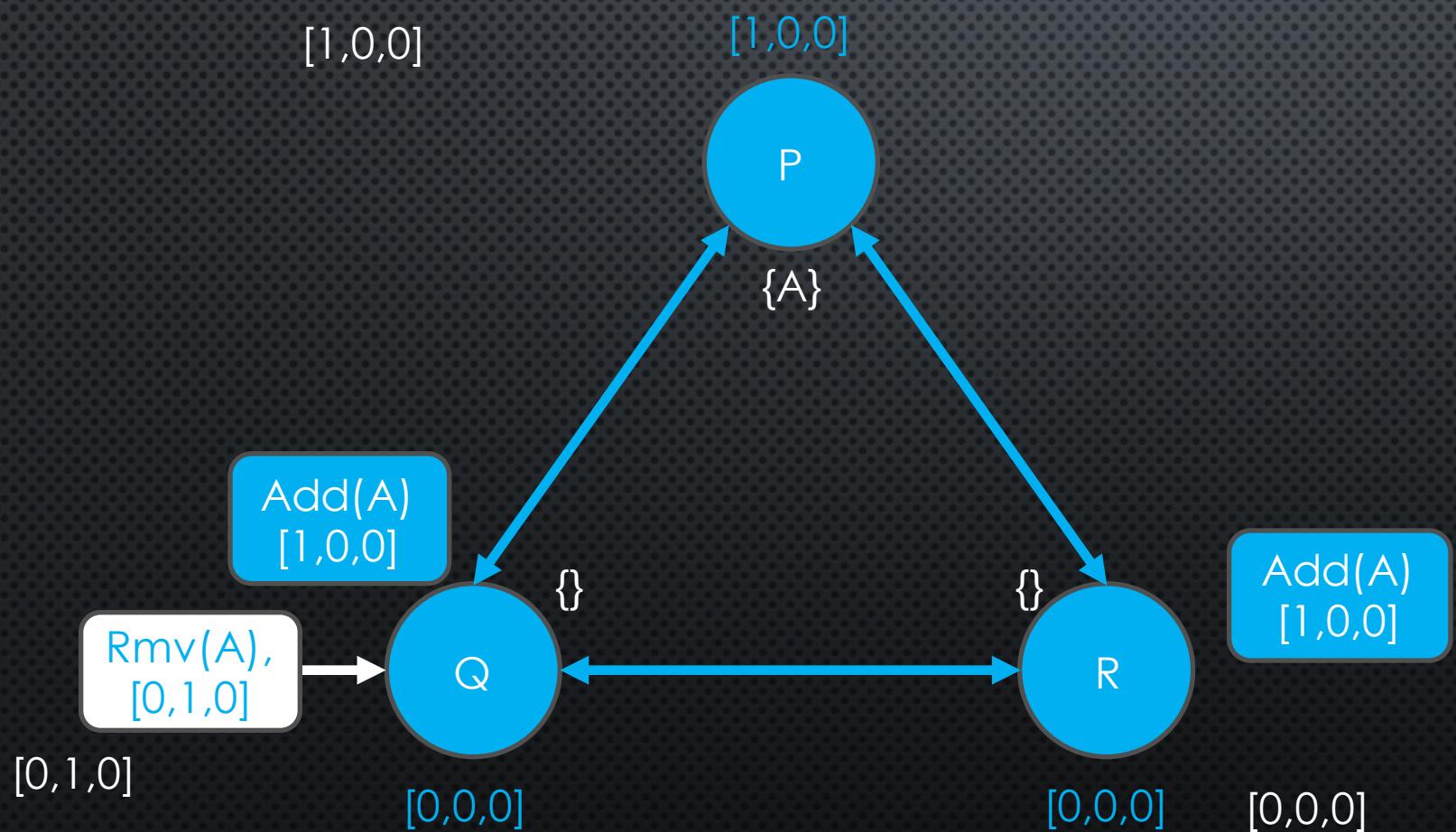
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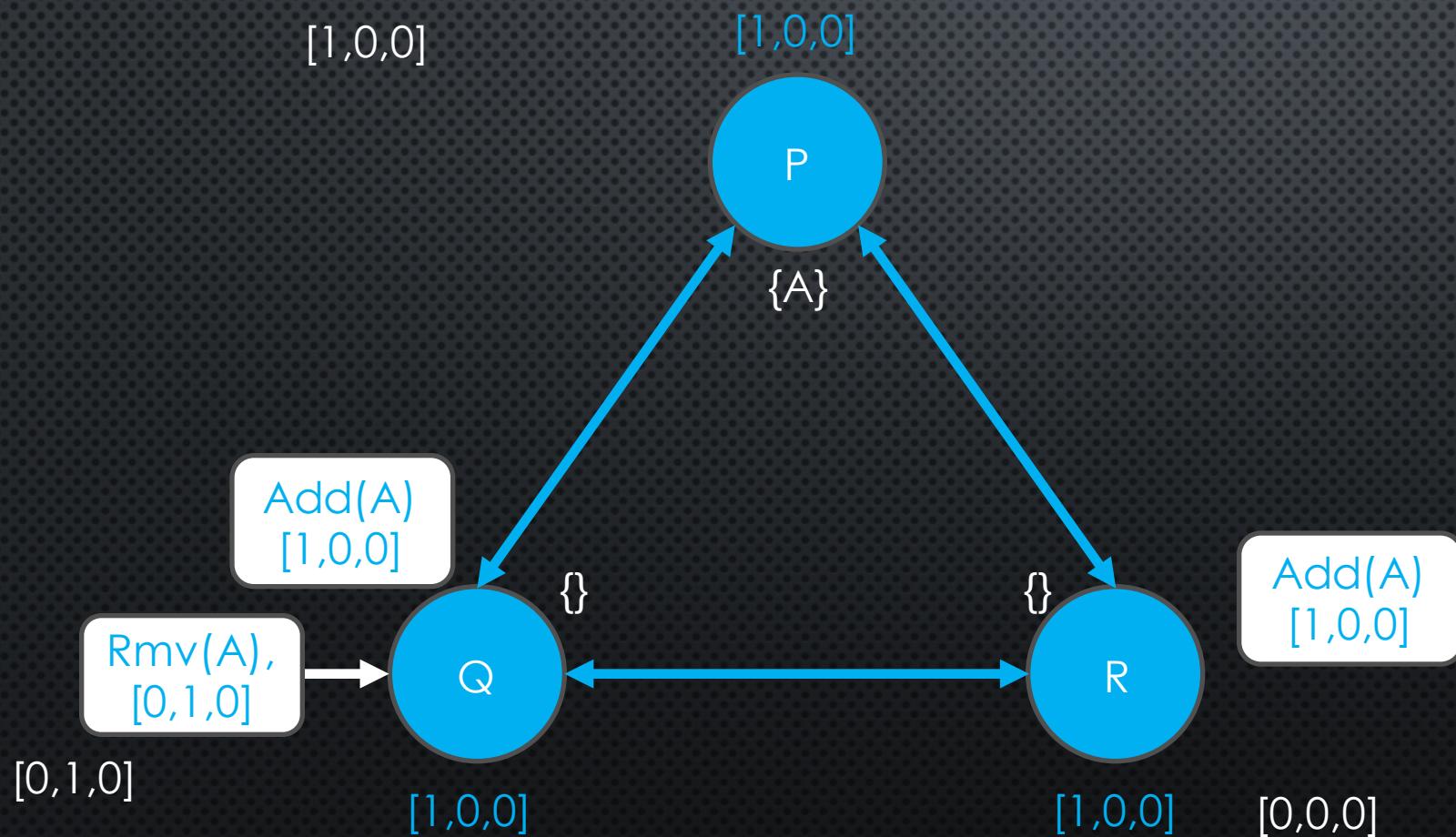
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