ACR: AUTOMATIC CHECKPOINT/RESTART FOR SOFT AND HARD ERROR PROTECTION.

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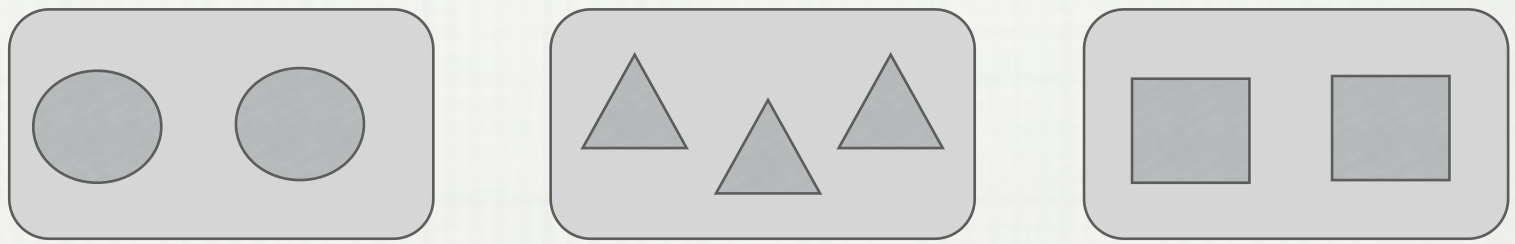
Parallel Programming Lab, UIUC

CONTENTS

BACKGROUND

TASK



NODE A

NODE B

NODE C

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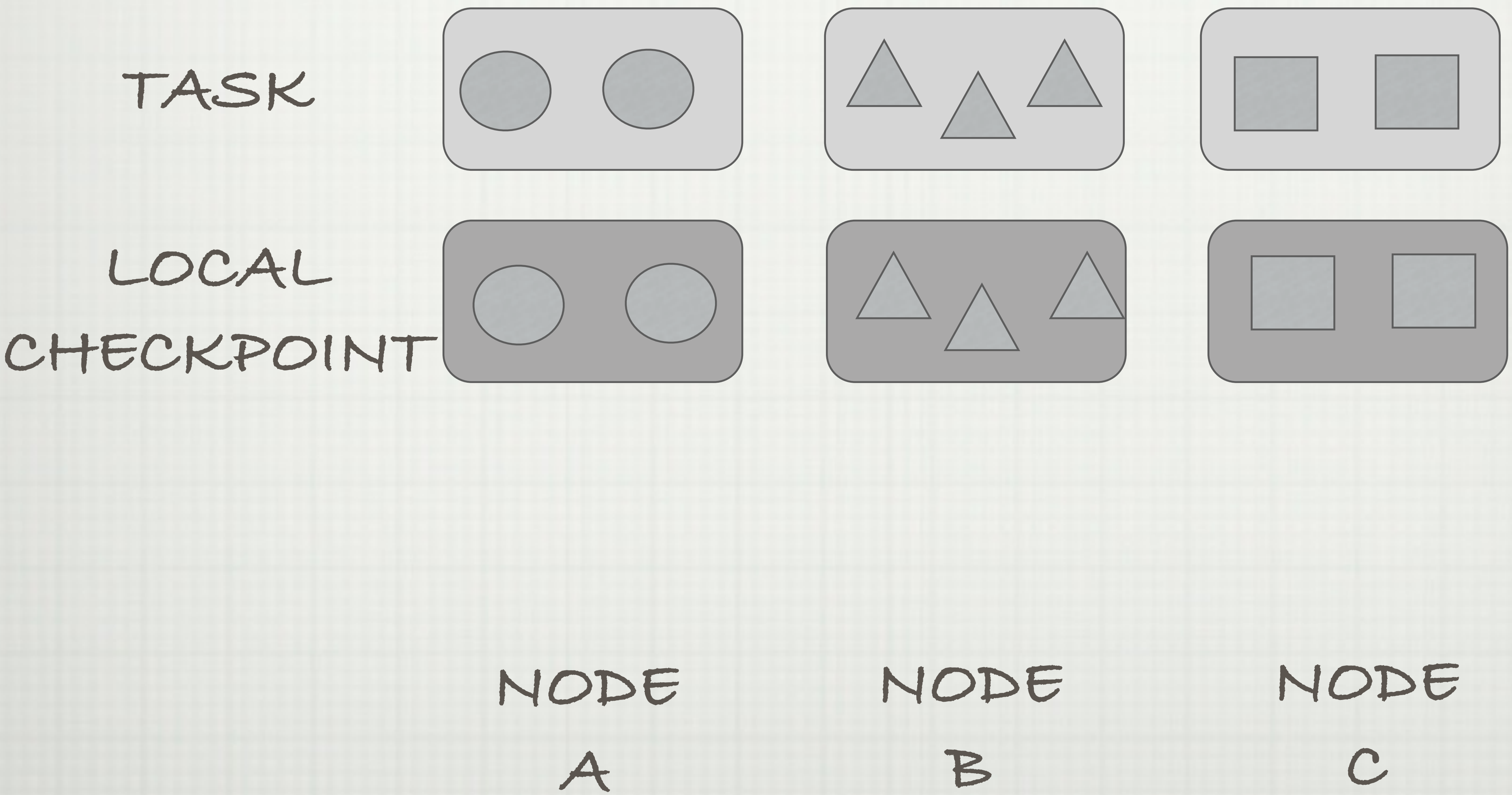

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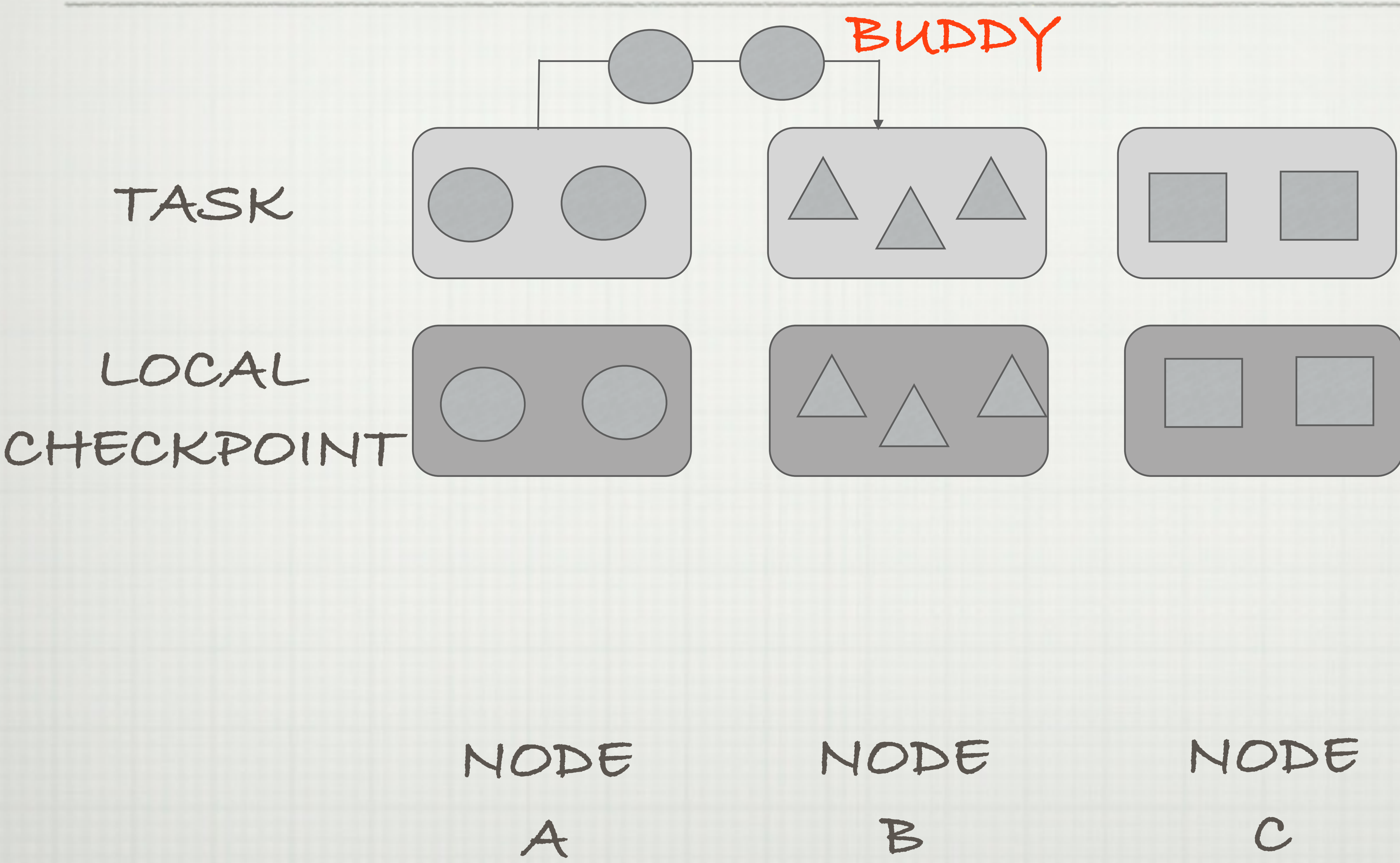

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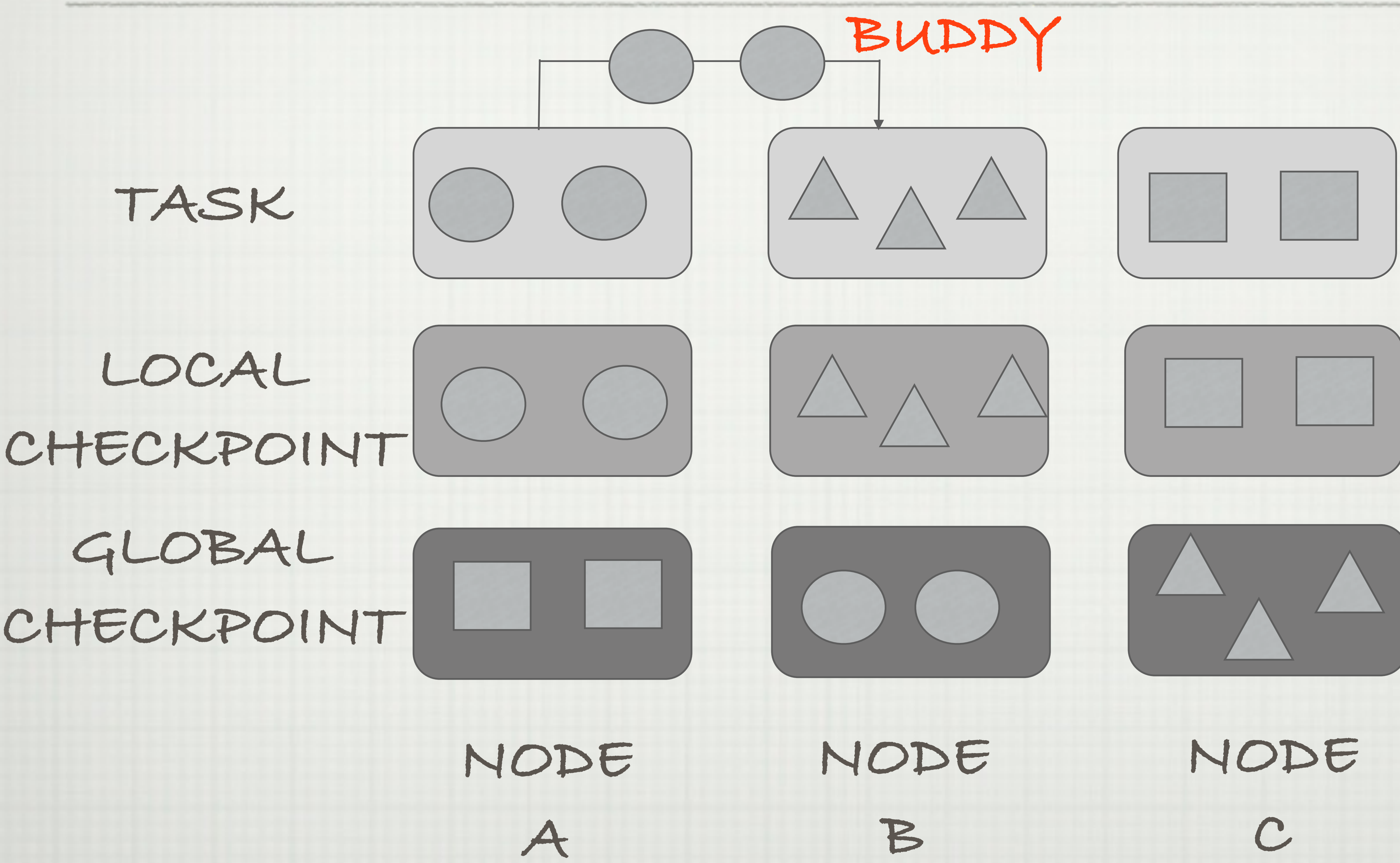
BUDDY
TASK
LOCAL CHECKPOINT
GLOBAL CHECKPOINT
NODE A
NODE B
NODE C

MOTIVATION

- New challenge: soft error.
  - An unintended change in the state of an electronic device that alters the information that it stores without destroying its functionality.
  - Detectable and correctable: single bit flip
  - Detectable and uncorrectable: double bit flips
  - Undetectable, uncorrectable and incorrect program outcome

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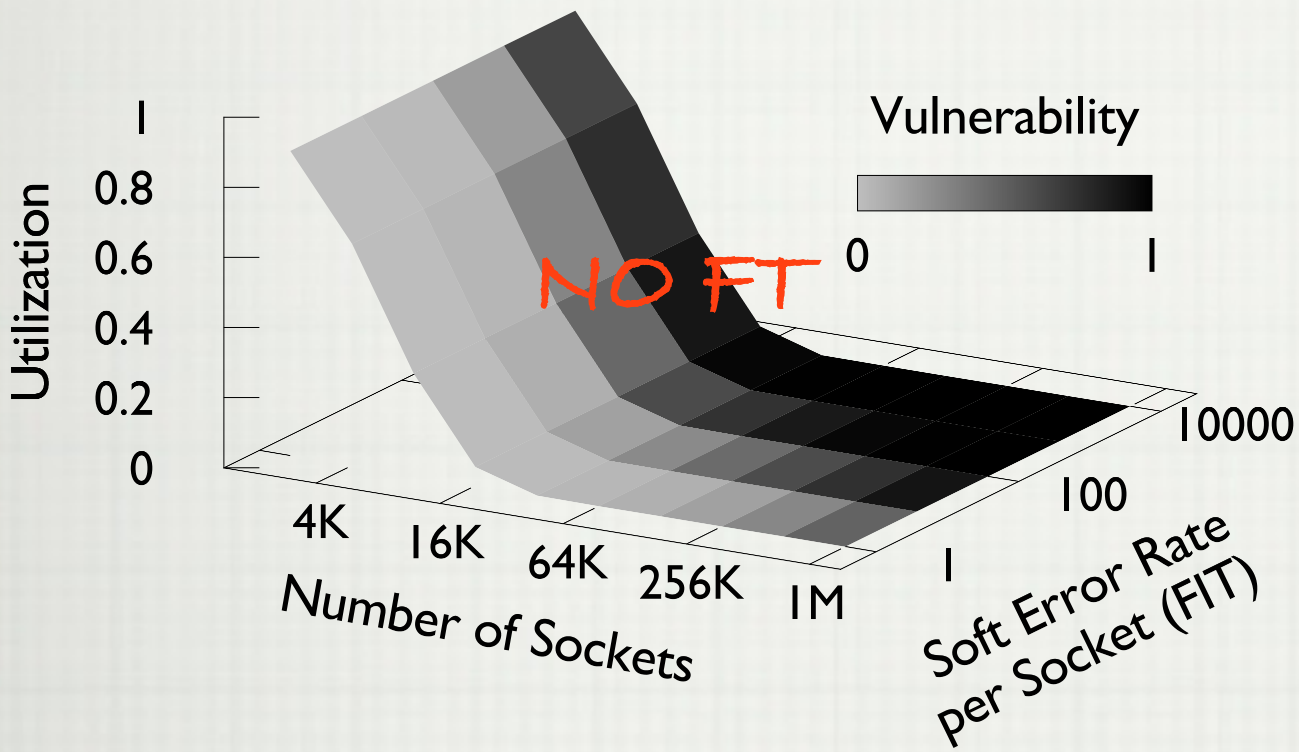
SILENT DATA CORRUPTION

MOTIVATION

- Why soft failure rate will increase?
  - Computer electronic's sensitivity to radiation increases as their dimensions and operating voltage decreases
    - The requirements for high performance and low power.
- What may happen if soft failure rate keeps increasing?

