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FairRide: Near-Optimal Fair Cache Sharing

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Ali Ghodsi,
Ion Stoica

Caches are crucial

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memCached

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ALLUXIO

Spark

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Cache sharing

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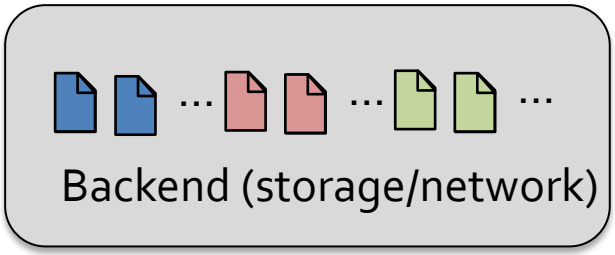

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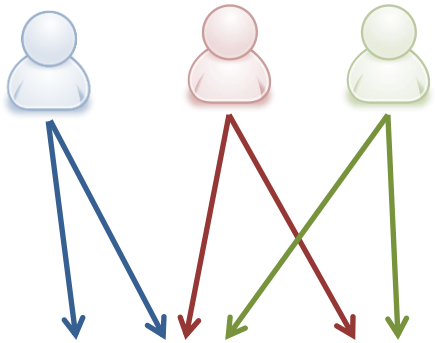

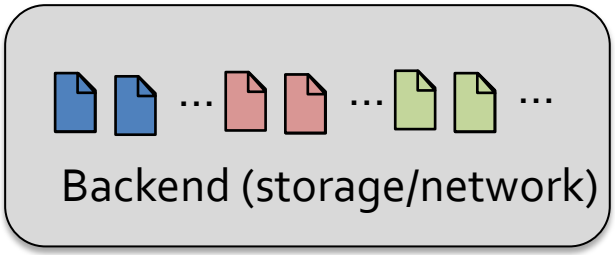

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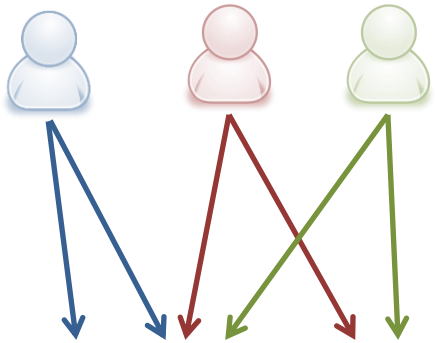

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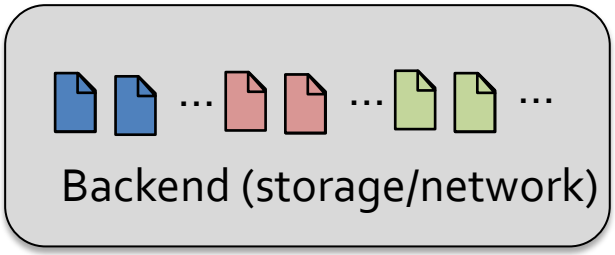

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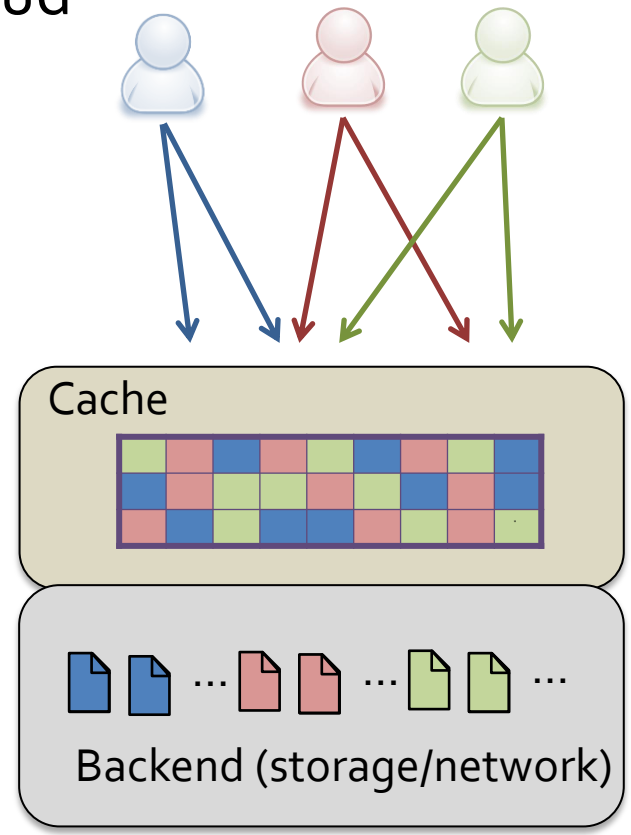

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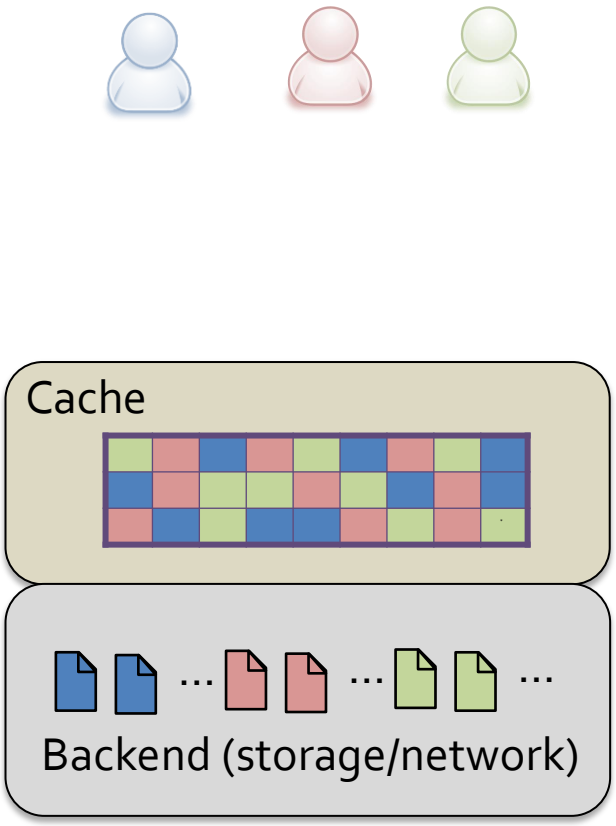

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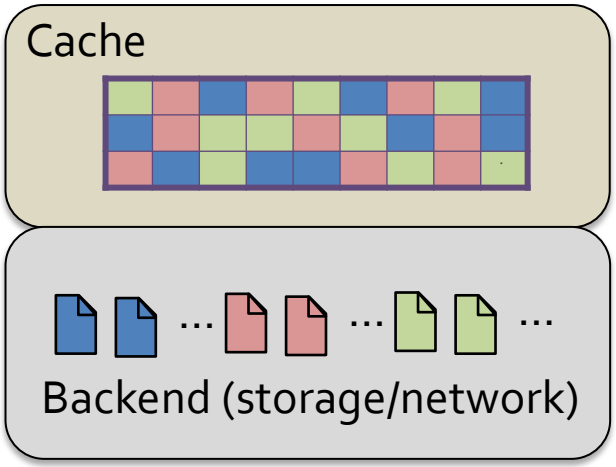

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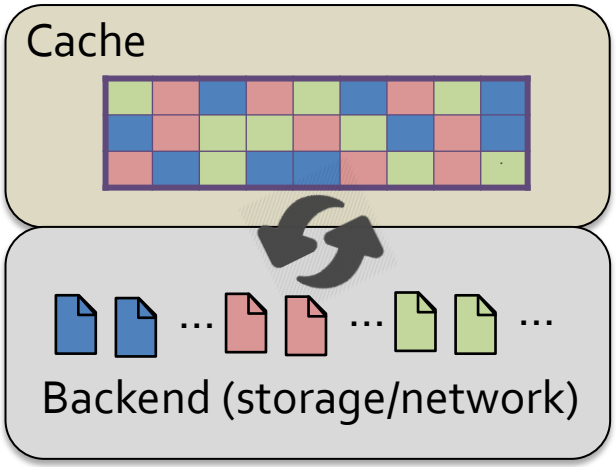

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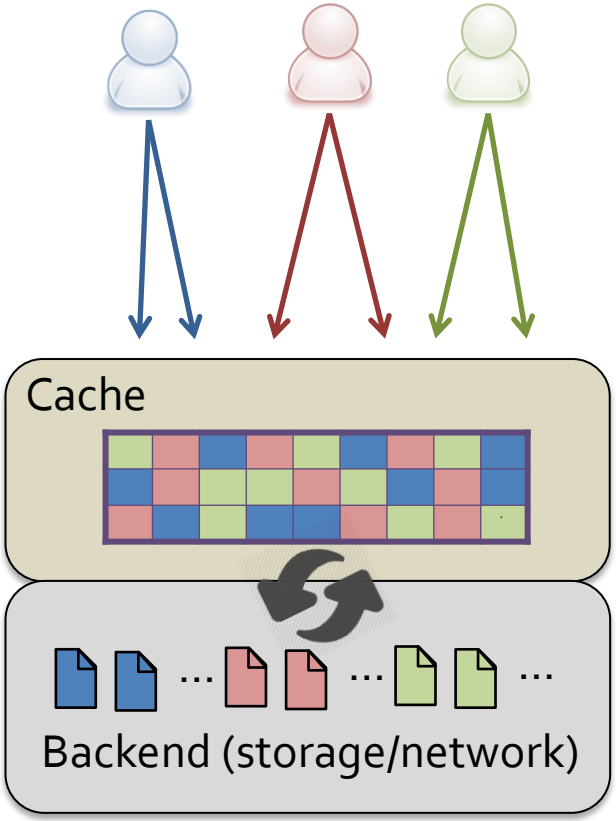

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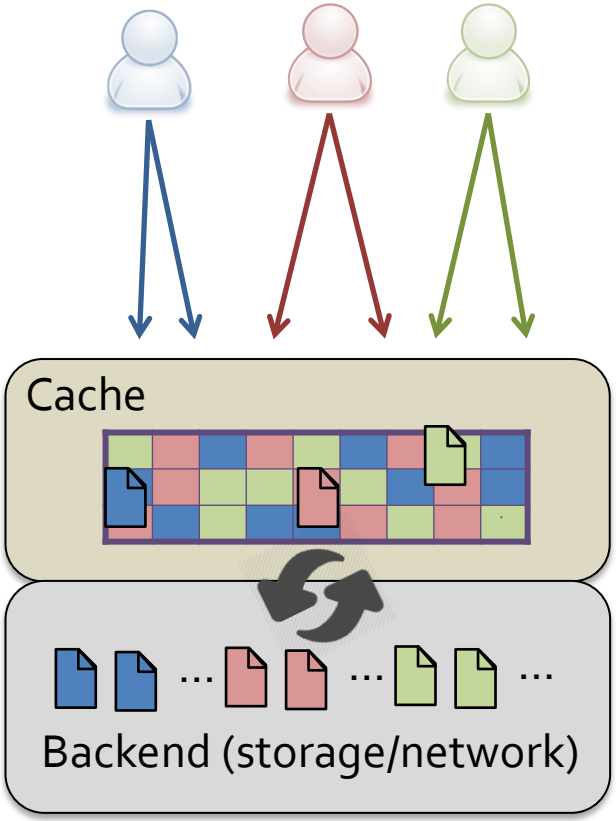

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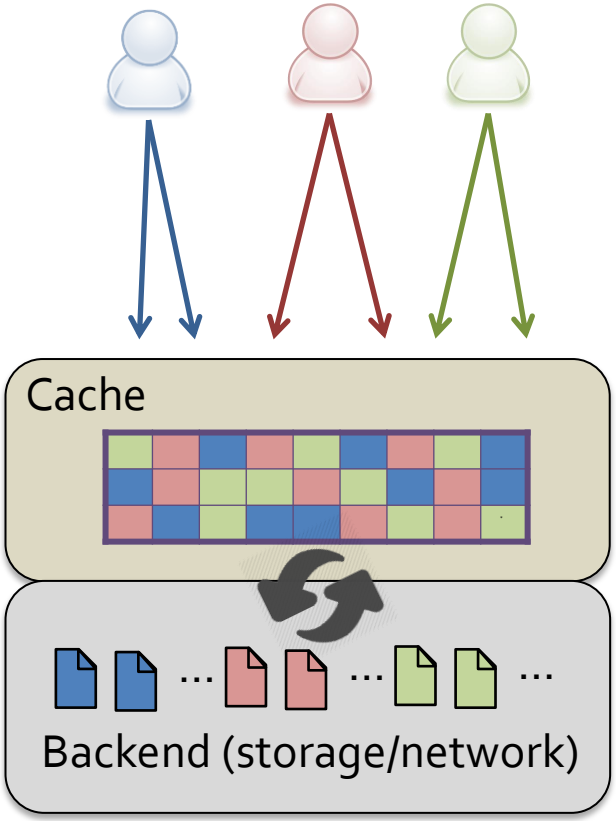

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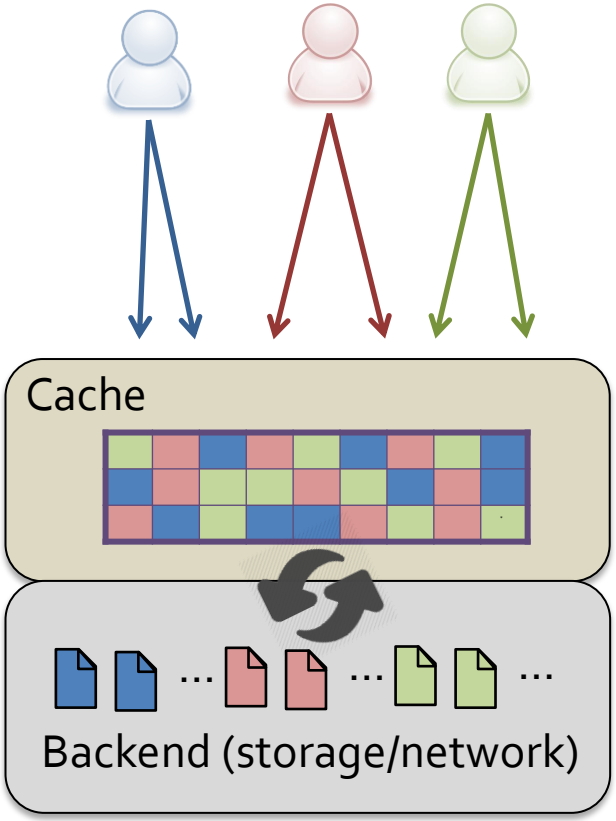