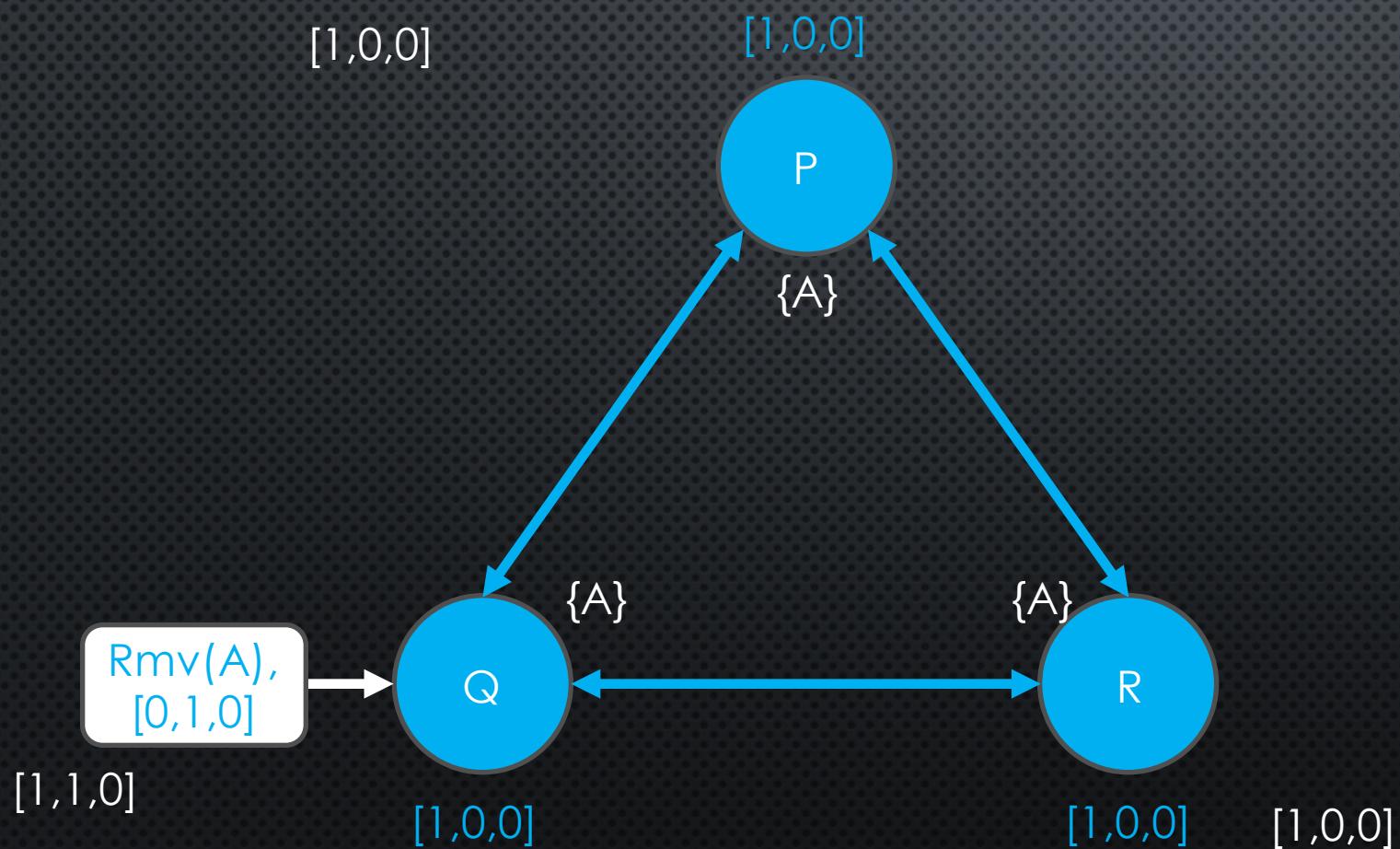
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- P bcasts Add(A)
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- All nodes deliver Add(A)