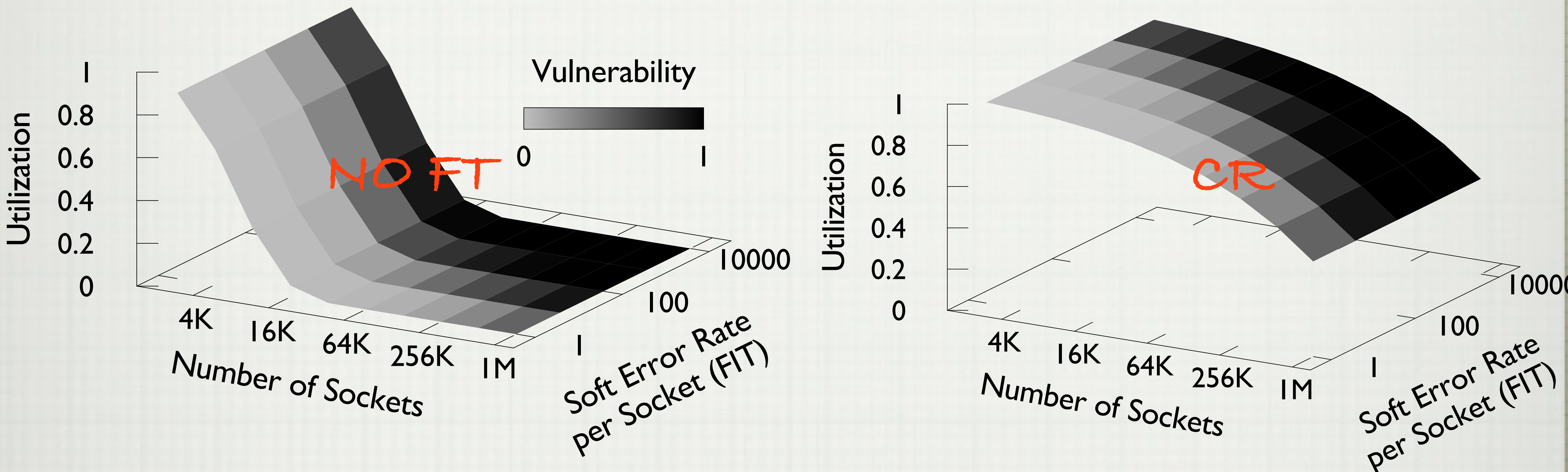
MOTIVATION

MOTIVATION



Vulnerability
0
1
NO FT
Utilization
1
0.8
0.6
0.4
0.2
0
4K
16K
64K
256K
1M
Number of Sockets
1
100
10000
Soft Error Rate per Socket (FIT)

MOTIVATION



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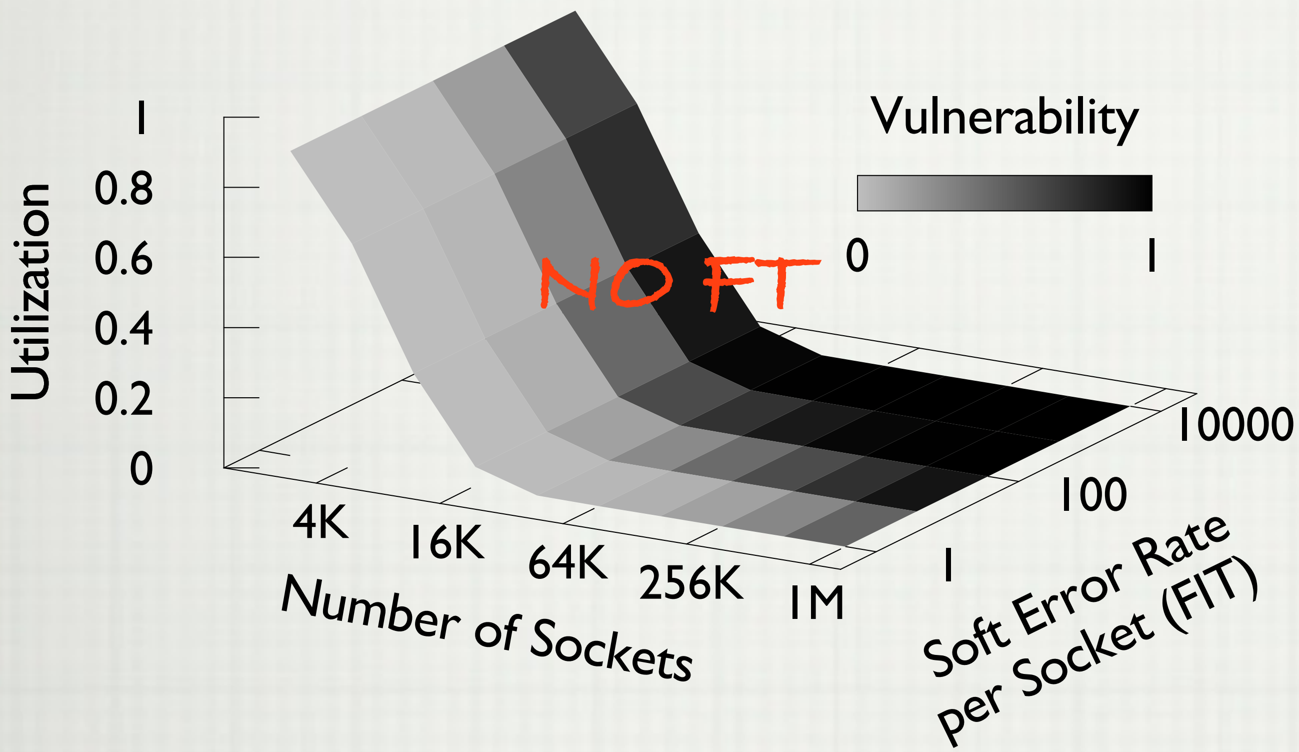
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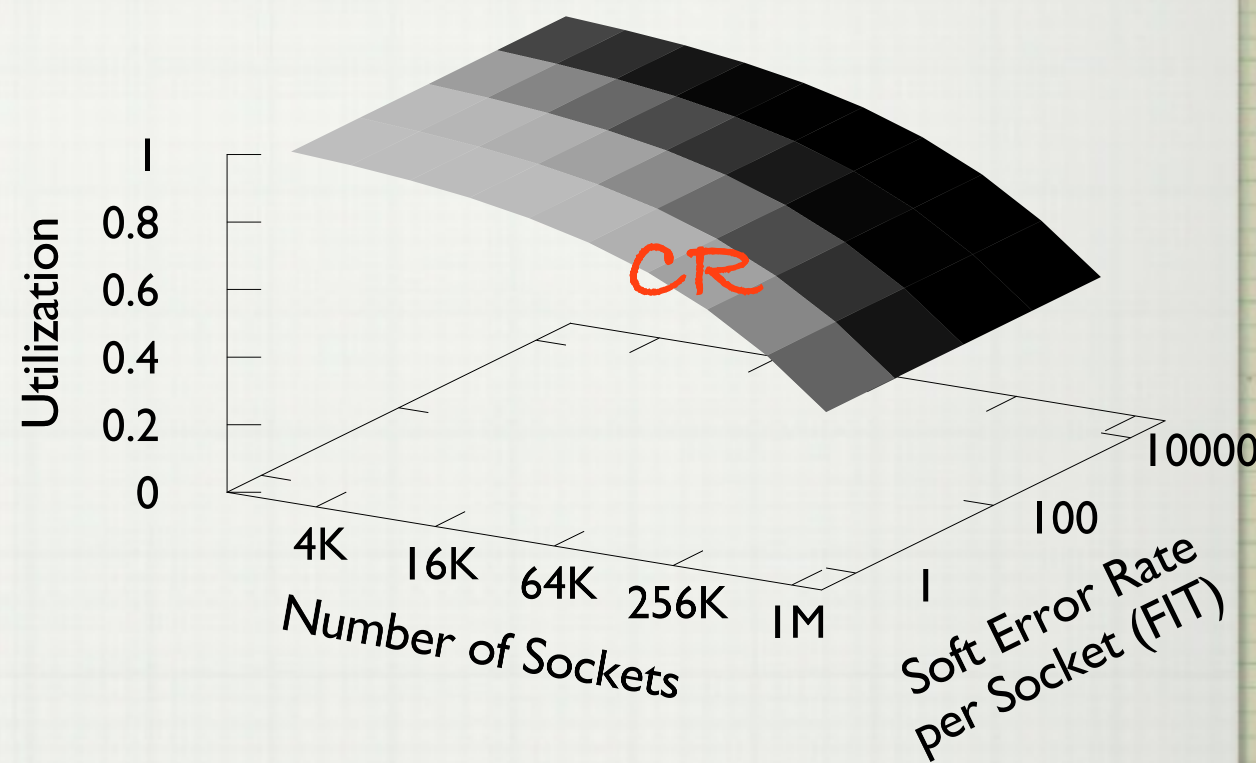
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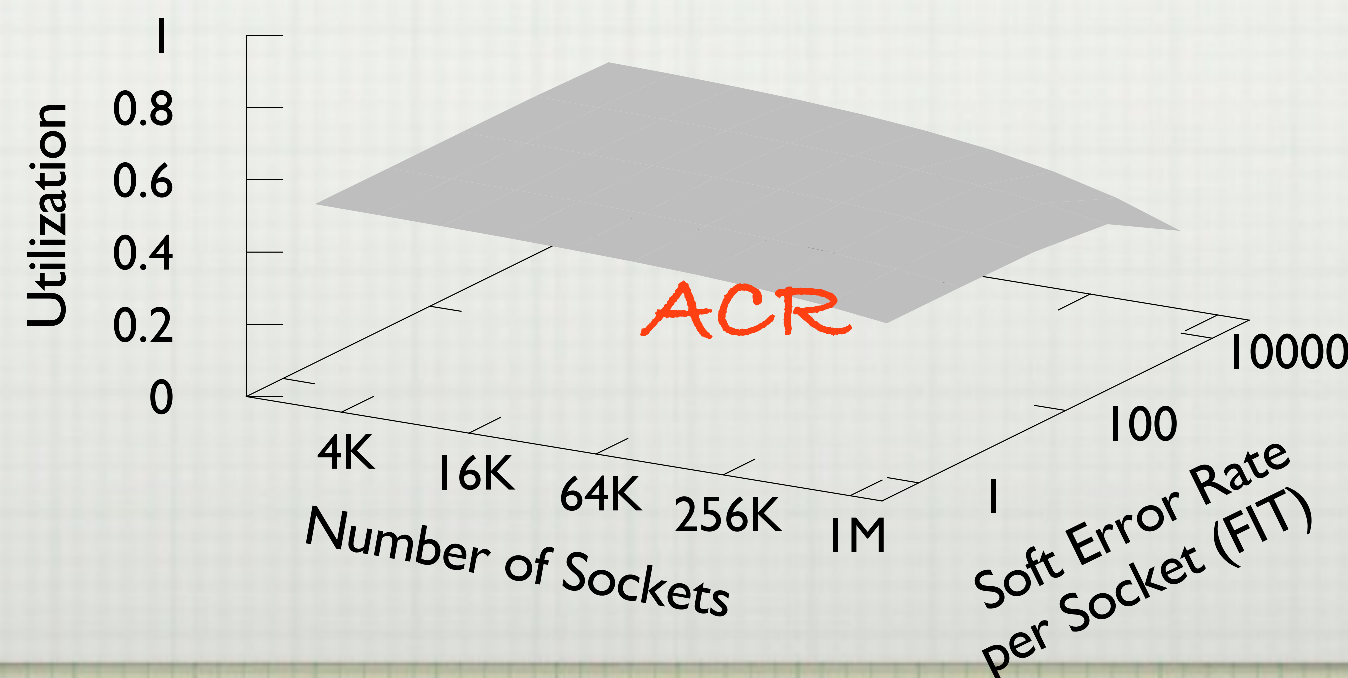
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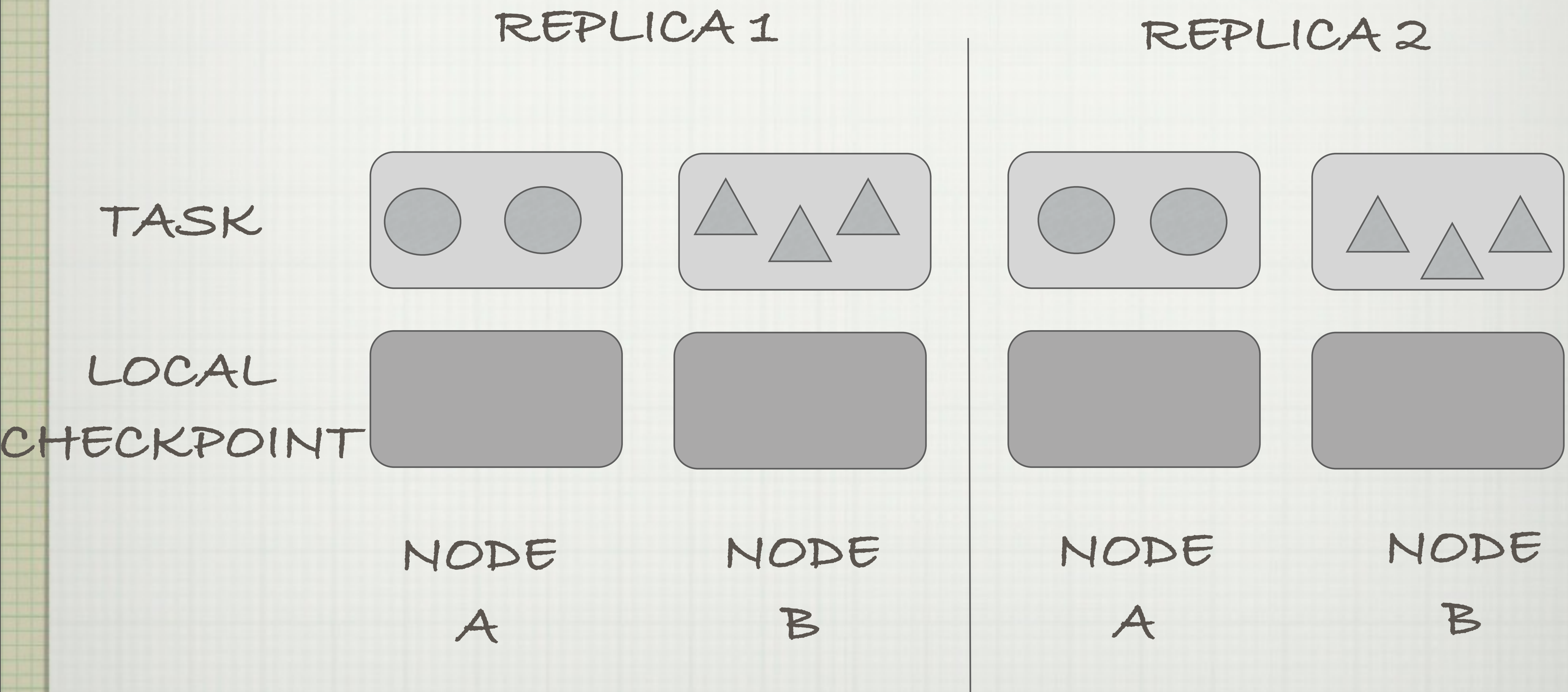
REPLICATION ENHANCED CHECKPOINTING



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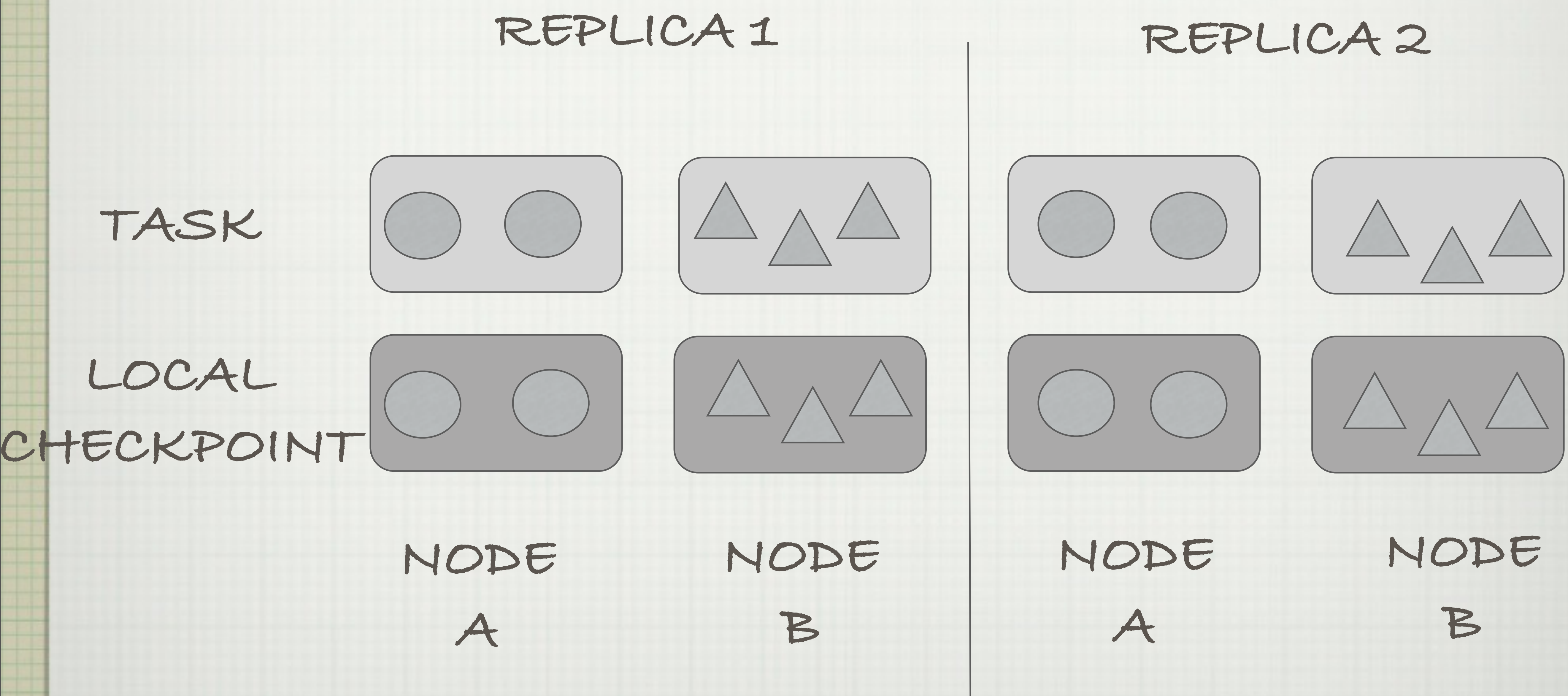

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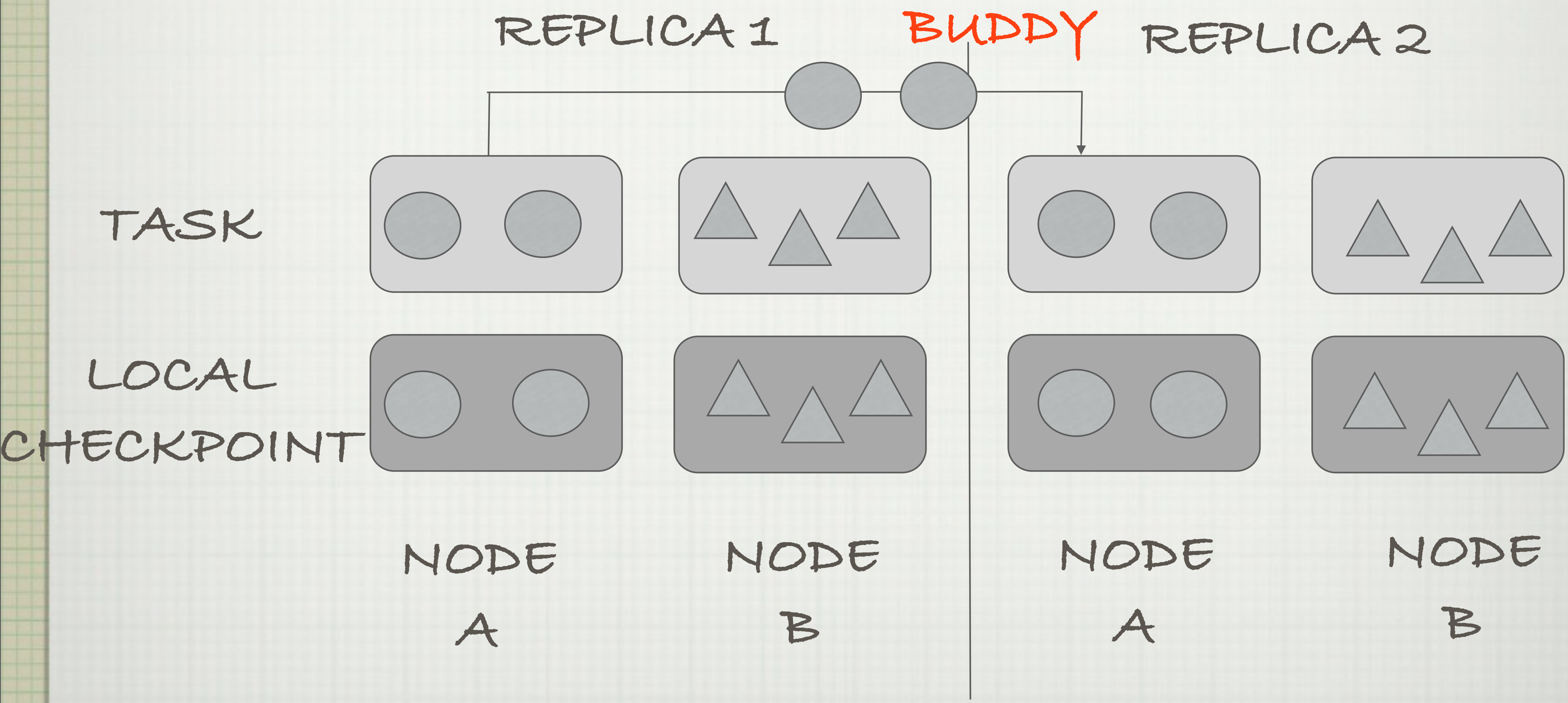