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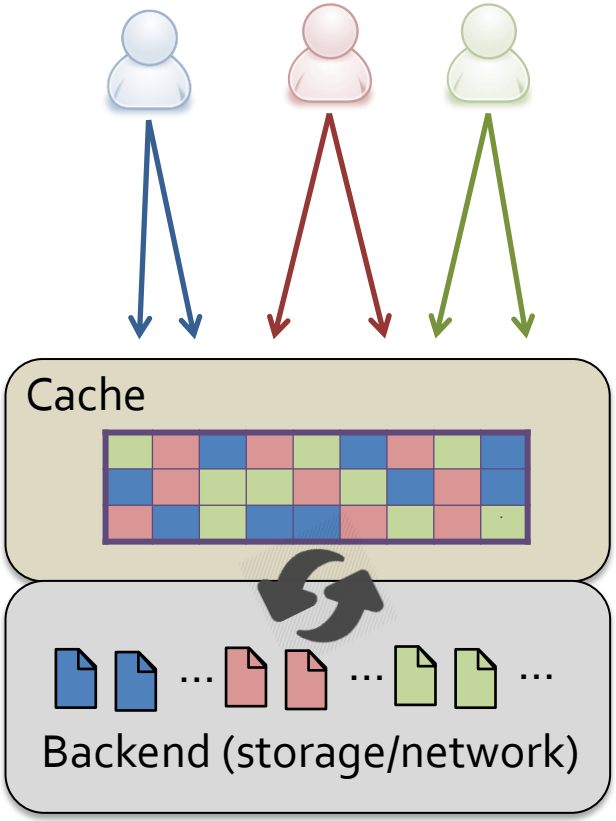

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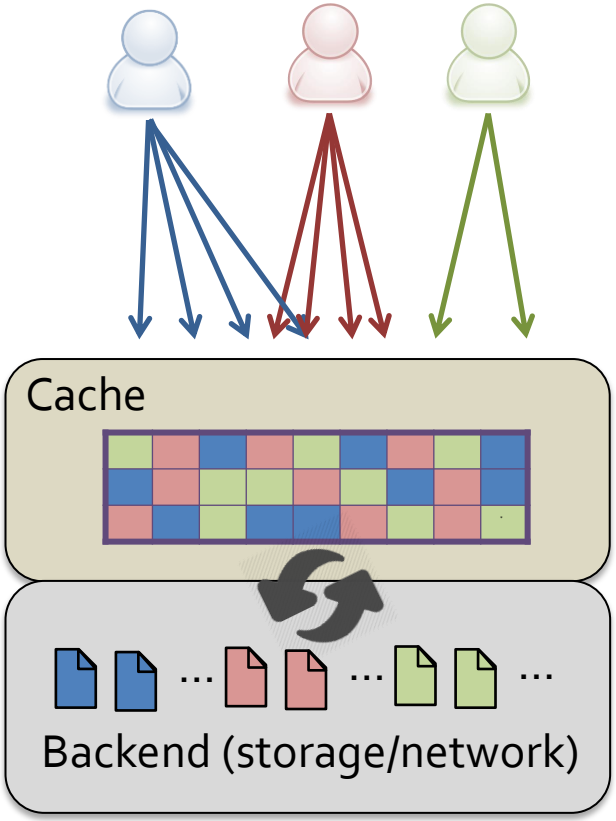

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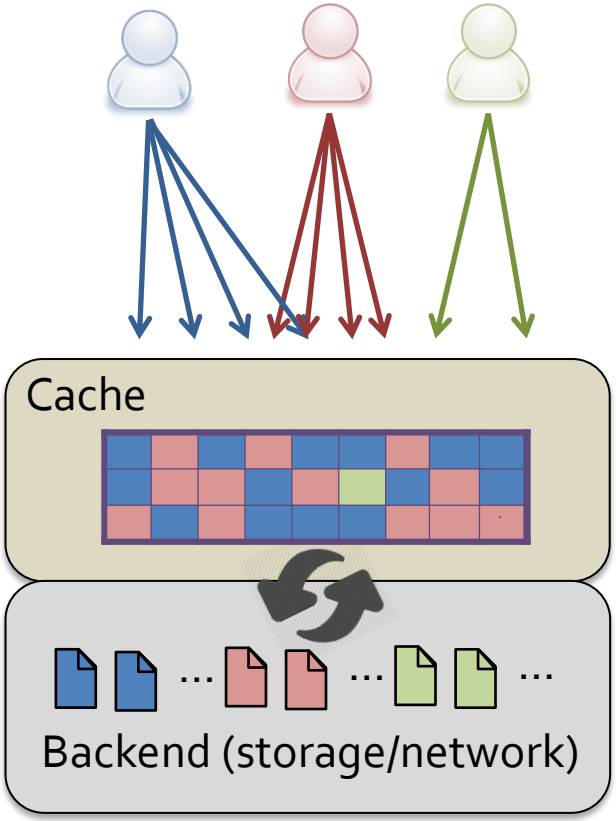

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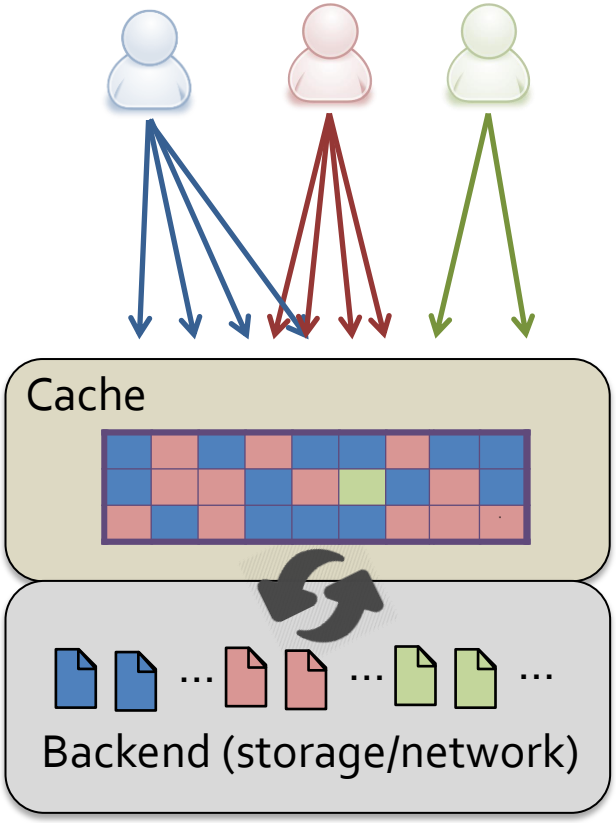

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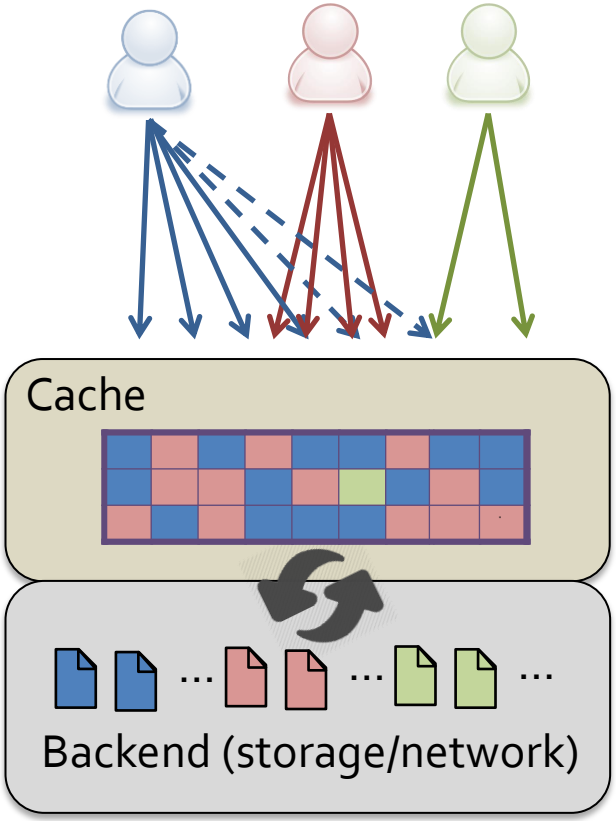

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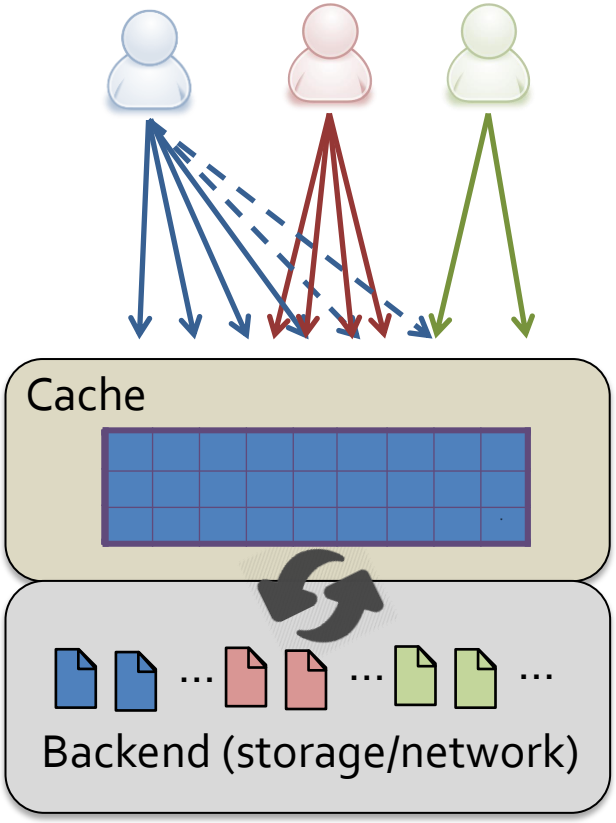

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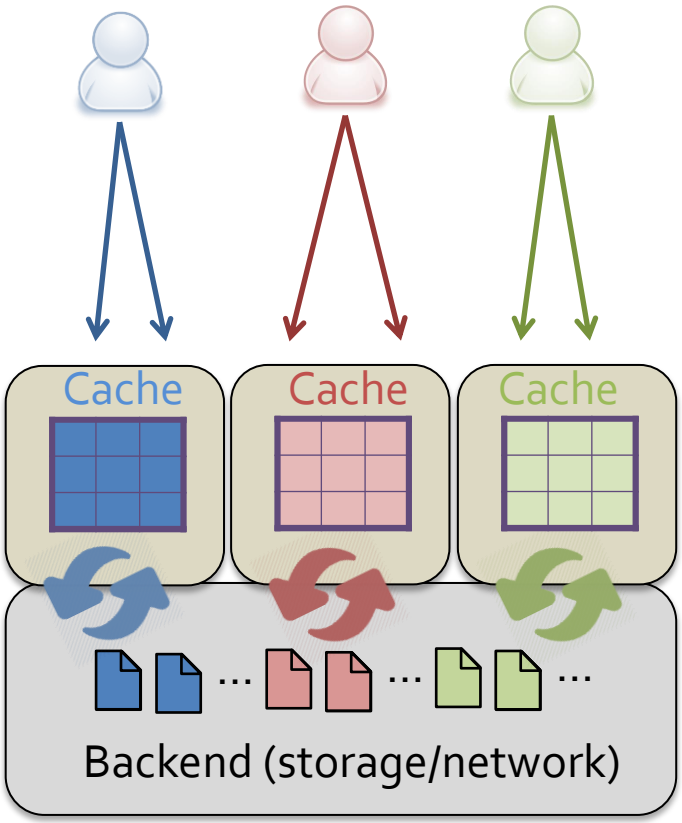

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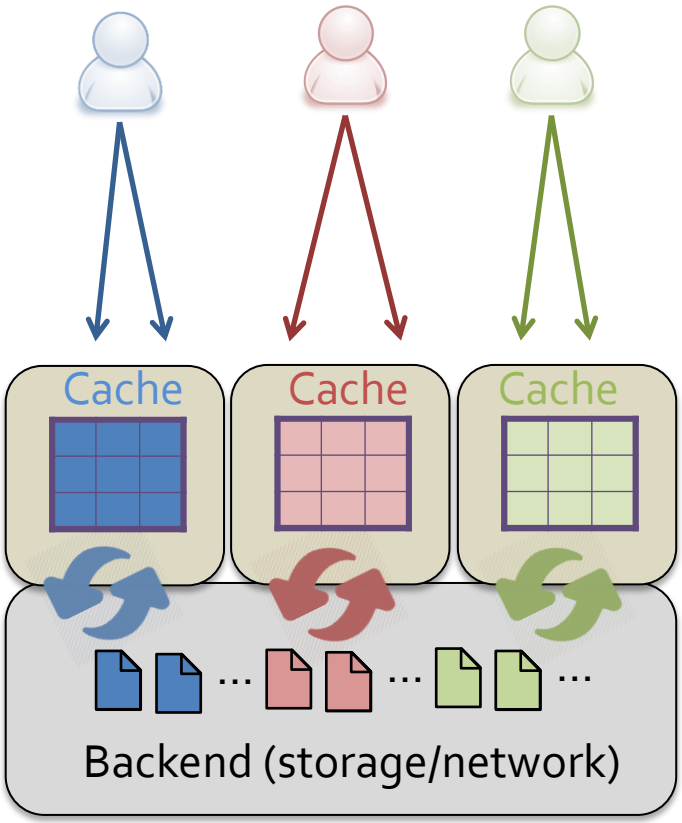