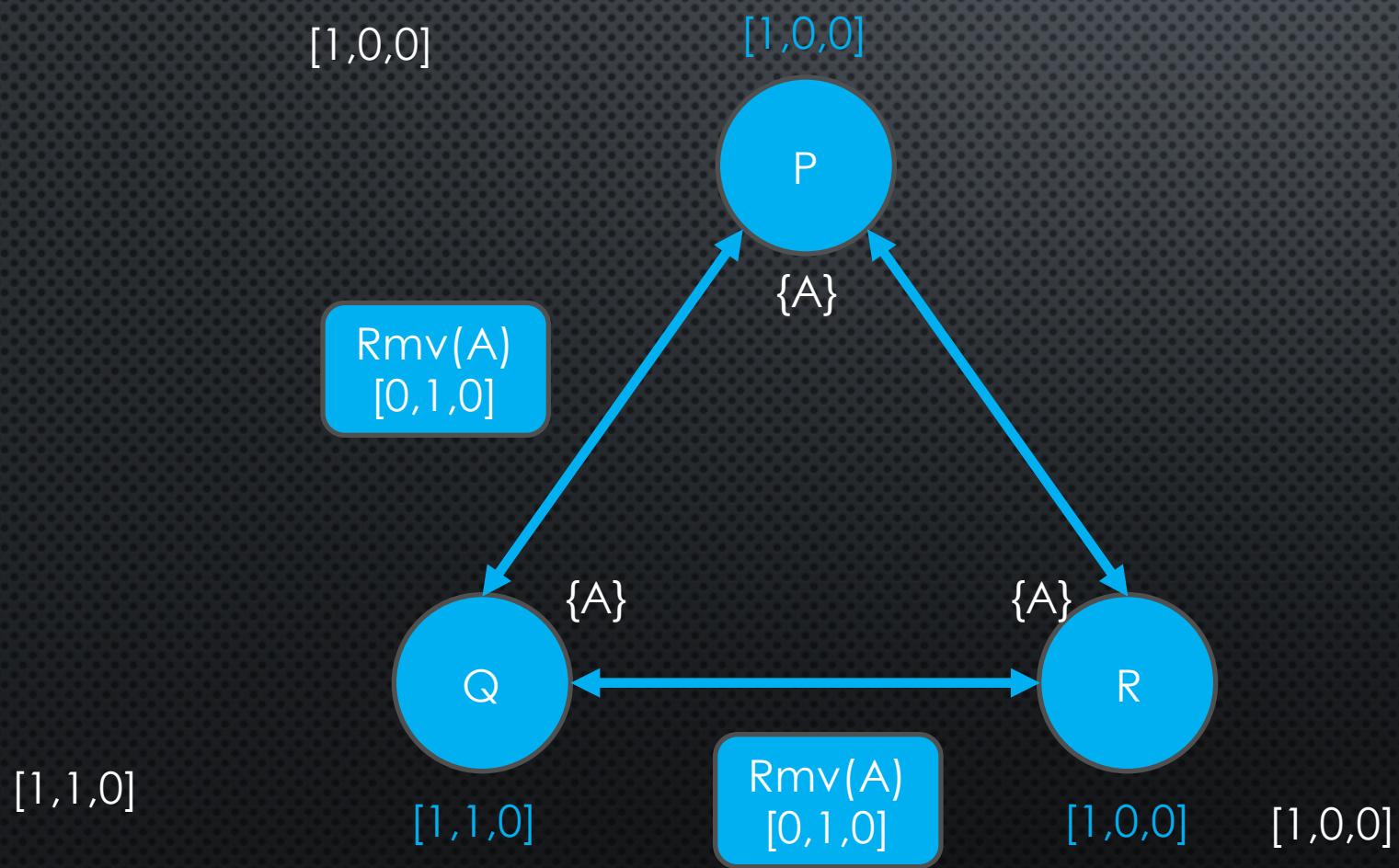
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