7

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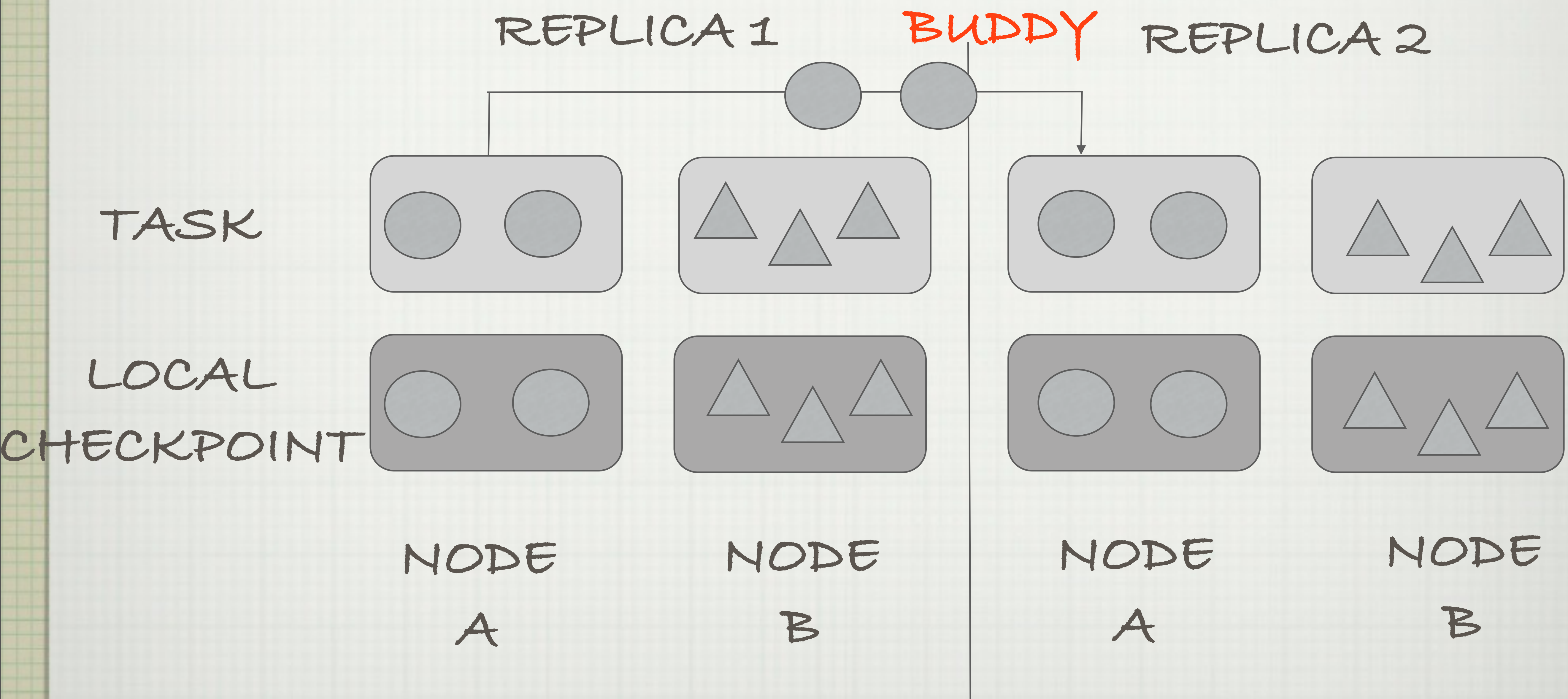
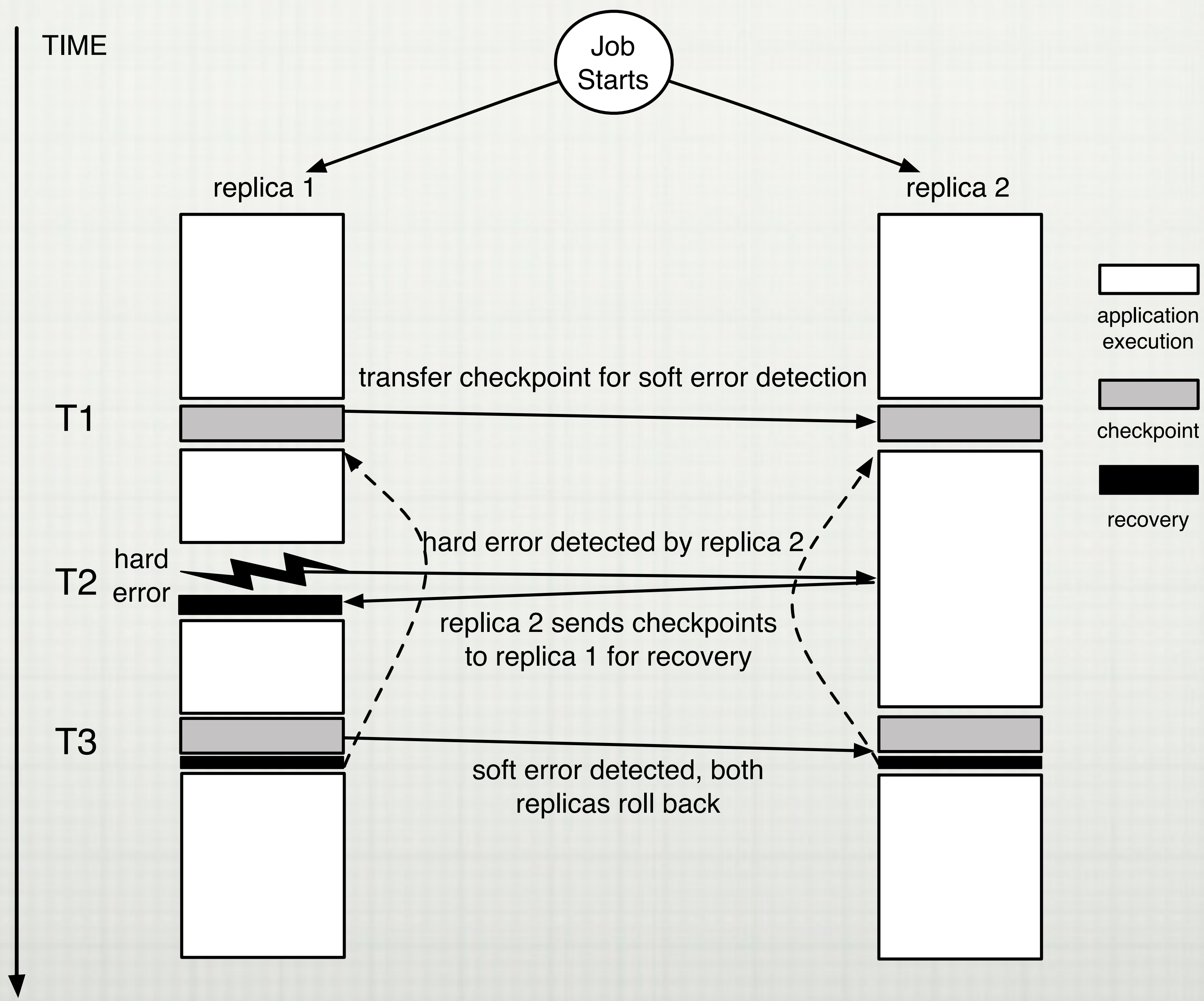


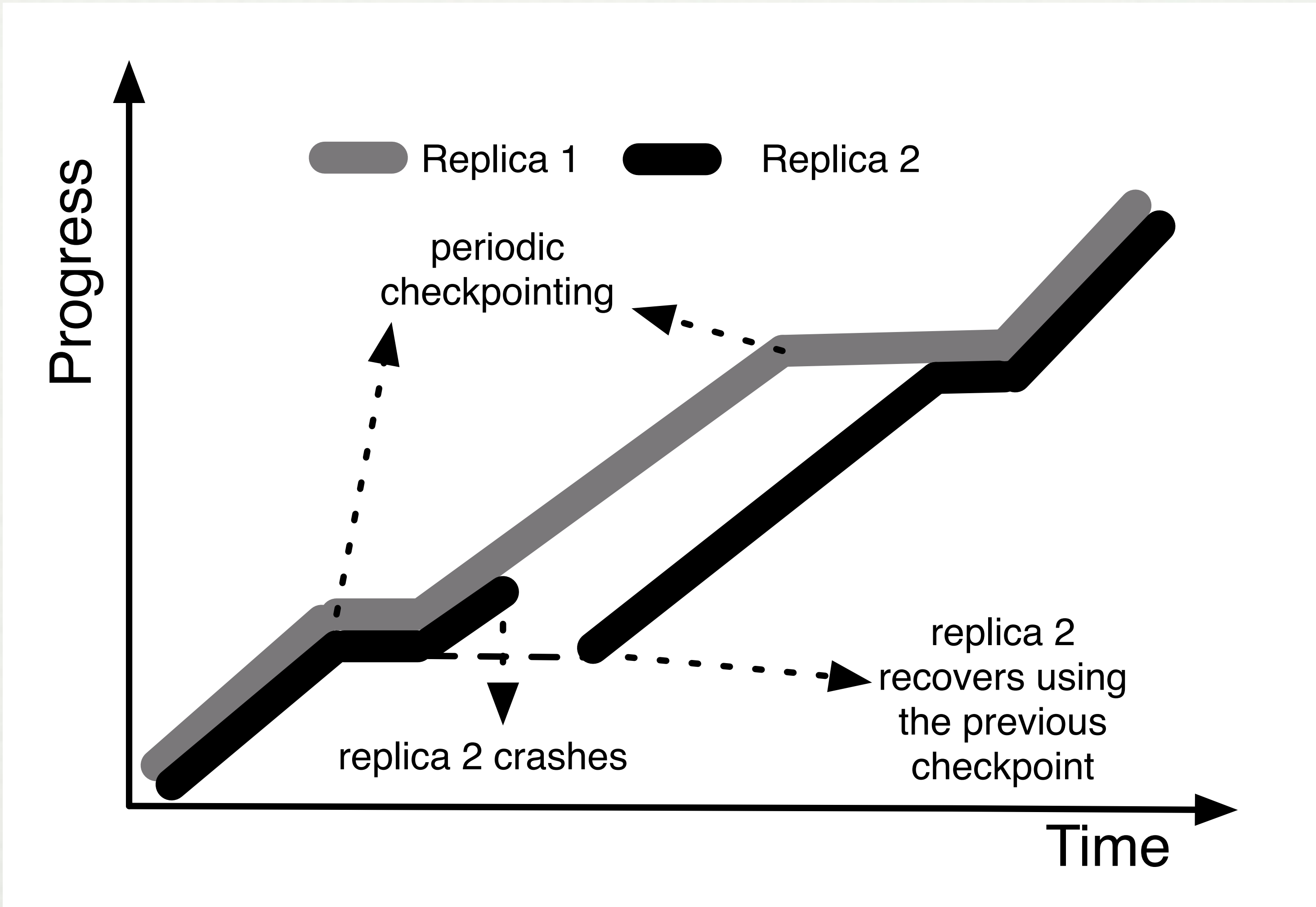
Comparison for soft data corruption

REPLICATION ENHANCED CHECKPOINTING



8

DIFFERENT WAYS TO RESTART FROM HARD ERROR



Strong resilience

Recover from the previous checkpoint

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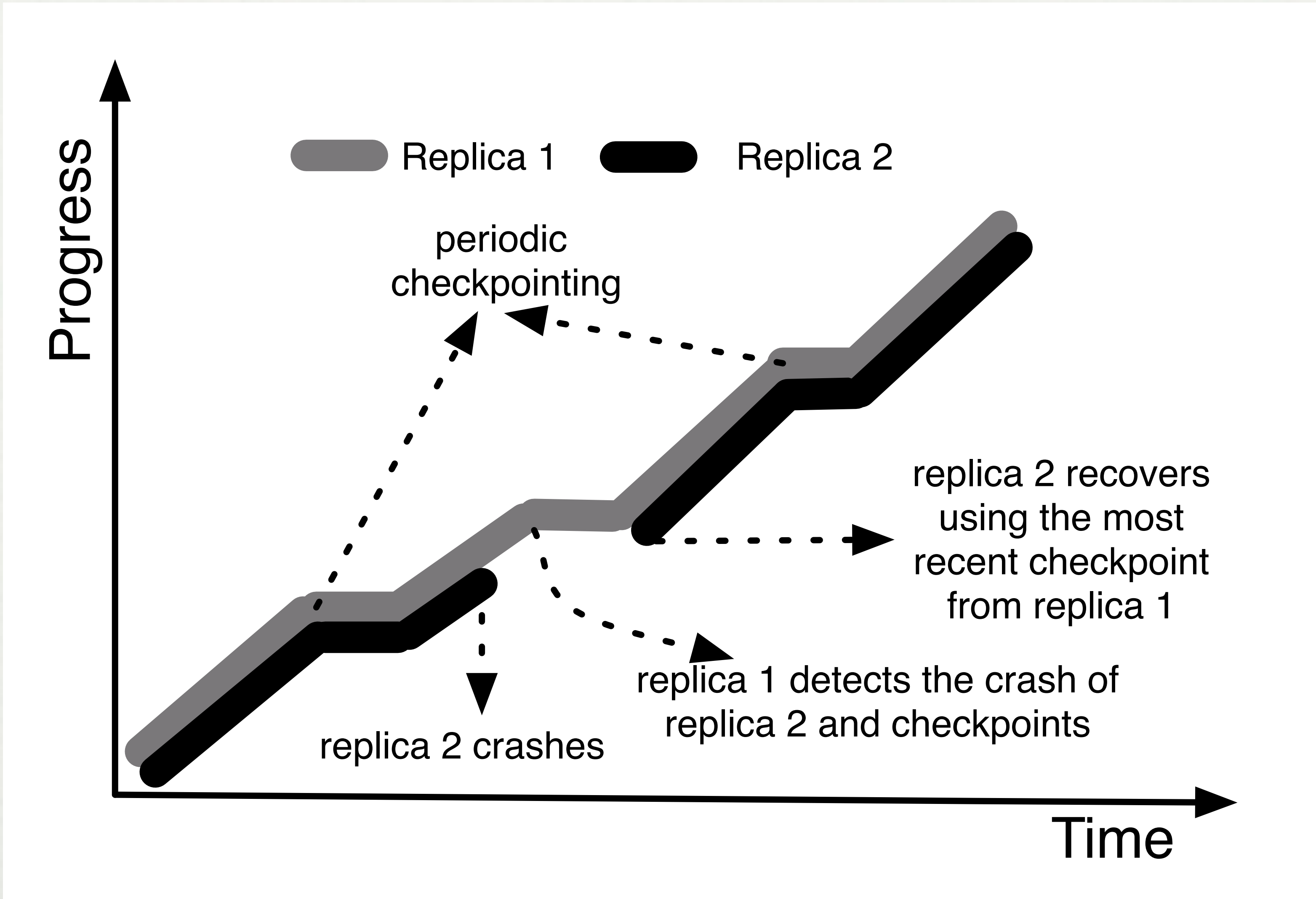
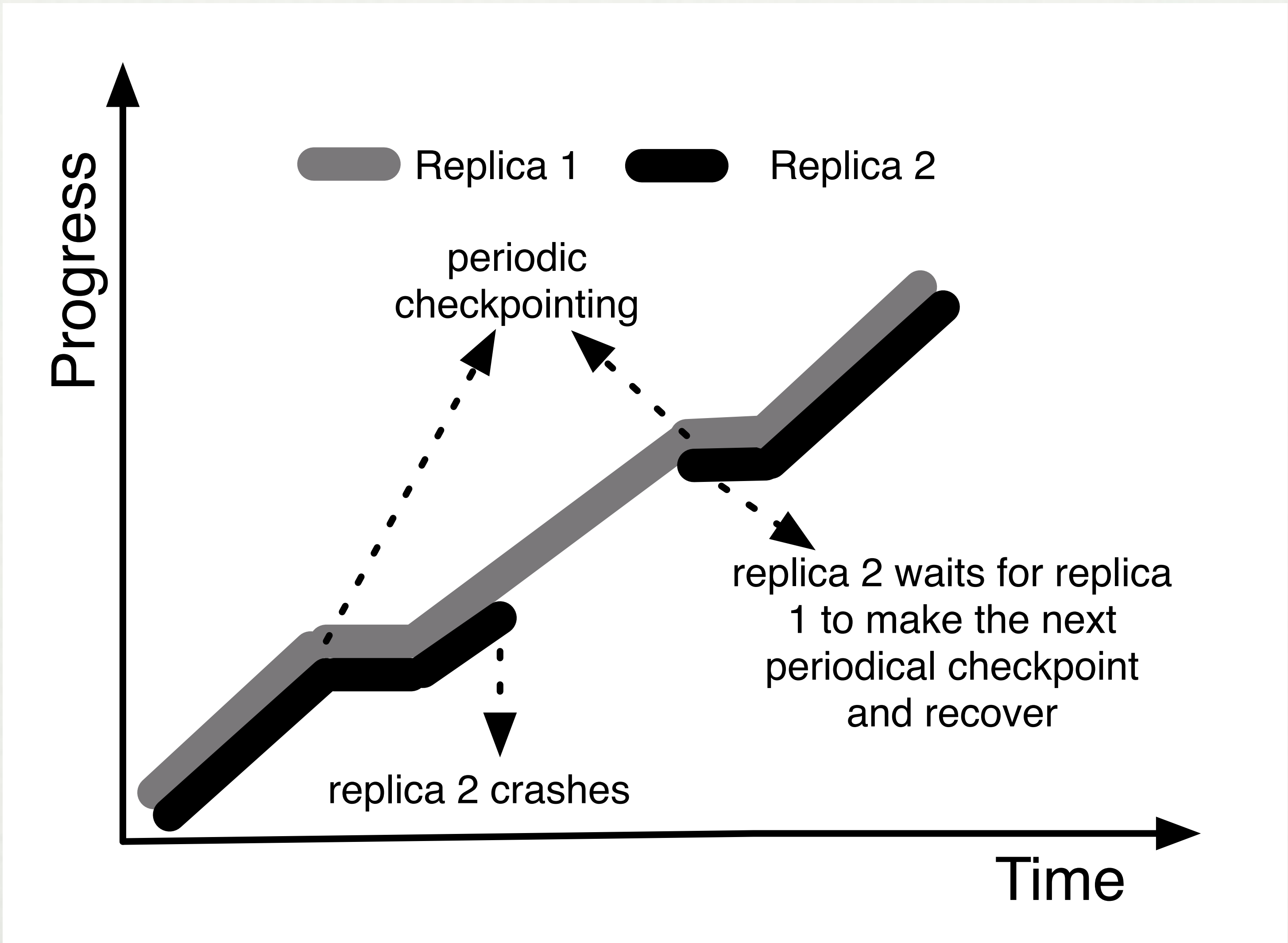