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Strategy-proof

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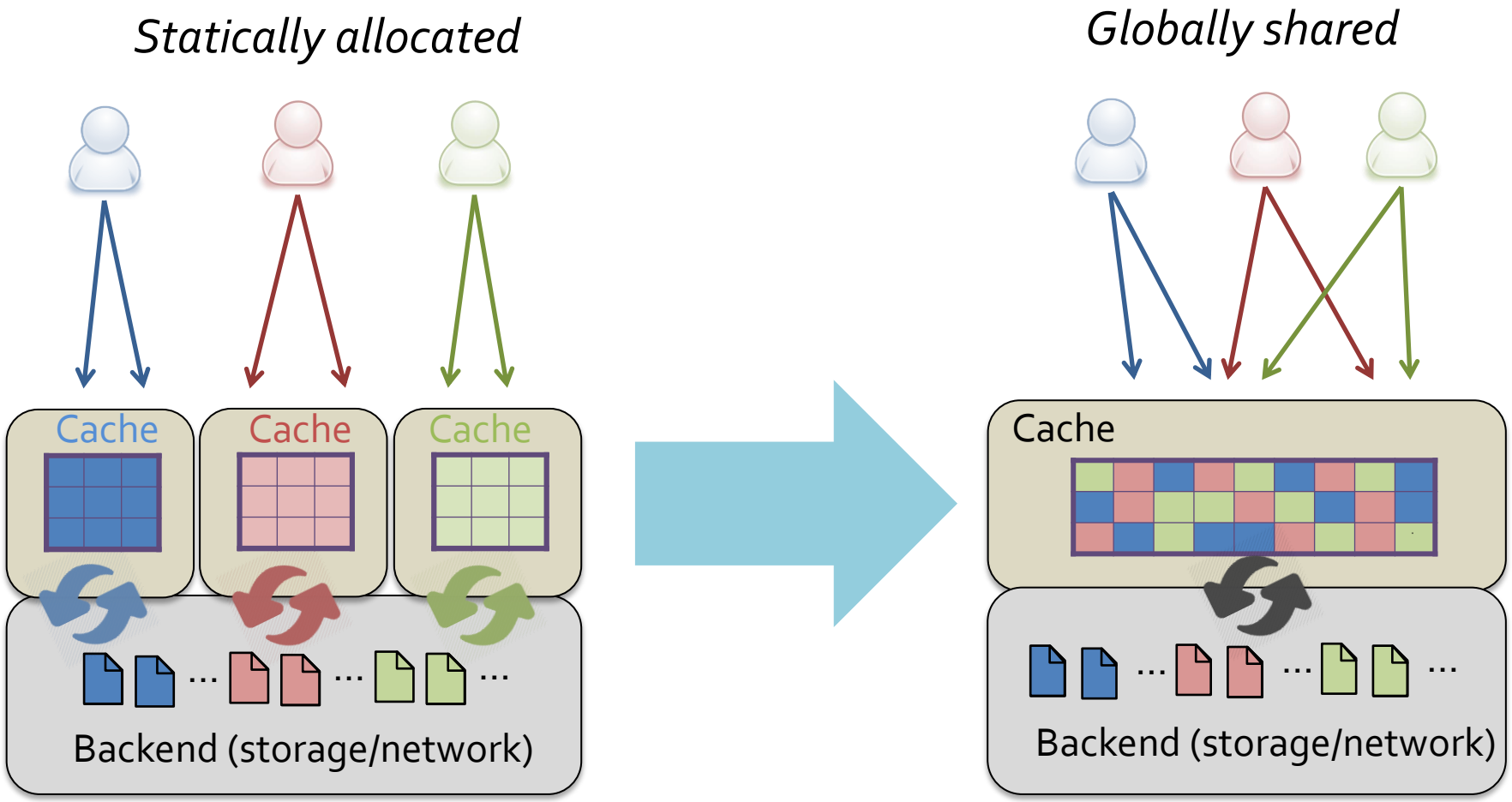

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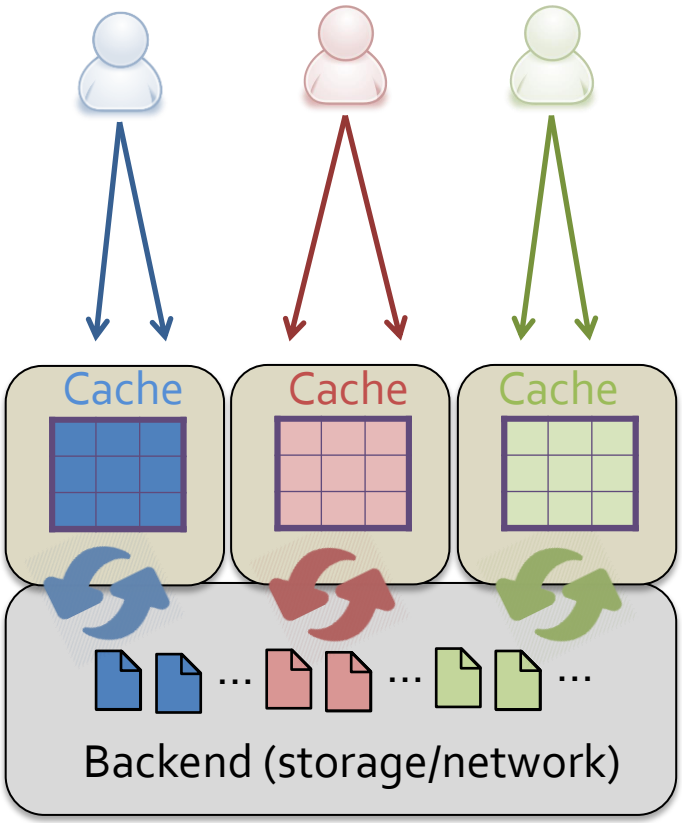

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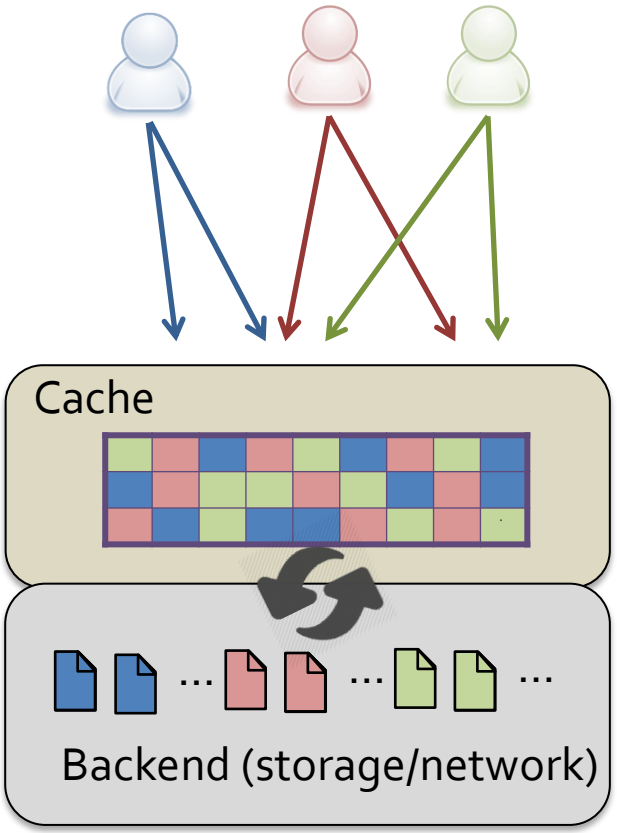

Higher utilization

Share data

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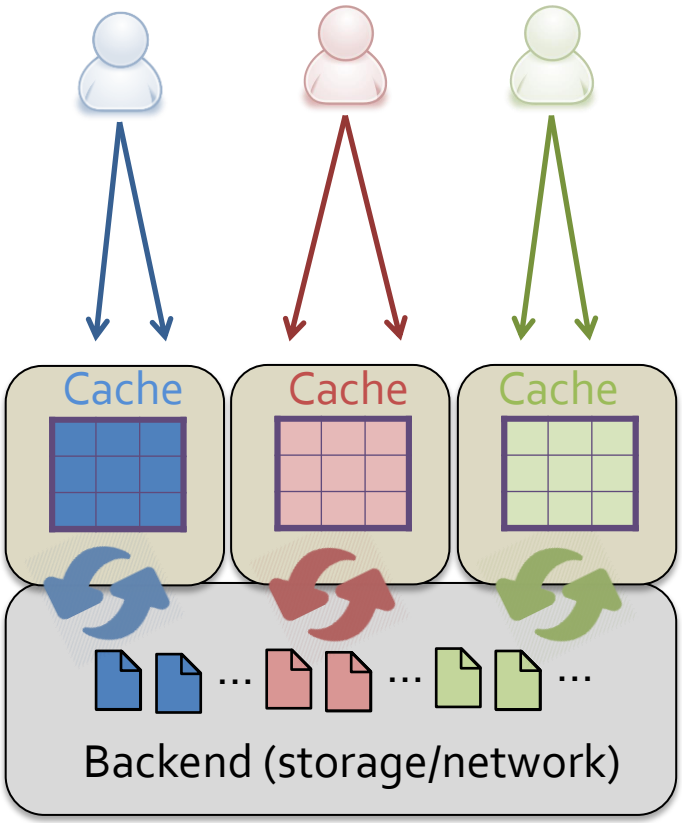

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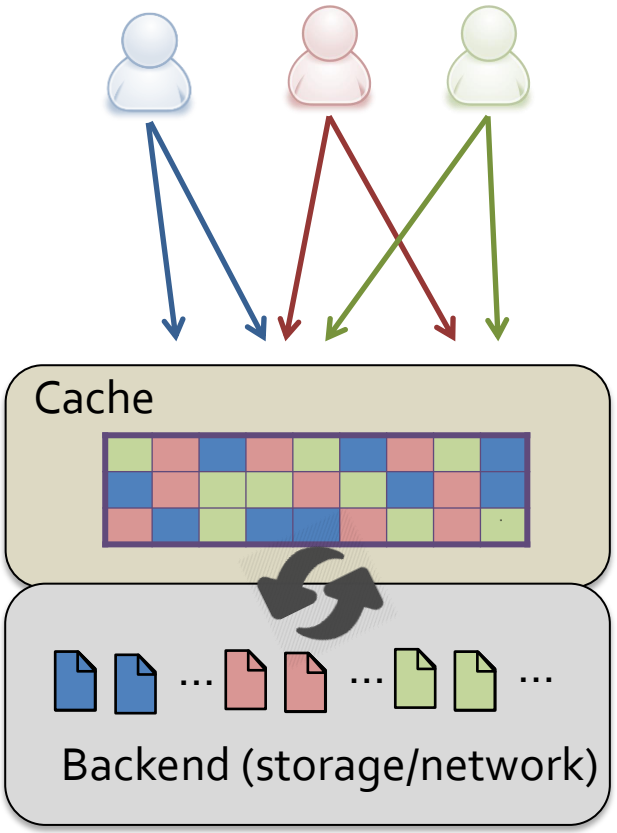

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- **A new policy that is near-optimal and outperforms other policies when users cheat.**

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◆ Results hold with varied file sizes, access partial files, p_j is binary, etc.

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- How well does FairRide work in practice?

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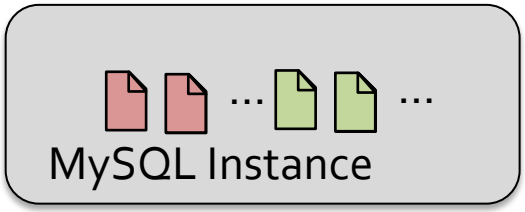

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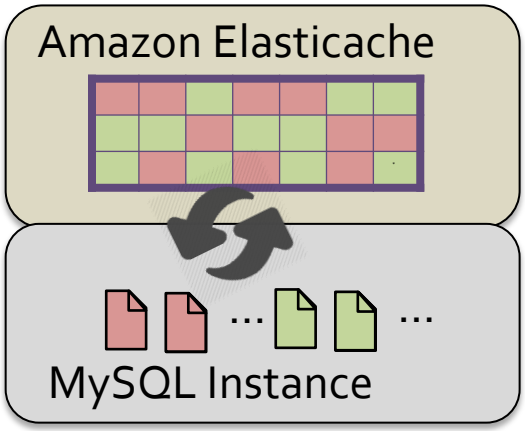

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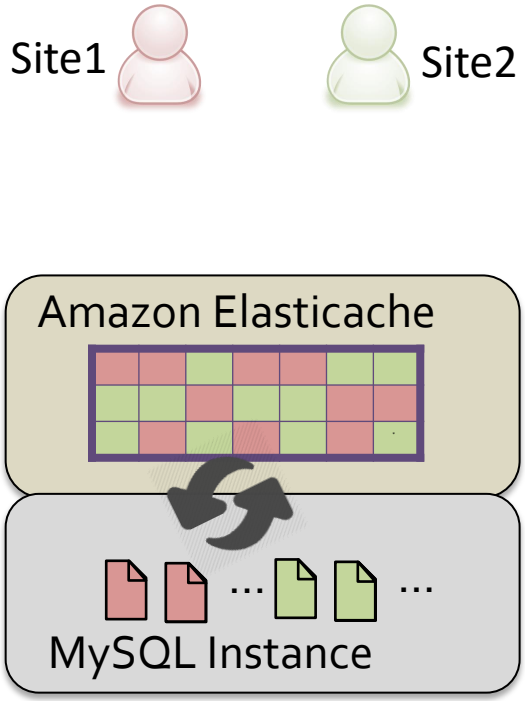

