SCALE OUT AND CONQUER:

ARCHITECTURAL DECISIONS BEHIND DISTRIBUTED IN-MEMORY SYSTEMS

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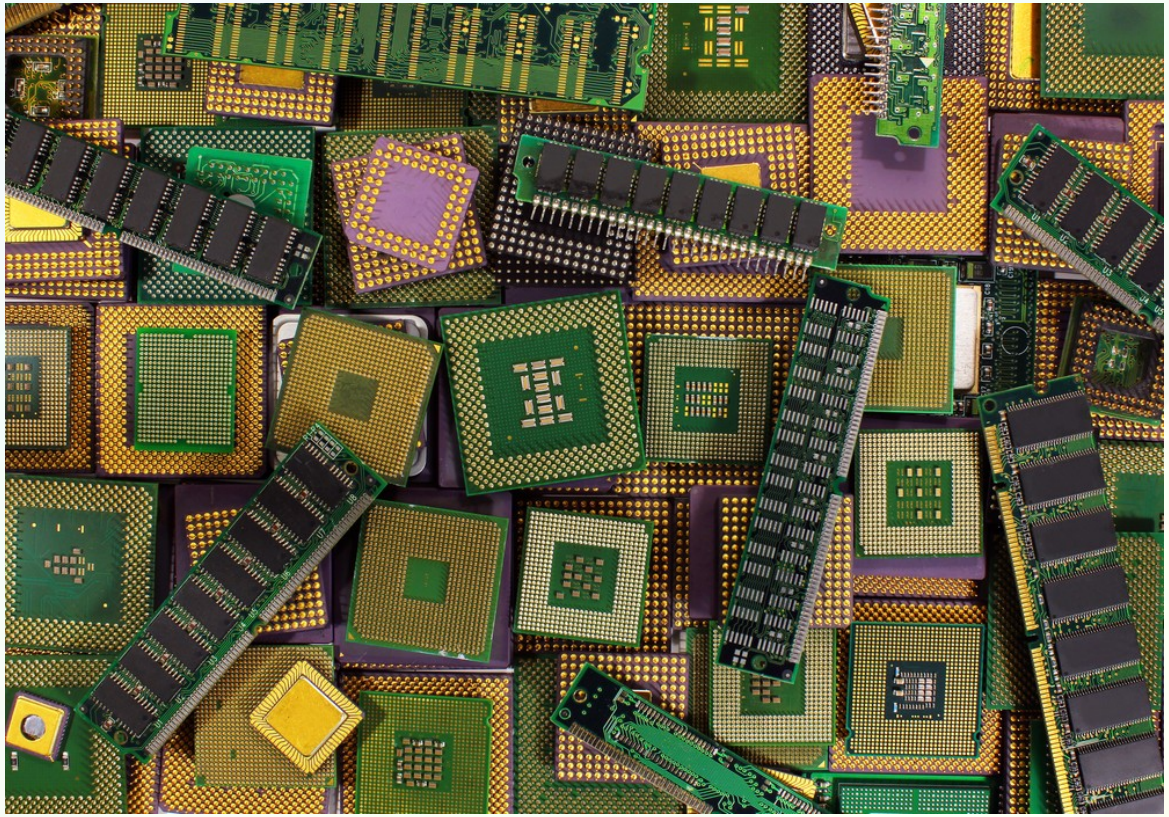
YAKOV ZHDANOV

WHO?

Yakov Zhdanov:
- GridGain's Product Development VP
- With GridGain since 2010
- Apache Ignite committer and PMC
- Passion for performance & scalability
- Finding ways to make product better
- St. Petersburg, Russia

WHY IN-MEMORY?



PLAN

1. Data partitioning and affinity functions examples

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2. Data affinity colocation

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3. Synchronization in distributed systems

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4. Multithreading: local architecture

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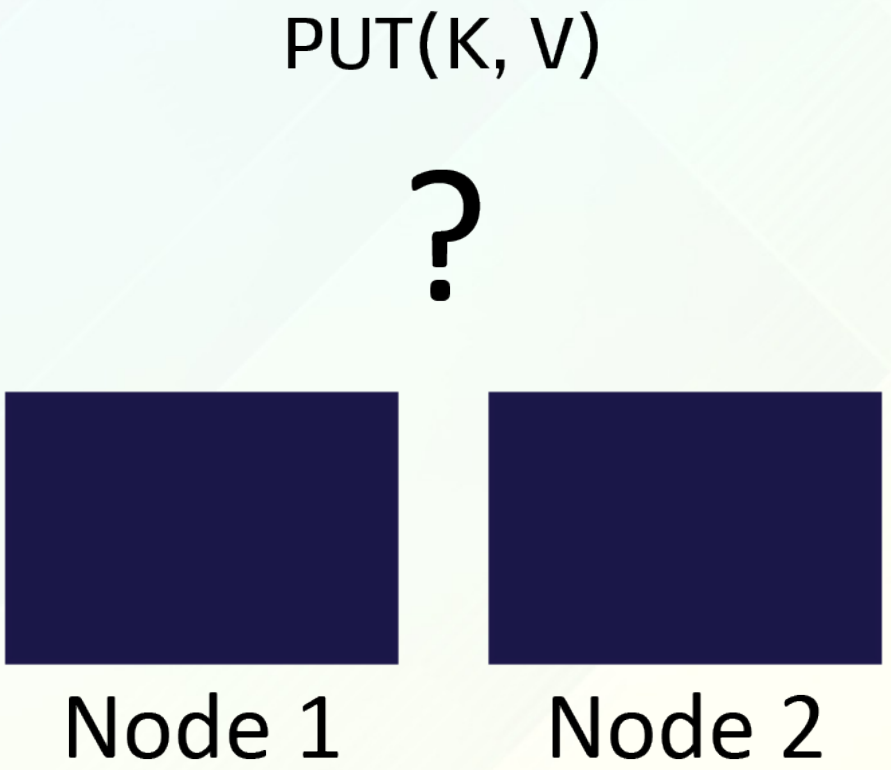
4. Multithreading: local architecture

WHERE?

On which node of the cluster does the key reside?



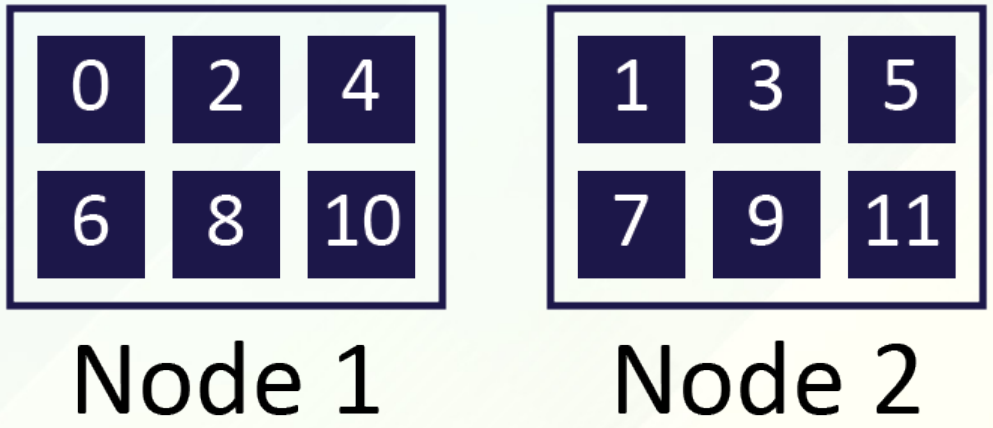
AFFINITY

Partition → Node

AFFINITY

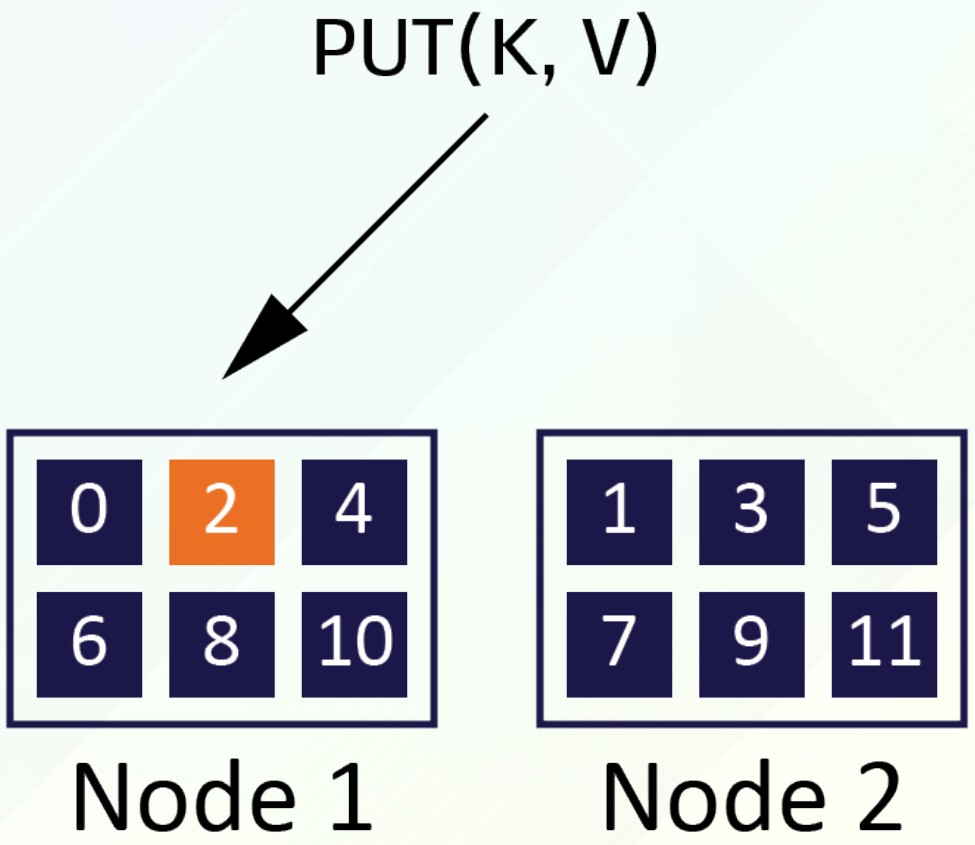
PUT(K, V)

?