Medium resilience

Healthy replica schedules an immediate checkpoint

DIFFERENT WAYS TO RESTART FROM HARD ERROR



Weak resilience

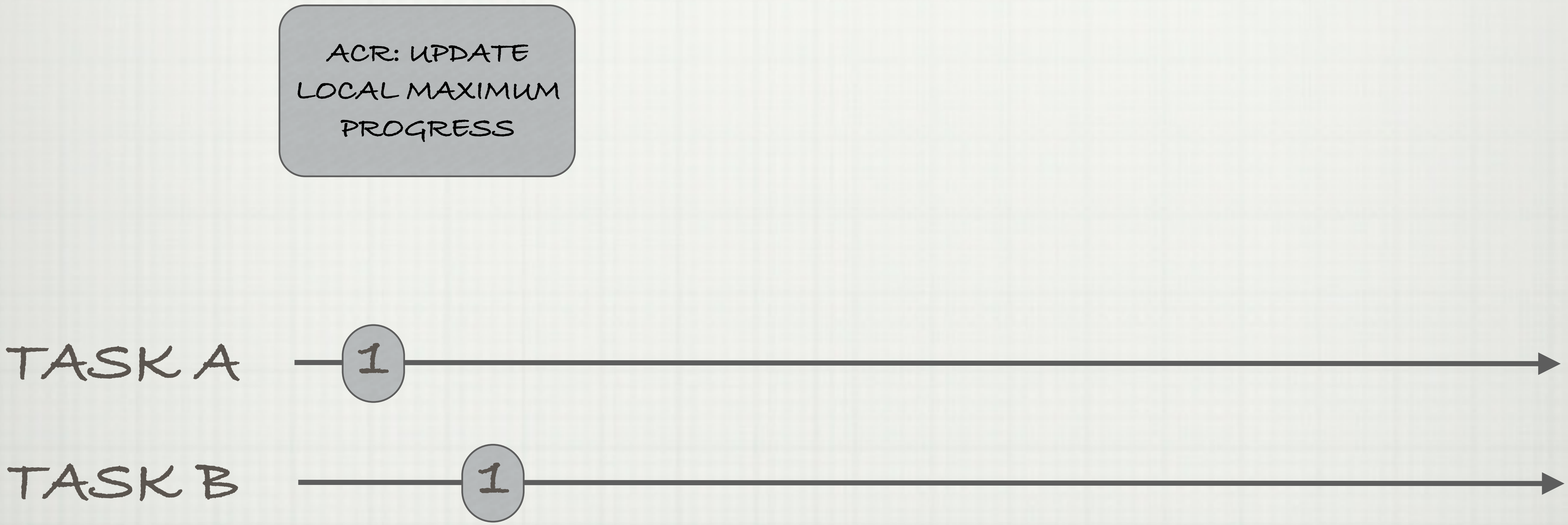
Recover from the next checkpoint

AUTOMATIC CHECKPOINT DECISION

- "Schedule" immediate checkpoint
  - Asynchronous application: no barriers
  - Program will hang after restart if inconsistent states are
- Solution: asynchronous consensus based on scheme available in Charm++*

*MENON ET.AL "AUTOMATED LOAD BALANCING INVOCATION BASED ON APPLICATION CHARACTERISTICS" CLUSTER, 2012

AUTOMATIC CHECKPOINT DECISION



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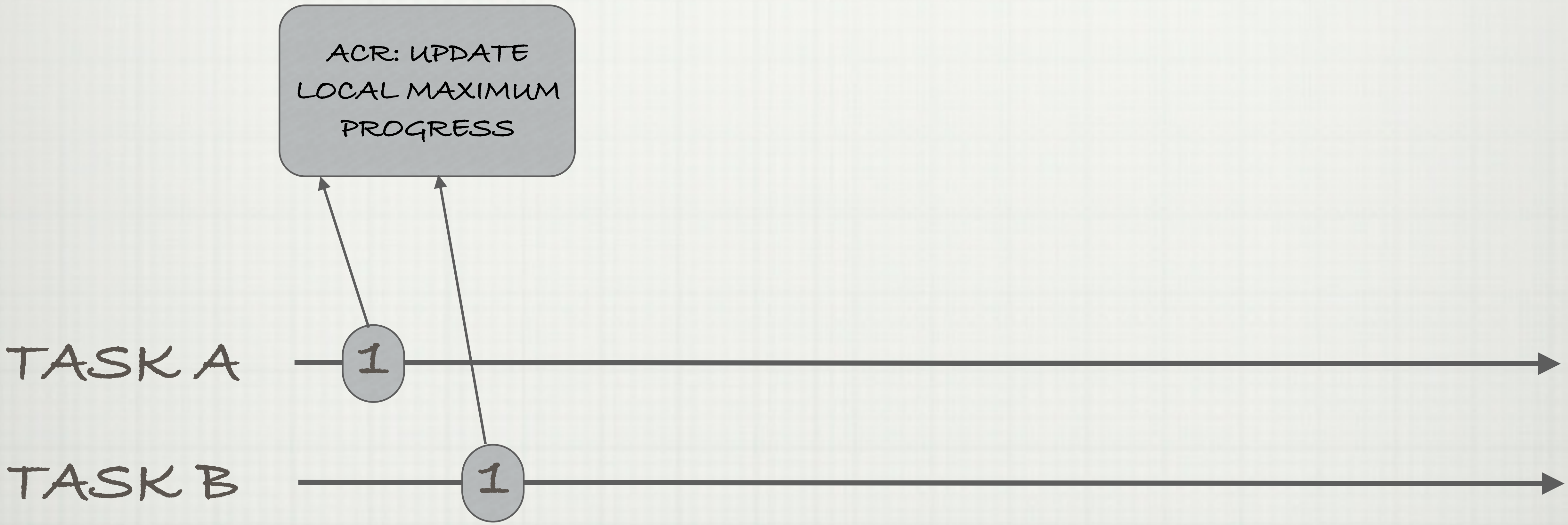

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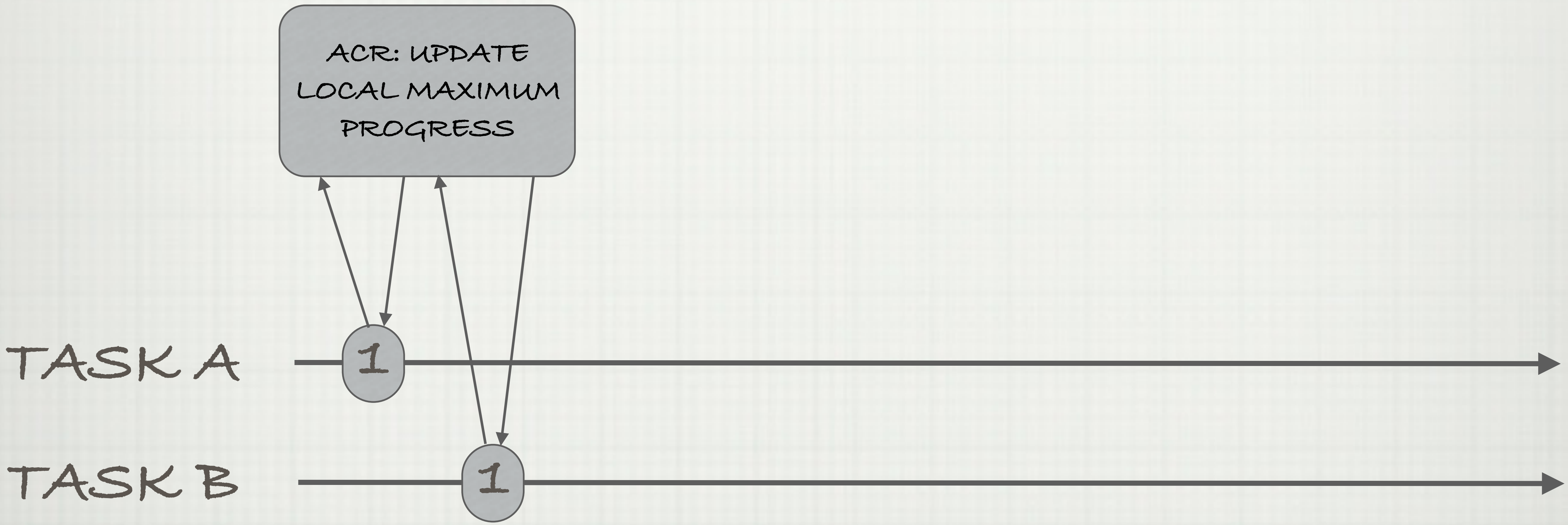

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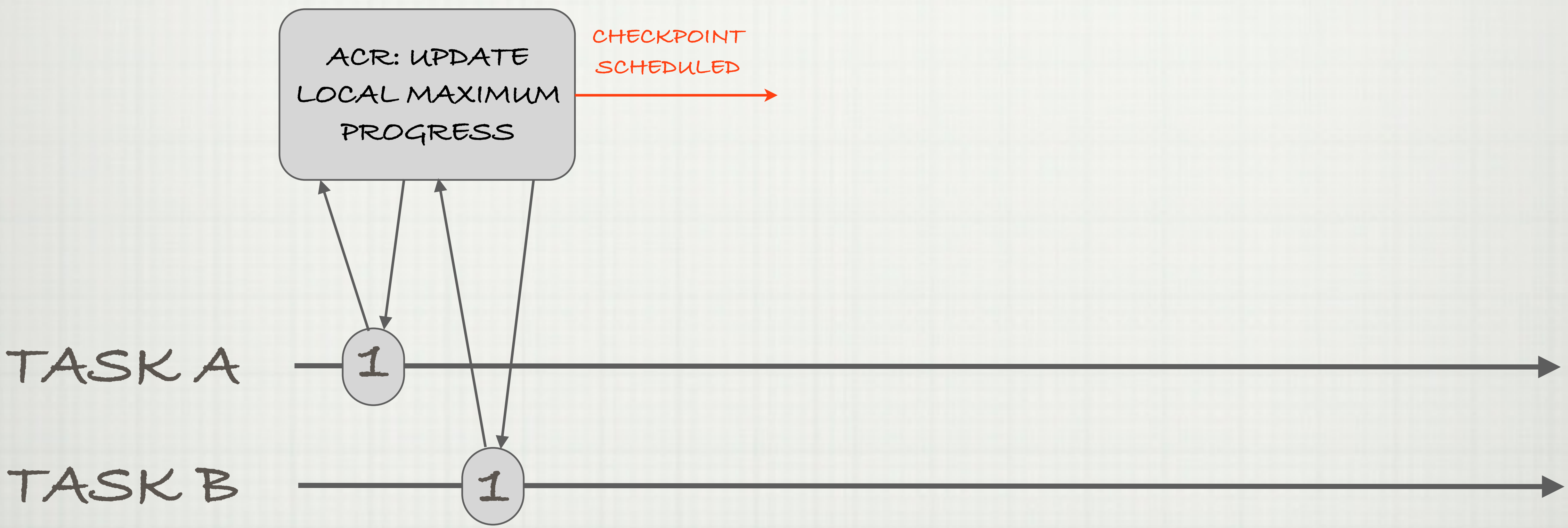

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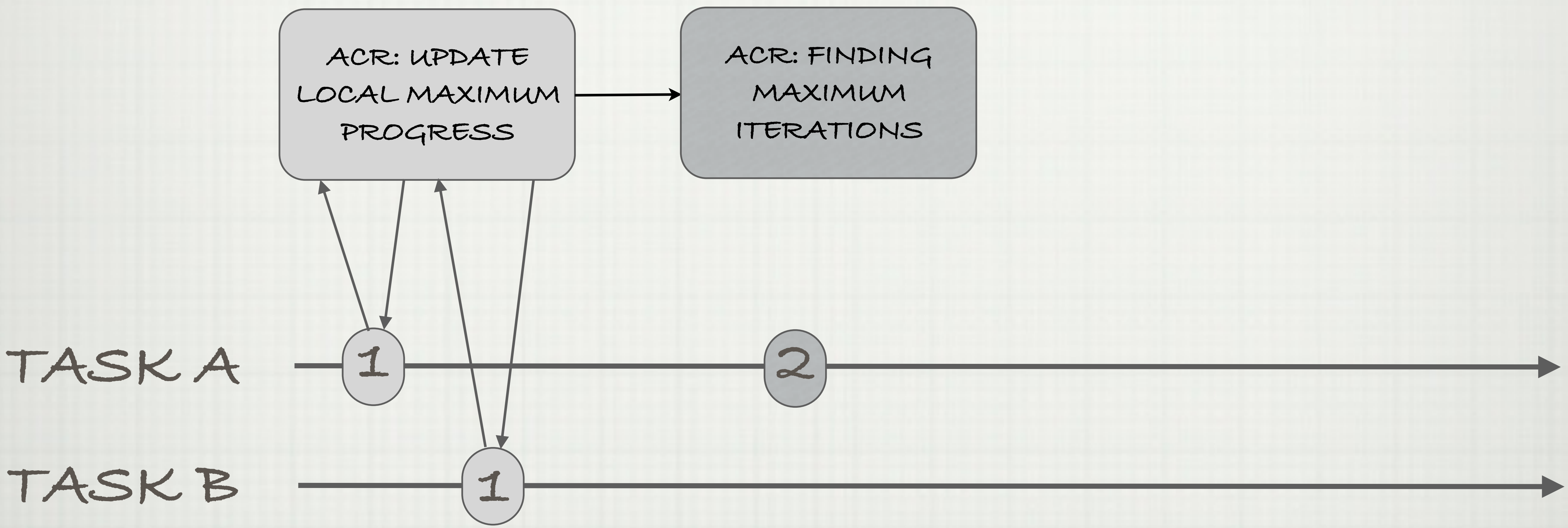

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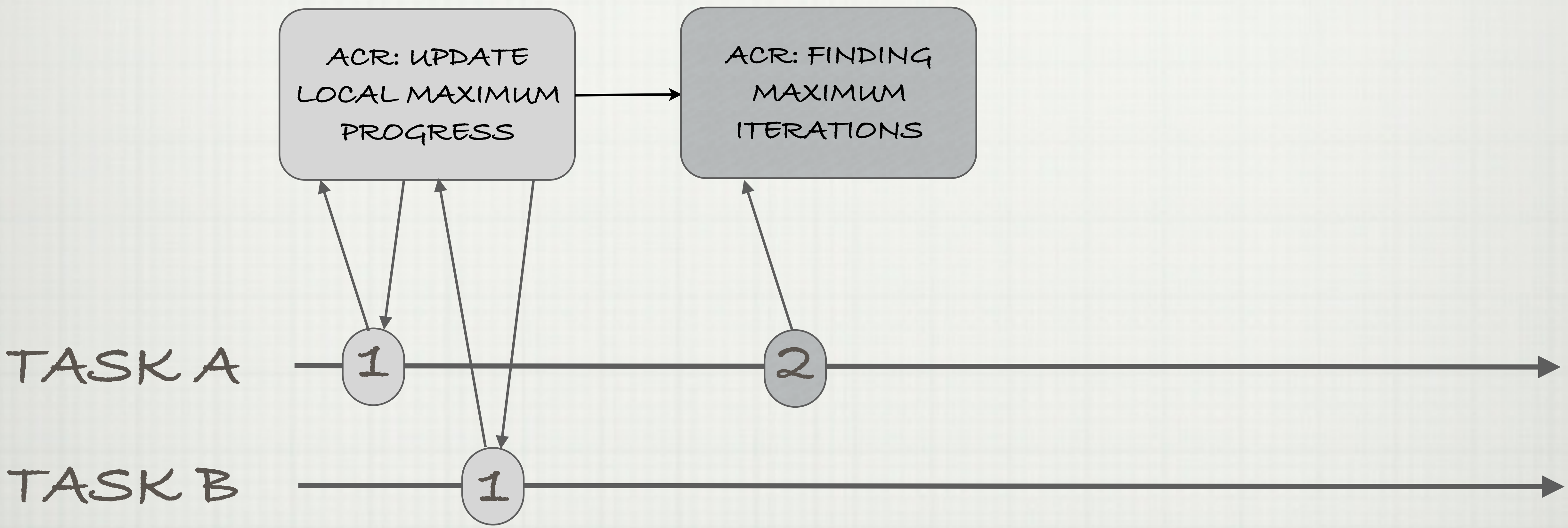