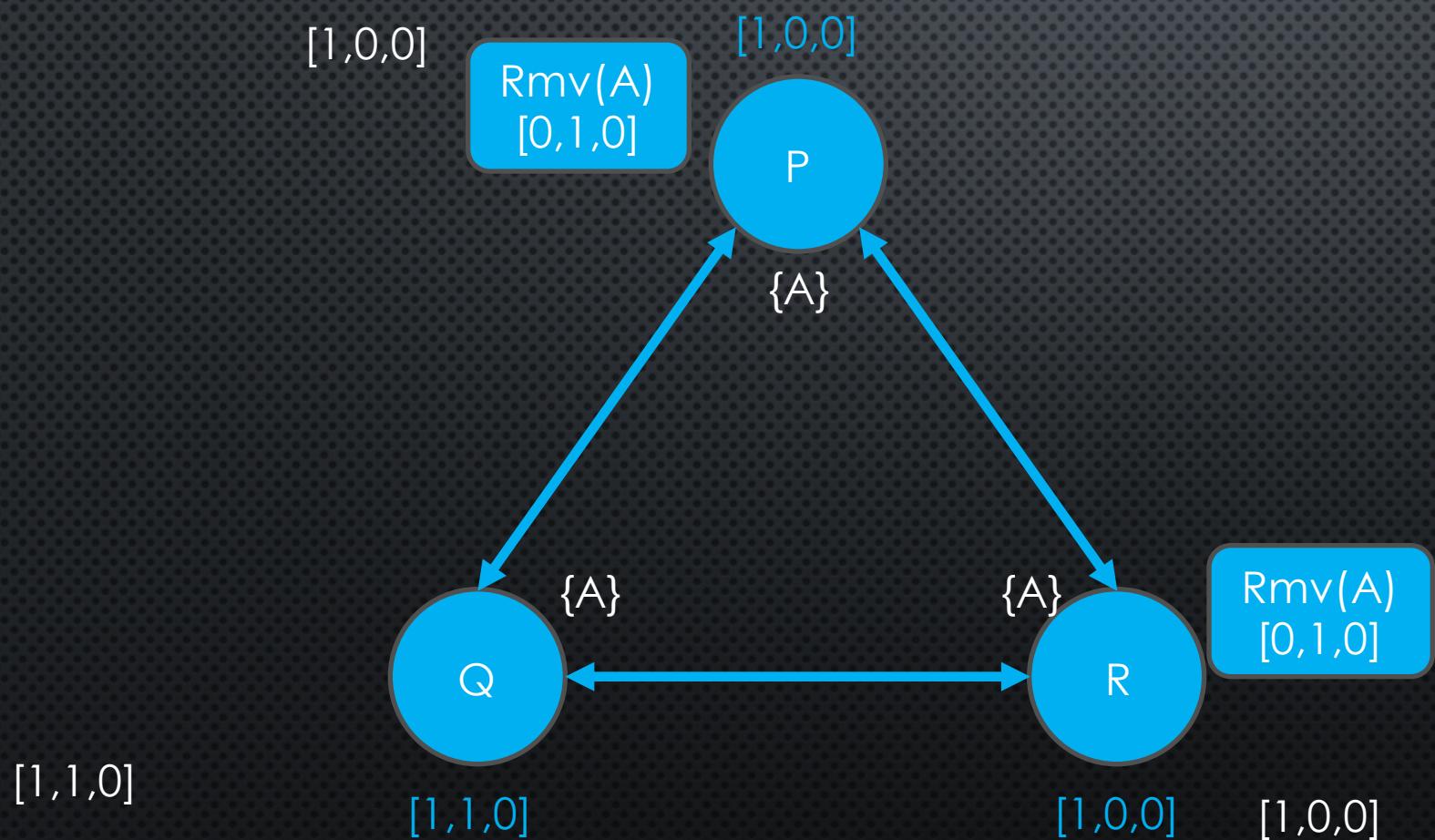
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Scenario 2:

- Both ops tagged at App level
- P bcasts Add(A)
- $Rmv(A)$ is still in the queue waiting to be bcast by Q
- All nodes deliver Add(A)
- Q dequeues $Rmv(A)$ and bcasts it

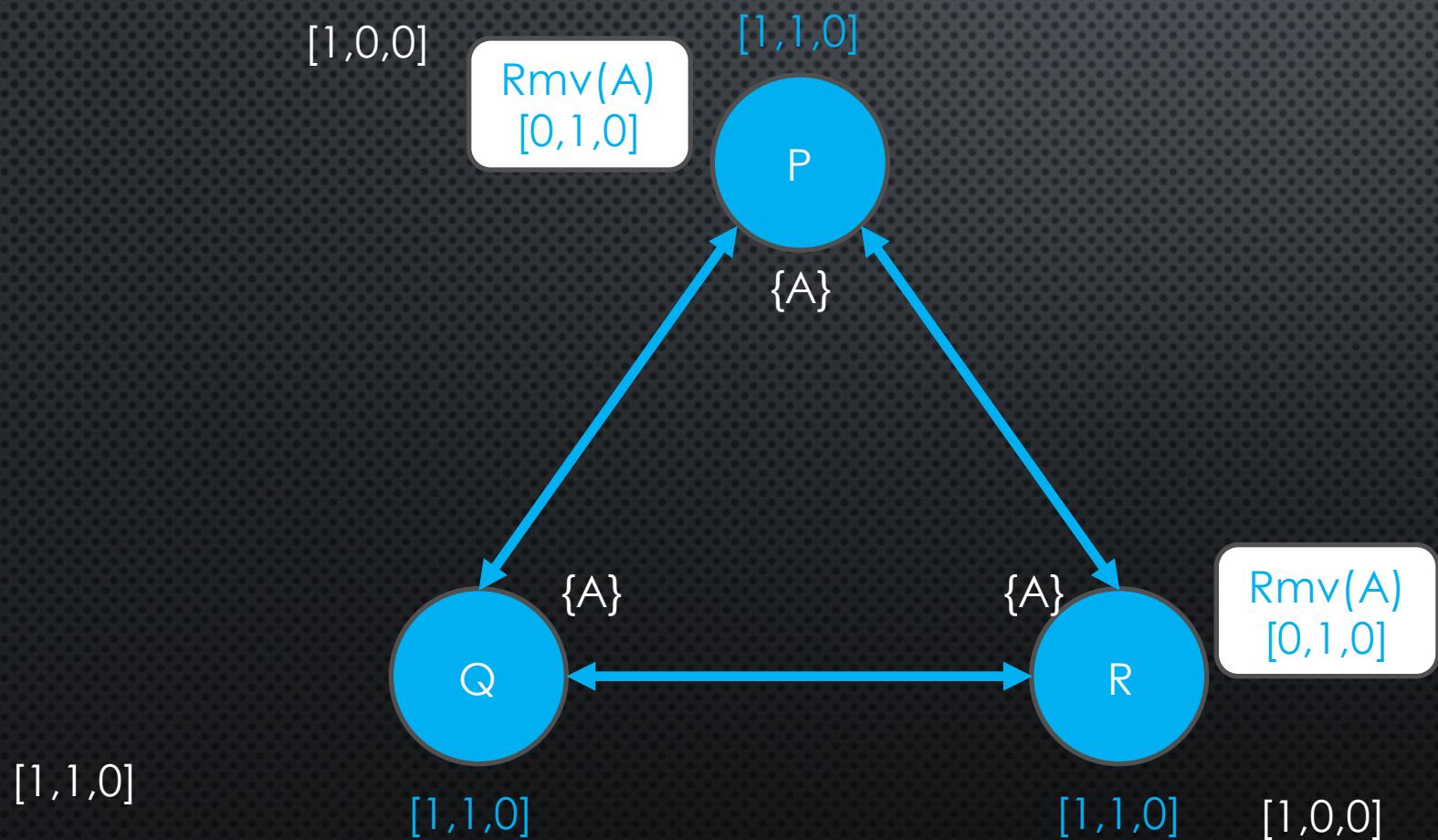