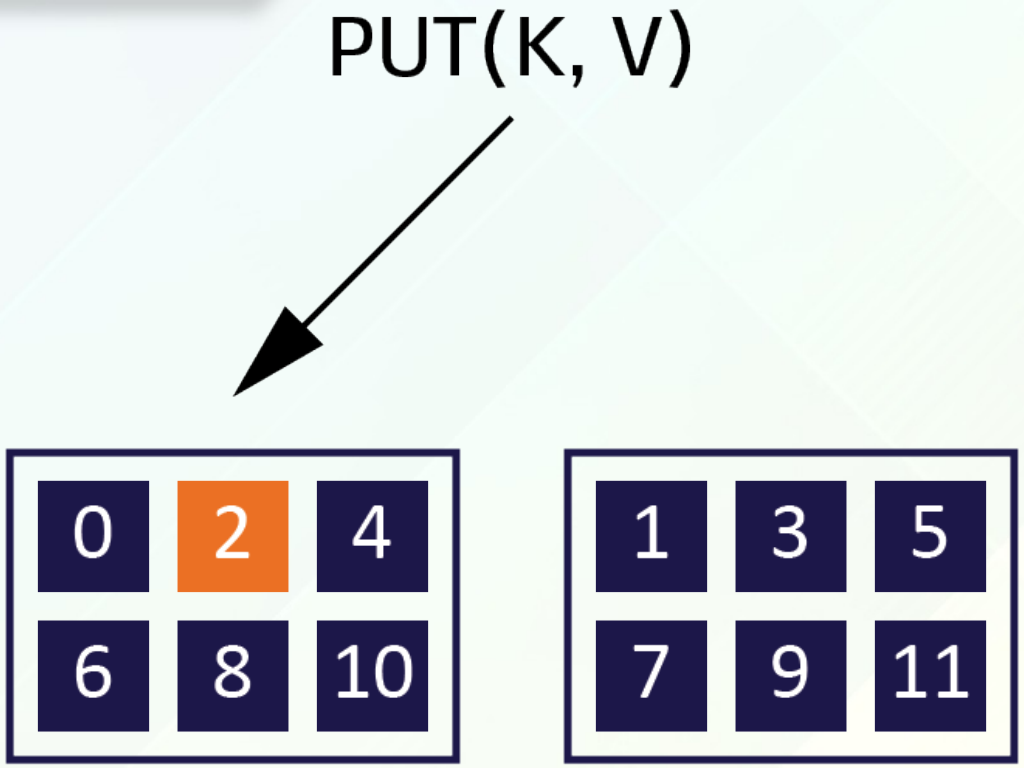


AFFINITY

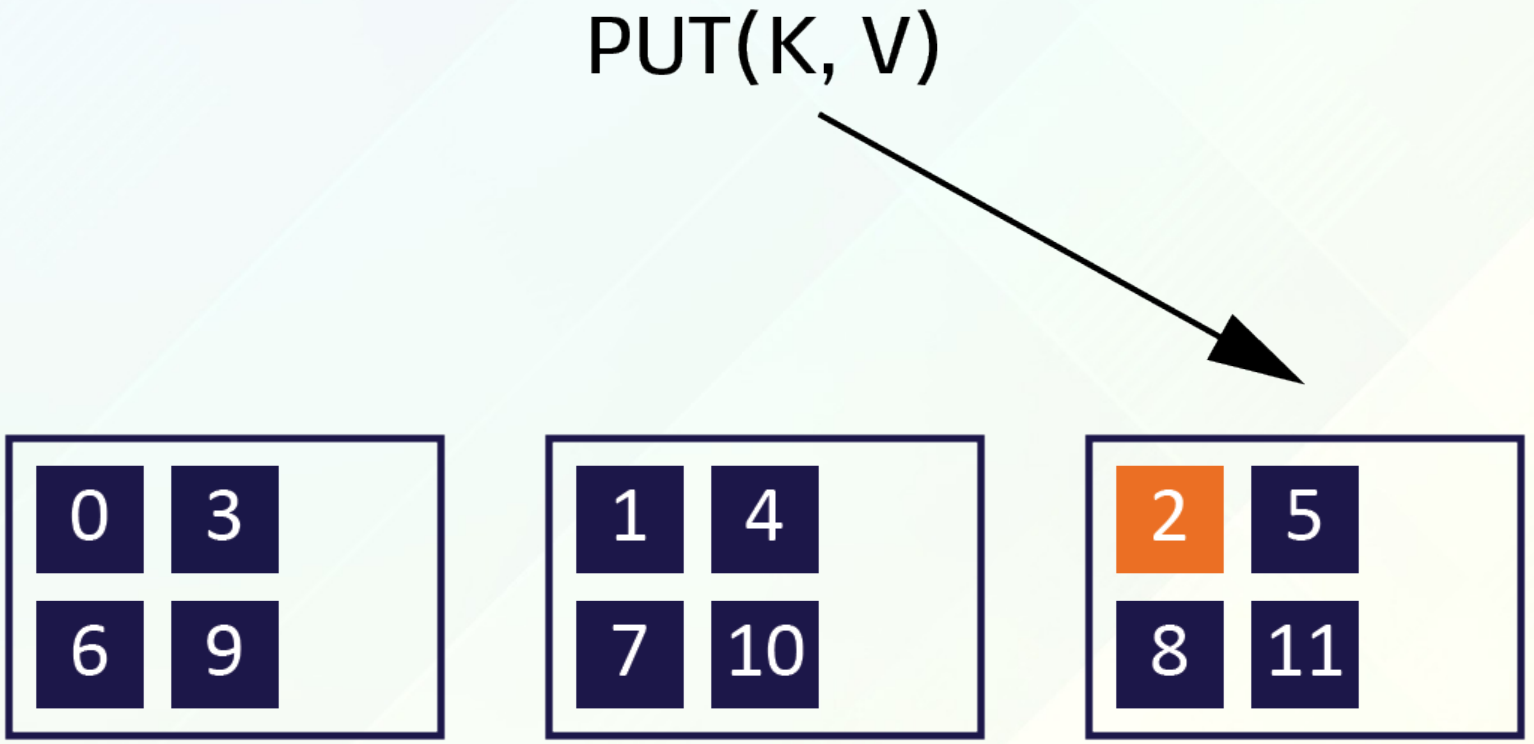
AFFINITY



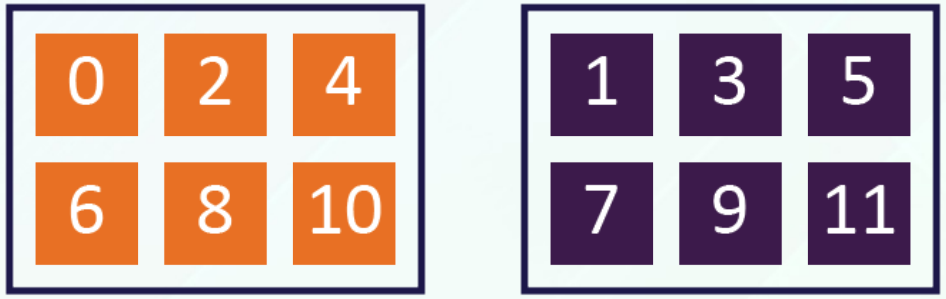
NAIVE AFFINITY



NAIVE AFFINITY

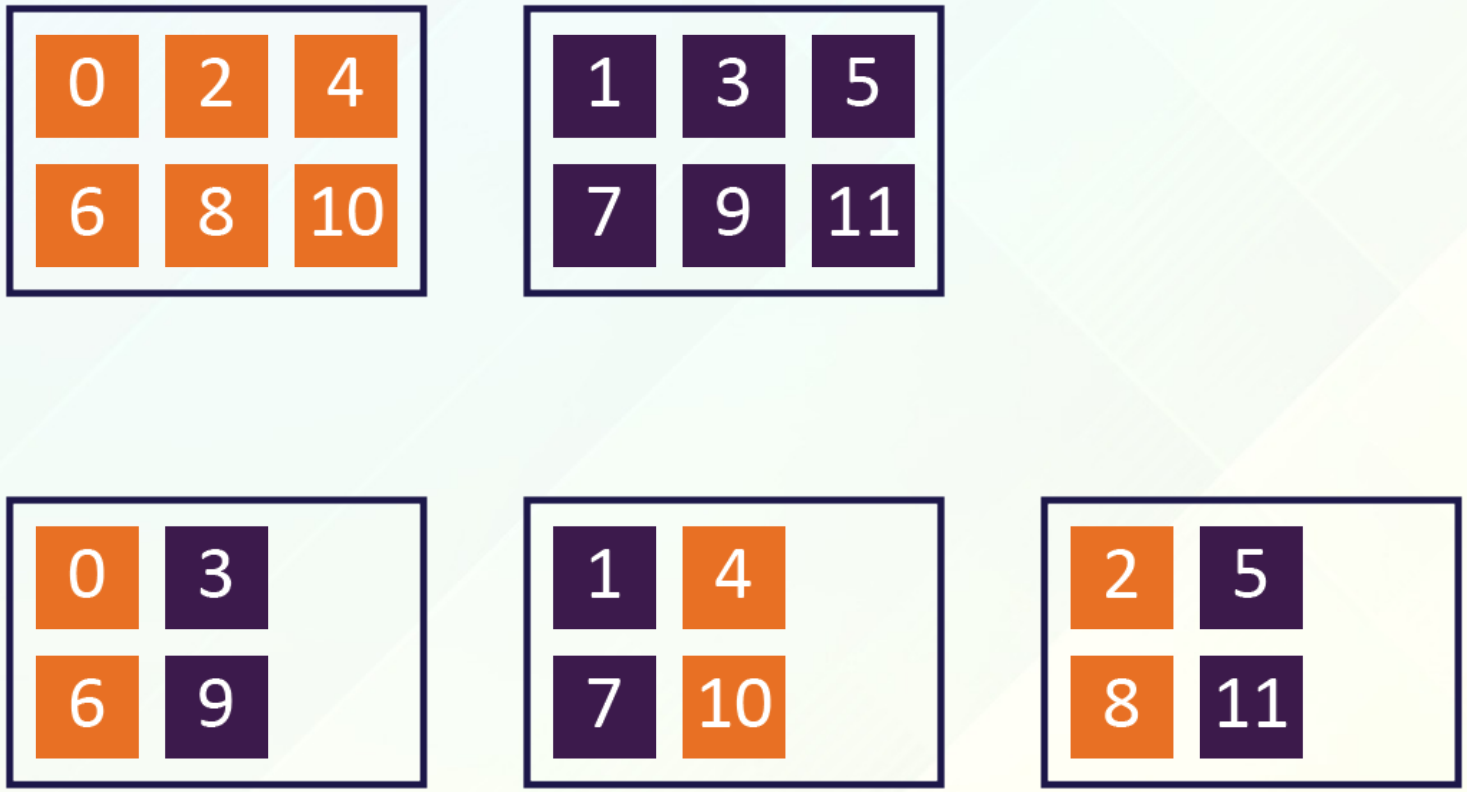


NAIVE AFFINITY

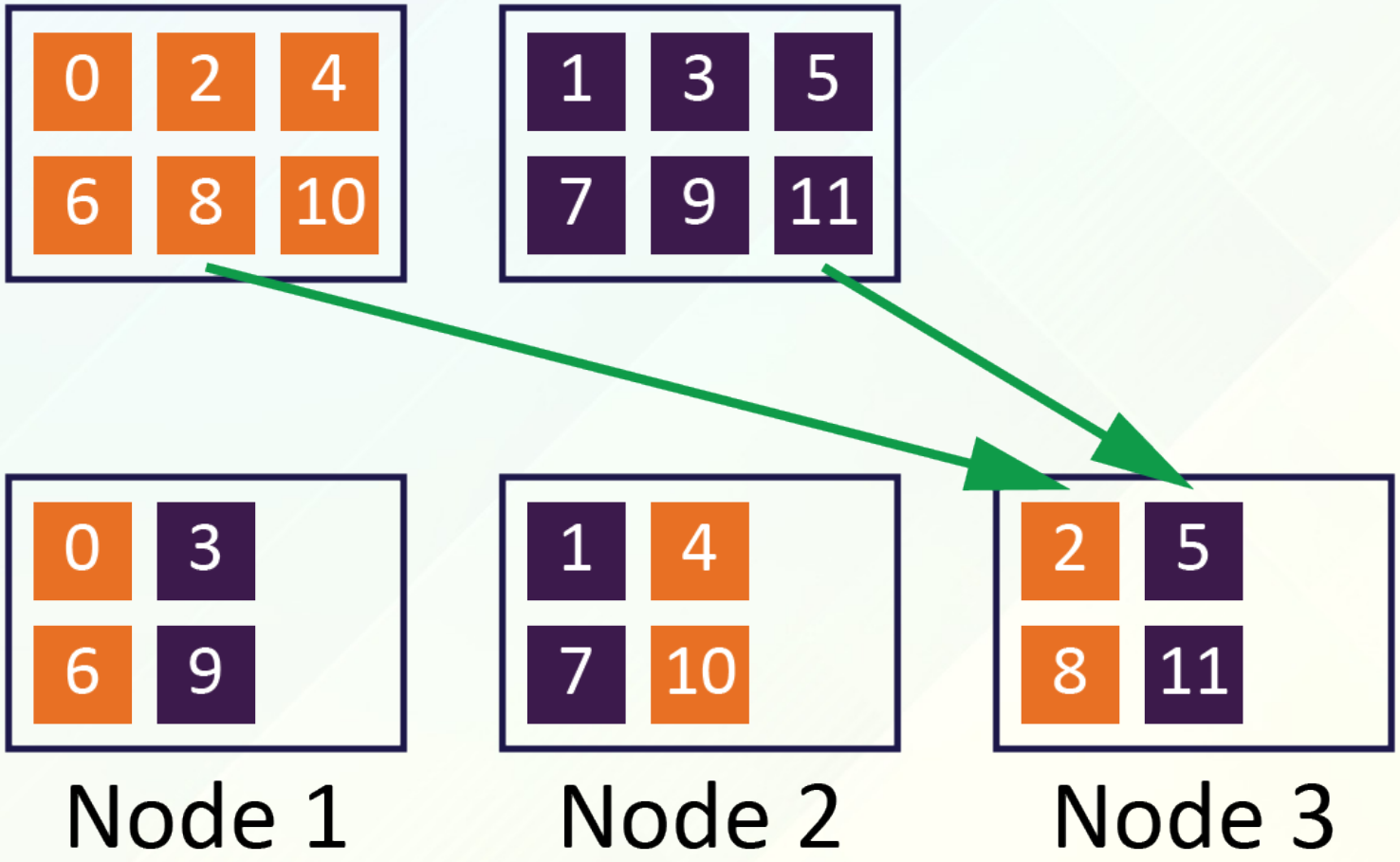


Node 1 Node 2

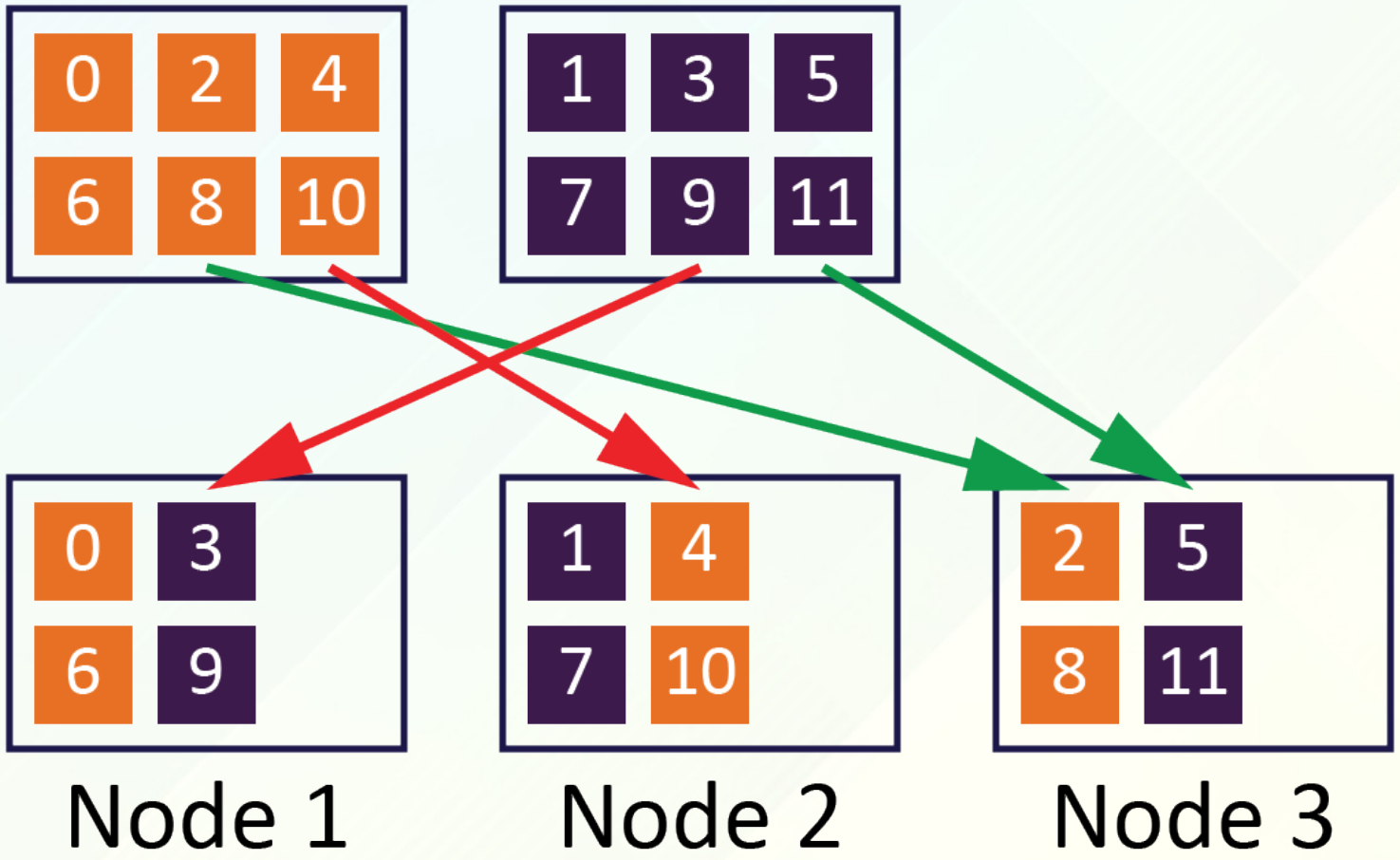
NAIVE AFFINITY



NAIVE AFFINITY



NAIVE AFFINITY



NAIVE AFFINITY

Problem: partition to node mapping depends on nodes count.

NODE = F (PARTITION, **NODES_COUNT**);

AFFINITY: BETTER ALGORITHMS

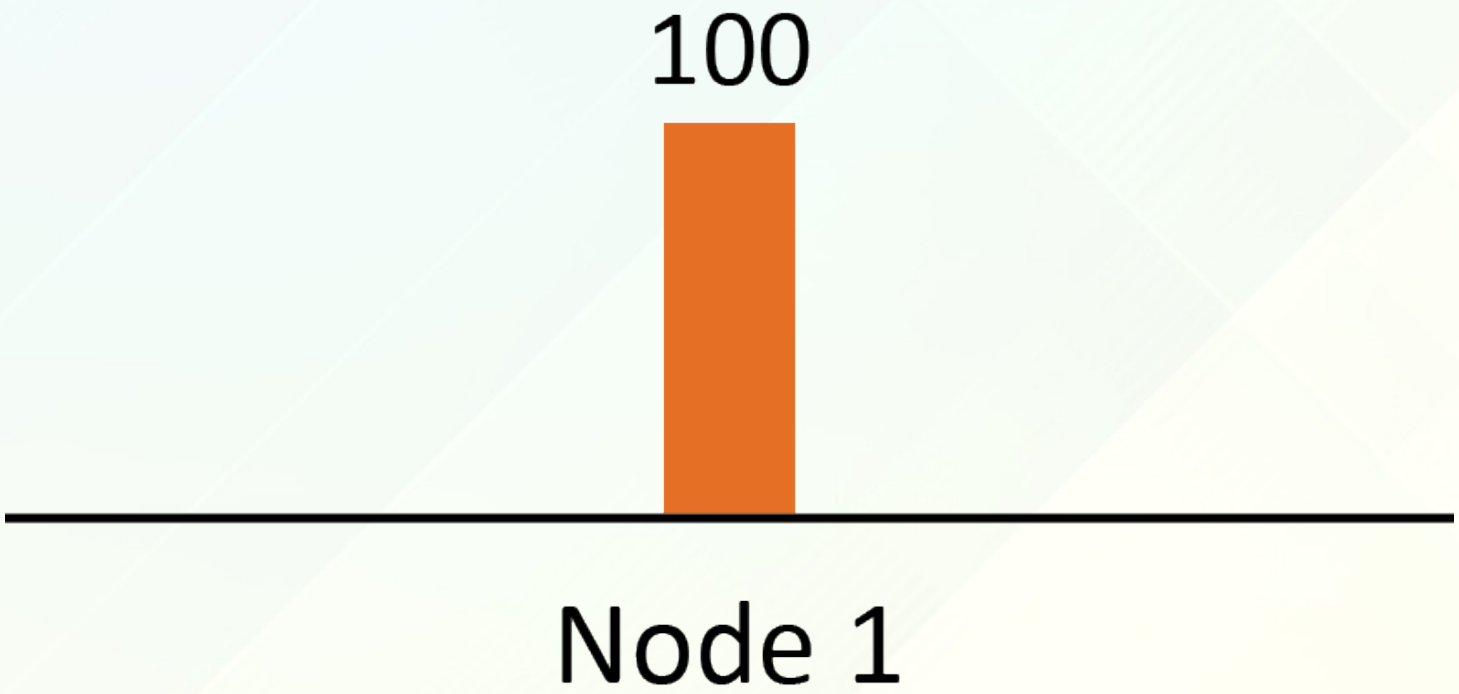
- Consistent hashing [1]
- Rendezvous hashing (or highest random weight - HRW) [2]

[1] https://en.wikipedia.org/wiki/Consistent_hashing
[2] https://en.wikipedia.org/wiki/Rendezvous_hashing

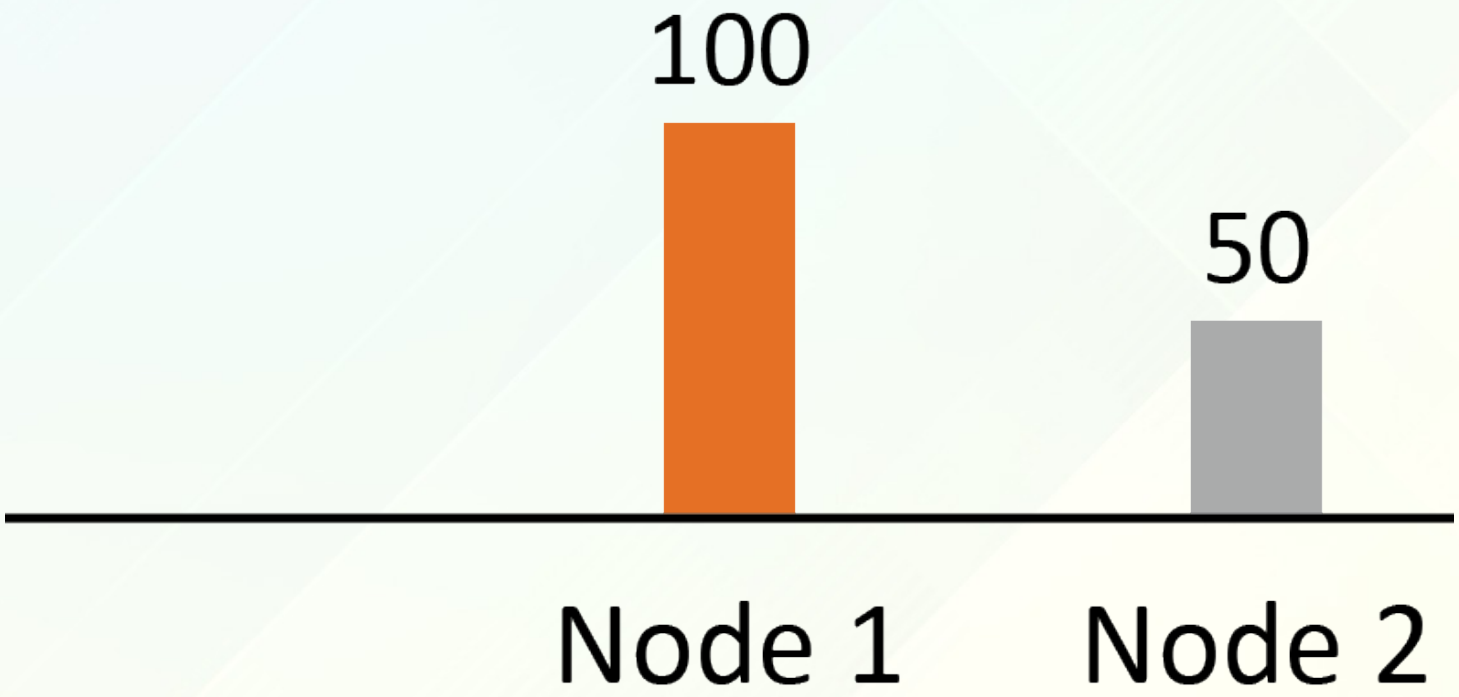
RENDEZVOUS AFFINITY

WEIGHT = W(PARTITION, NODE);