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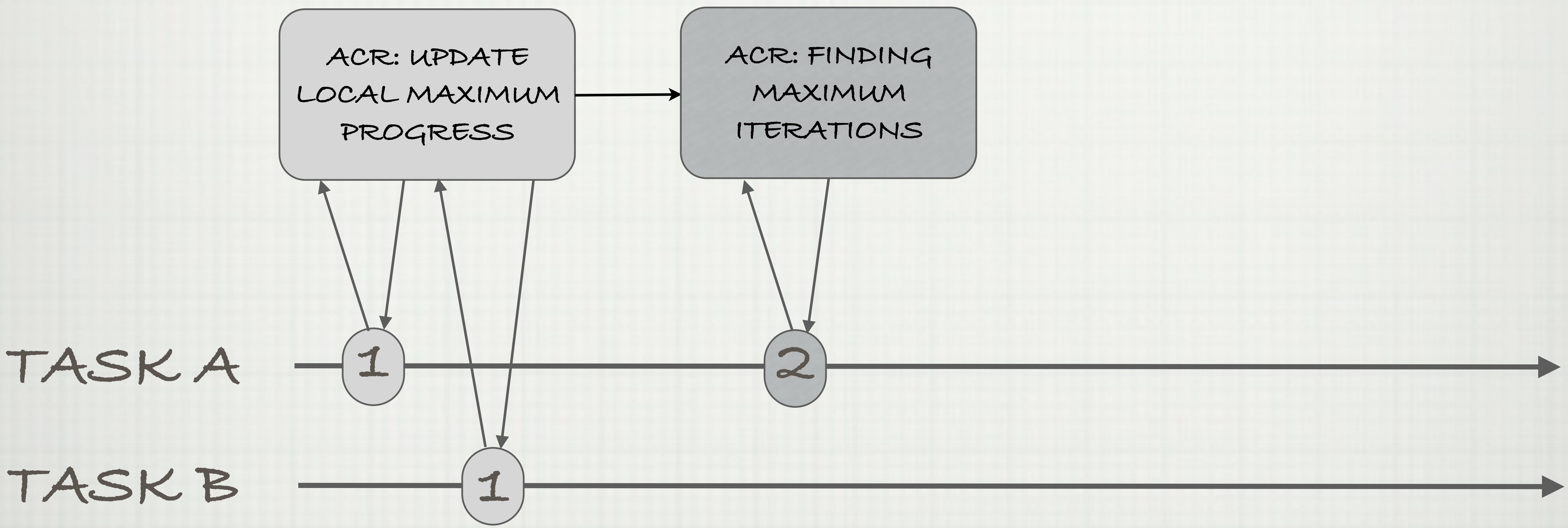

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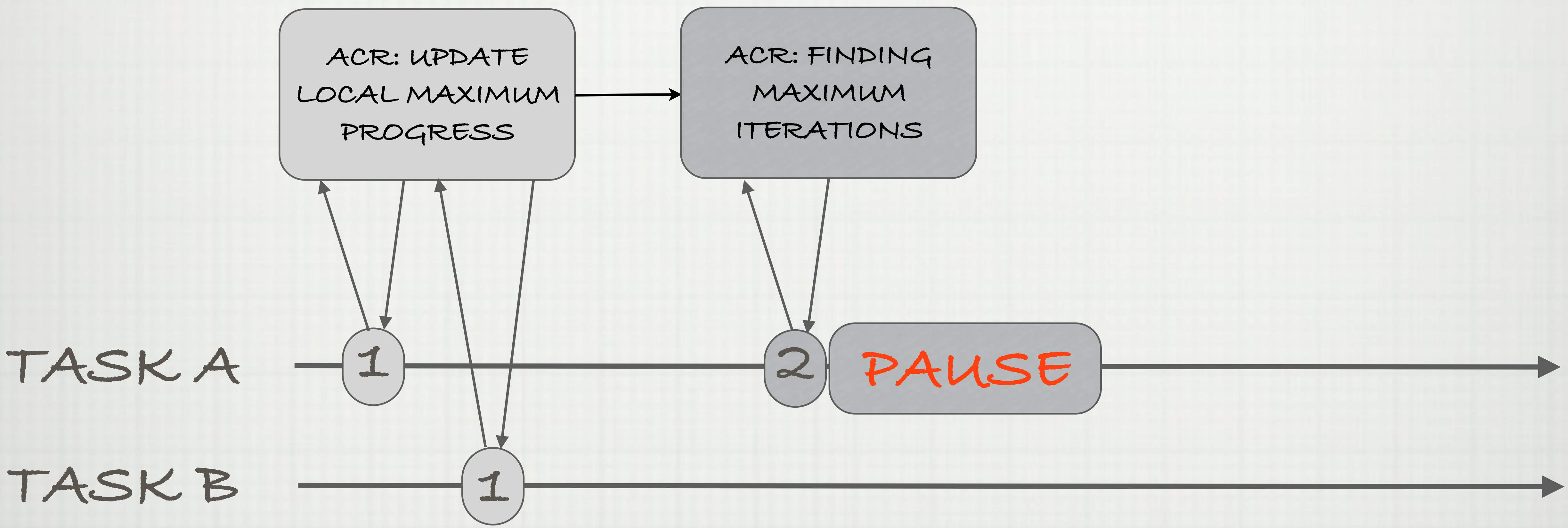

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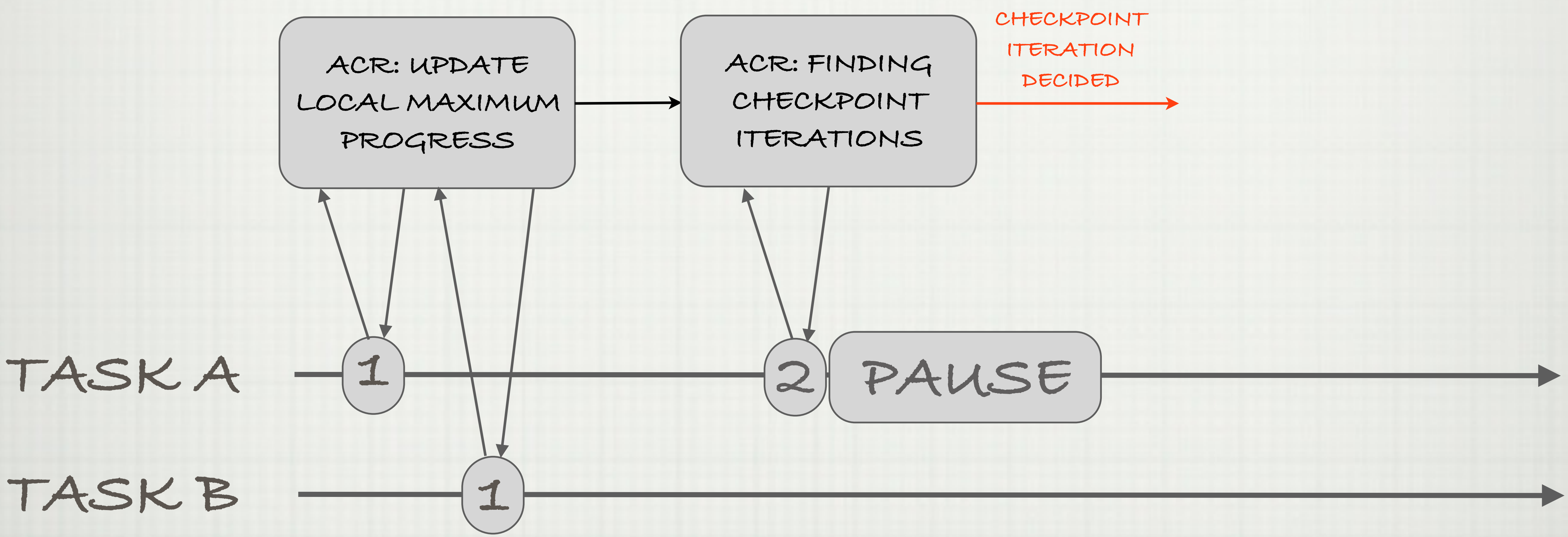

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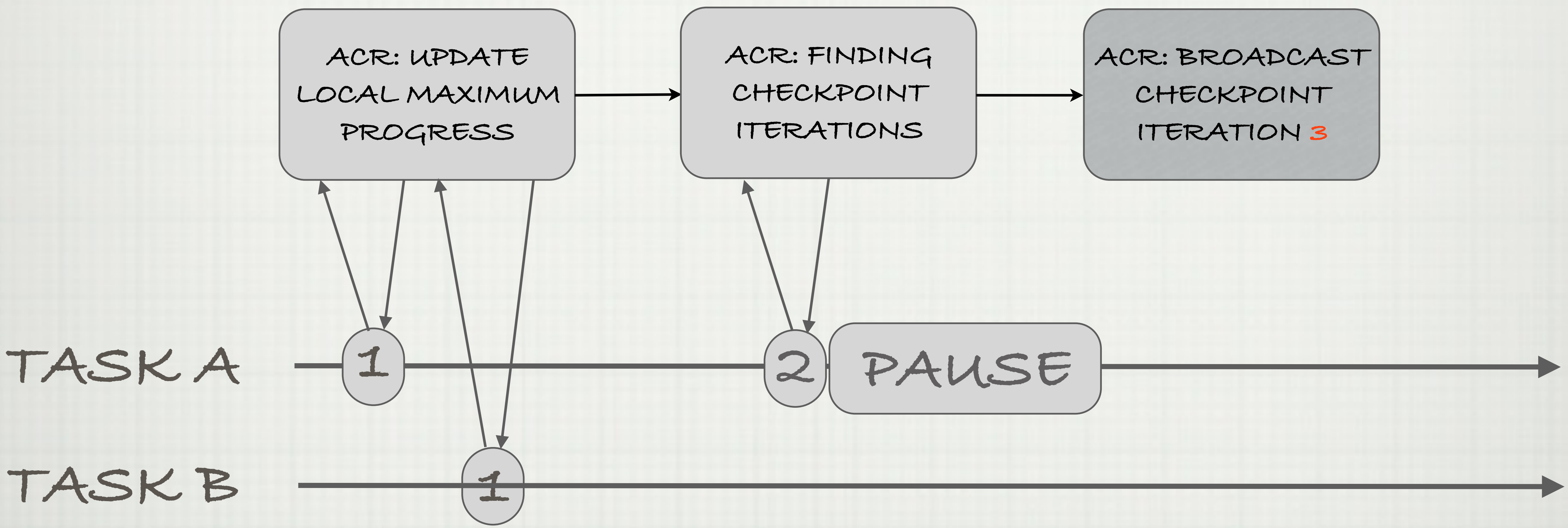

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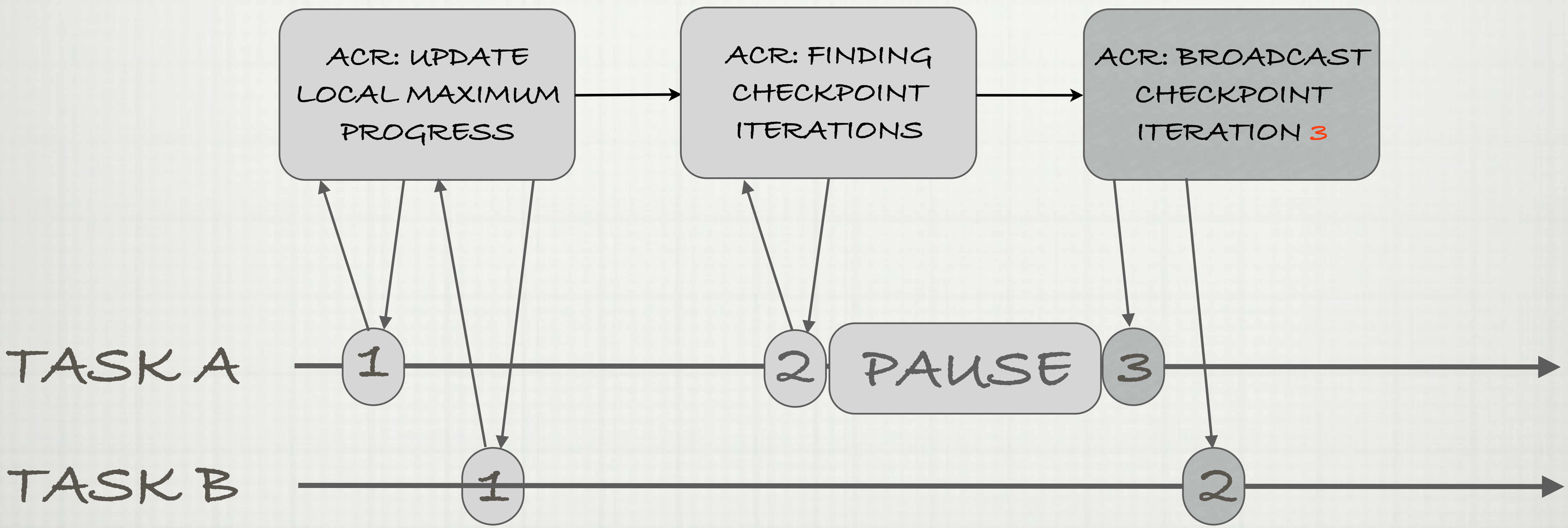

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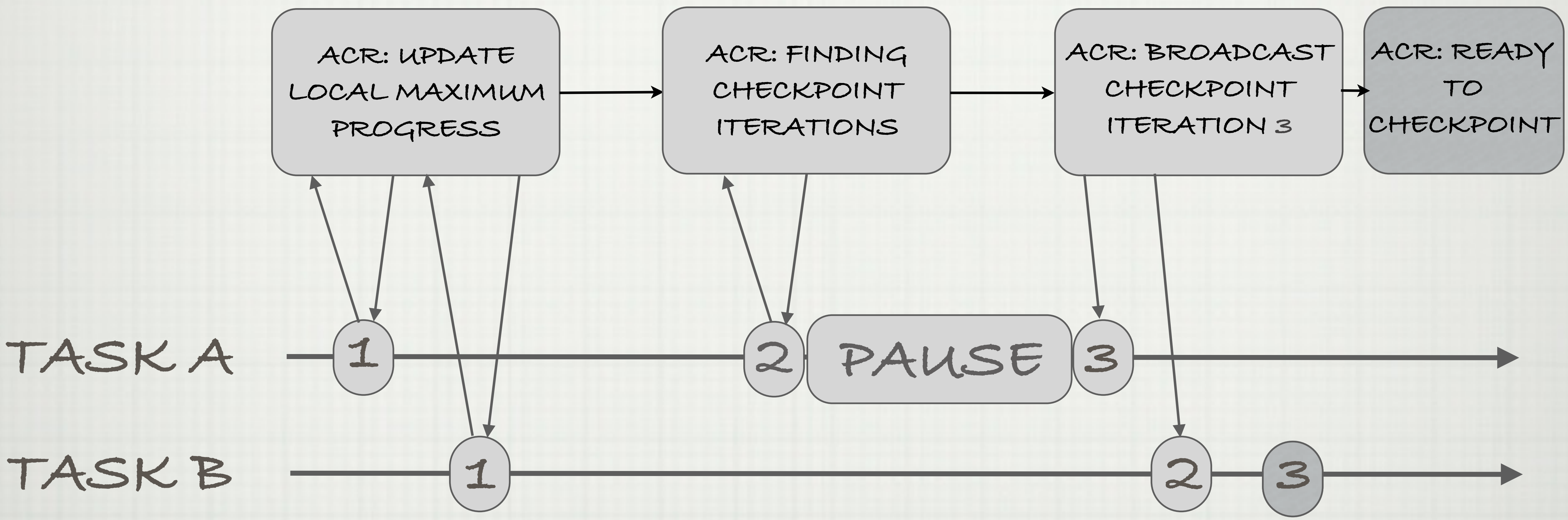

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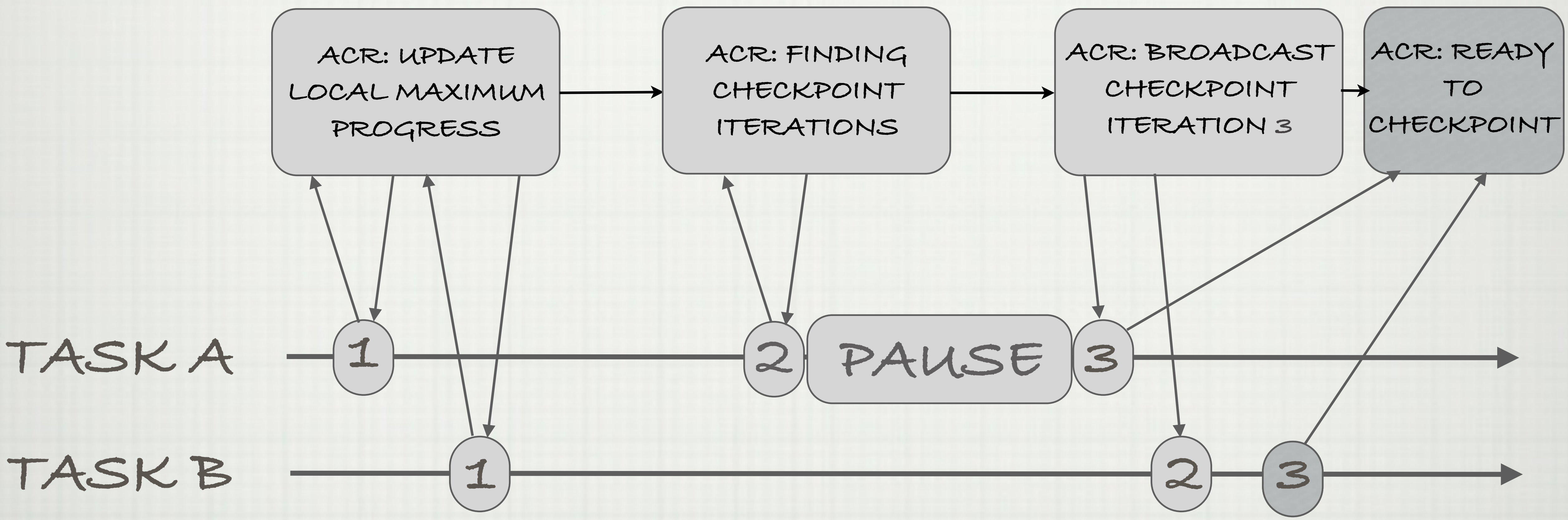
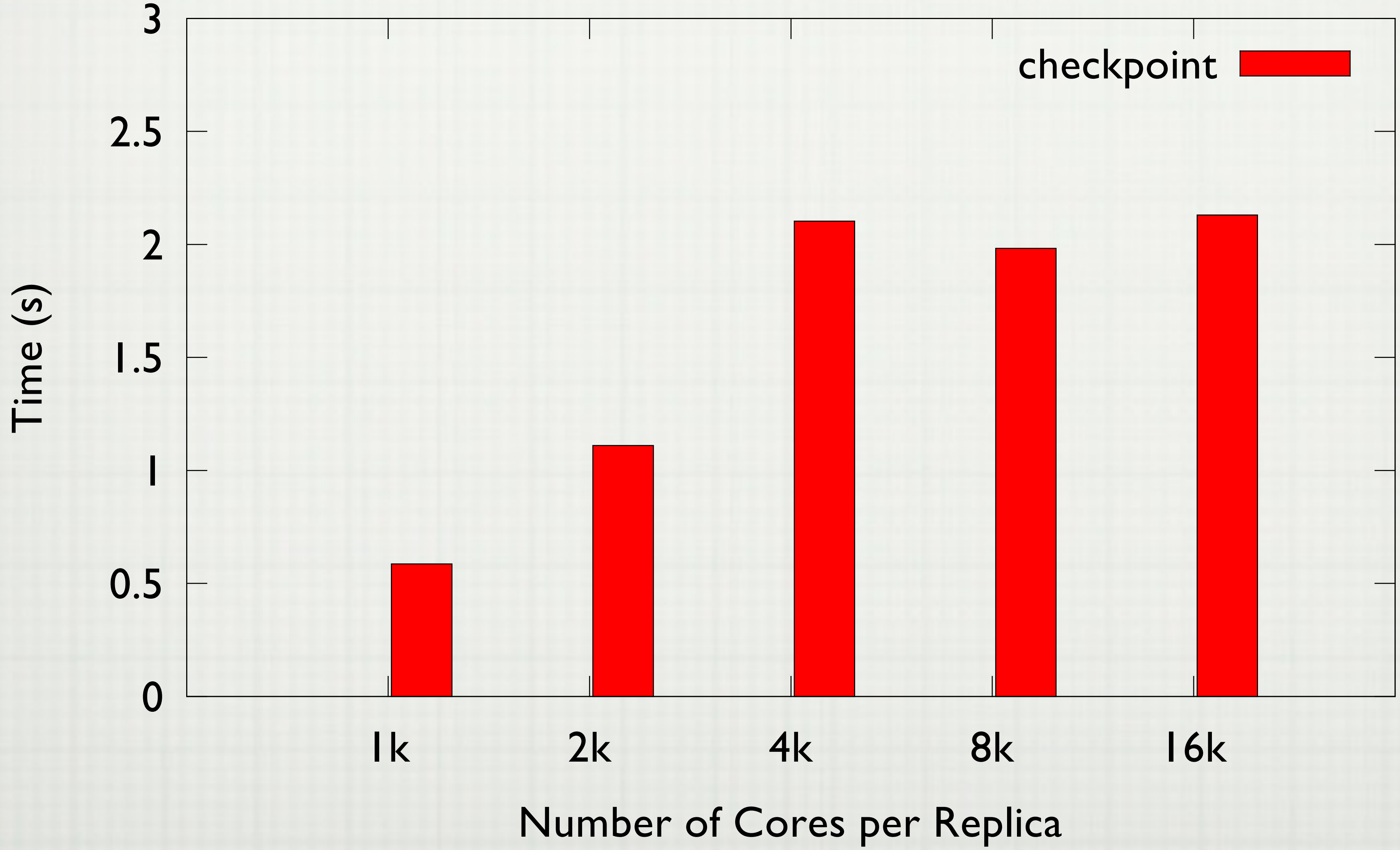