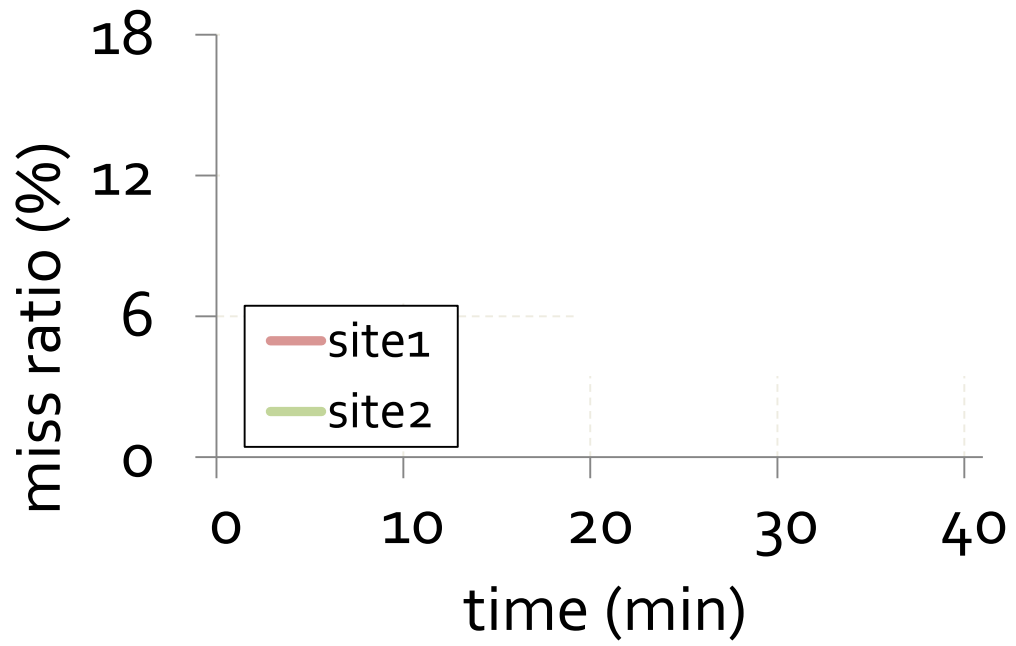

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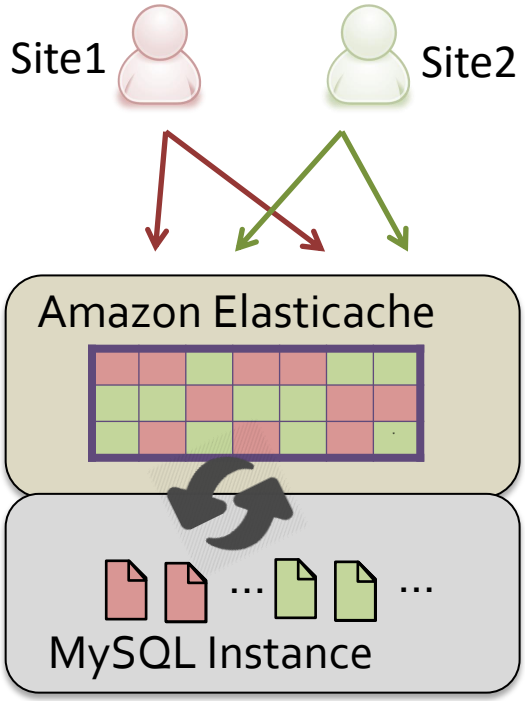

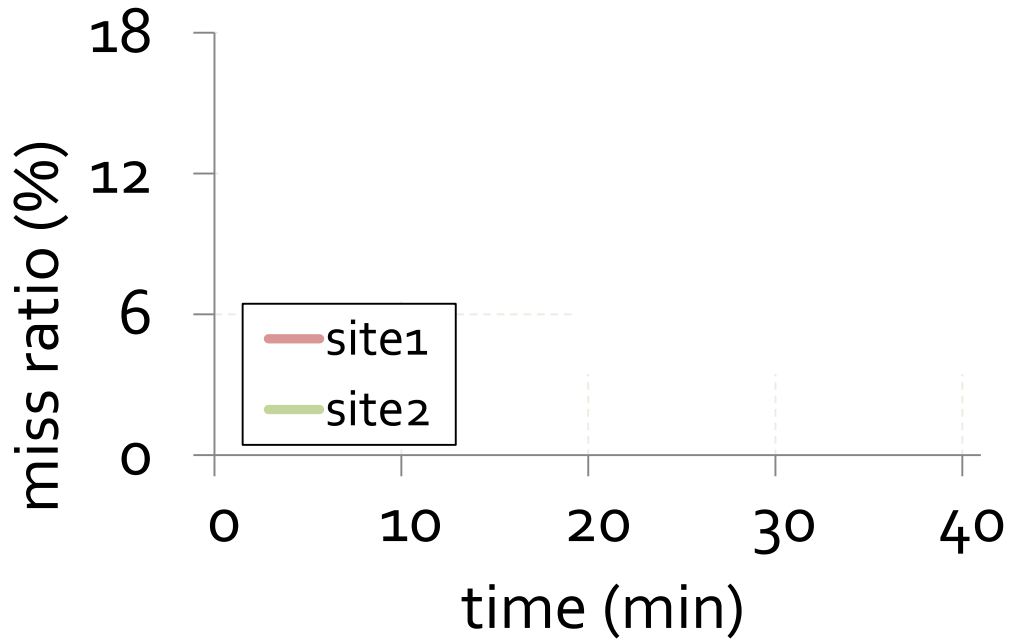

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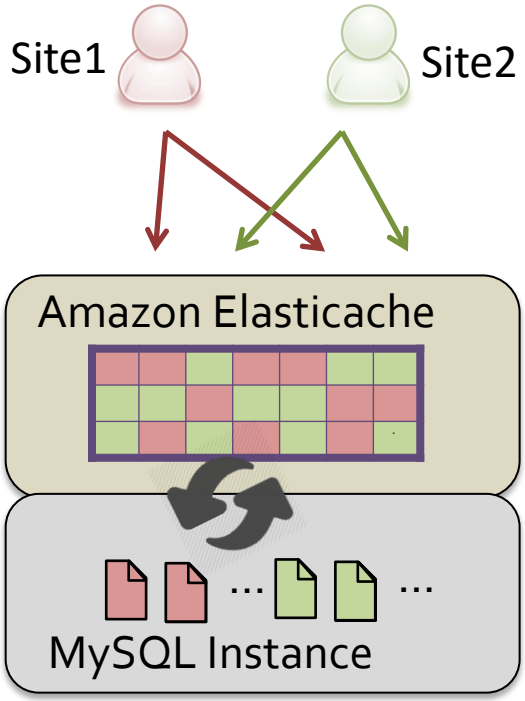

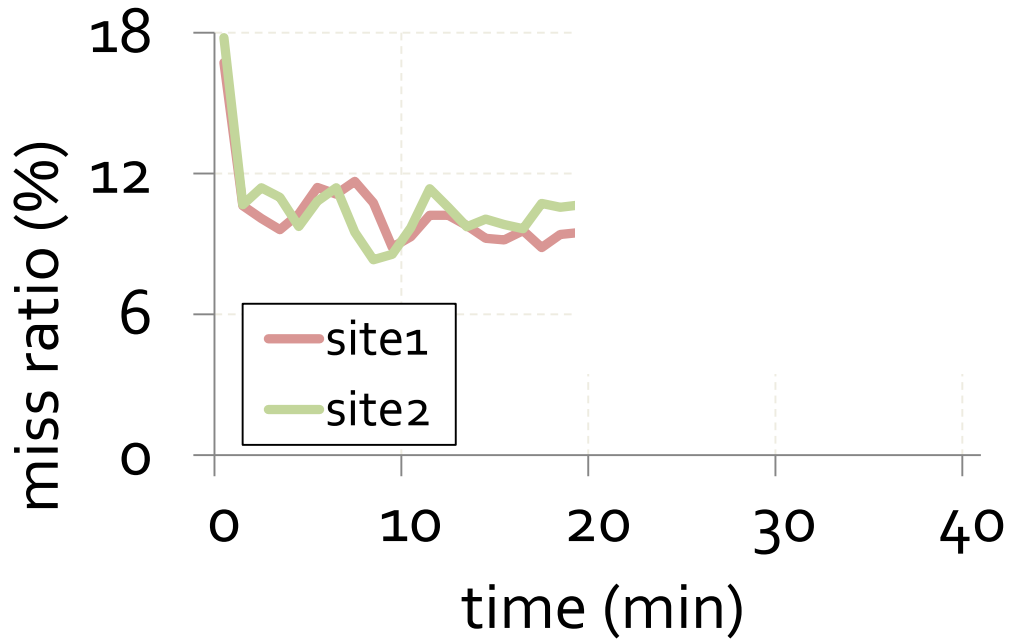

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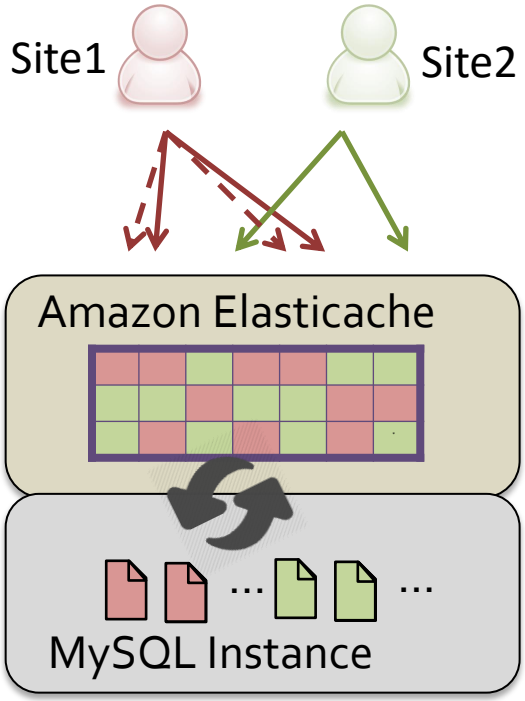

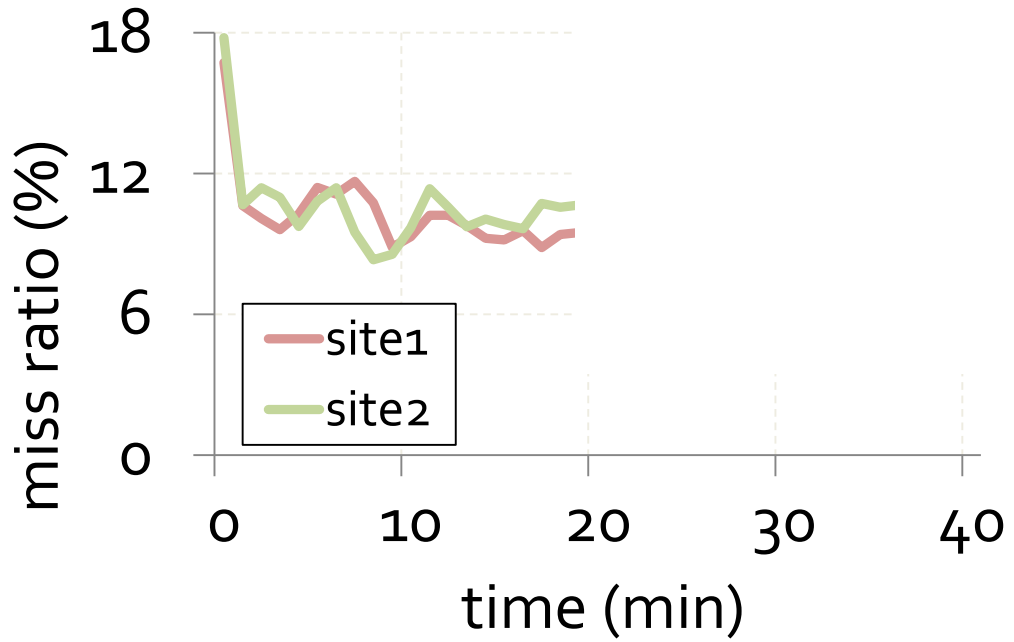

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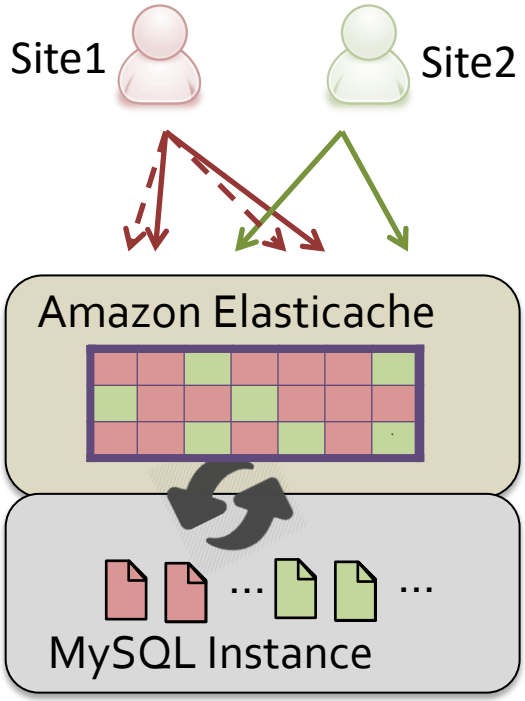