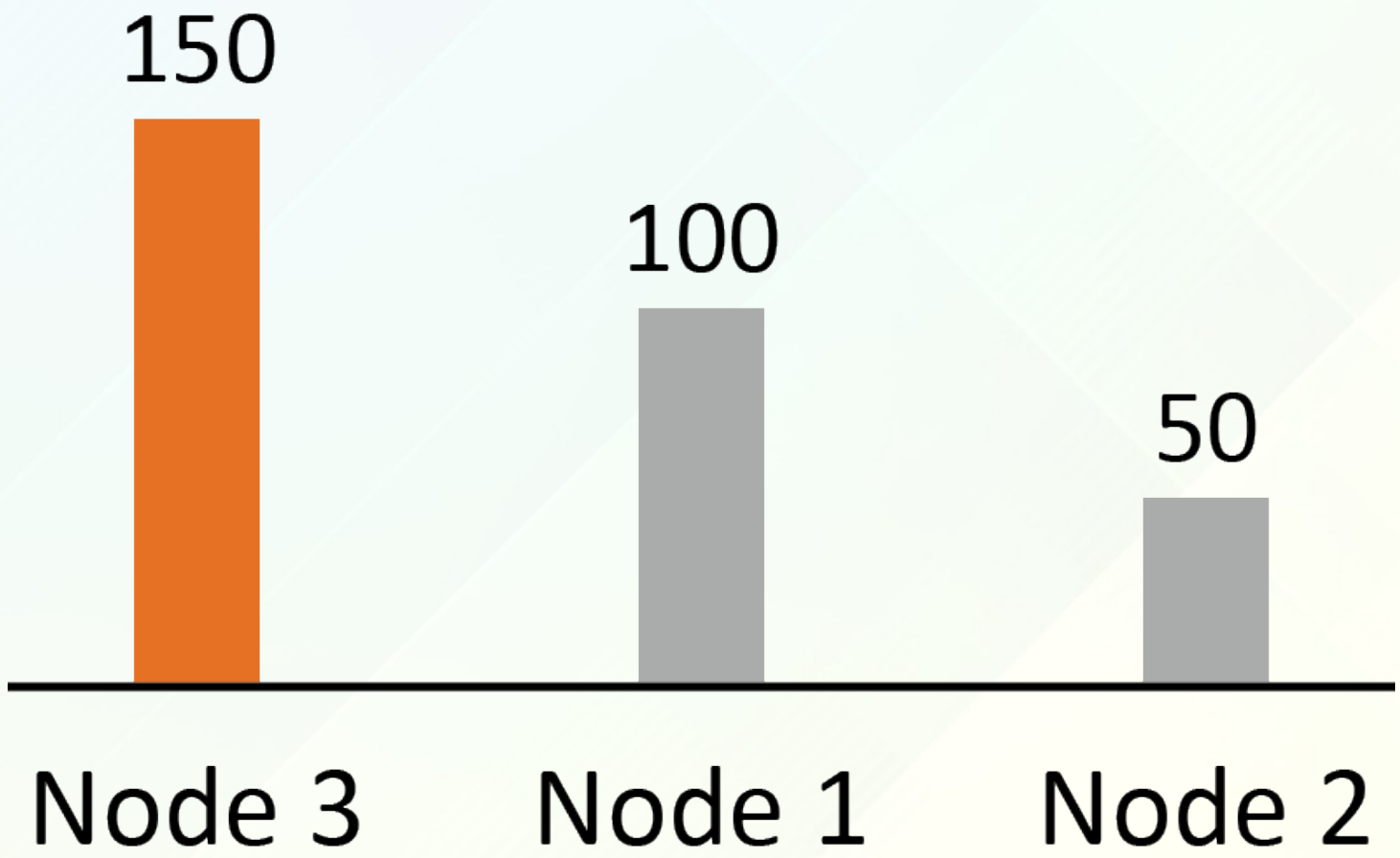
RENDEZVOUS AFFINITY



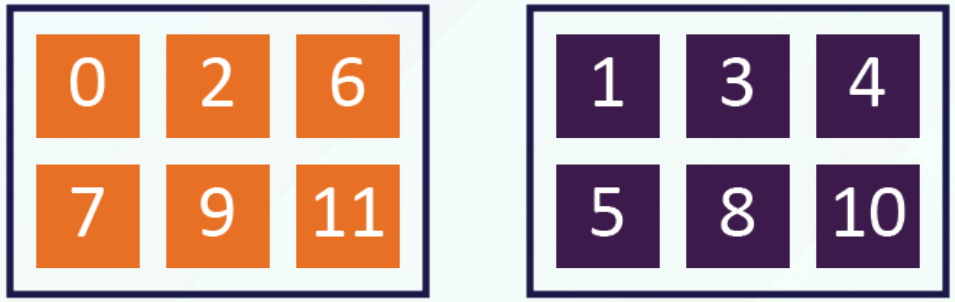
RENDEZVOUS AFFINITY



RENDEZVOUS AFFINITY

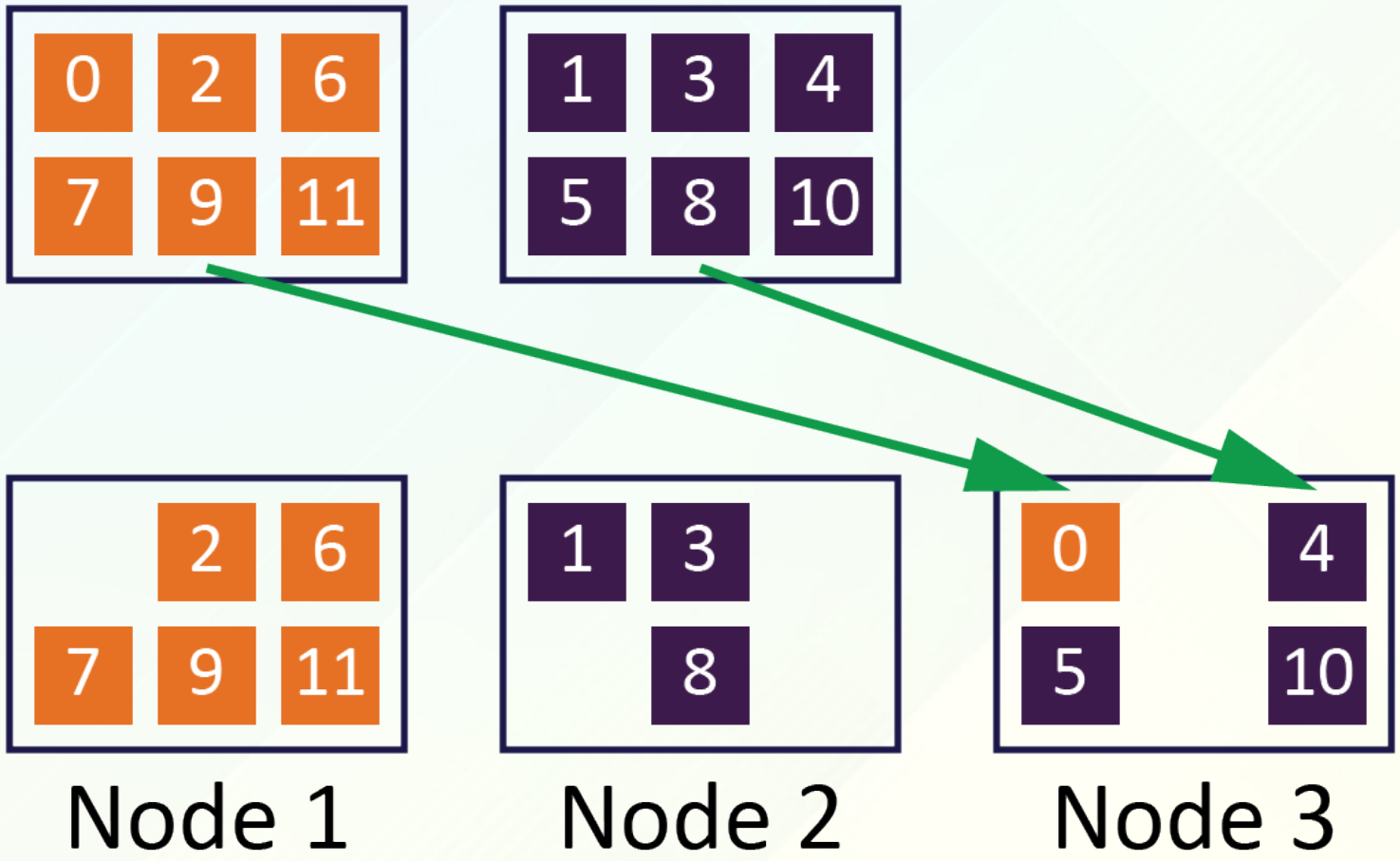


RENDEZVOUS AFFINITY

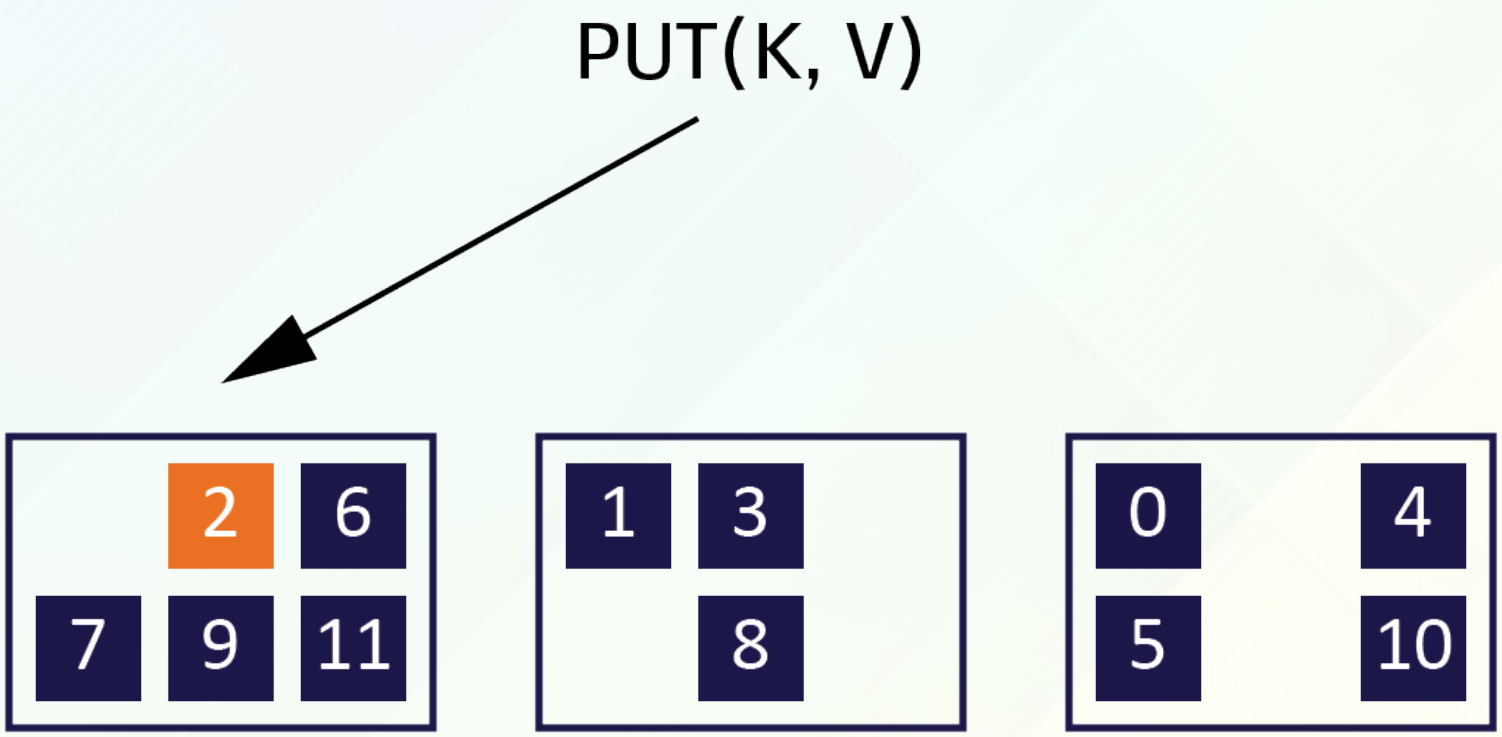


Node 1 Node 2

RENDEZVOUS AFFINITY



RENDEZVOUS AFFINITY: EVEN DISTRIBUTION?



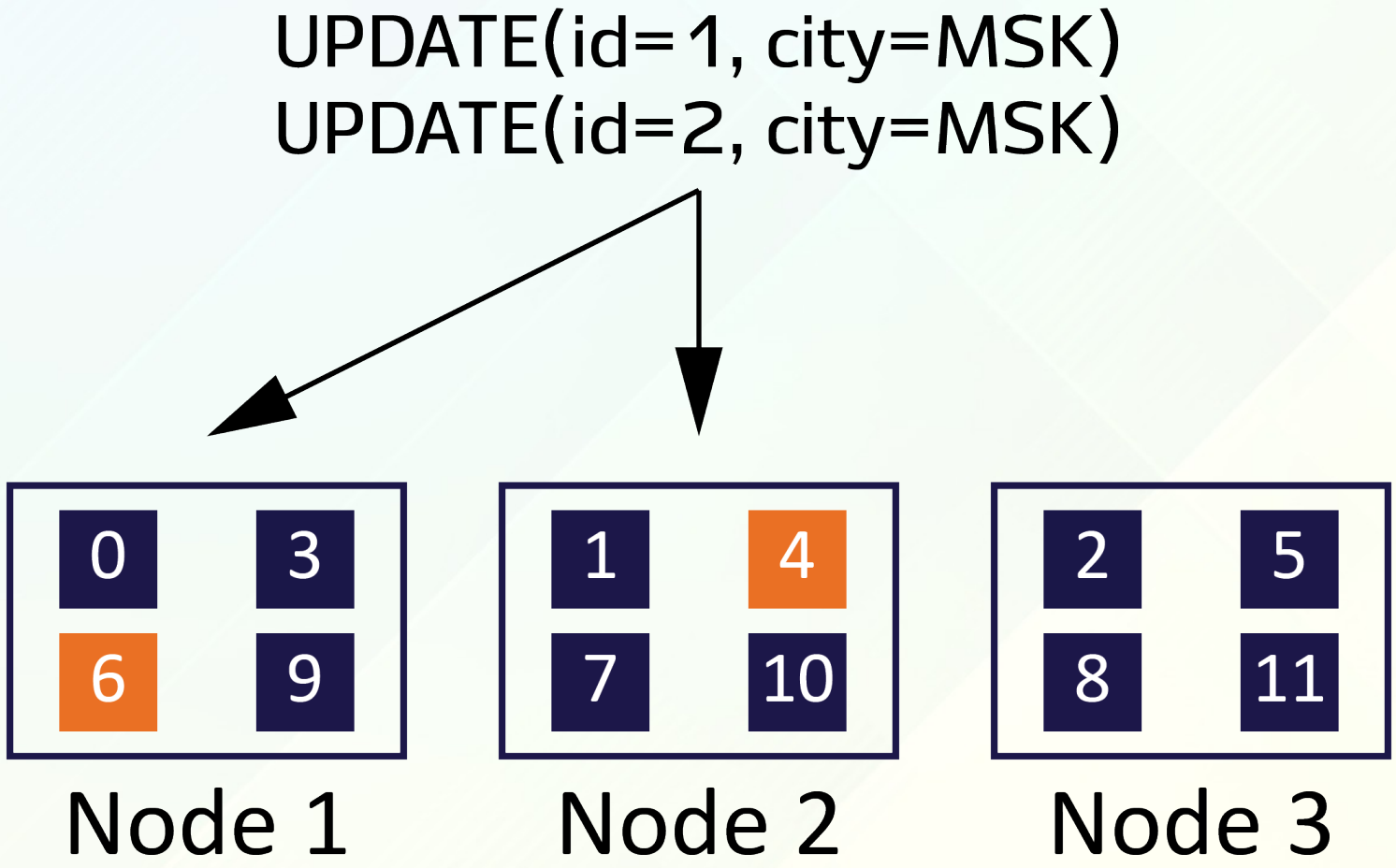
PLAN

1. Data partitioning and affinity functions examples
2. Data affinity colocation
3. Synchronization in distributed systems
4. Multithreading: local architecture

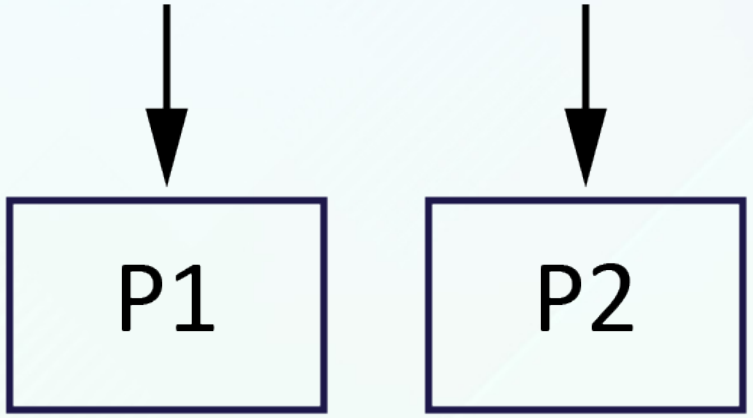
TRANSACTIONS: NO COLOCATION

```
1: class Customer {
2:         long id;
3:         City city;
4: }
```