BASE PERFORMANCE



JACOBI3D BGP

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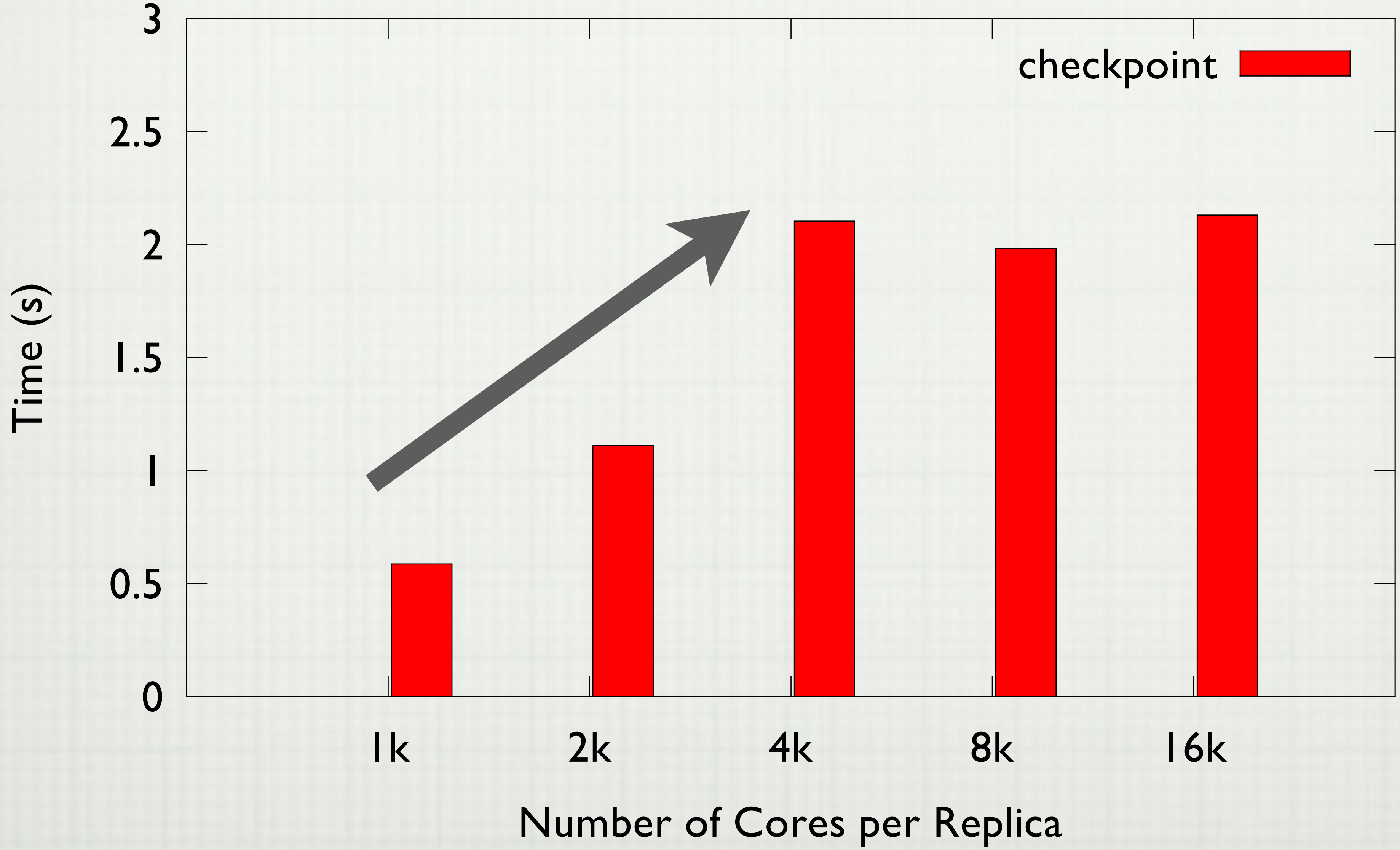

JACOBI3D BGP

OPTIMIZATION: TOPOLOGY AWARE MAPPING

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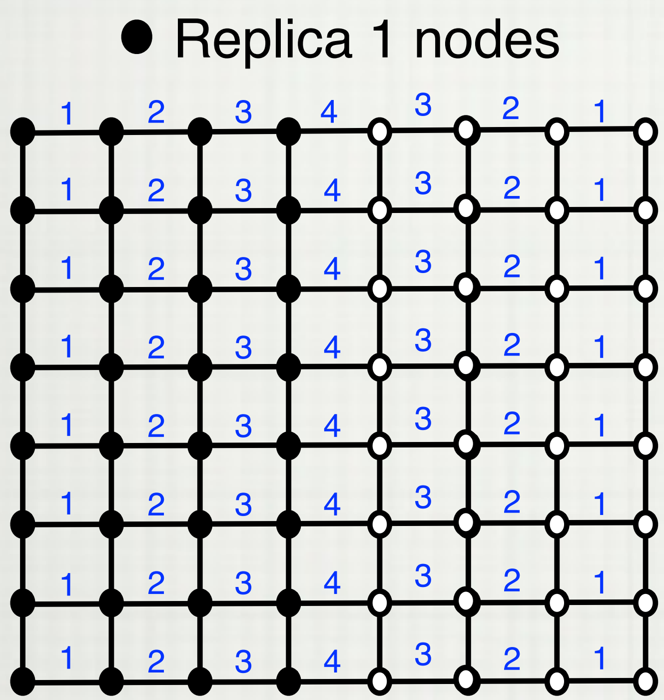
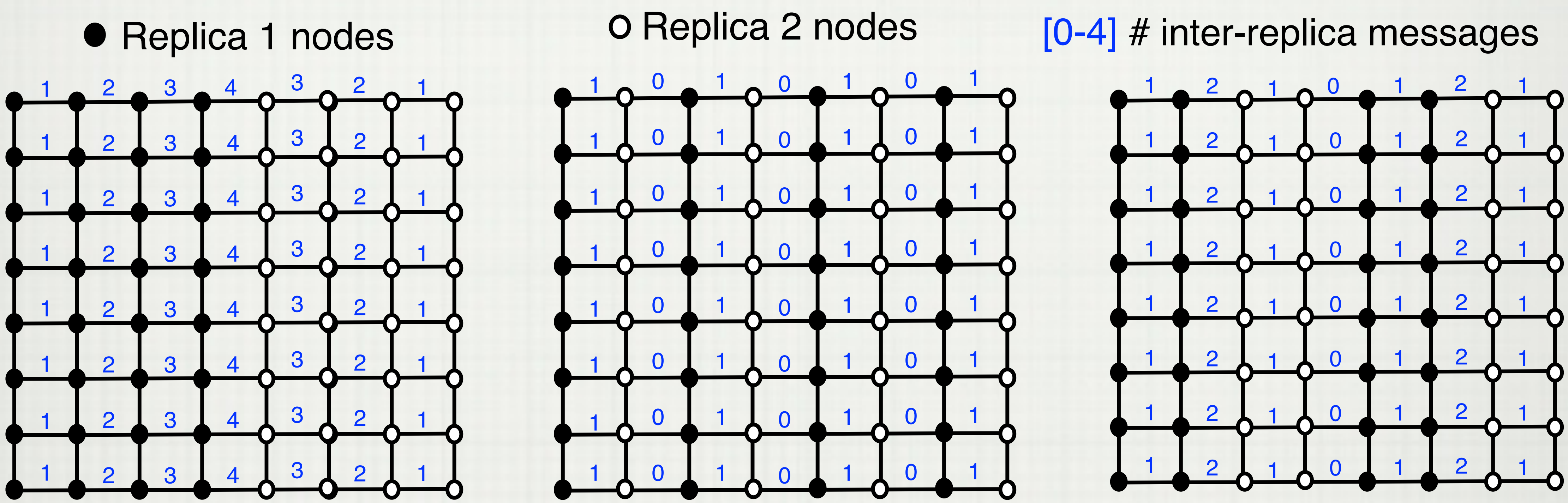


(a) Default-mapping

OPTIMIZATION: TOPOLOGY AWARE MAPPING



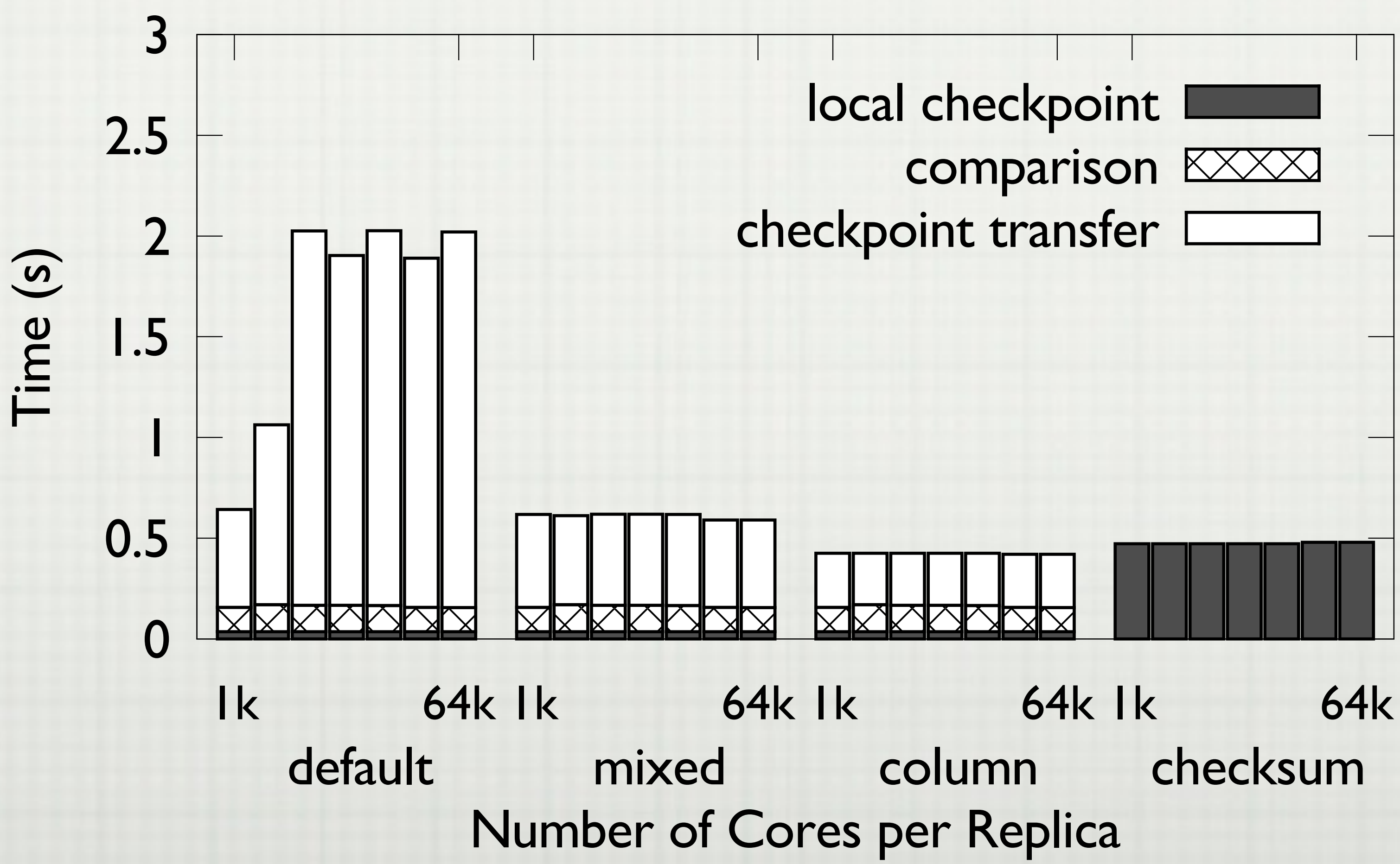
(a) Default-mapping (b) Column-mapping (c) Mixed-mapping

1) Reduce the inter-replica communication distance.

2) Trade-off between inter and intra replica communication.

OPTIMIZATION: CHECKSUM

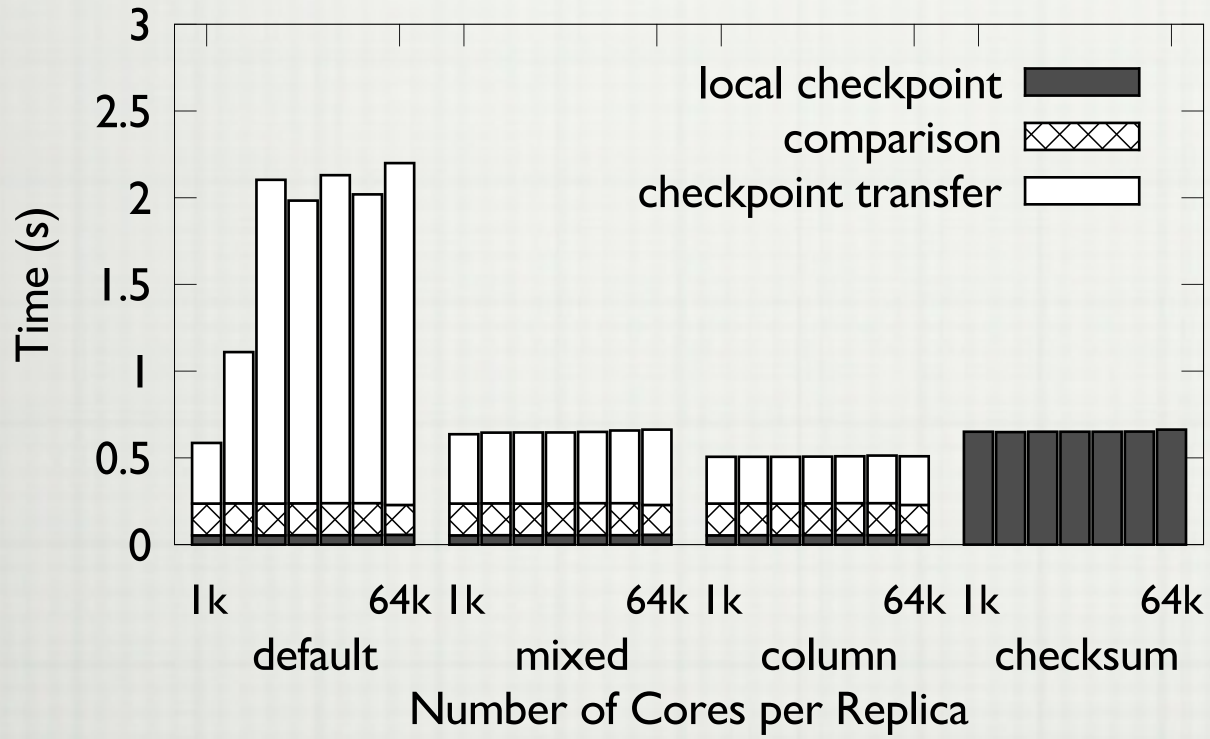
- TRANSFER THE CHECKSUM OF 1 INTEGER INSTEAD OF THE WHOLE CHECKPOINTS
- FLOATING POINT ROUND-OFF ERROR