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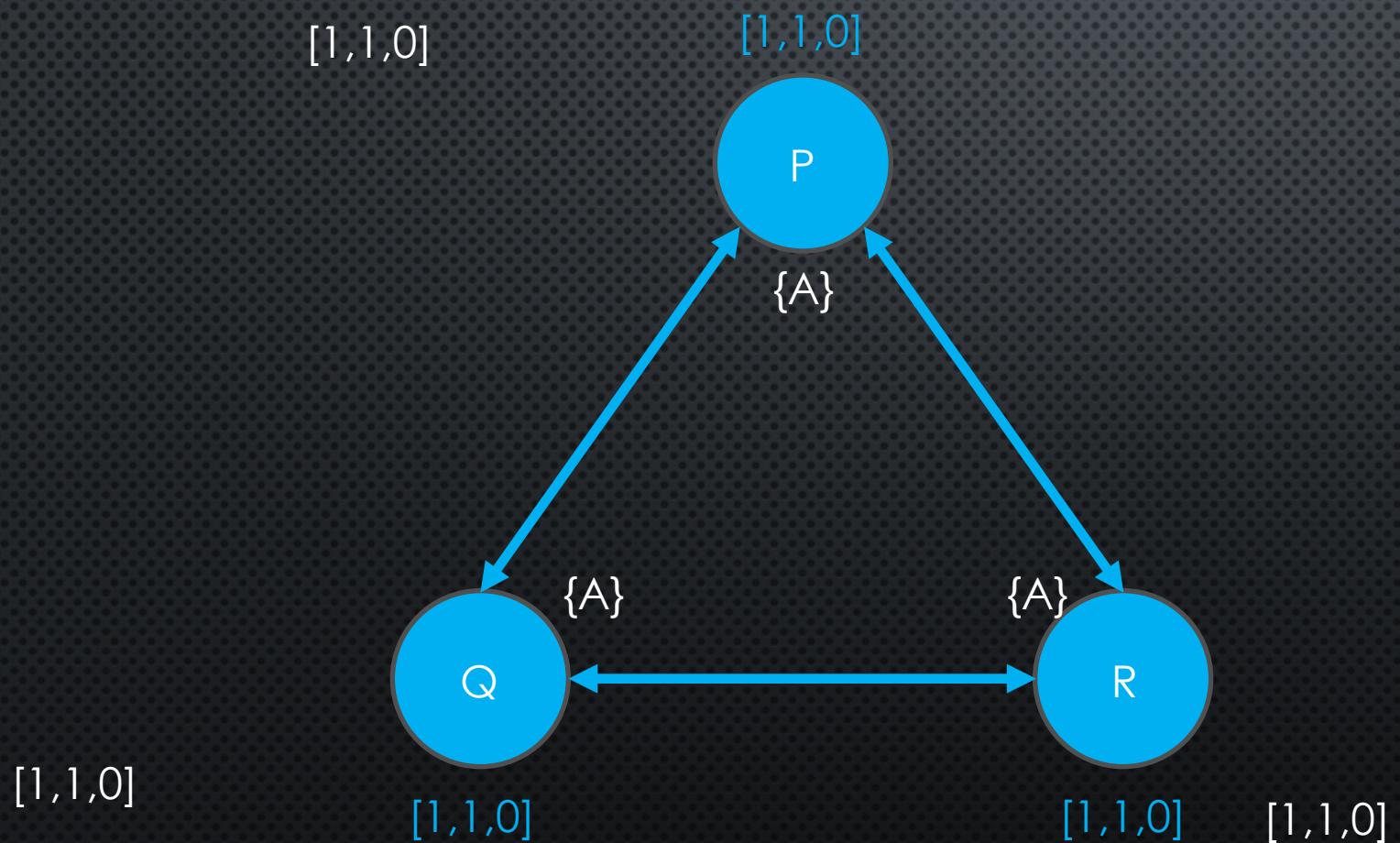
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- $\text{Rmv}(A)$ delivered at P and R