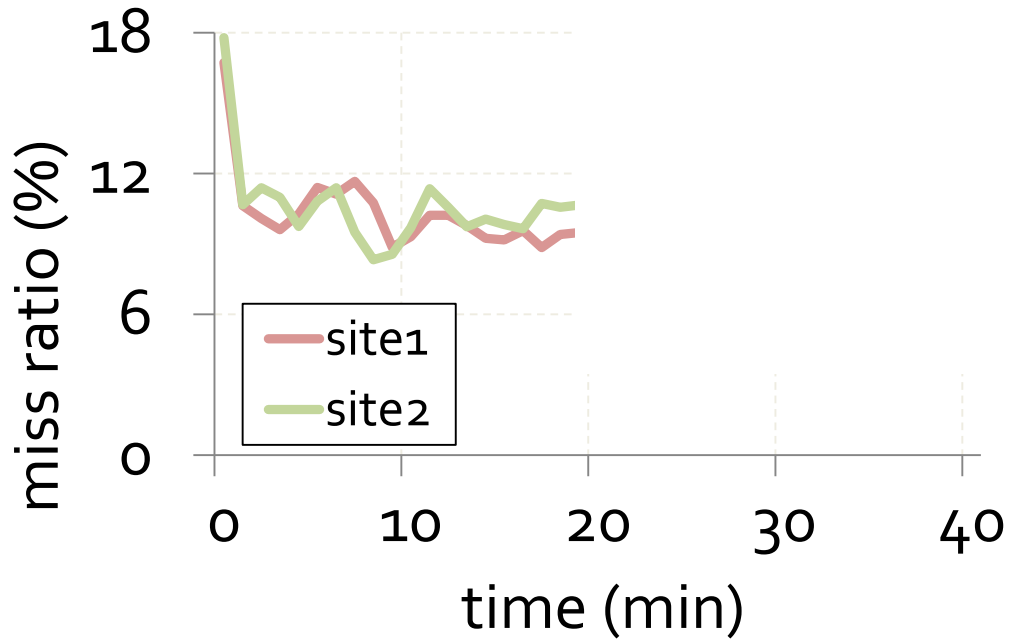

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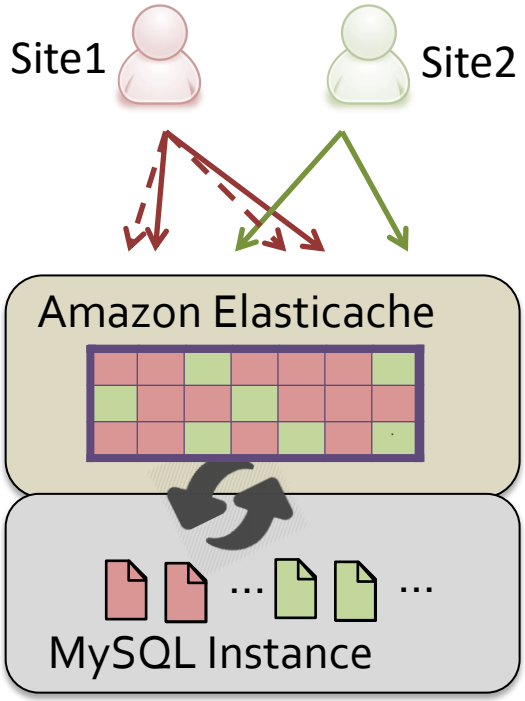

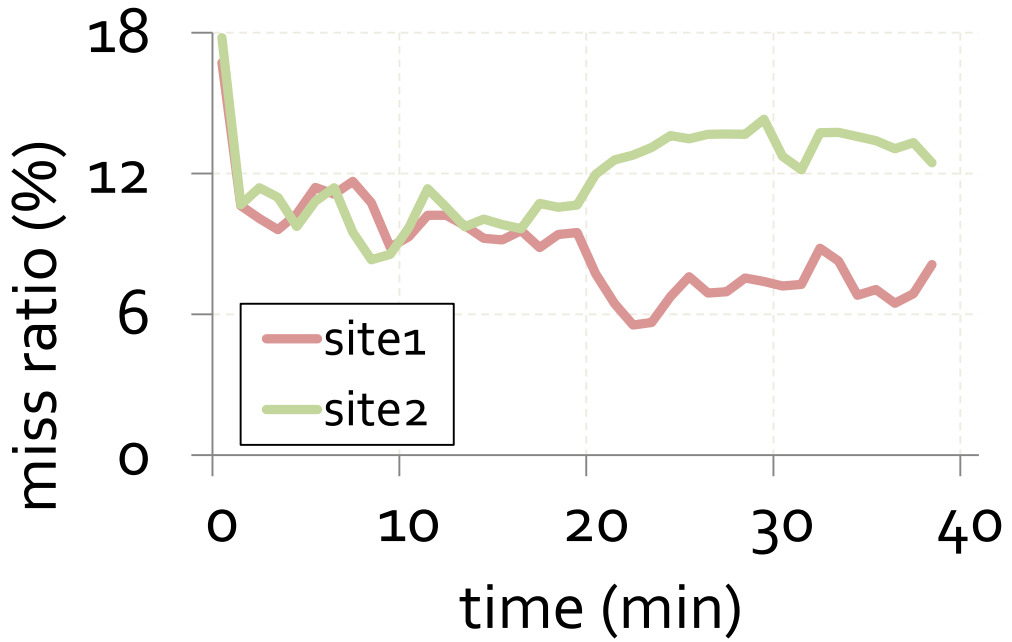

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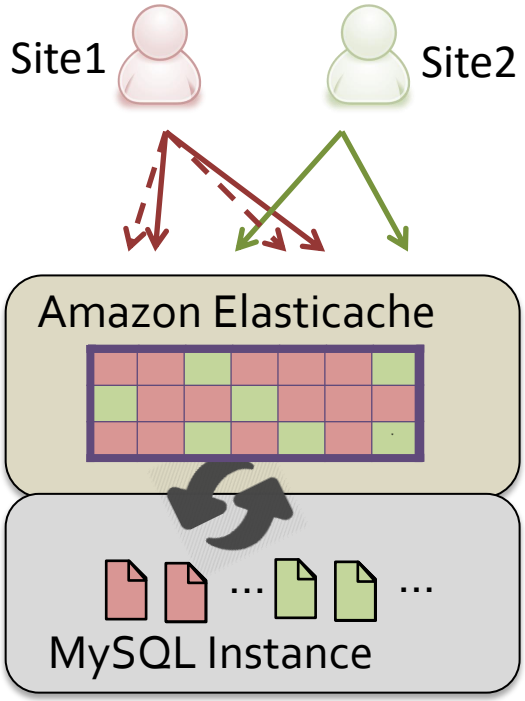

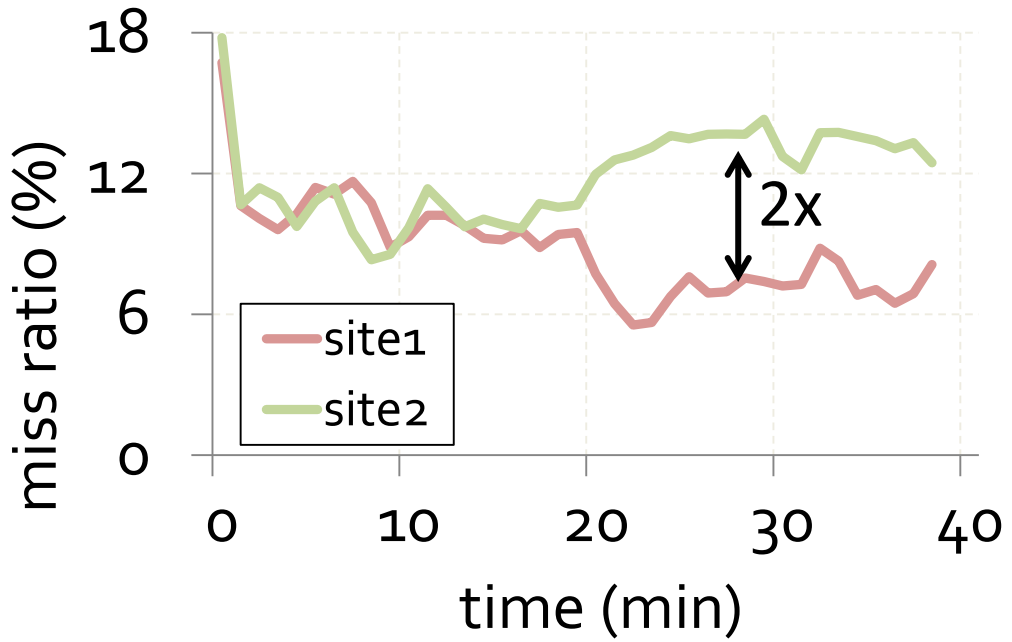

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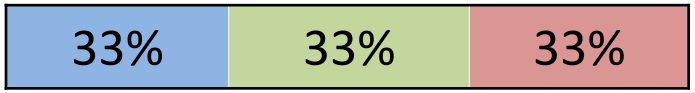

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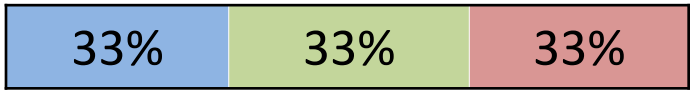

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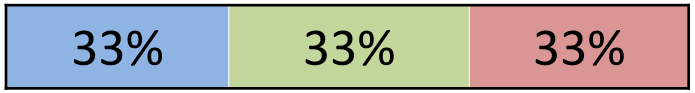
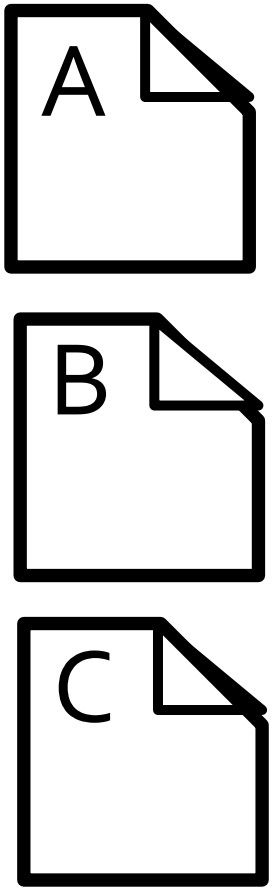


  - Handles if some users want less than fair share

- Widely successful to other resources:
  - OS: round robin, prop sharing, lottery sched…
  - Networking: fair queueing, wfq, wf2q, csfq, drr…
  - Datacenter: DRF, Hadoop fair sched, Quincy…

An example

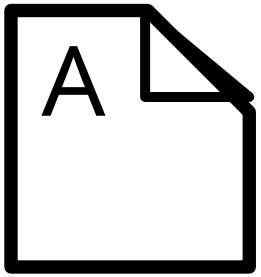
An example

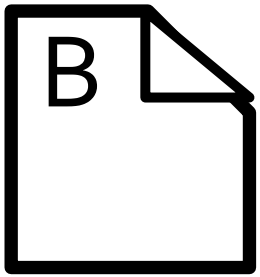


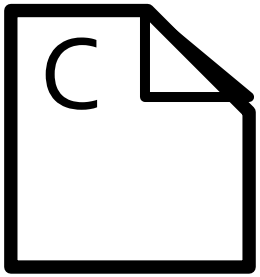
An example

Alice

Bob







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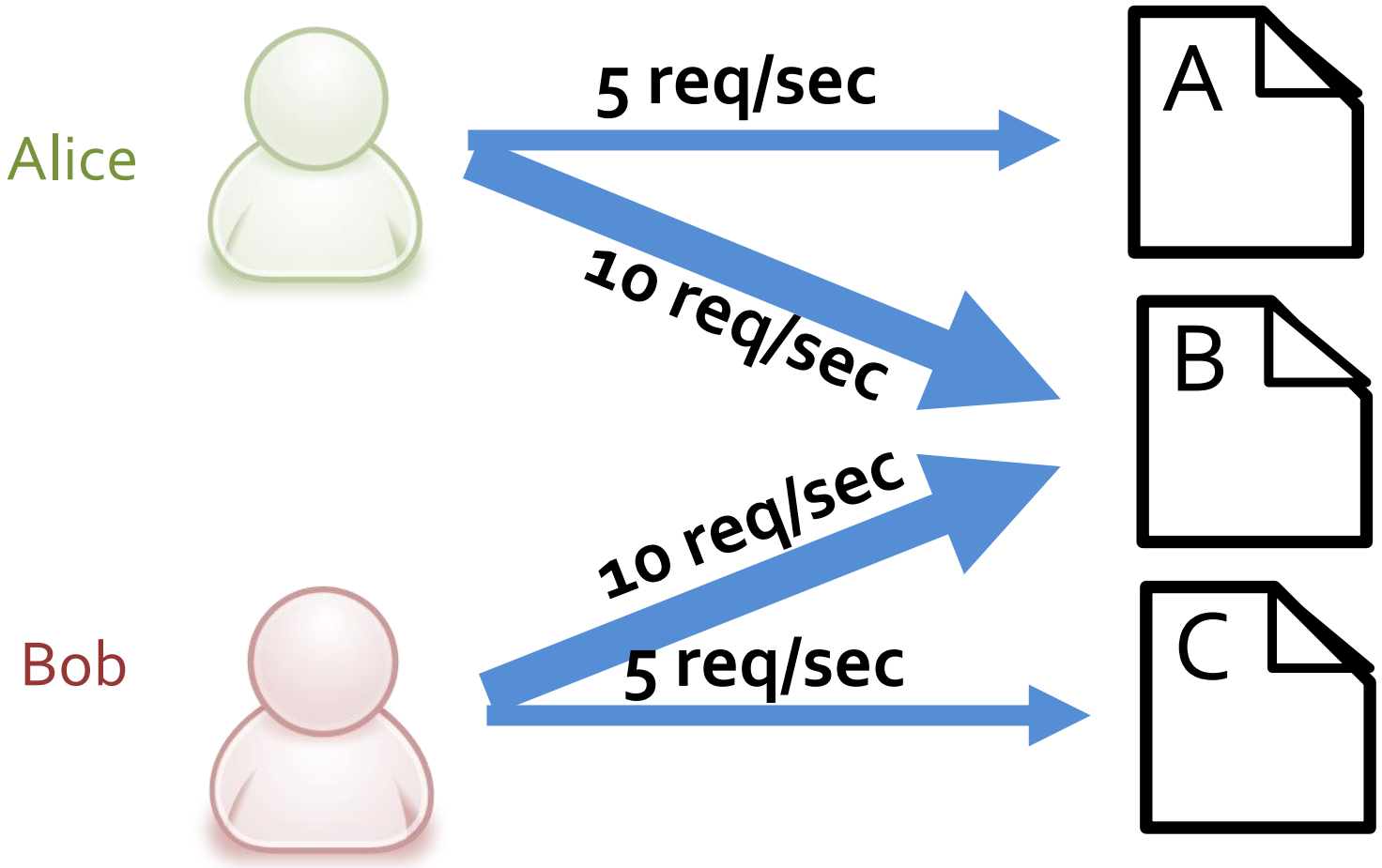