TRANSACTIONS: NO COLOCATION

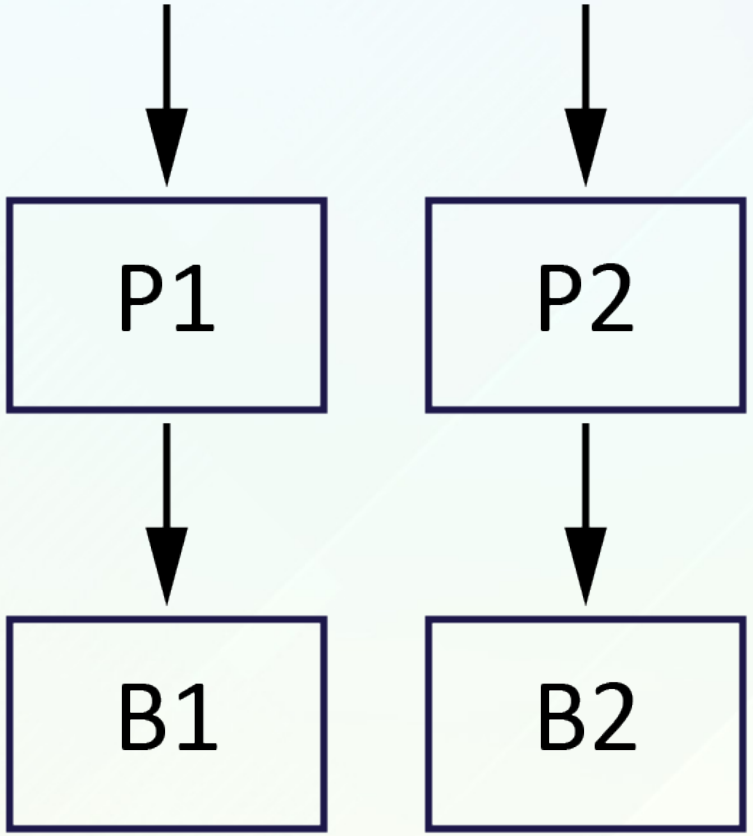


TRANSACTIONS: NO COLOCATION



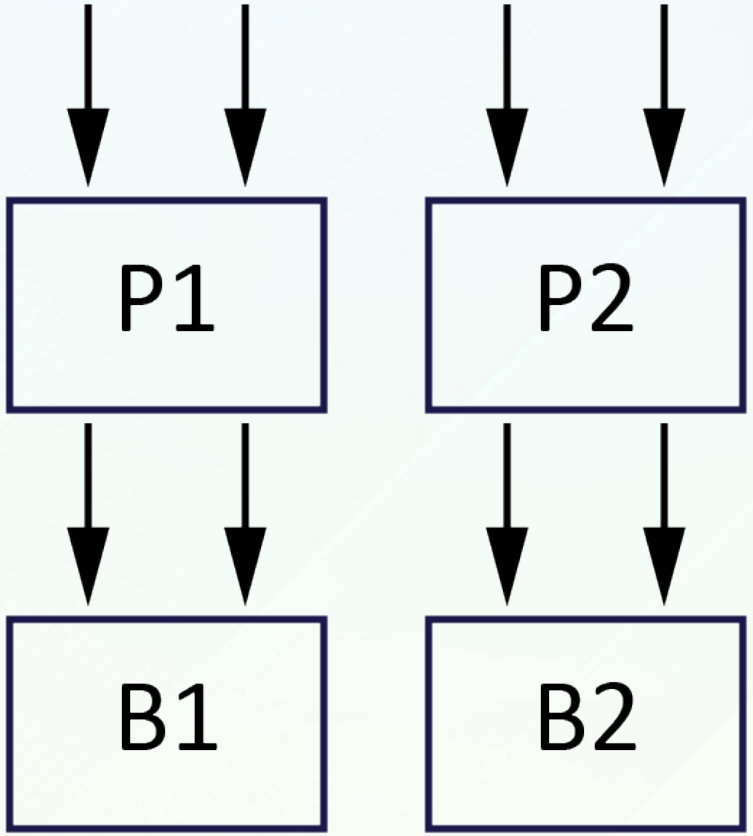
2 (2 nodes)

TRANSACTIONS: NO COLOCATION



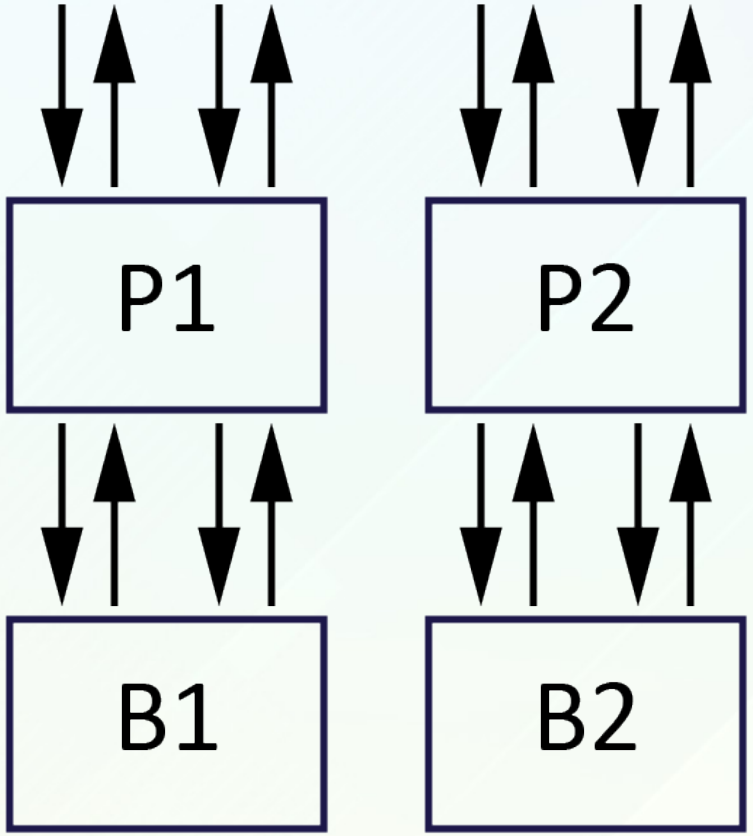
2 (2 nodes)
2 (primary + backup)

TRANSACTIONS: NO COLOCATION



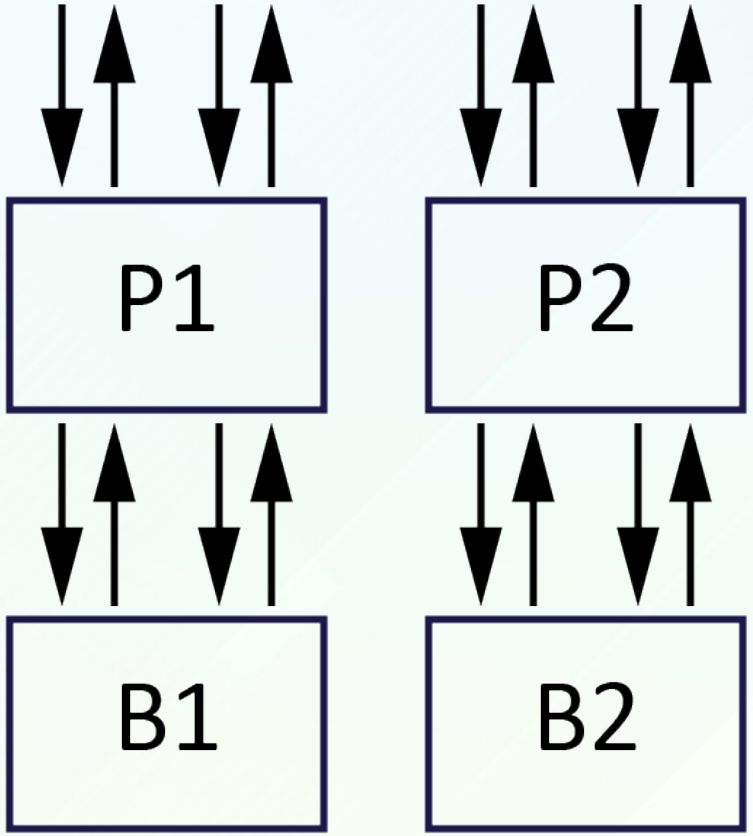
2 (2 nodes)
2 (primary + backup)
2 (two-phase commit)

TRANSACTIONS: NO COLOCATION



2 (2 nodes)
2 (primary + backup)
2 (two-phase commit)
2 (request-response)

TRANSACTIONS: NO COLOCATION



2 (2 nodes)
2 (primary + backup)
2 (two-phase commit)
2 (request-response)

16
Messages

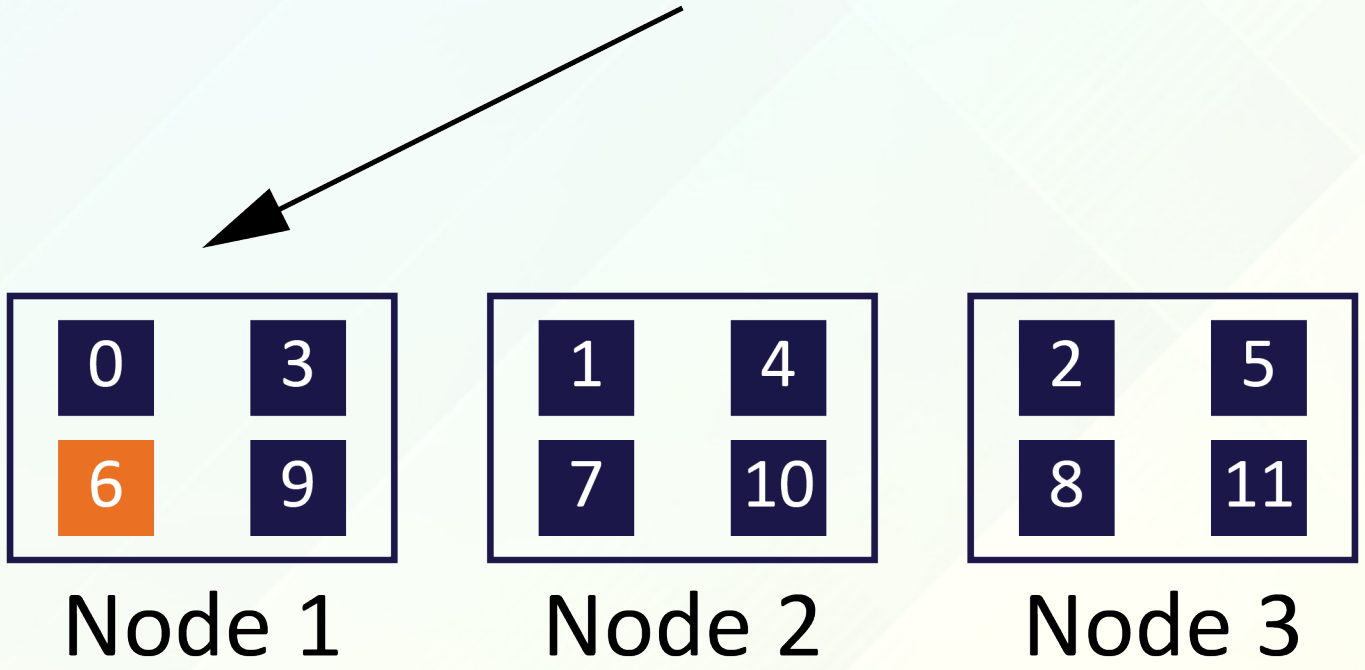
TRANSACTIONS: NO COLOCATION

TRANSACTIONS: WITH COLOCATION

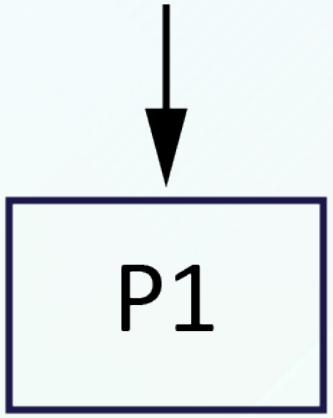
```
1: class Customer {
2:     long id;
3:
4:     @AffinityKeyMapped
5:     City city;
6: }
```

TRANSACTIONS: WITH COLOCATION

UPDATE(id=1, city=MSK)
UPDATE(id=2, city=MSK)

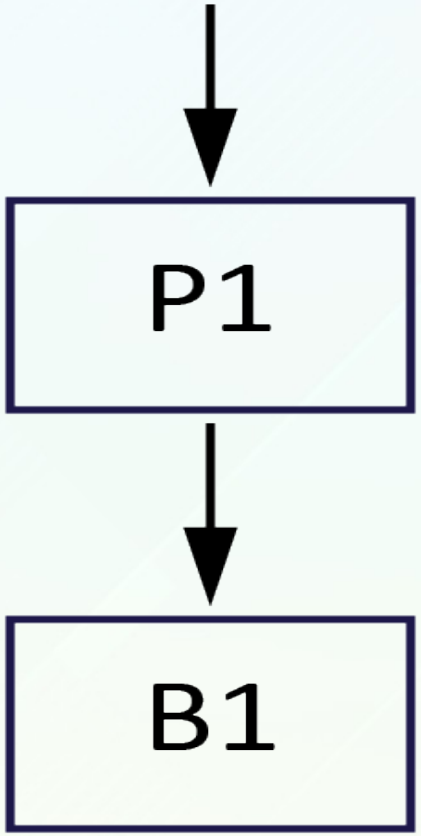


TRANSACTIONS: WITH COLOCATION



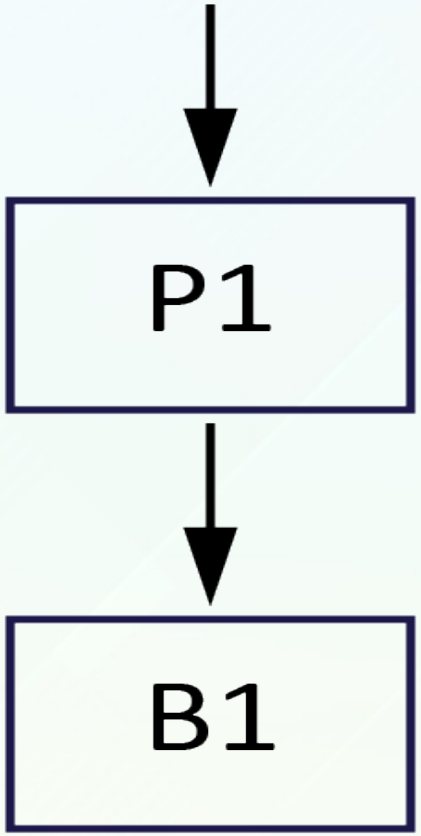
1 (1 node)

TRANSACTIONS: WITH COLOCATION



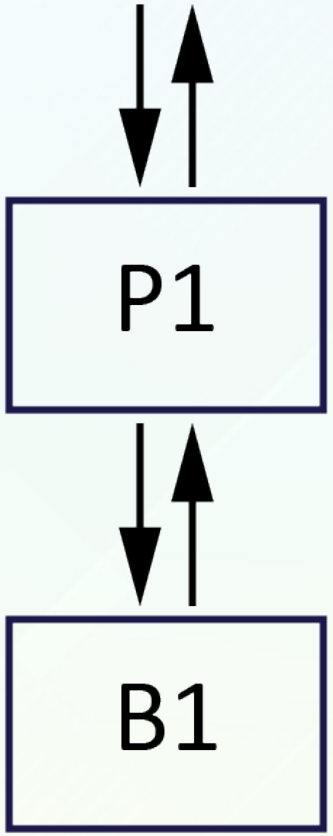
1 (1 node)
2 (primary + backup)

TRANSACTIONS: WITH COLOCATION



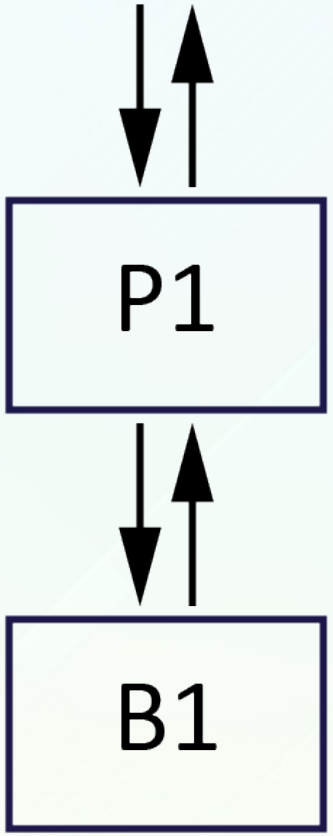
1 (1 node)
2 (primary + backup)
(one-phase commit)

TRANSACTIONS: WITH COLOCATION




```
1 (1 node)
2 (primary + backup)
  (one-phase commit)
1 (request-response)
```

TRANSACTIONS: WITH COLOCATION



1 (1 node)
2 (primary + backup)
(one-phase commit)
1 (request-response)