SOLUTION 3



Scenario 2:

- Both ops tagged at App level
- P bcasts Add(A)
- Rmv(A) is still in the queue waiting to be bcast by Q
- All nodes deliver Add(A)
- Q dequeues Rmv(A) and bcasts it
- Rmv(A) delivered at P and R
- $[1,0,0]$ concurrent $[0,1,0]$
 - Add Wins: A is there

A WELCOME SIDE EFFECT

- AS YOU NOTICED IN SOLUTION 2 (SCENARIO 2):
 - CAUSAL DELIVERY SOMETIMES TAGS CONCURRENT OPERATIONS AS ONE HAPPENED-BEFORE THE OTHER
 - THIS LEADS TO OVER ORDERING OPERATIONS AND COULD INCLUDE EXTRA DELAY ON DELIVERY
 - THIS ALSO HAPPENS IN SOLUTION 1
 - THIS DOES NOT HAPPEN IN SOLUTION 3

COMPARISON

	Solution 1	Solution 2	Solution 3
Tagging at Middleware	yes	yes	no
Tagging at Application	yes	no	yes
Characterization of Happened-before	correct	incorrect	correct
Over Ordering operations	yes	yes	no
Unneeded Slower Delivery	yes	yes	yes
Solves the problem	yes	no	yes

Questions ?

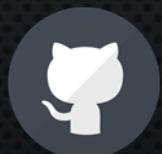
Slides: <https://bit.ly/tagged-causal>

Erlang implementation:

- Reliable Causal Broadcast: <https://github.com/gyounes/RCB>
- Tagged Reliable Causal Broadcast: https://github.com/gyounes/trcb_base



@g_unis



gyounes