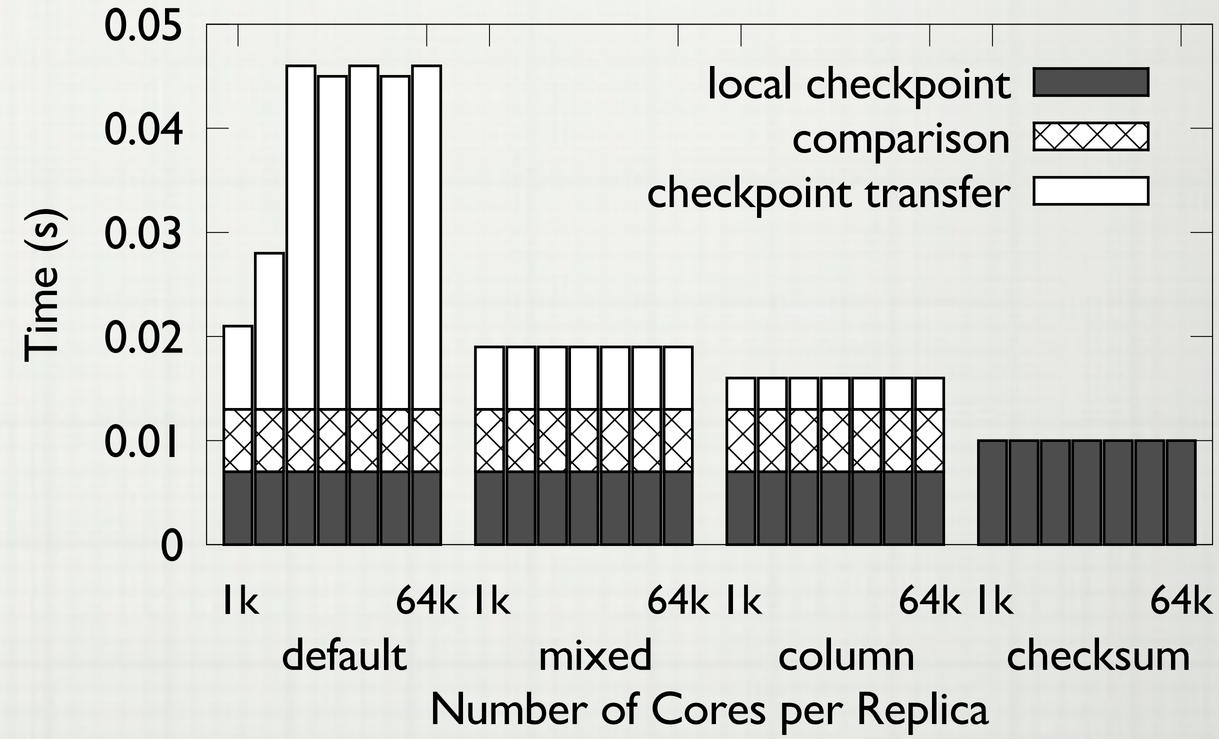
EXPERIMENTAL RESULTS: MINI-APPLICATIONS

Benchmark	Description	Configuration per core	Memory Pressure
Jacobi3D	7-point stencil	64*64*128	High
HPCCG	Unstructured implicit finite element method	40*40*40	High
LULESH	Unstructured explicit mesh	32*32*64	High
LeanMD	Short-range non-bonded force calculation in NAMD	4000 atoms	Low
miniMD	Mimic the performance in LAMMPS	1000 atoms	Low

EXPERIMENTAL RESULTS: CHECKPOINT

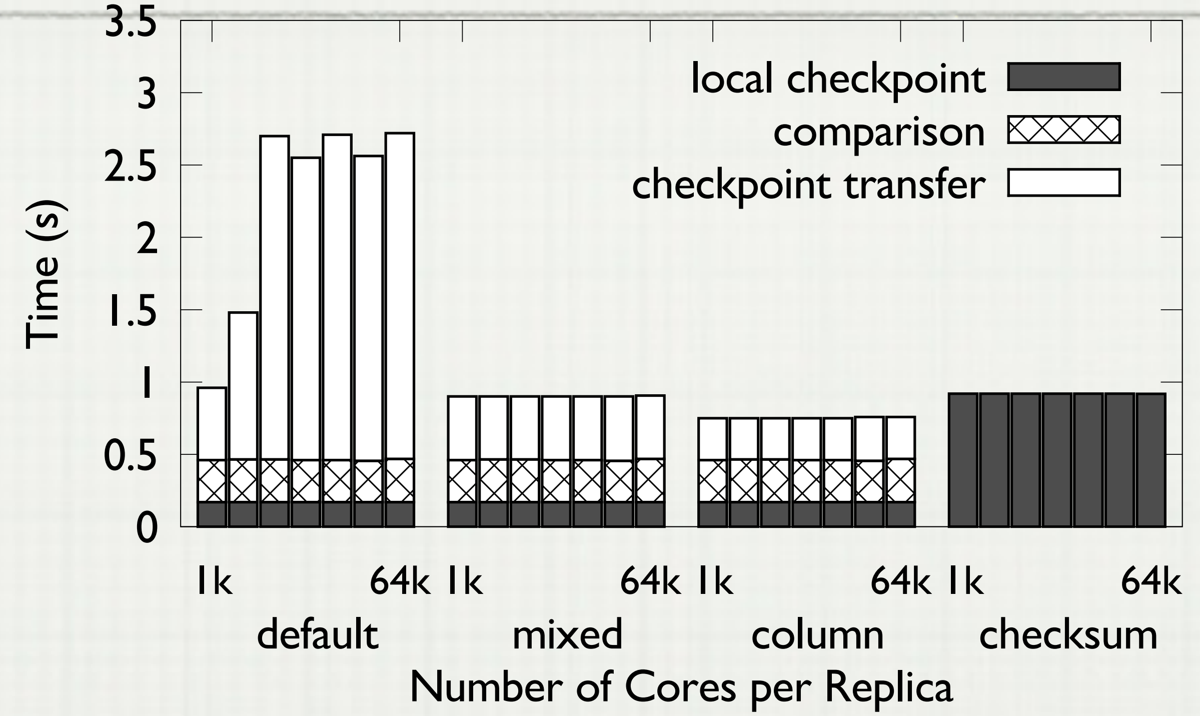


JACOBI3D AMPI



LEANMD

EXPERIMENTAL RESULTS: CHECKPOINT



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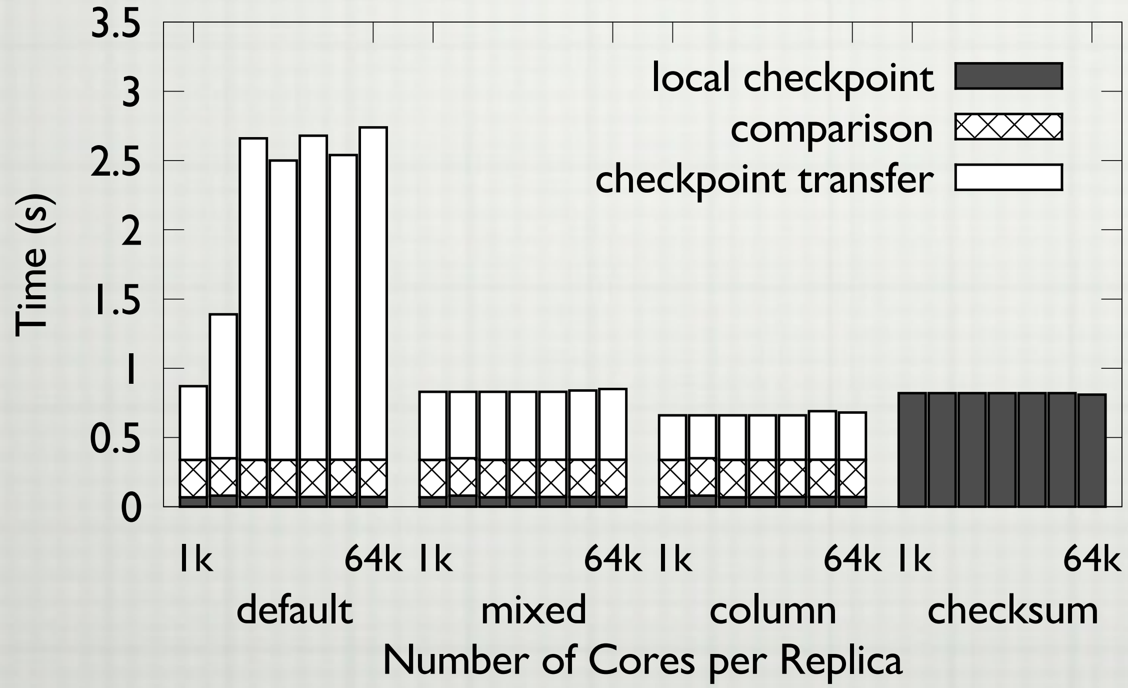

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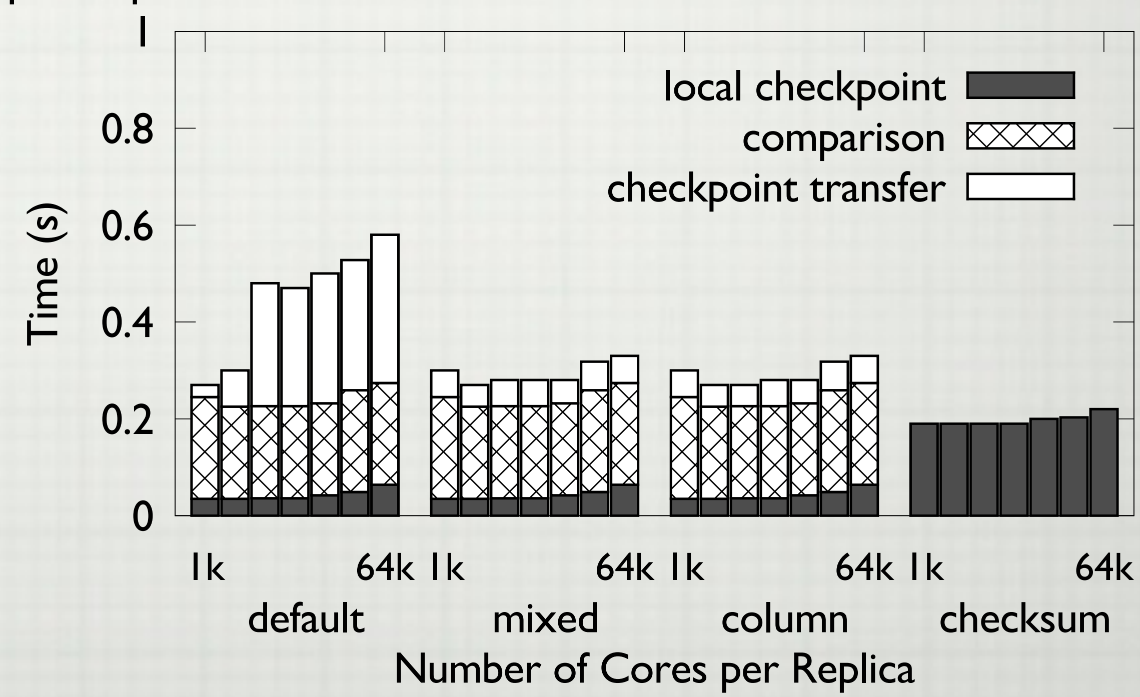
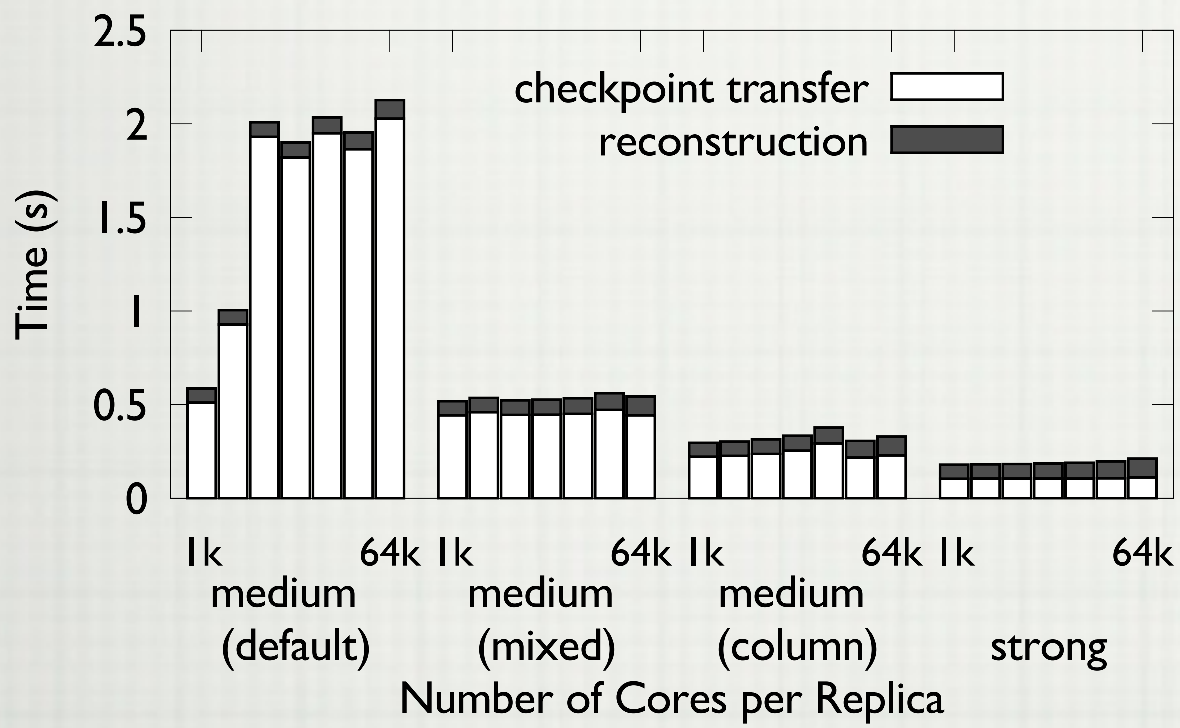


MINIMD

EXPERIMENTAL RESULTS: RESTART



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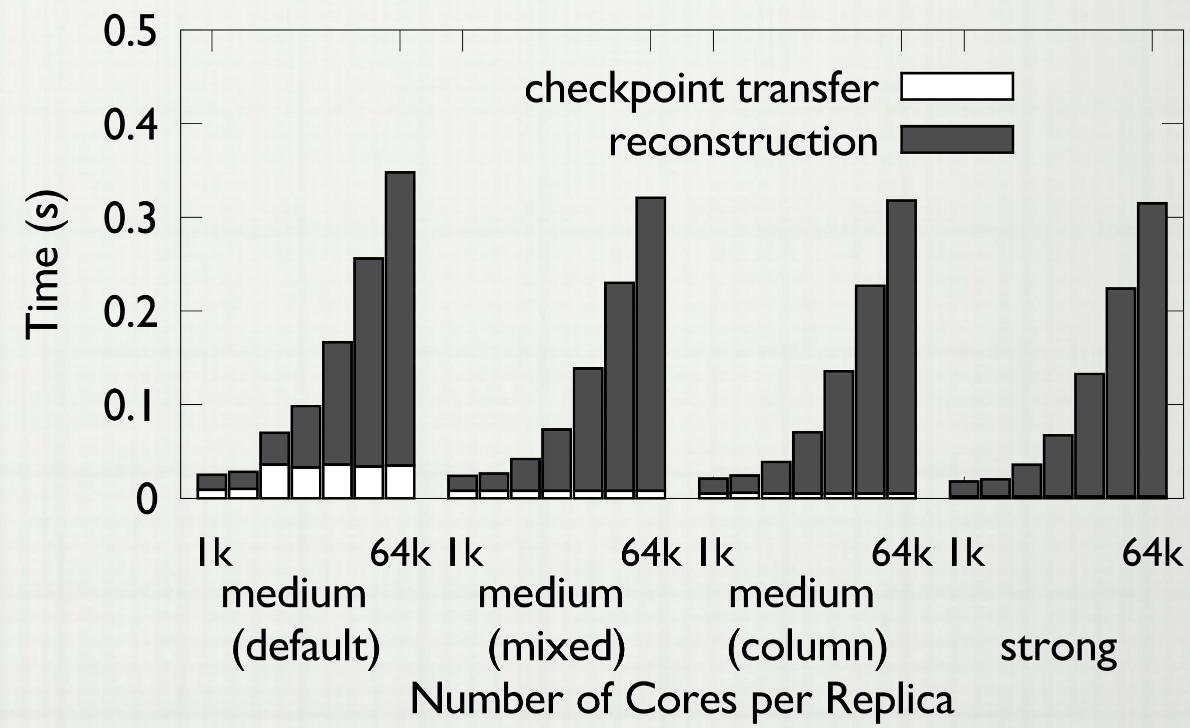

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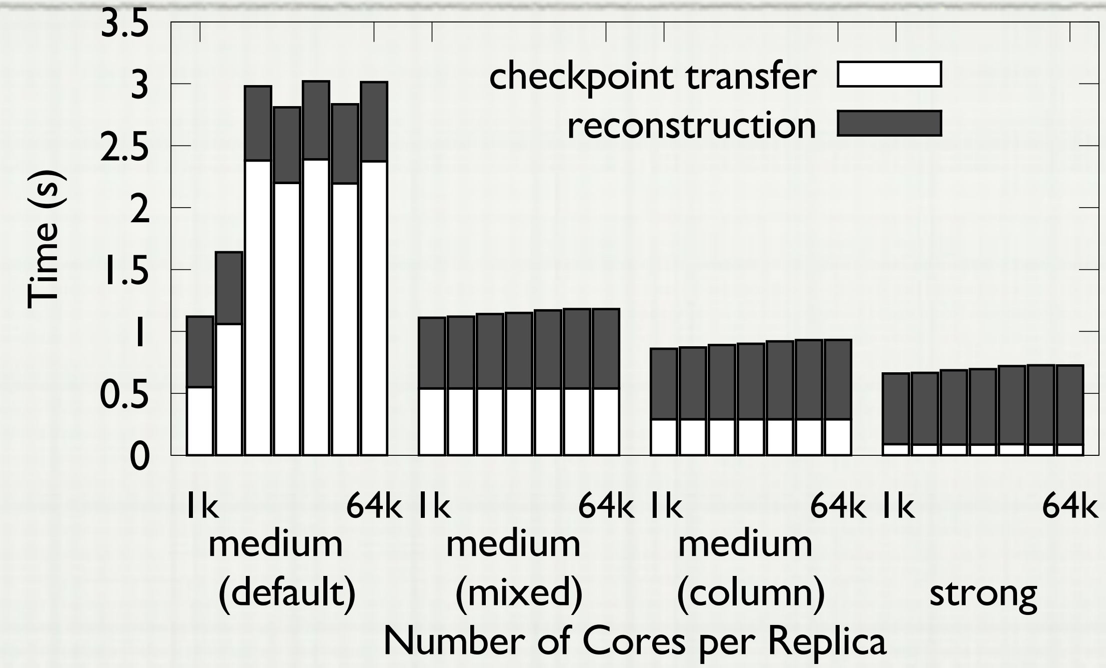