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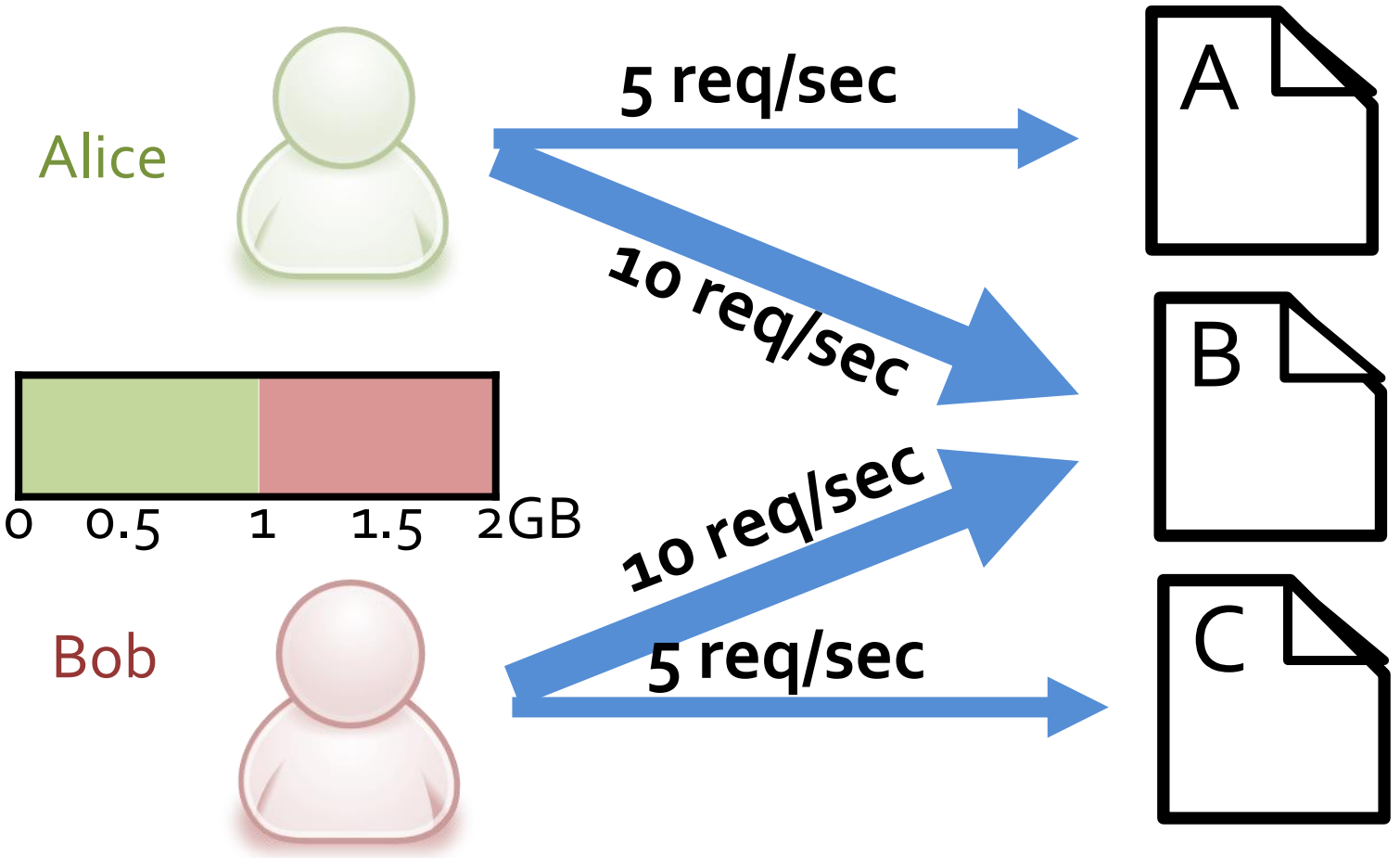
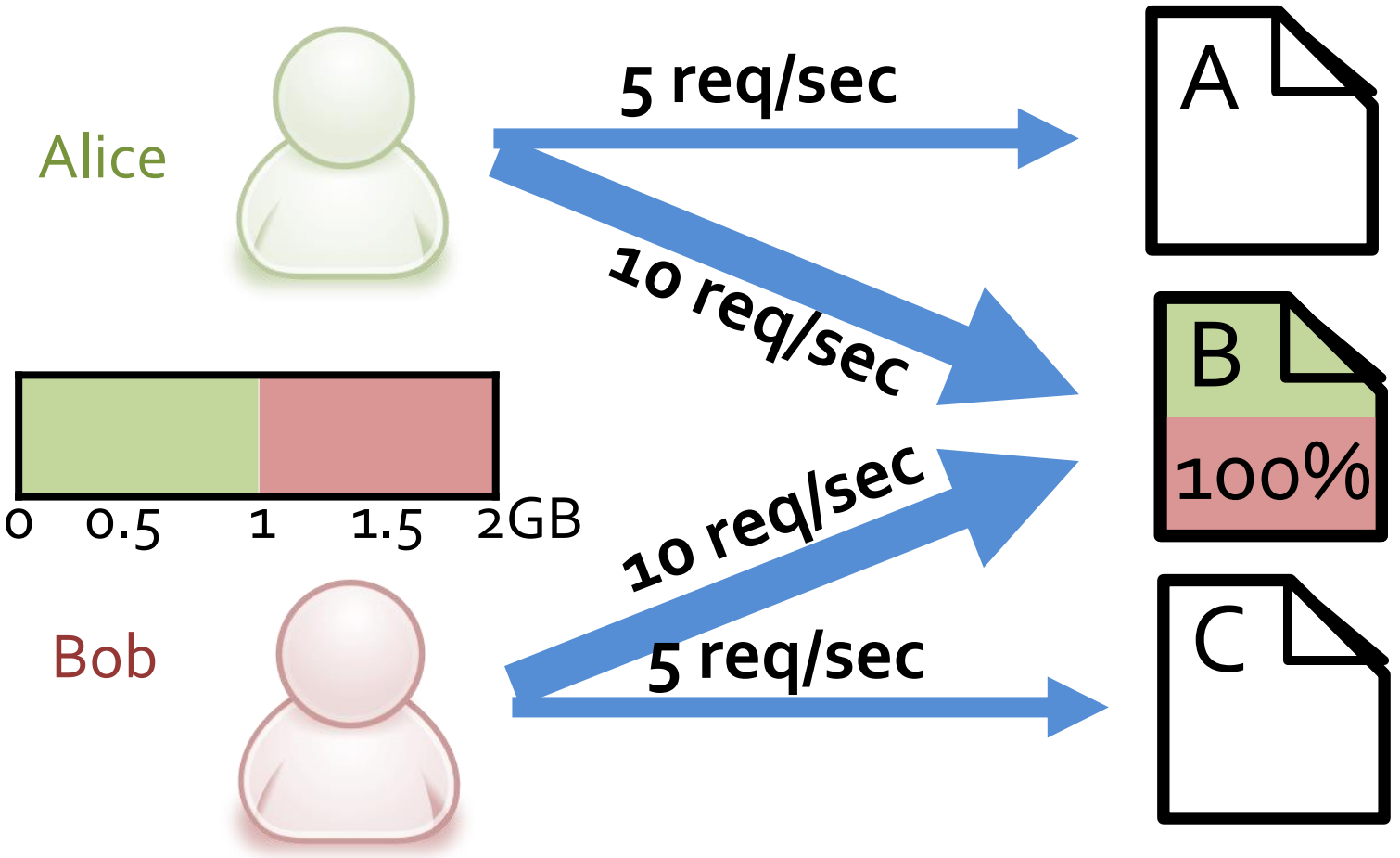


file sizes = 1GB, total cache = 2GB

An example



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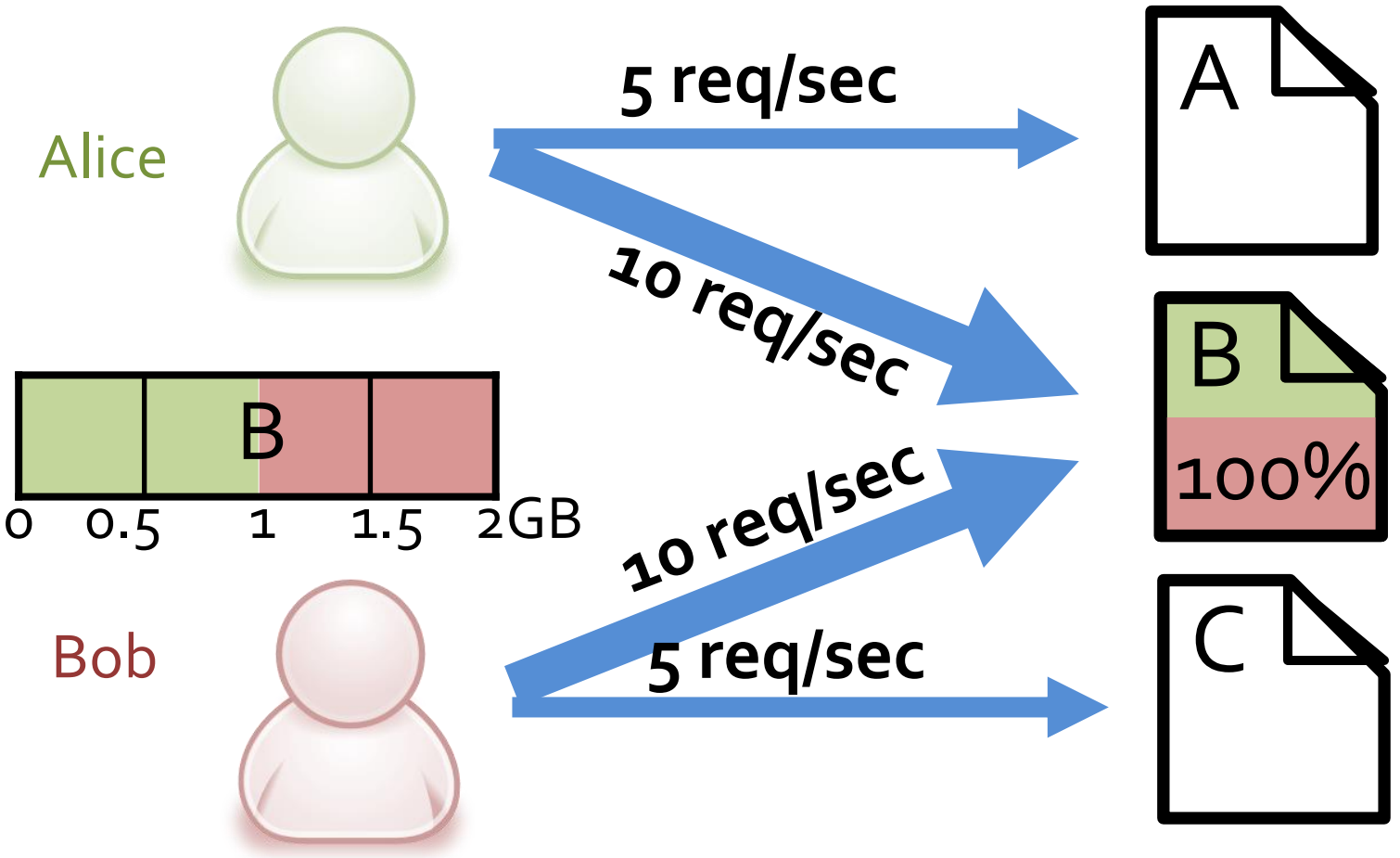

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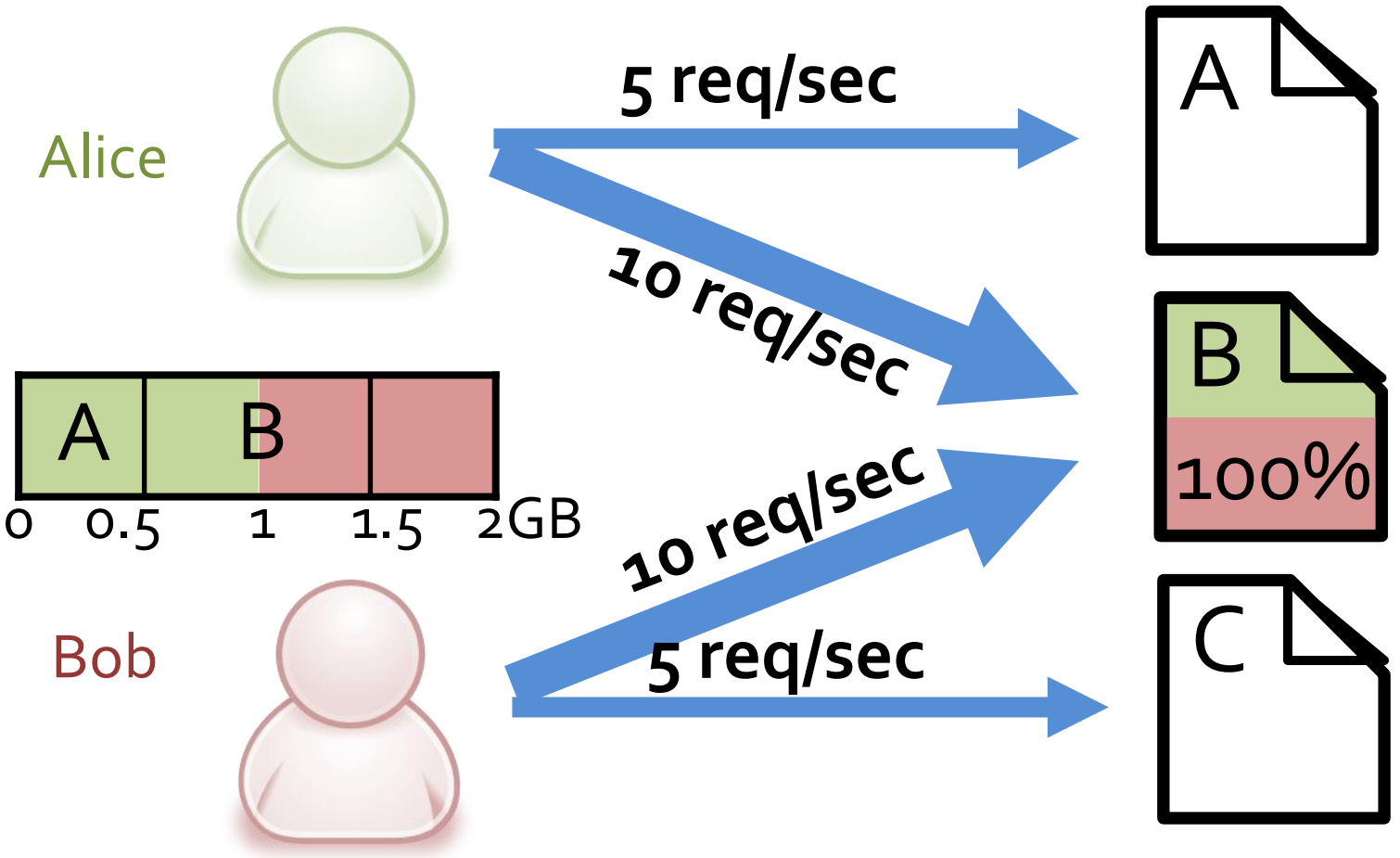