4 Messages

TRANSACTIONS: COLOCATION VS NO COLOCATION

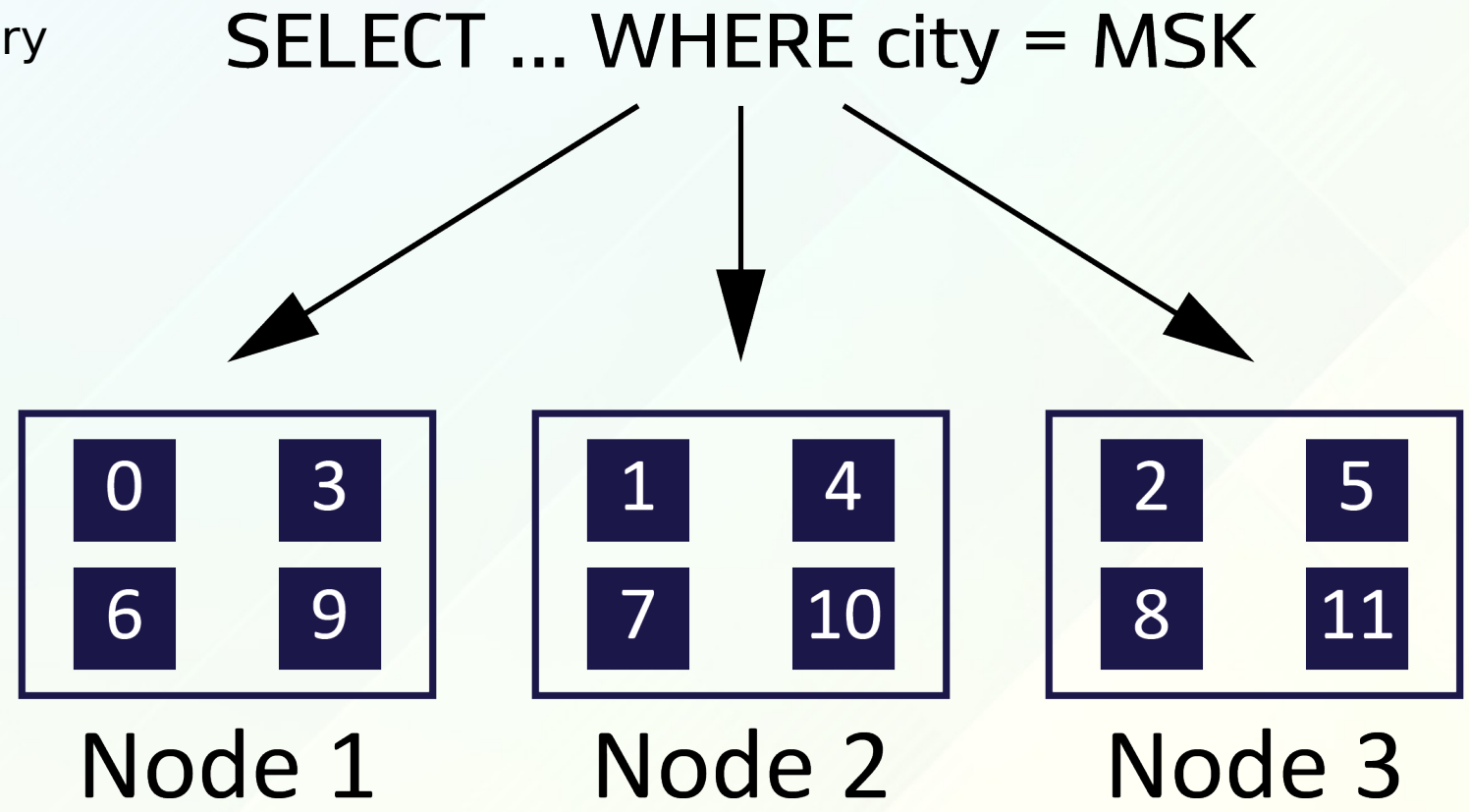
4 Messages

VS

16 Messages

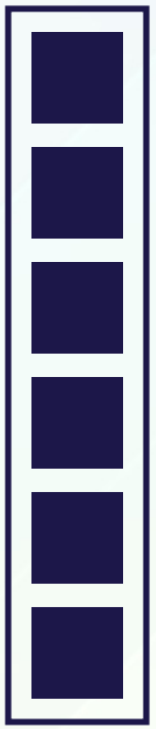
SQL

Let’s run a query on our data



SQL

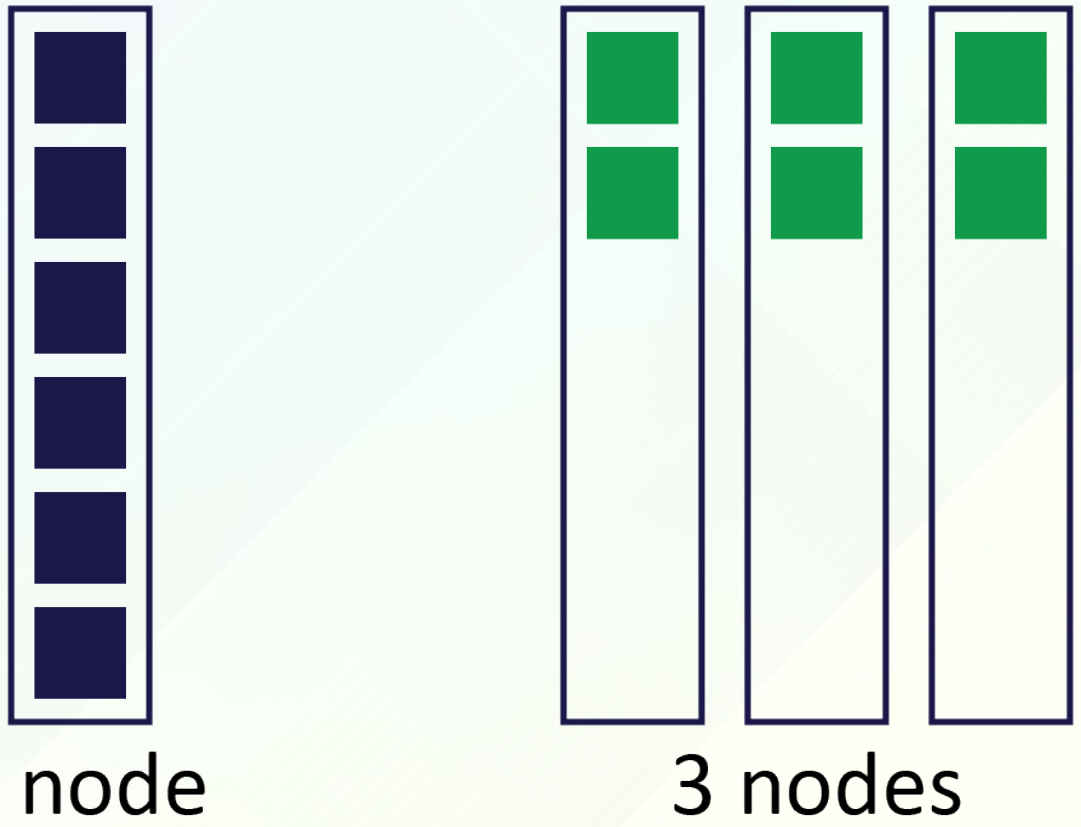
No colocation:
FULL SCAN



1 node

SQL

No colocation:
FULL SCAN



No colocation:
FULL SCAN

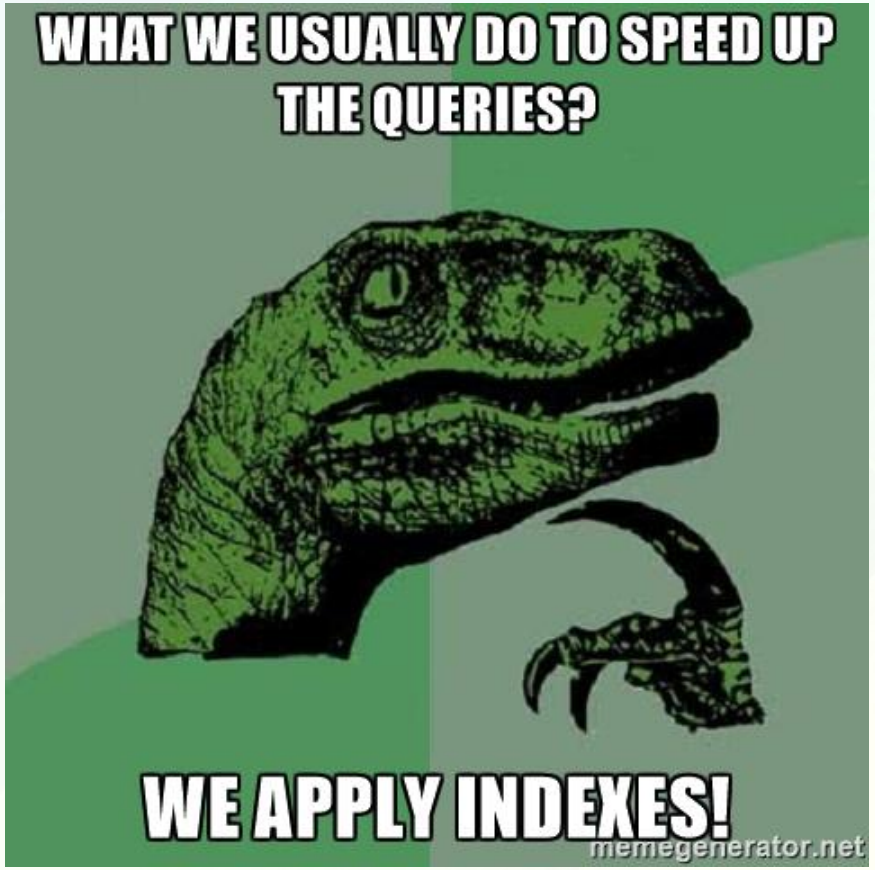
1/3x Latency

No colocation:
FULL SCAN

1/3x Latency

3x Capacity

SQL


WHAT WE USUALLY DO TO SPEED UP THE QUERIES?
WE APPLY INDEXES!
memegenerator.net

SQL

1 node

SQL

1 node

N nodes

What about complexity?

$$\log 1\_000\_000 \approx 20$$

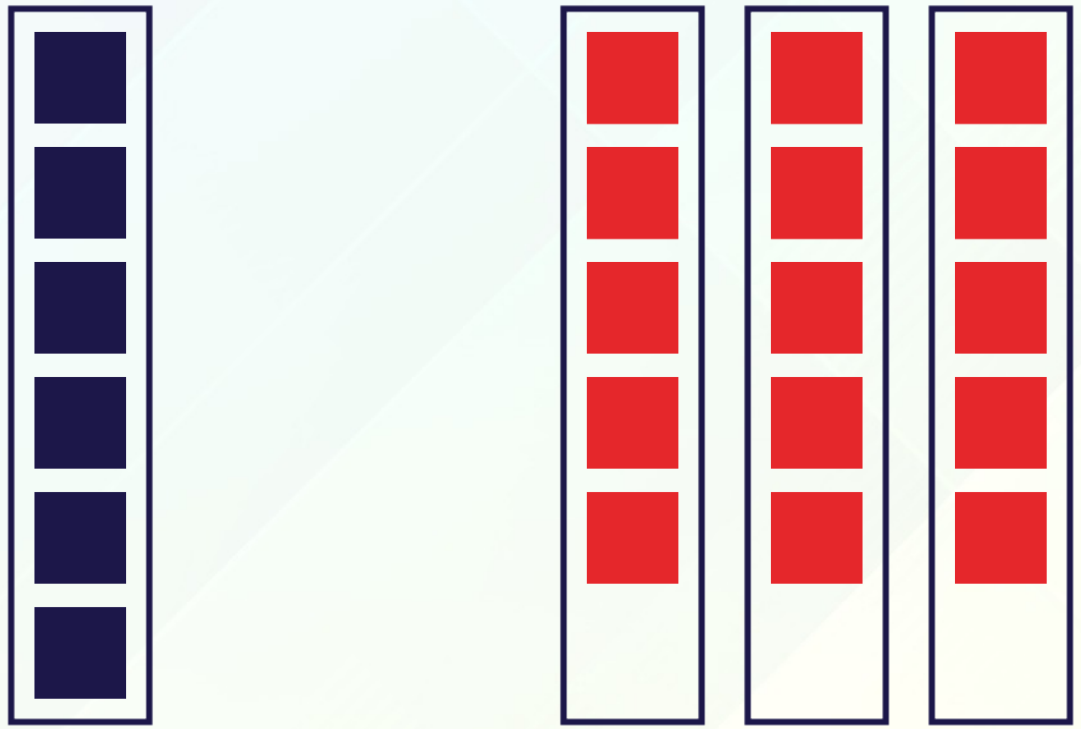
What about complexity?

```
log 1_000_000 ≈ 20
```

vs

```
log   333_333 ≈ 18
log   333_333 ≈ 18
log   333_333 ≈ 18
```

SQL: INDEXED



1 node

3 nodes

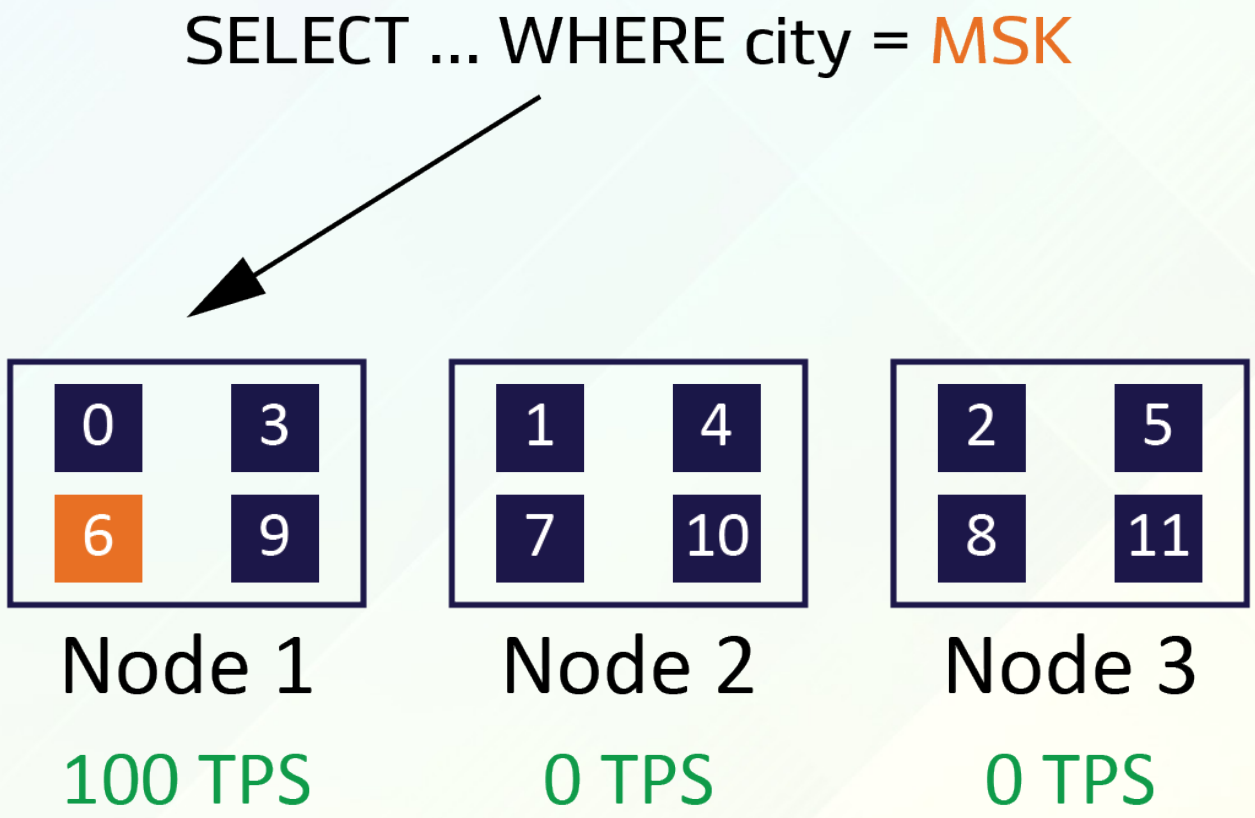
No colocation:
INDEXED QUERY

Same latency!

Same capacity!

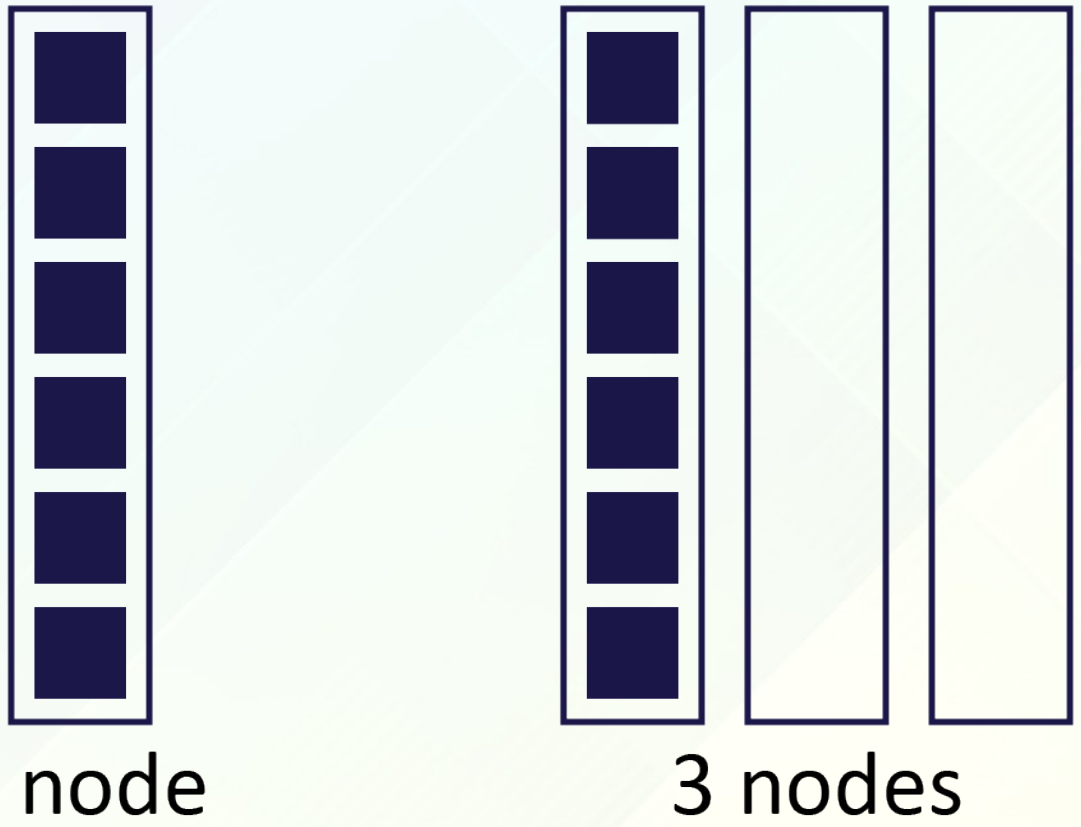
SQL: INDEX AND COLOCATION

Colocation:
INDEXED QUERY



SQL

Colocation:
INDEXED QUERY



SQL: INDEX AND COLOCATION

Colocation:
INDEXED QUERY

Same latency

But 3x capacity!

SQL: EVEN DISTRIBUTION WITH COLOCATION?