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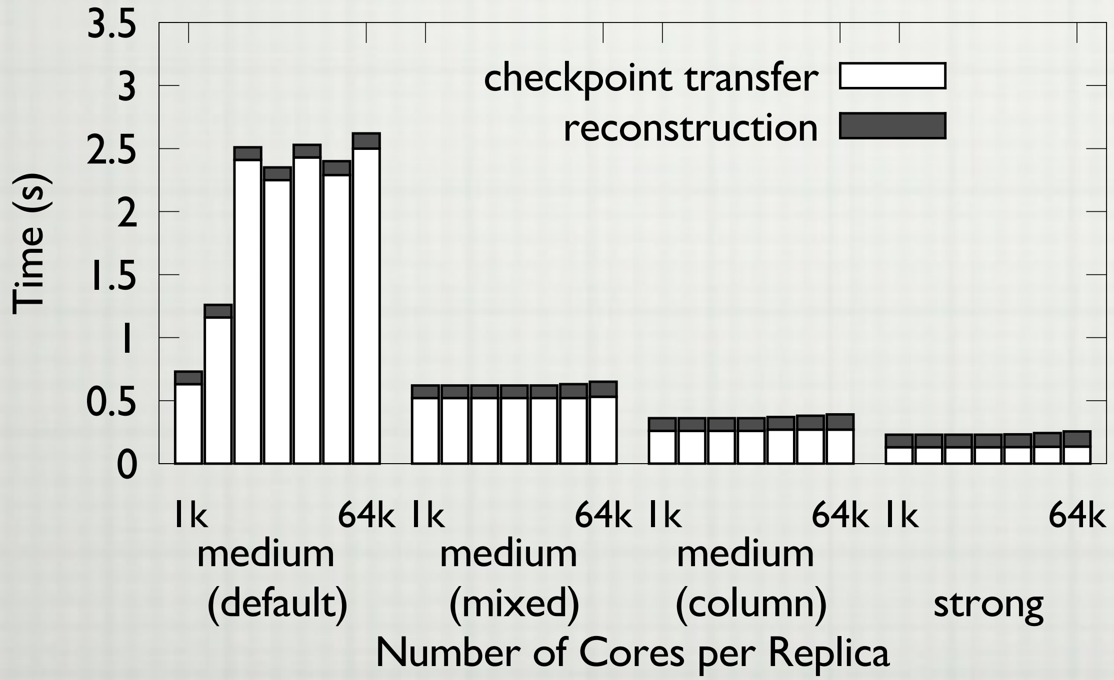

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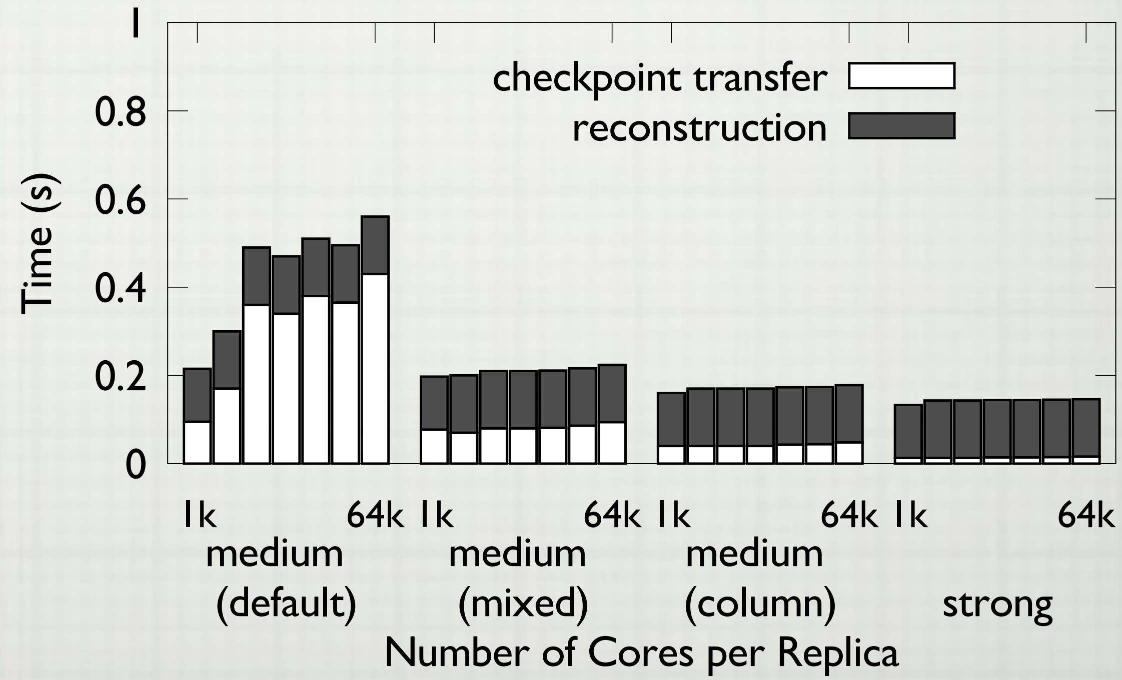
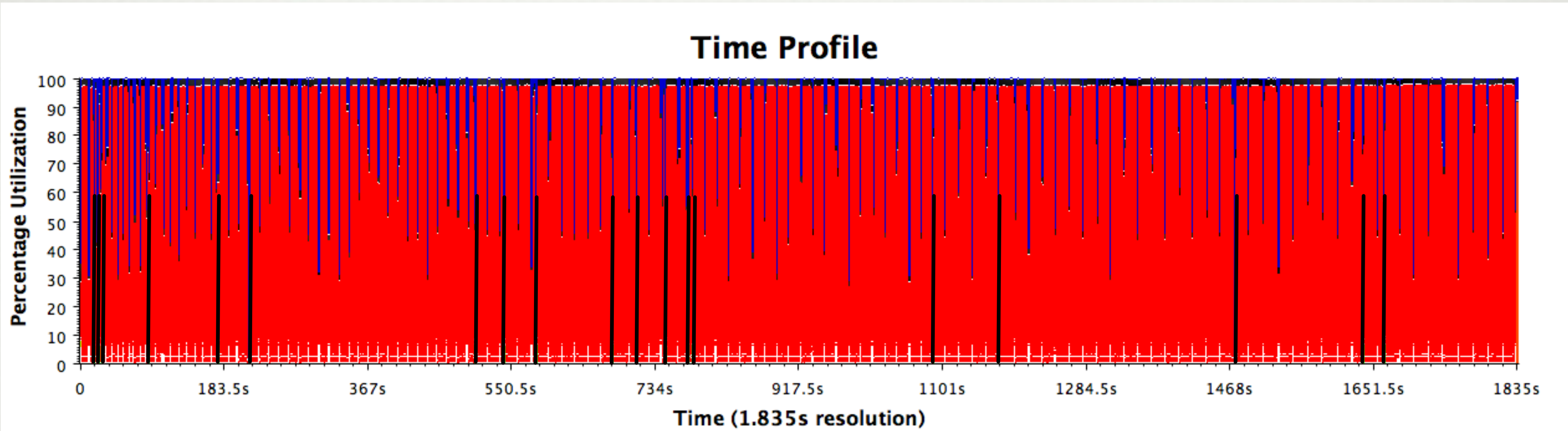


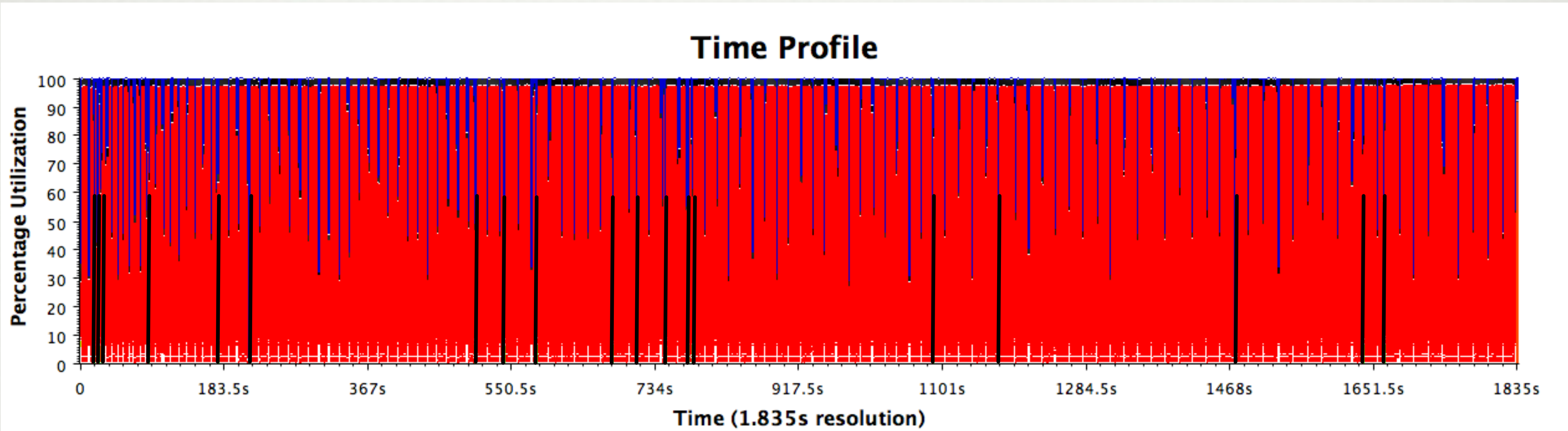
MINIMD

ADAPTING TO FAILURES



- Failures are injected according to Weibull process: shape parameter 0.6
- 19 failures are injected in a 30mins Jacobi3d run. 14 failures are injected in the first half while 5 failures are injected in the second half.
- Real failures injected: node becomes irresponsive
- Automatic restart: with the support of spare nodes and thus no need to submit the job again

ADAPTING TO FAILURES



- Runtime system observes the change in failure rate based on the failure history.
- Adjusts the optimum checkpoint period based on Daly's model.
- Checkpoint period changes from 6s in the beginning to 17s in the end.

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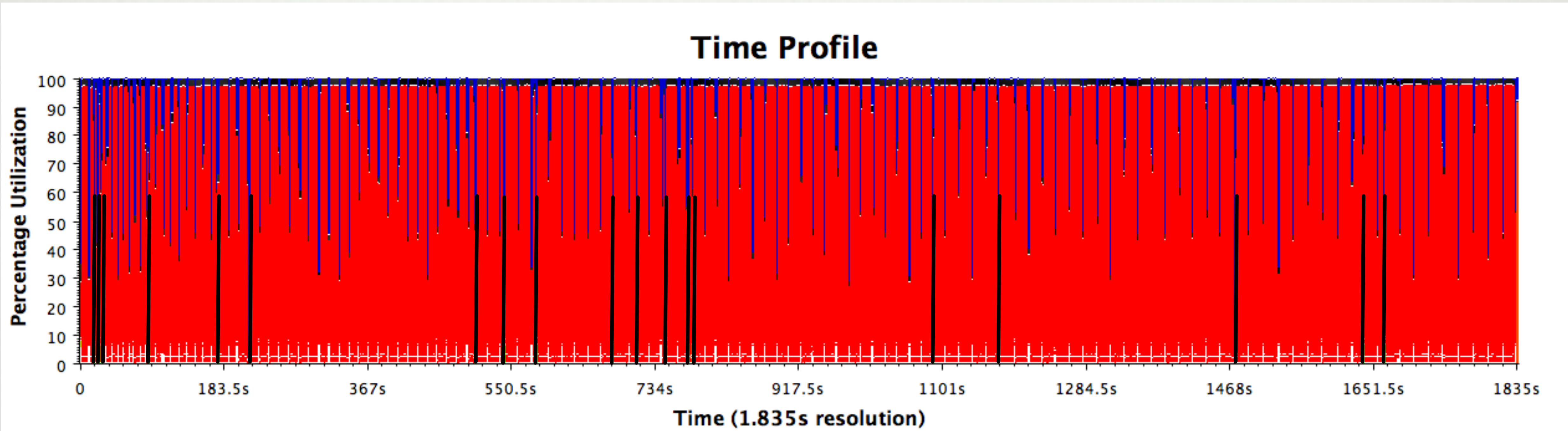

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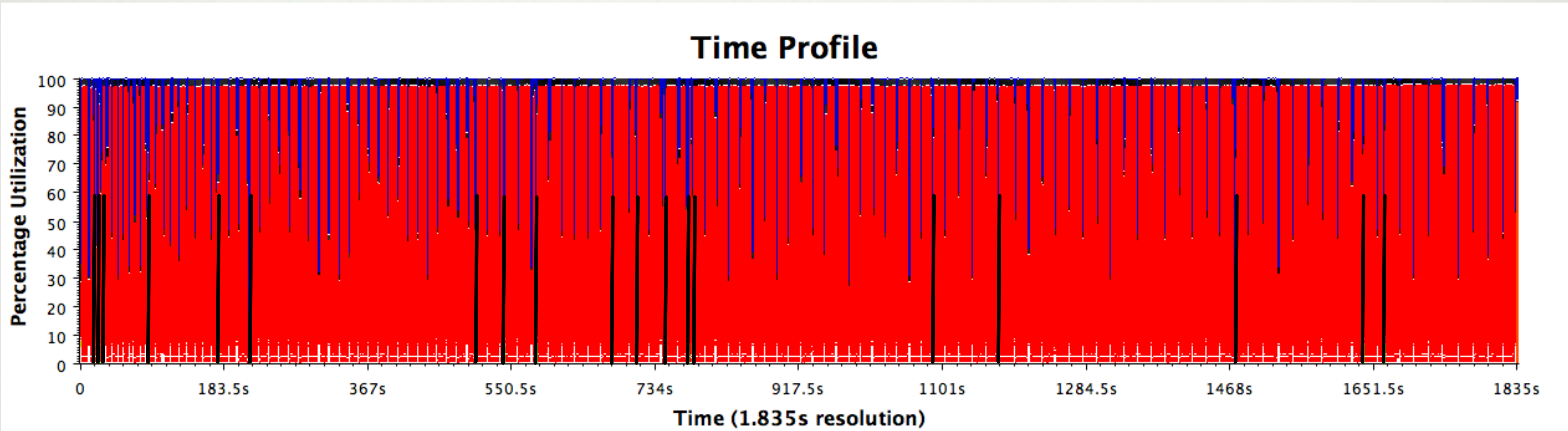

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17s

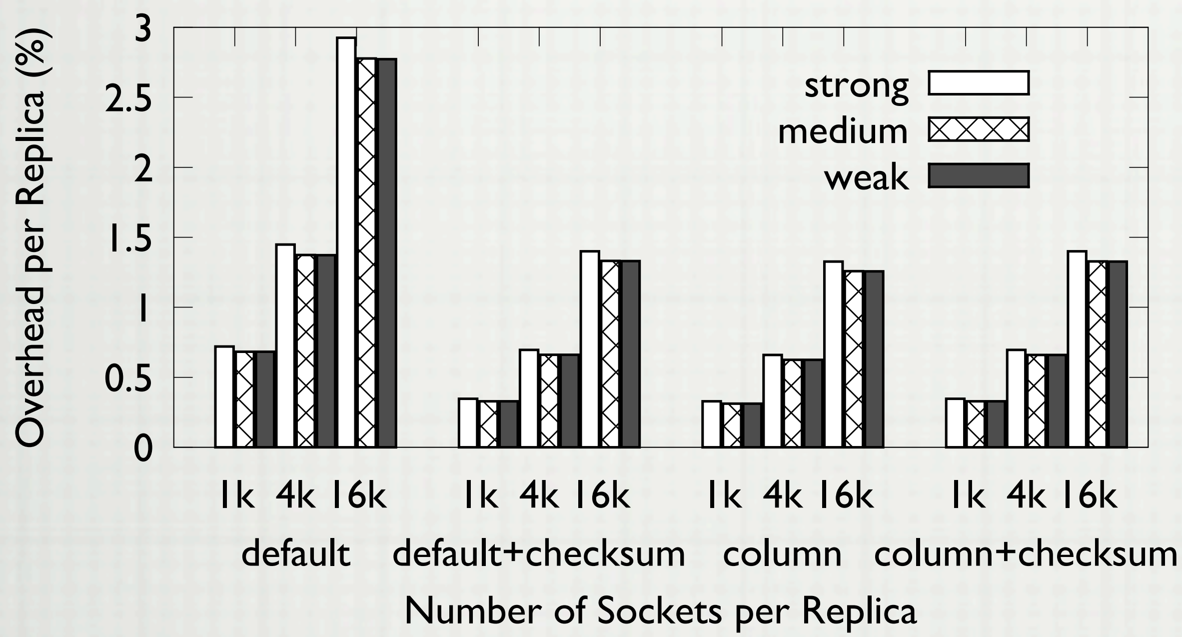
CONCLUSION

- Protection for both hard errors and silent data corruption is important
- Replication enables synergistic handling of errors
- Good scalability
- Automatic checkpoint decision
  - Restart from hard errors
  - Adapting to different failure distributions

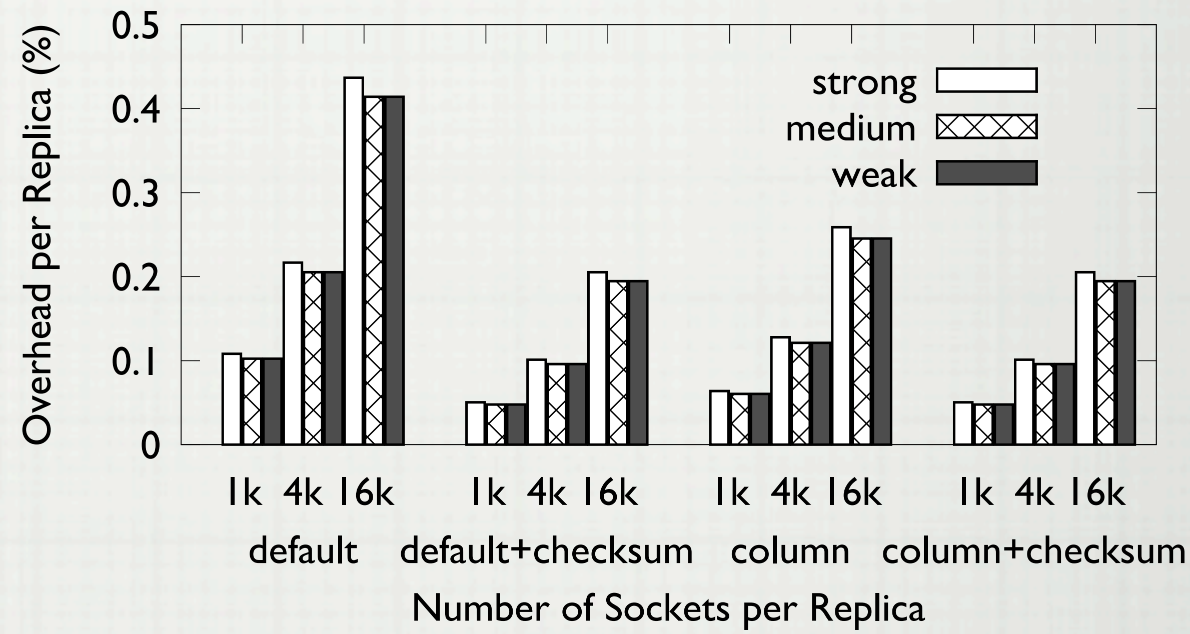
THANKS!

- QUESTIONS?
- CONTACT AT xiangni2@illinois.edu
- MORE INFO AT http://charm.cs.illinois.edu/research/ft

OVERHEAD



JACOBI3D



LEANMD

MODELING OF UTILIZATION AND VULNERABILITY