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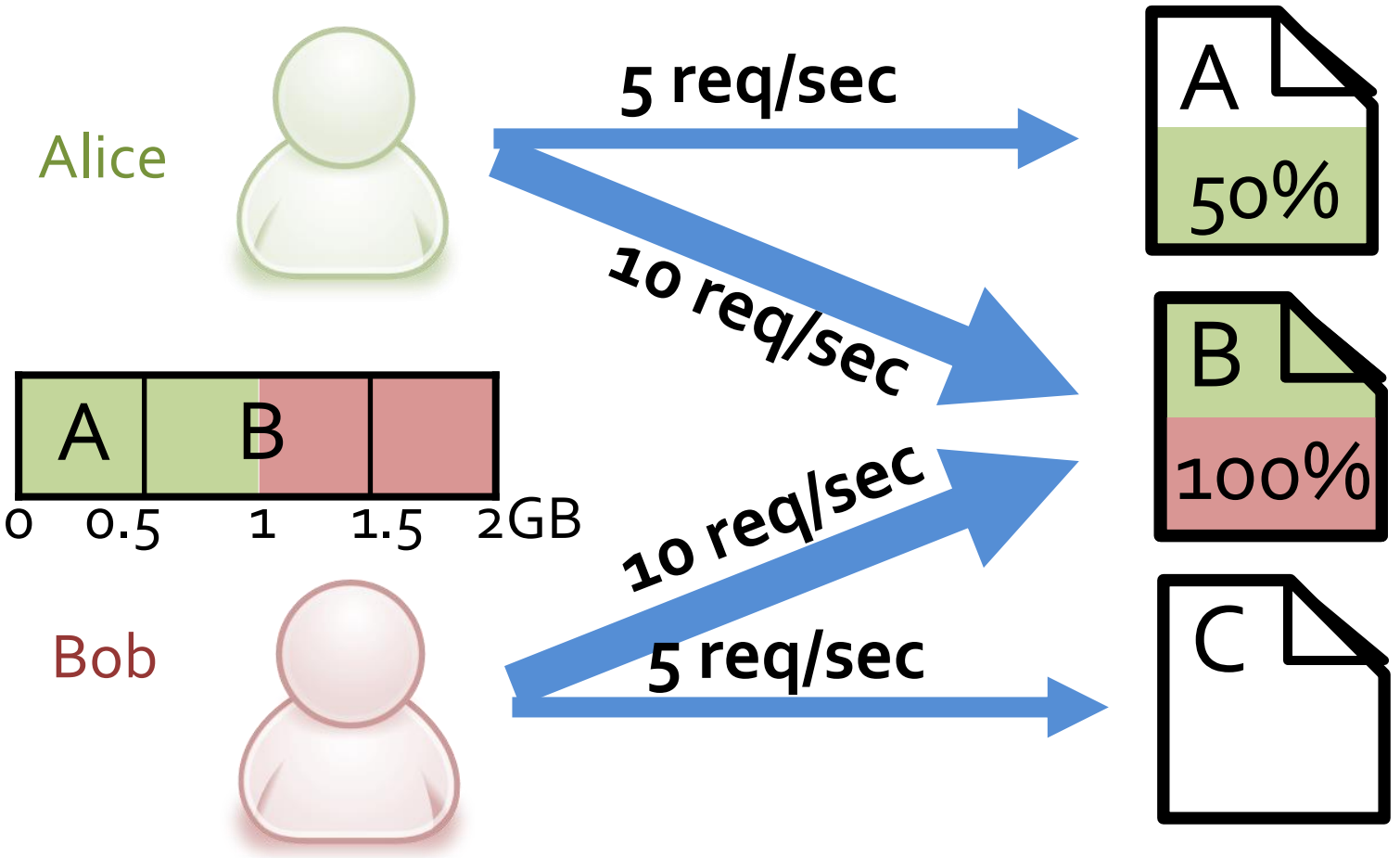
An example



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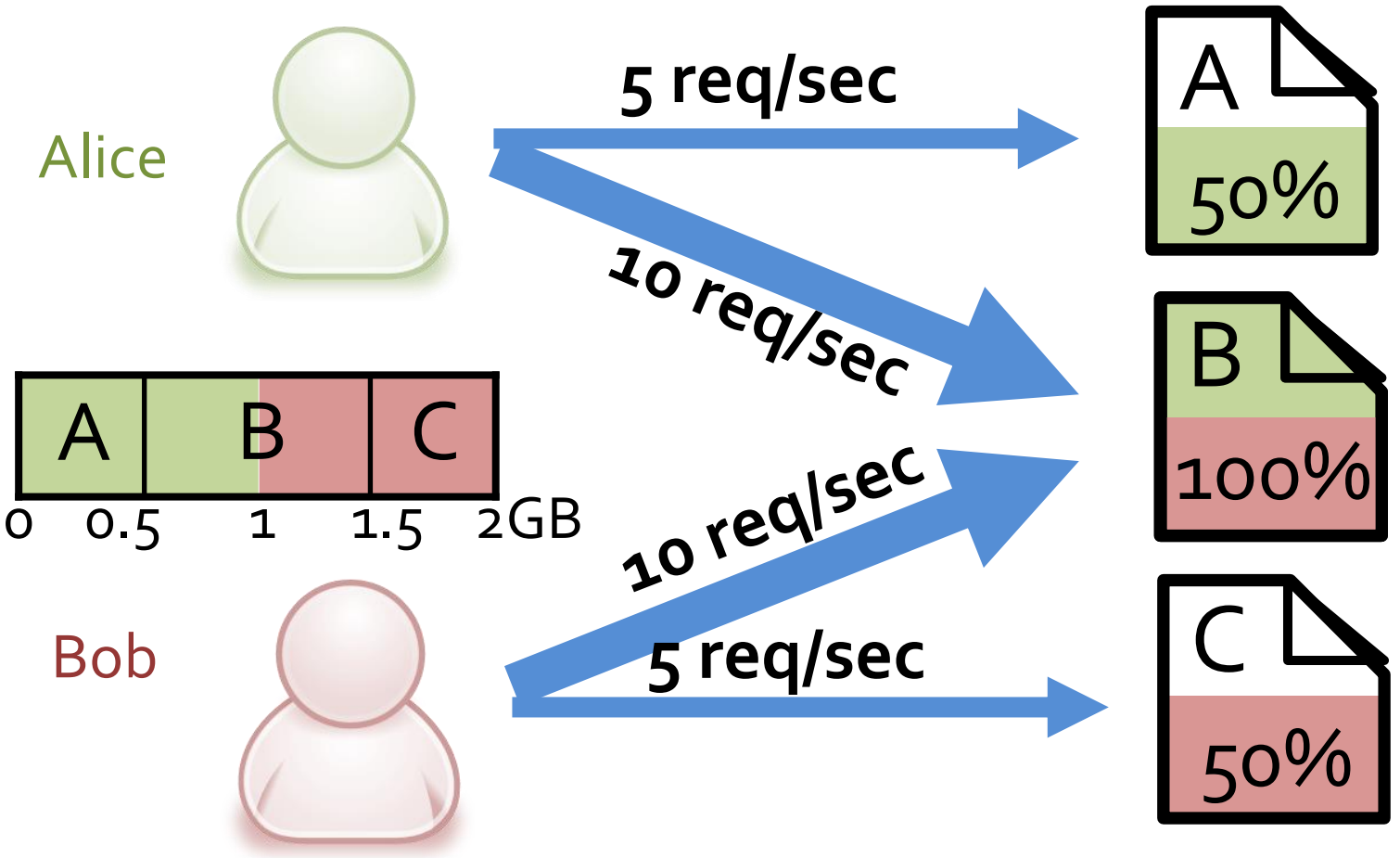

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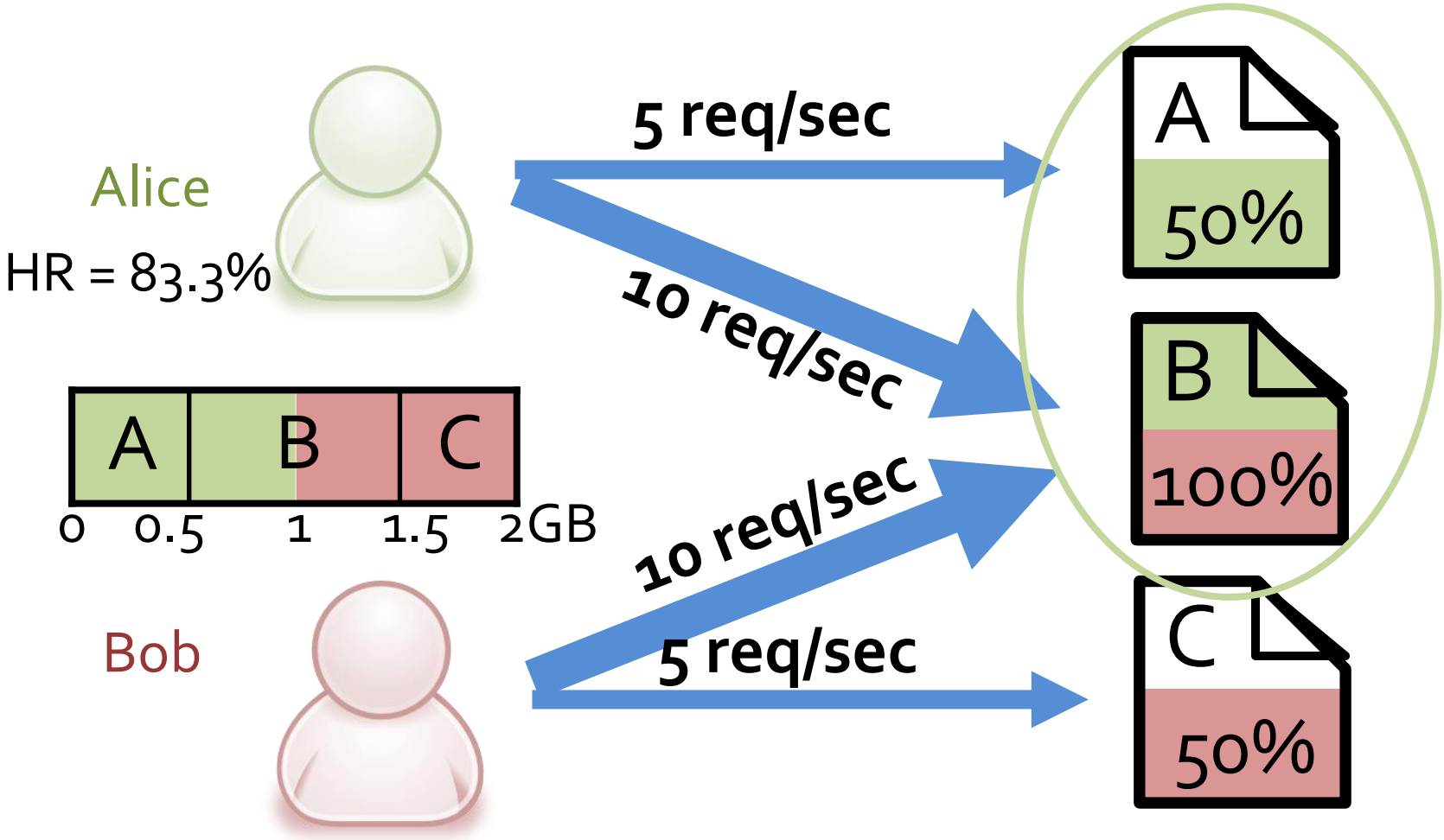