Node 1

100 TPS

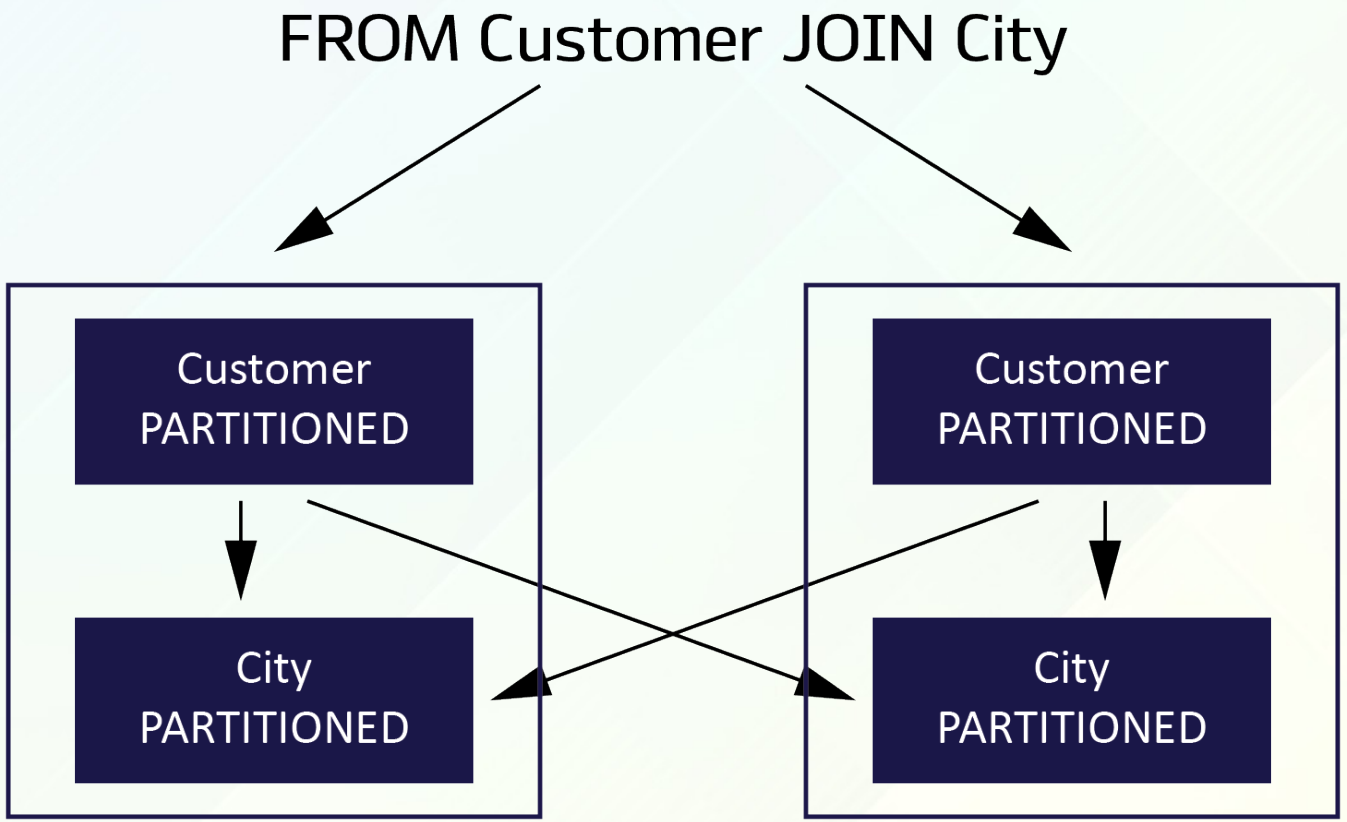
Node 2

50 TPS

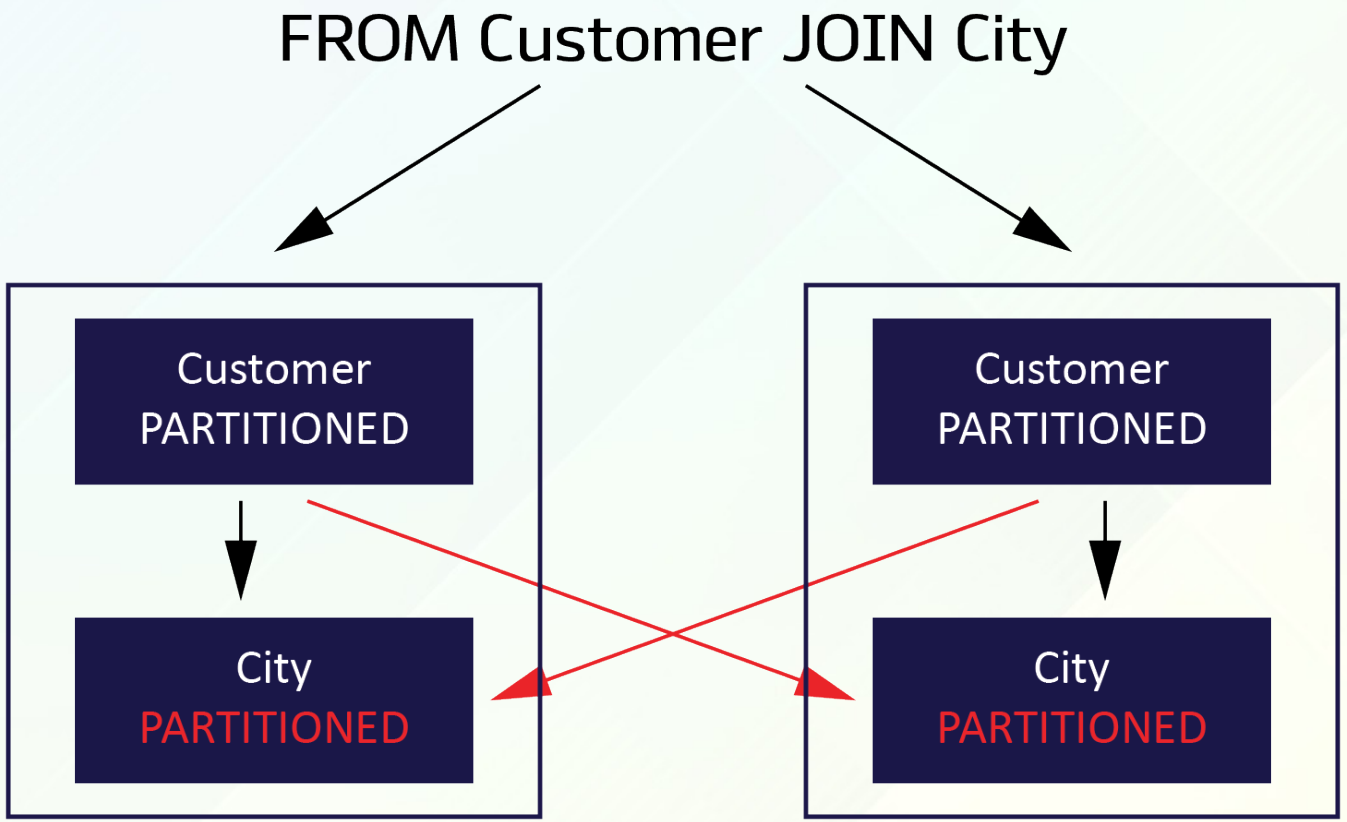
Node 3

10 TPS

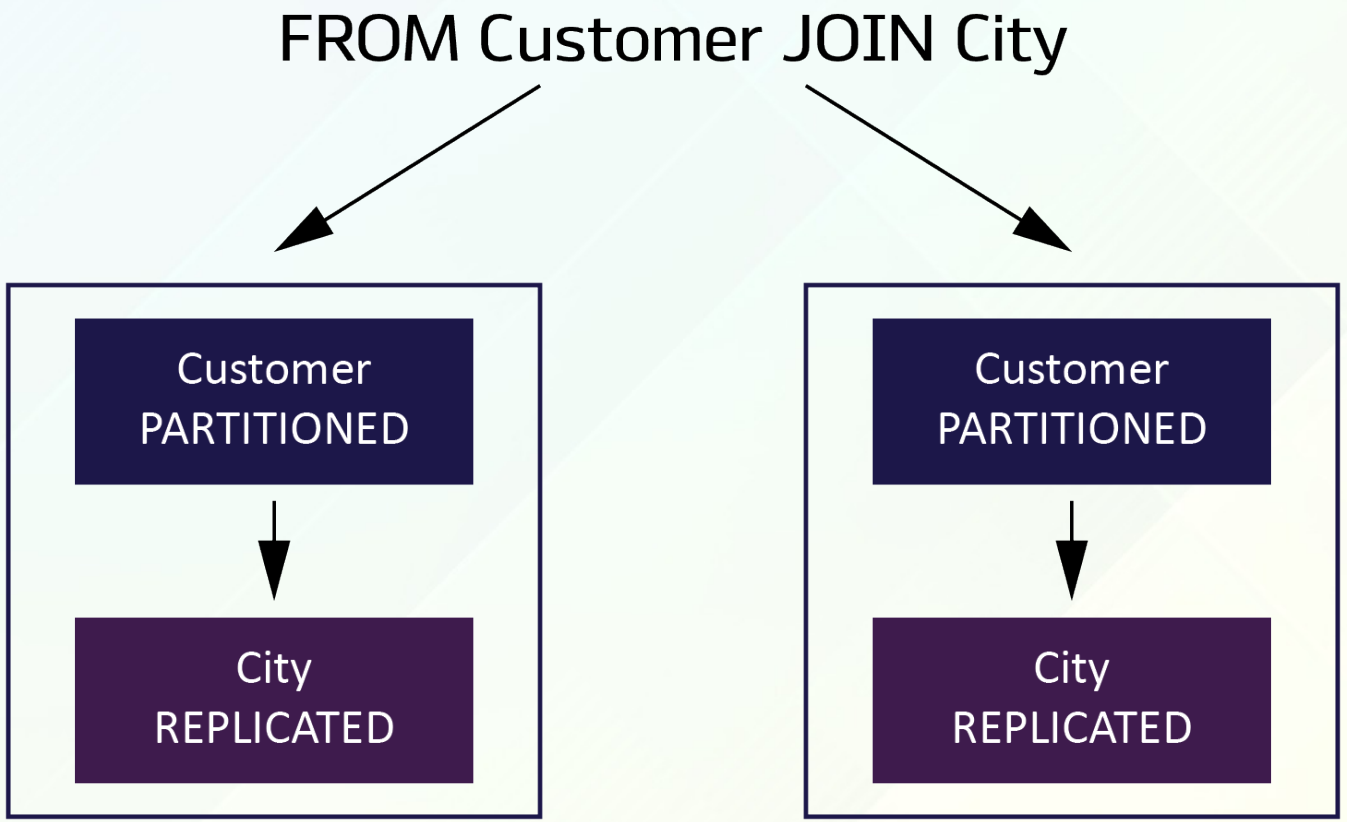
SQL: JOINS IN DISTRIBUTED ENVIRONMENT



SQL: JOINS WITH COLOCATION



SQL: JOINS WITH REPLICATION



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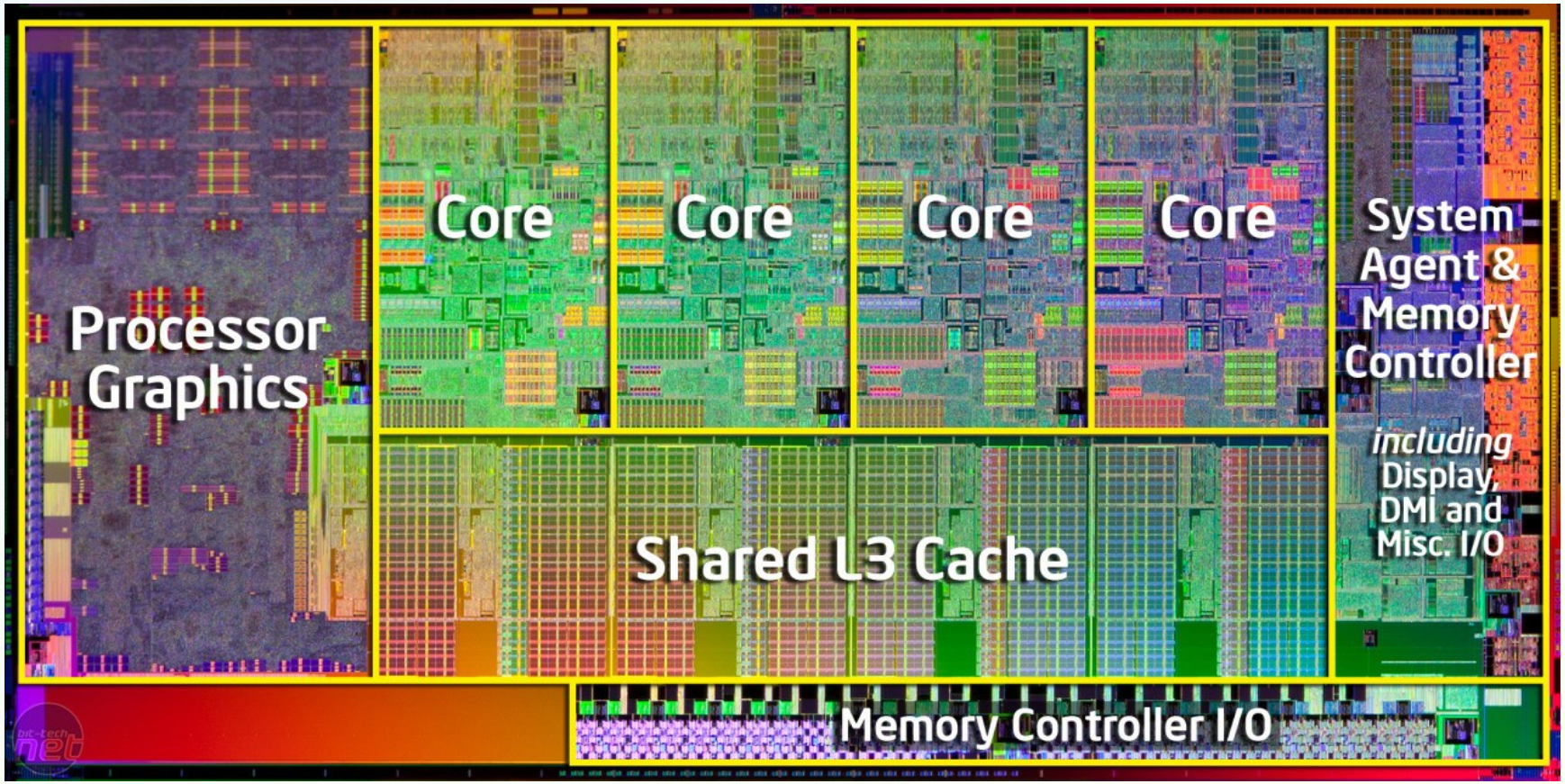
SYNCHRONIZATION: LOCAL COUNTER

```
1: AtomicLong ctr;
2:
3: long getNext() {
4:     return ctr.incrementAndGet();
5: }
```

SYNCHRONIZATION: LOCAL (RE-INVENTING A BICYCLE)

```
 1: AtomicLong ctr;
 2: ThreadLocal<Long> localCtr;
 3:
 4: long getNext() {
 5:     long res = localCtr.get();
 6:
 7:     if (res % 1000 == 0)
 8:         res = ctr.getAndAdd(1000);
 9:
10:     localCtr.set(++res);
11:
12:     return res;
13: }
```

SYNCHRONIZATION: LOCAL



SYNCHRONIZATION: DISTRIBUTED

SYNCHRONIZATION: COUNTER IN THE CLUSTER

Local implementation: millions ops/sec

Distributed implementation: thousands ops/sec

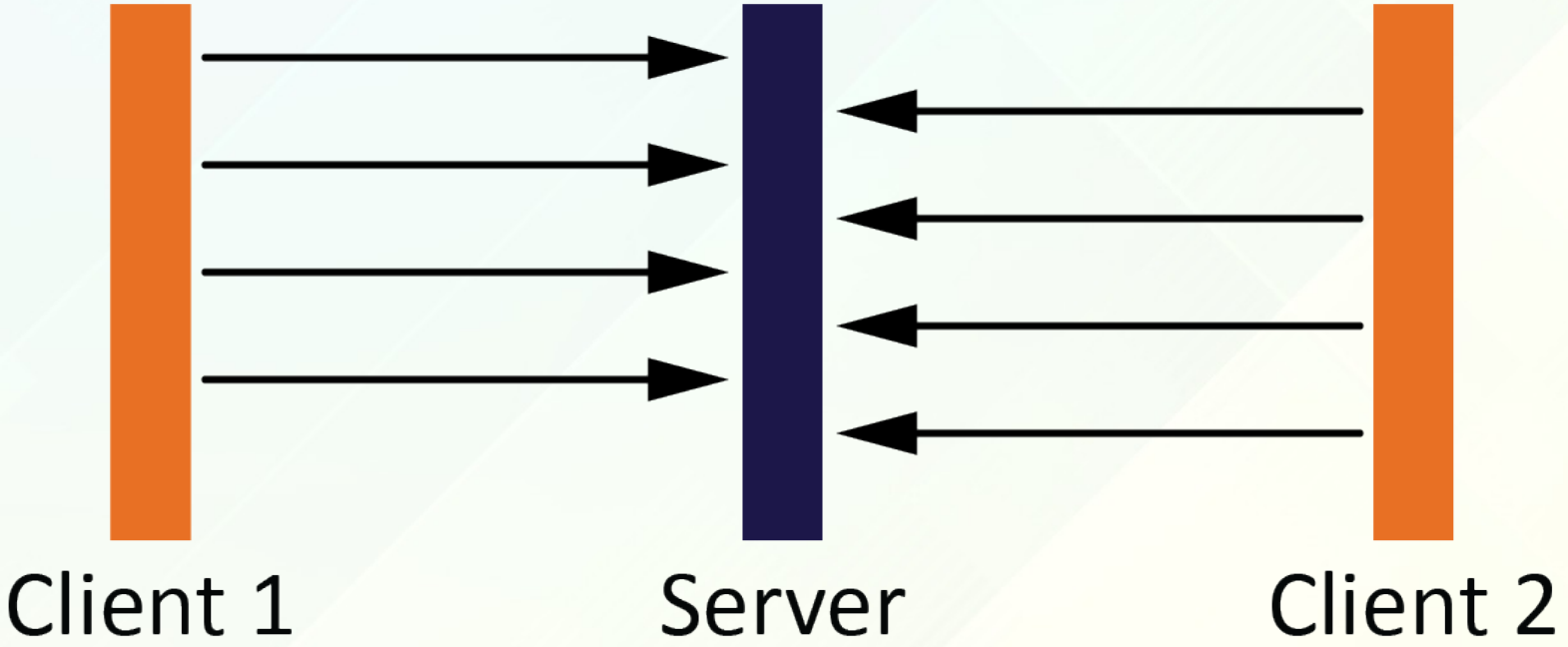
SYNCHRONIZATION: COUNTER IN THE CLUSTER

Proper requirements:

- Unique
- Monotonously growing
- 8 bytes

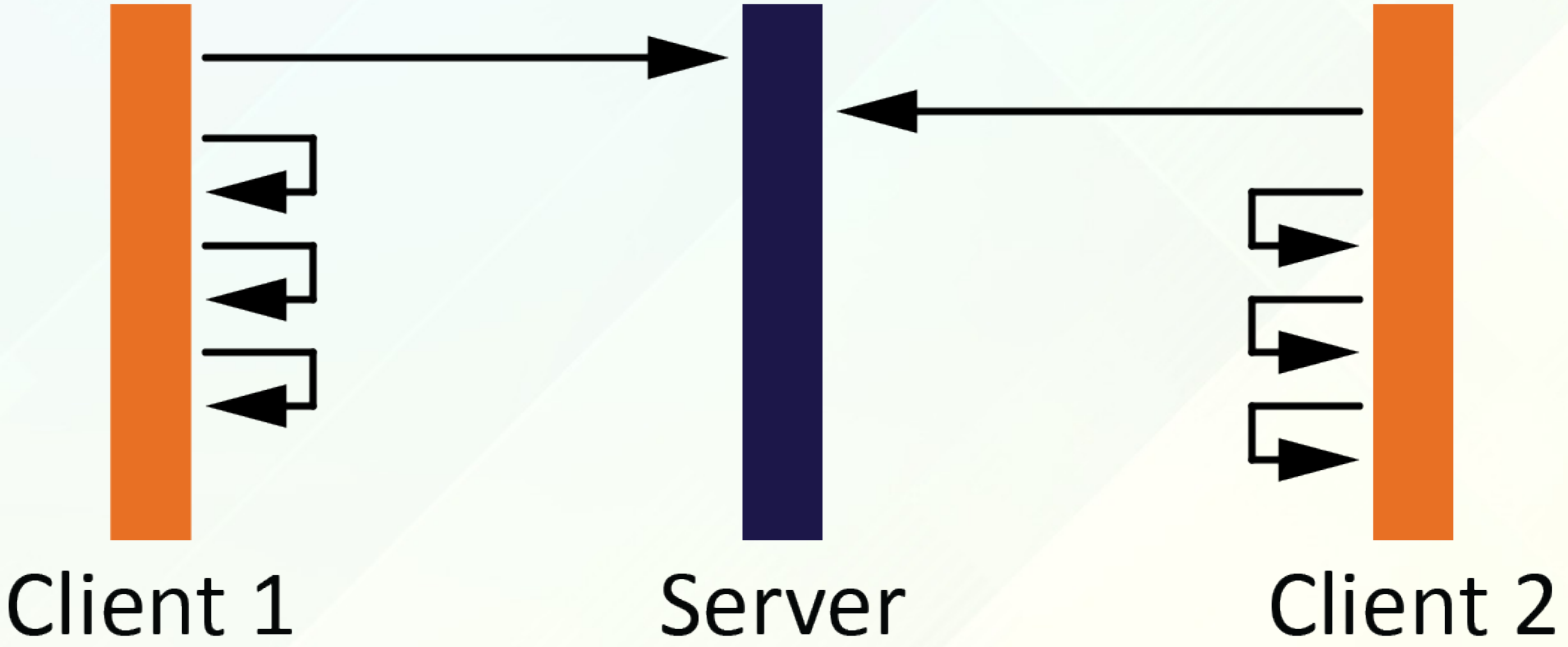
SYNCHRONIZATION: COUNTER IN THE CLUSTER

Requirements: unique, monotonous, 8 bytes.



SYNCHRONIZATION: COUNTER IN THE CLUSTER

Requirements: unique, ~~monotonous~~, 8 bytes.



SYNCHRONIZATION: COUNTER IN THE CLUSTER

Requirements: unique, ~~monotonous~~, ~~8 bytes~~.

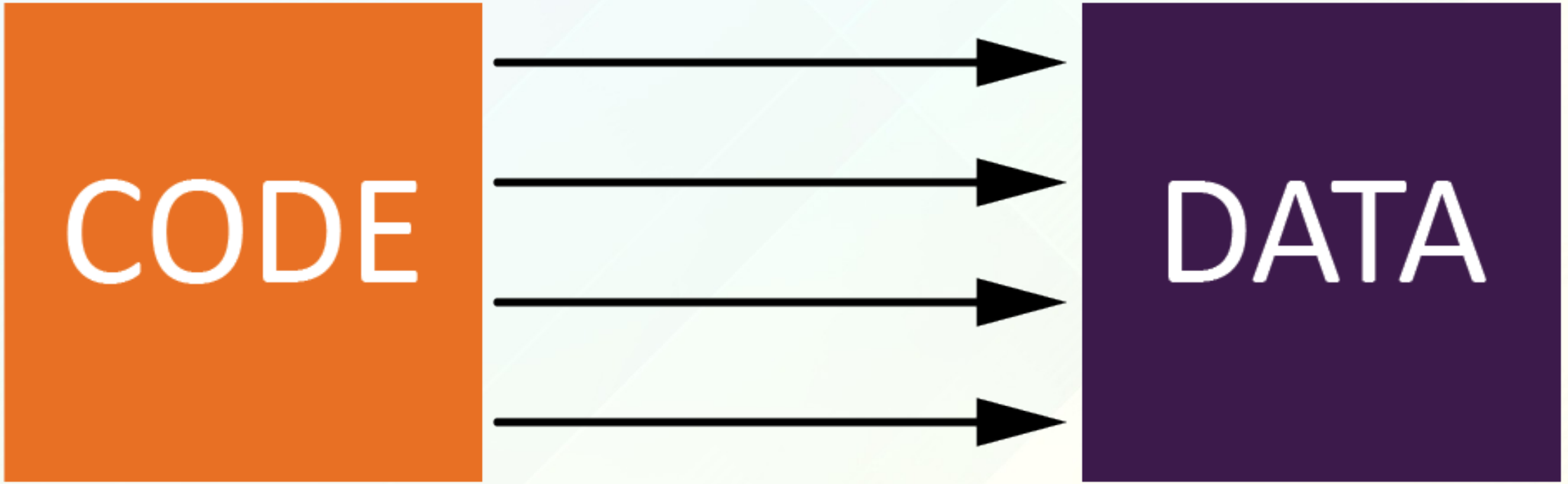
SYNCHRONIZATION: COUNTER IN THE CLUSTER

Requirements: unique, ~~monotonous~~, ~~8 bytes~~.

See also: `org.apache.ignite.lang.IgniteUuid`

SYNCHRONIZATION AS FRICTION FOR A CAR

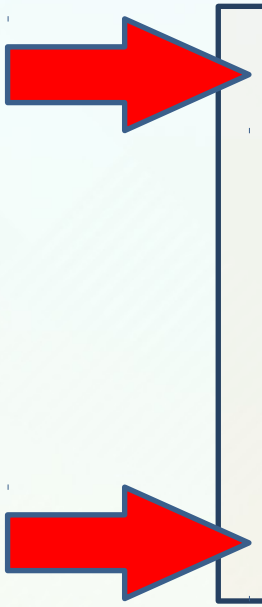
SYNCHRONIZATION: DATA TO CODE



SYNCHRONIZATION: DATA TO CODE

```
1: Account acc = cache.get(accKey);
3:
3: acc.add(100);
4:
5: cache.put(accKey, acc);
```

SYNCHRONIZATION: DATA TO CODE



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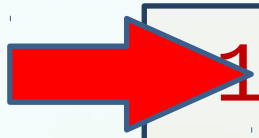
```

SYNCHRONIZATION: CODE TO DATA

SYNCHRONIZATION: CODE TO DATA

```
1: cache.invoke(accKey, (entry) -> {
1:     Account acc = entry.getValue();
3:
3:     acc.add(100);
4:
5:     entry.setValue(acc);
6: });
```

SYNCHRONIZATION: CODE TO DATA



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1:     Account acc = entry.getValue();
3:
3:     acc.add(100);
4:
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6: });
```
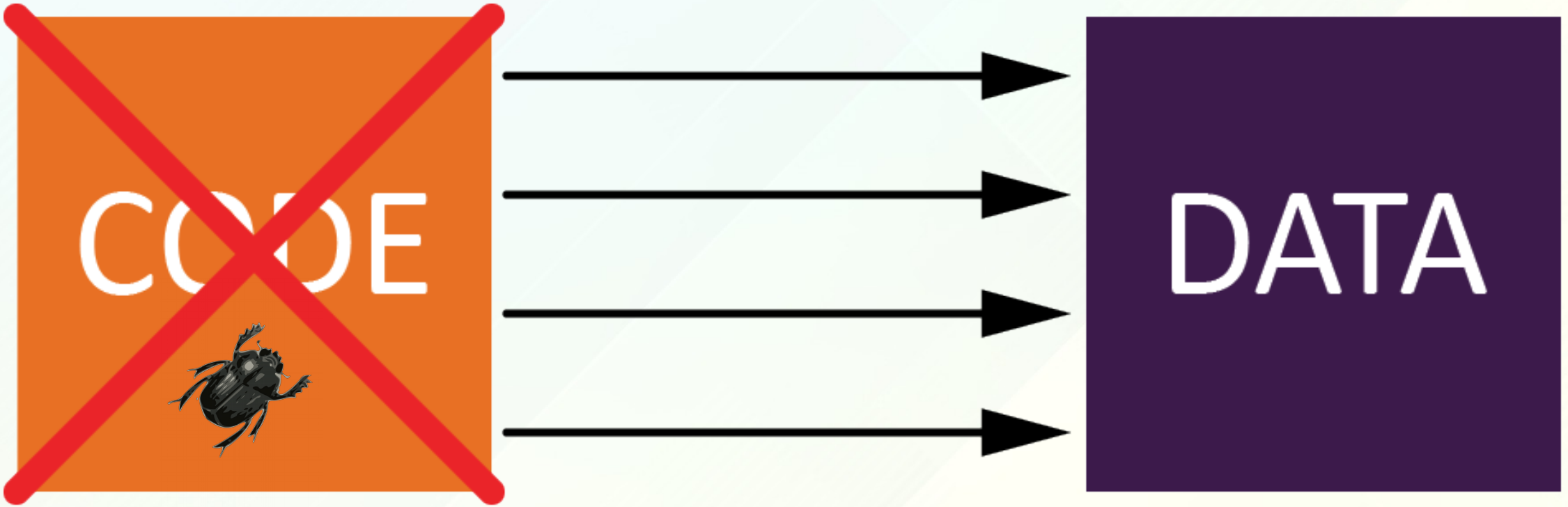

SYNCHRONIZATION: DATA TO CODE

What if we have a bug?!



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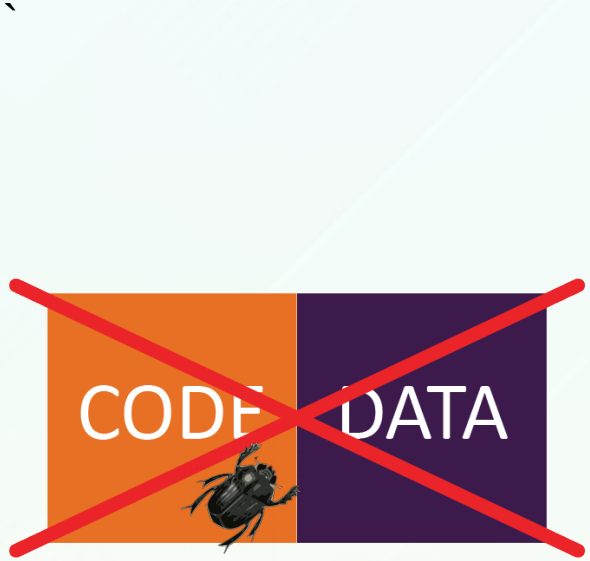
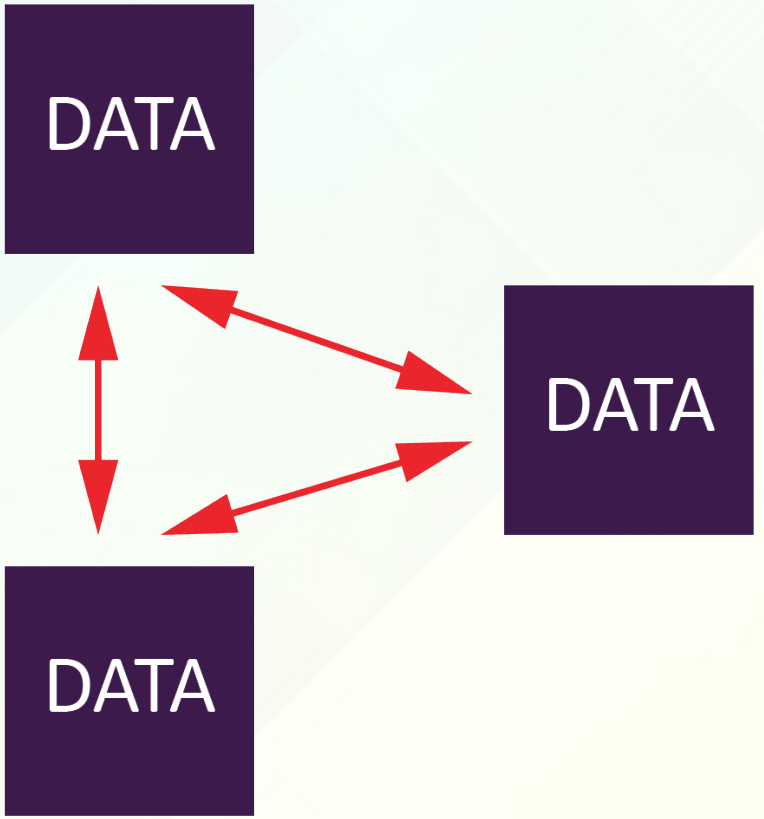
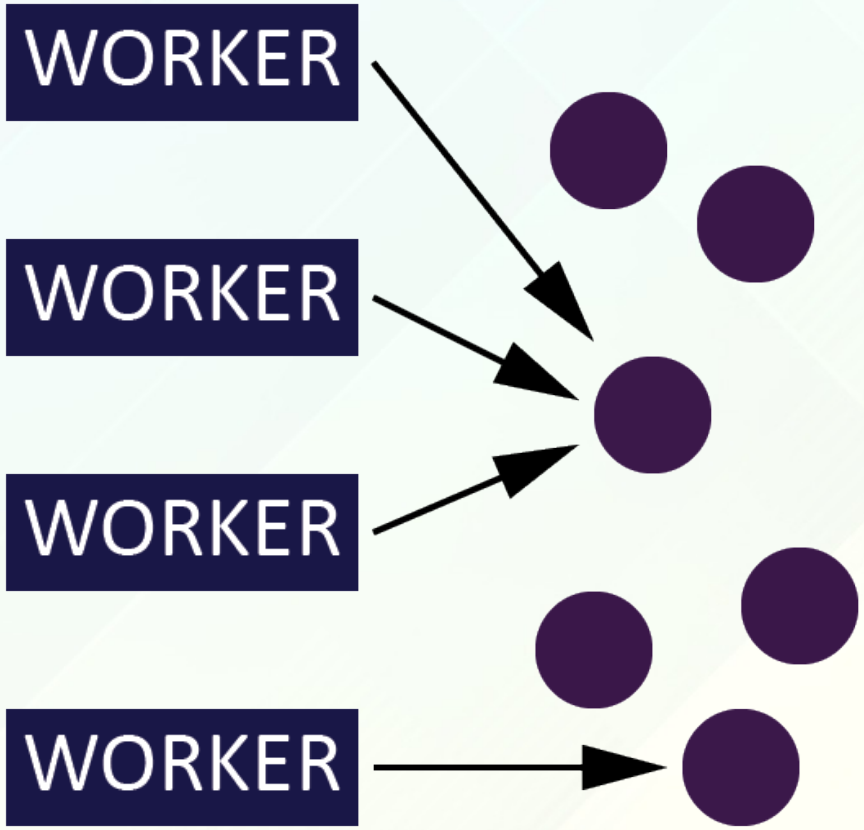




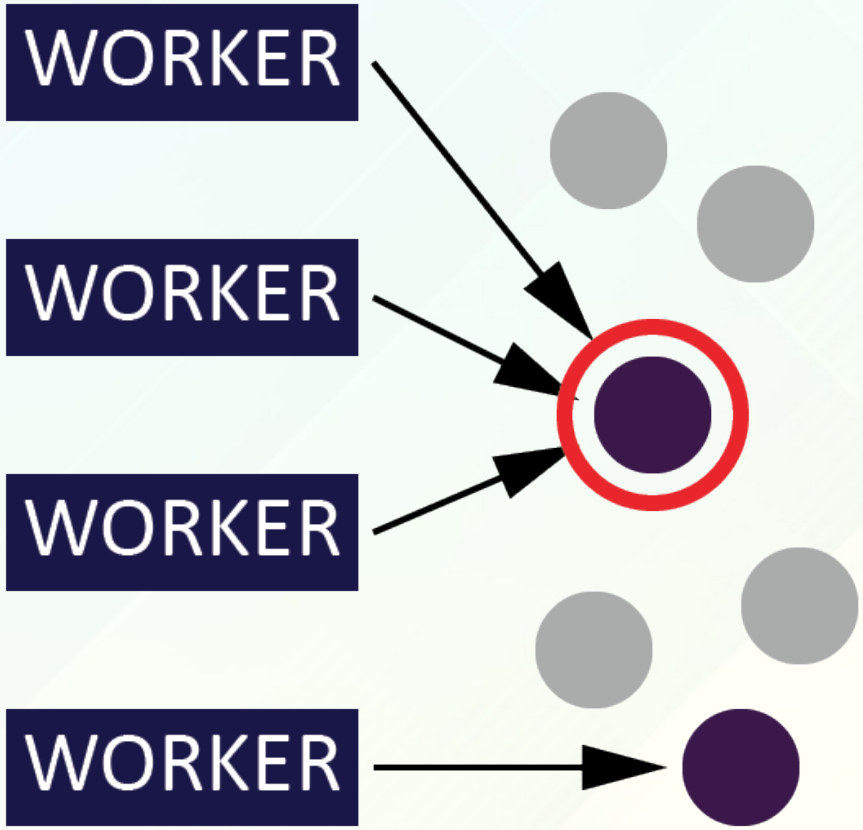
PLAN

1. Data partitioning and affinity functions examples
2. Data affinity colocation
3. Synchronization in distributed systems
4. Multithreading: local architecture

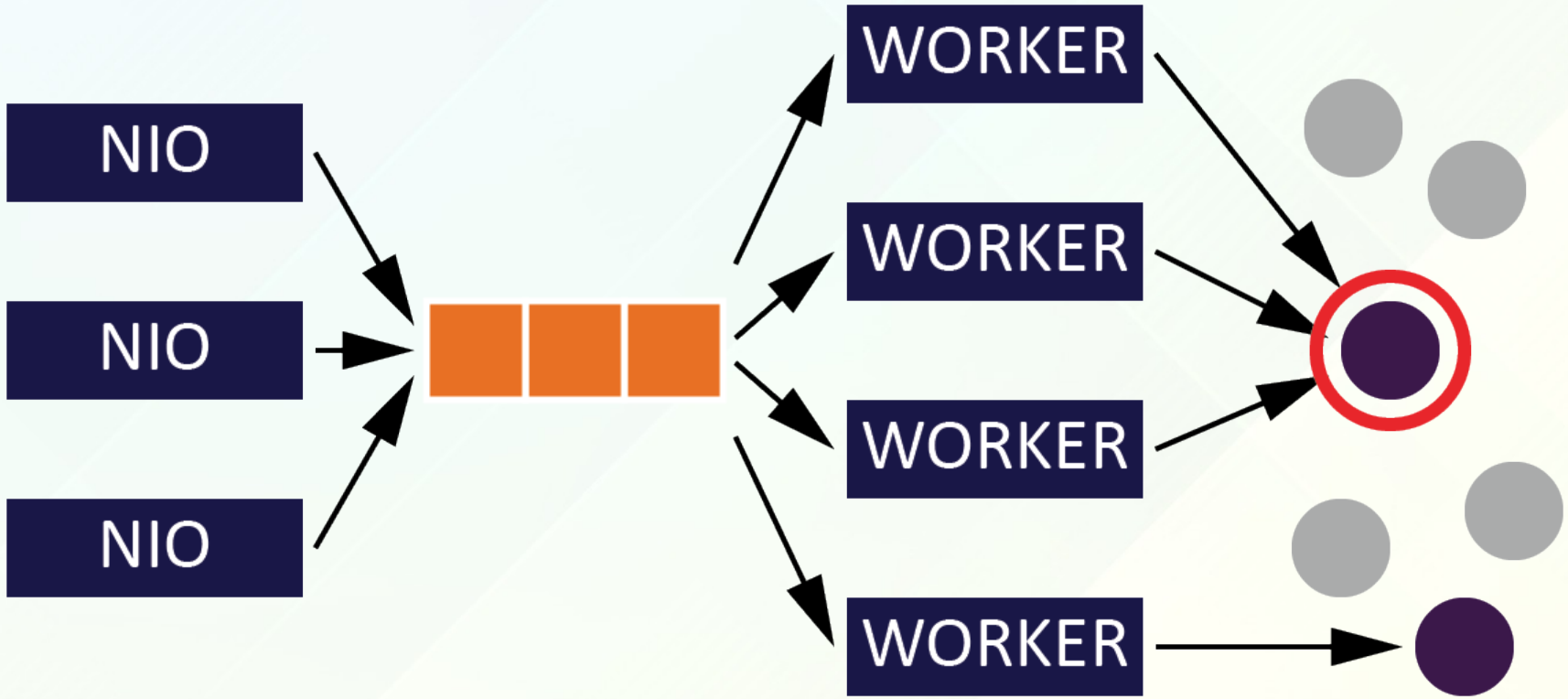
LOCAL TASKS DISTRIBUTION



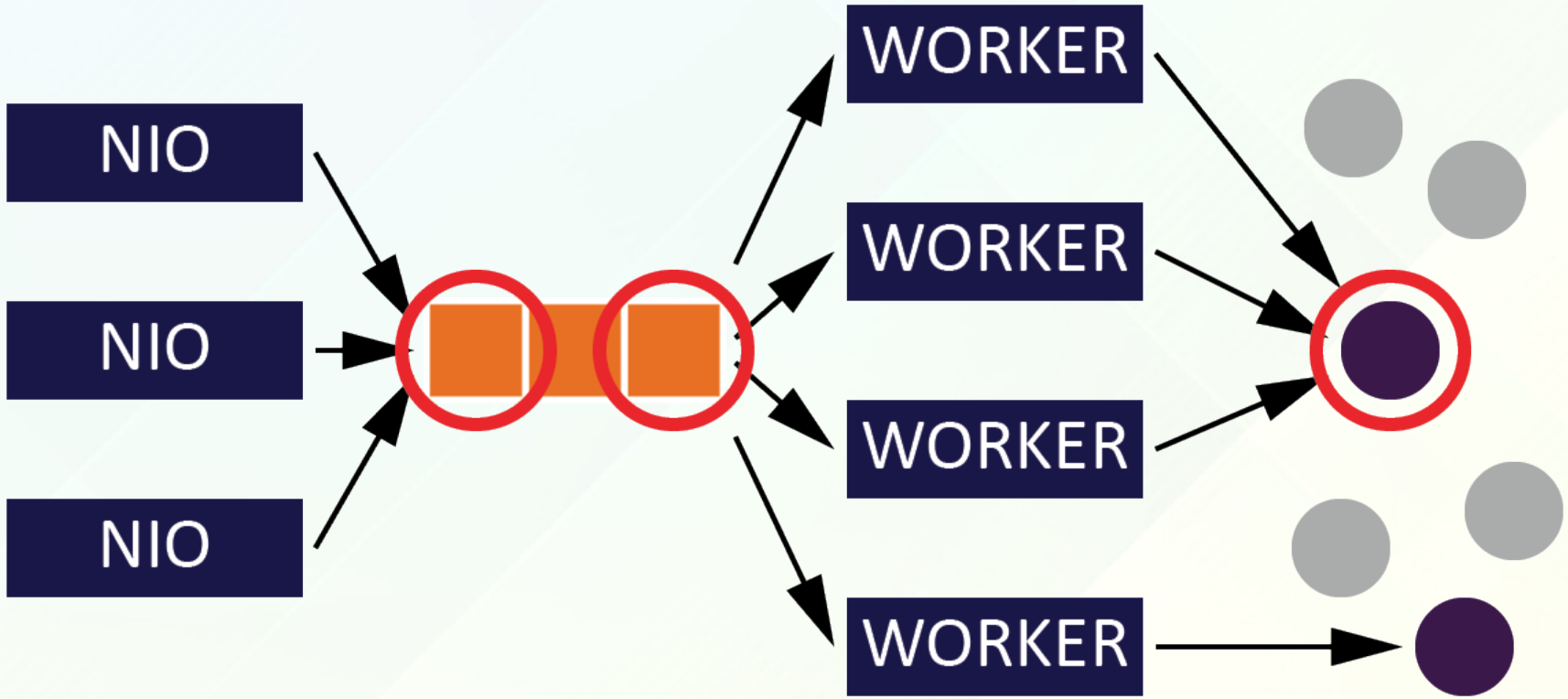
LOCAL TASKS DISTRIBUTION



LOCAL TASKS DISTRIBUTION

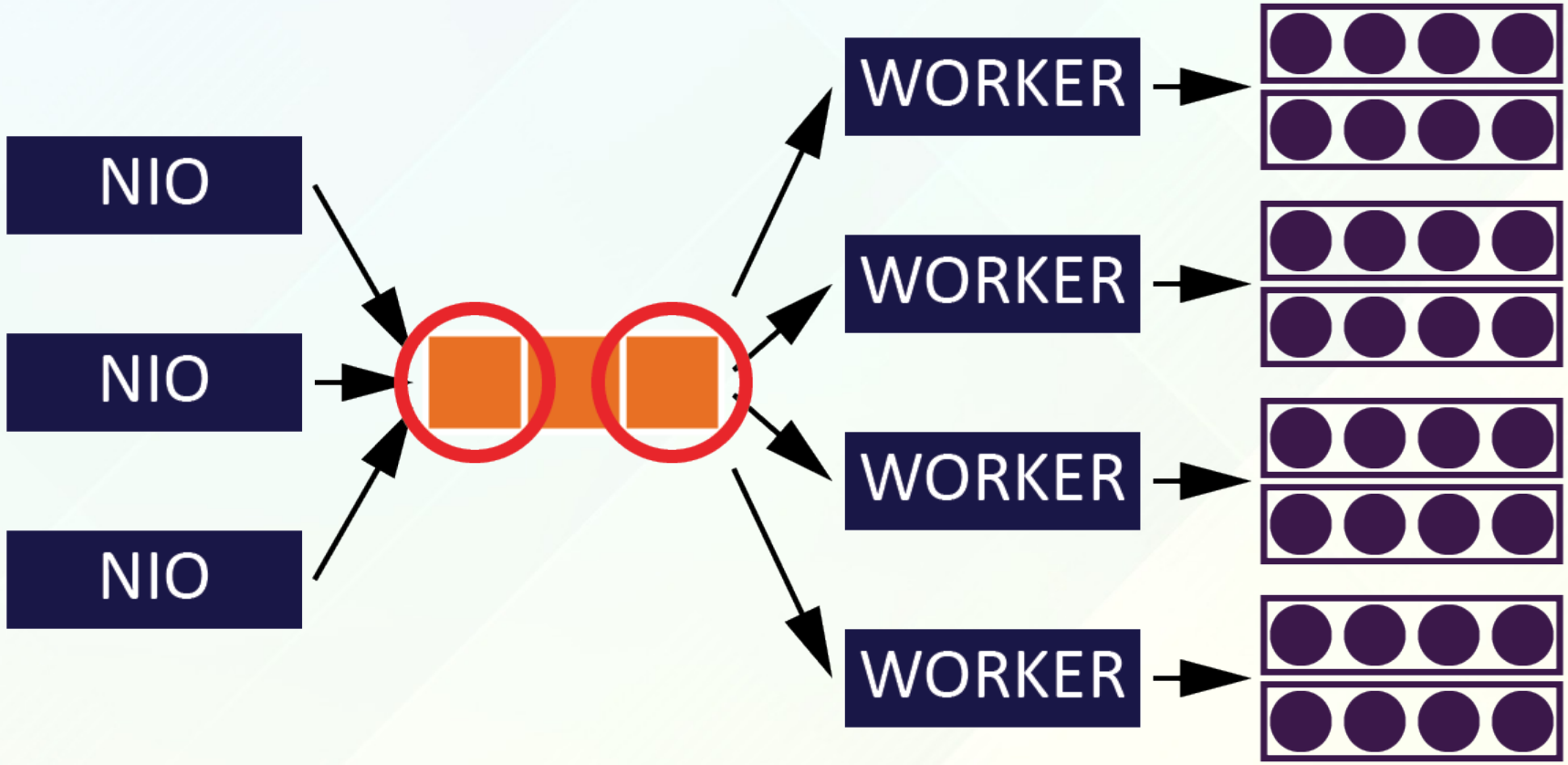


LOCAL TASKS DISTRIBUTION

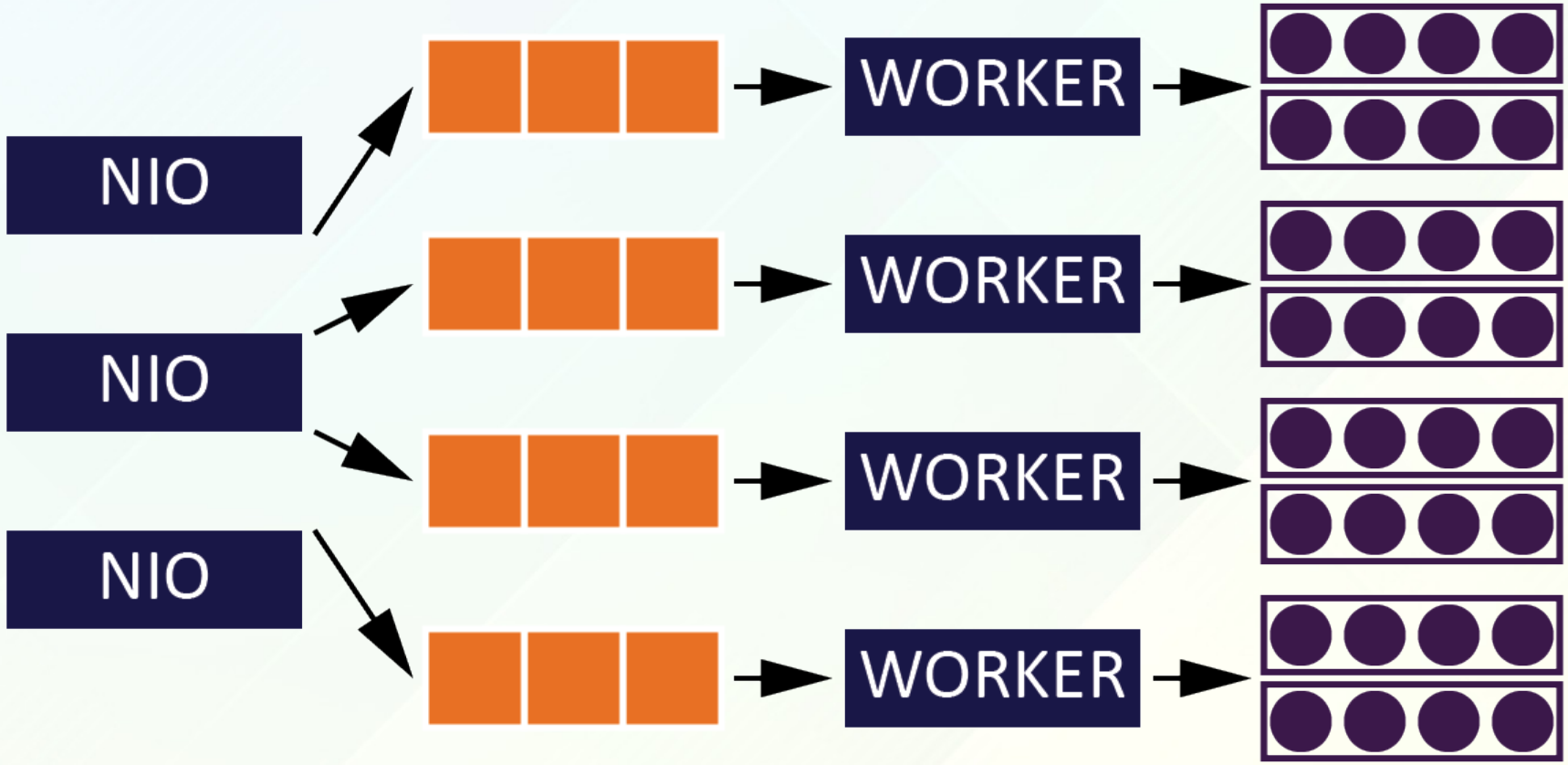


LOCAL TASKS DISTRIBUTION

LOCAL TASKS DISTRIBUTION: THREAD PER PARTITION



LOCAL TASKS DISTRIBUTION: THREAD PER PARTITION



LOCAL TASKS DISTRIBUTION: THREAD PER PARTITION

Node 1

100 TPS

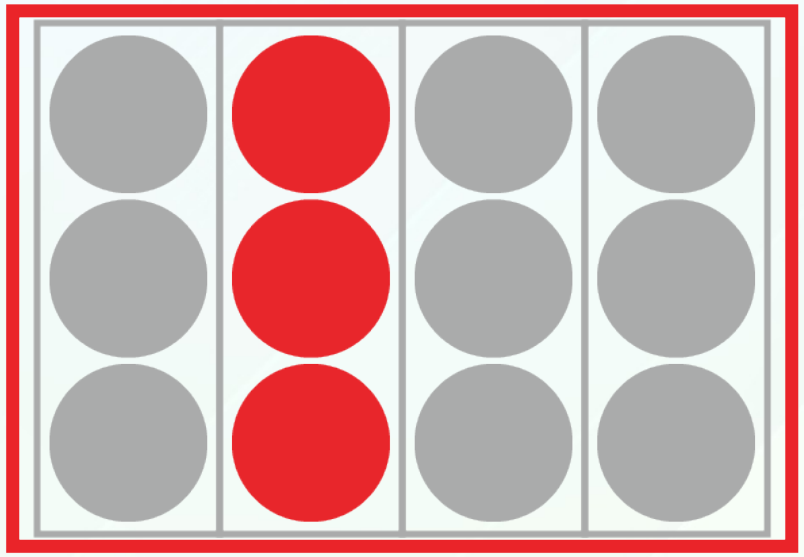
Node 2

50 TPS

Node 3

10 TPS

LOCAL TASKS DISTRIBUTION: THREAD PER PARTITION



Node 1

100 TPS

SPB

Node 2

50 TPS

NSK

Node 3

10 TPS

LESSONS LEARNED

1) **Data partitioning:** balance and stability

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LESSONS LEARNED

1) **Data partitioning:** balance and stability
2) **Colocation:** balance and efficiency
3) **Data model:** should be adopted accordingly
4) **Synchronization:** delicate and only when really needed
5) **Thread per partition:** can improve simple operations, but also may slow down complex ones

CONTACTS

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QUESTIONS?

ANY QUESTIONS?