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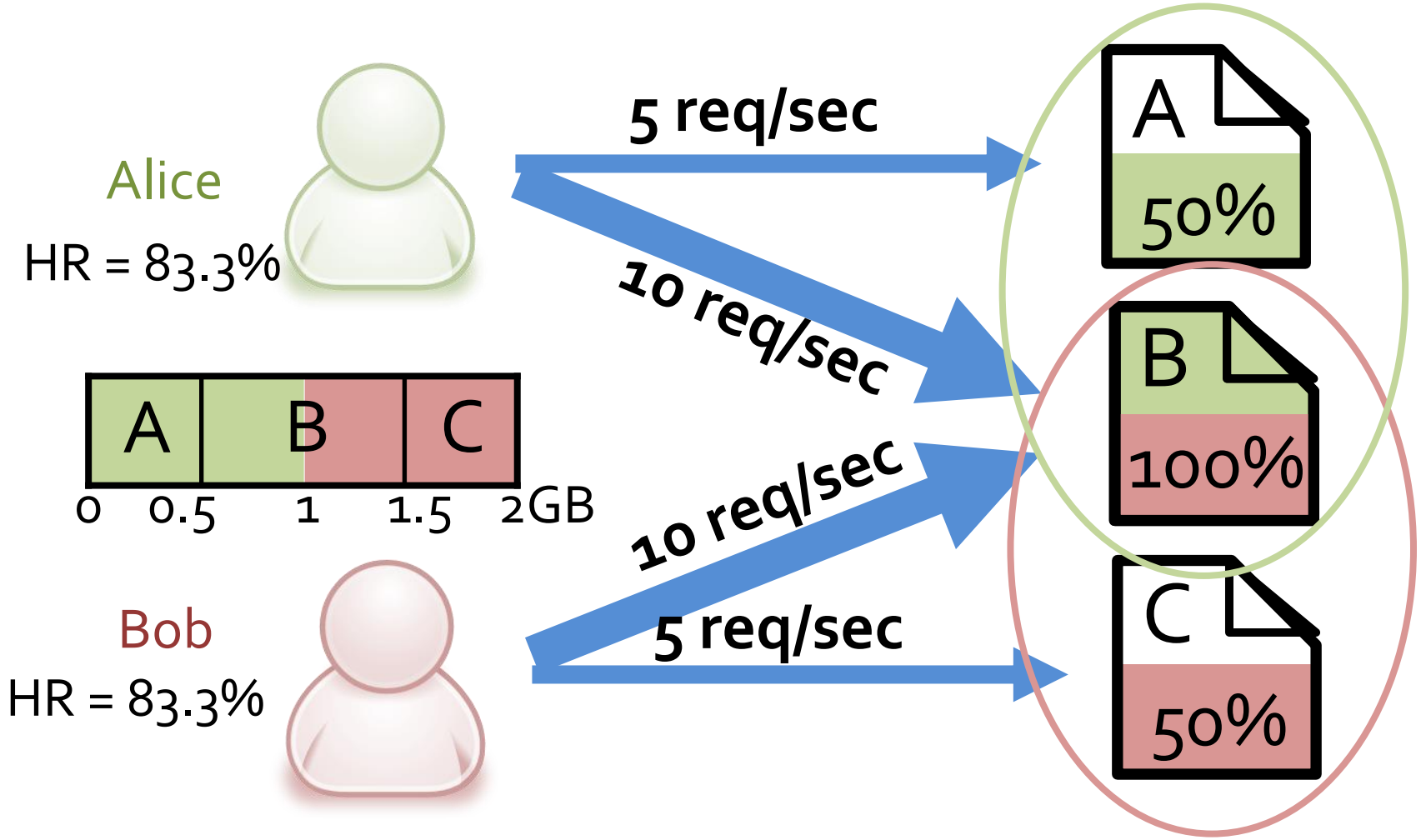


file sizes = 1GB, total cache = 2GB

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness			

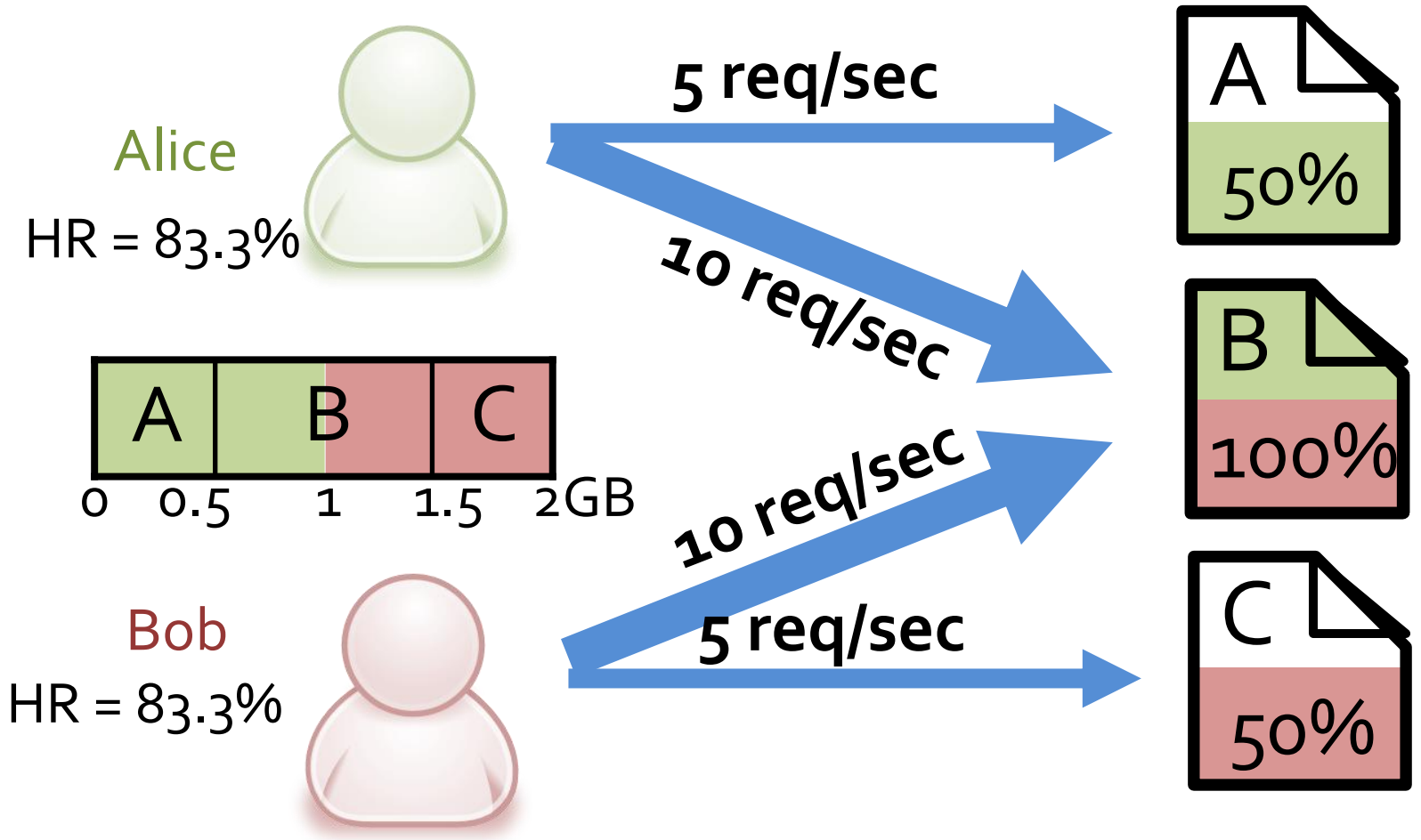
Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓		✓

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	?	✓

An example



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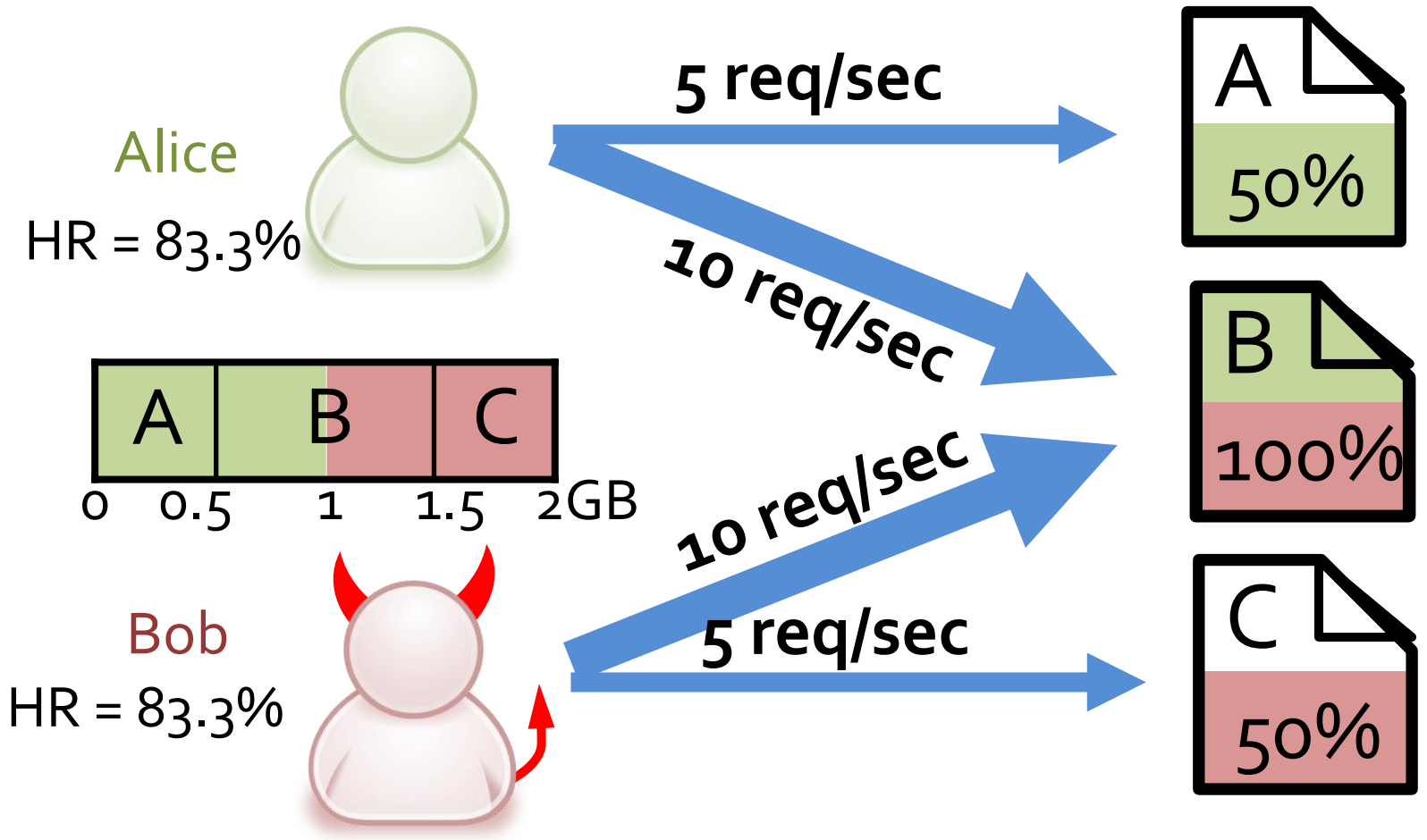

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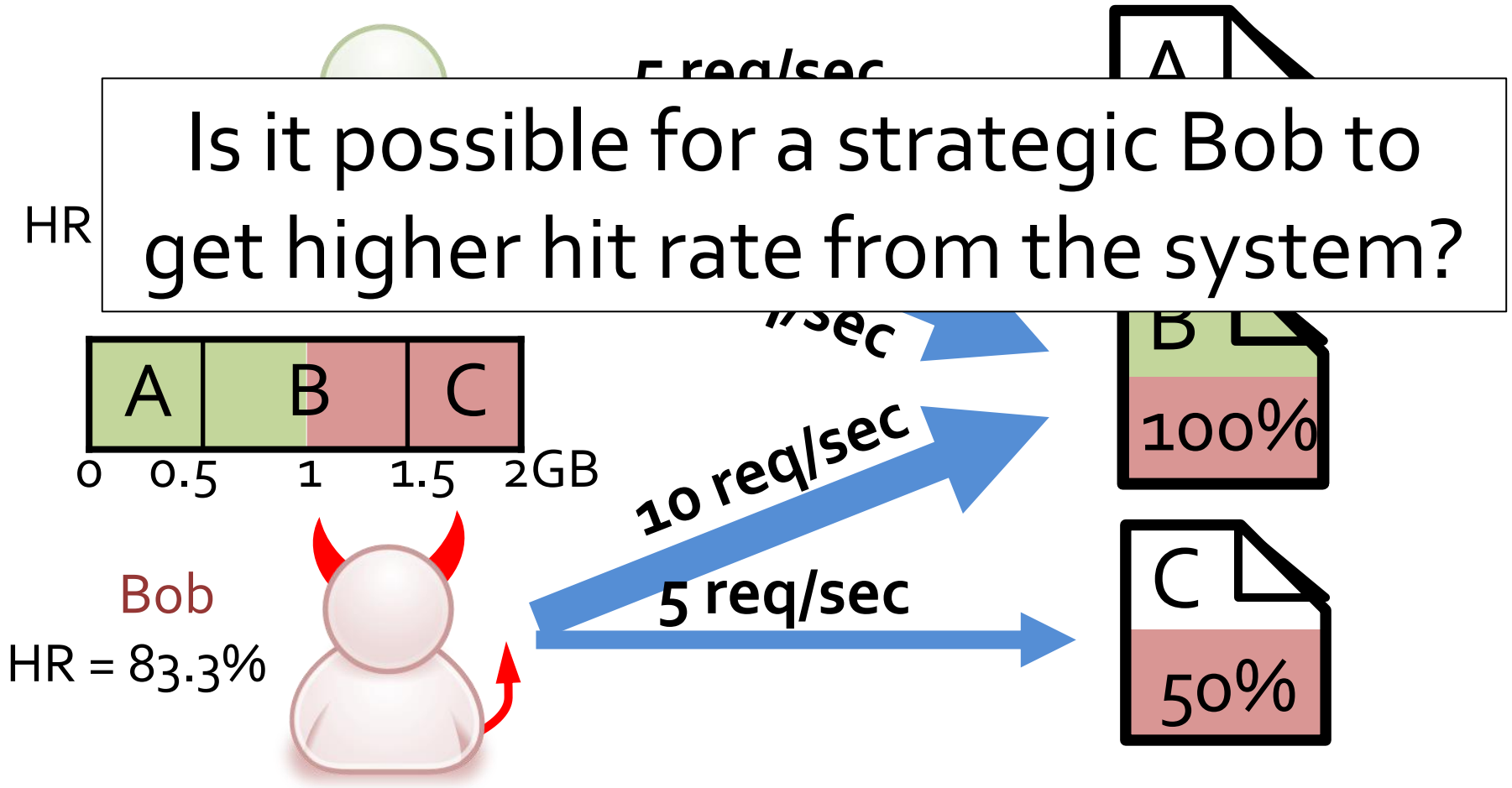

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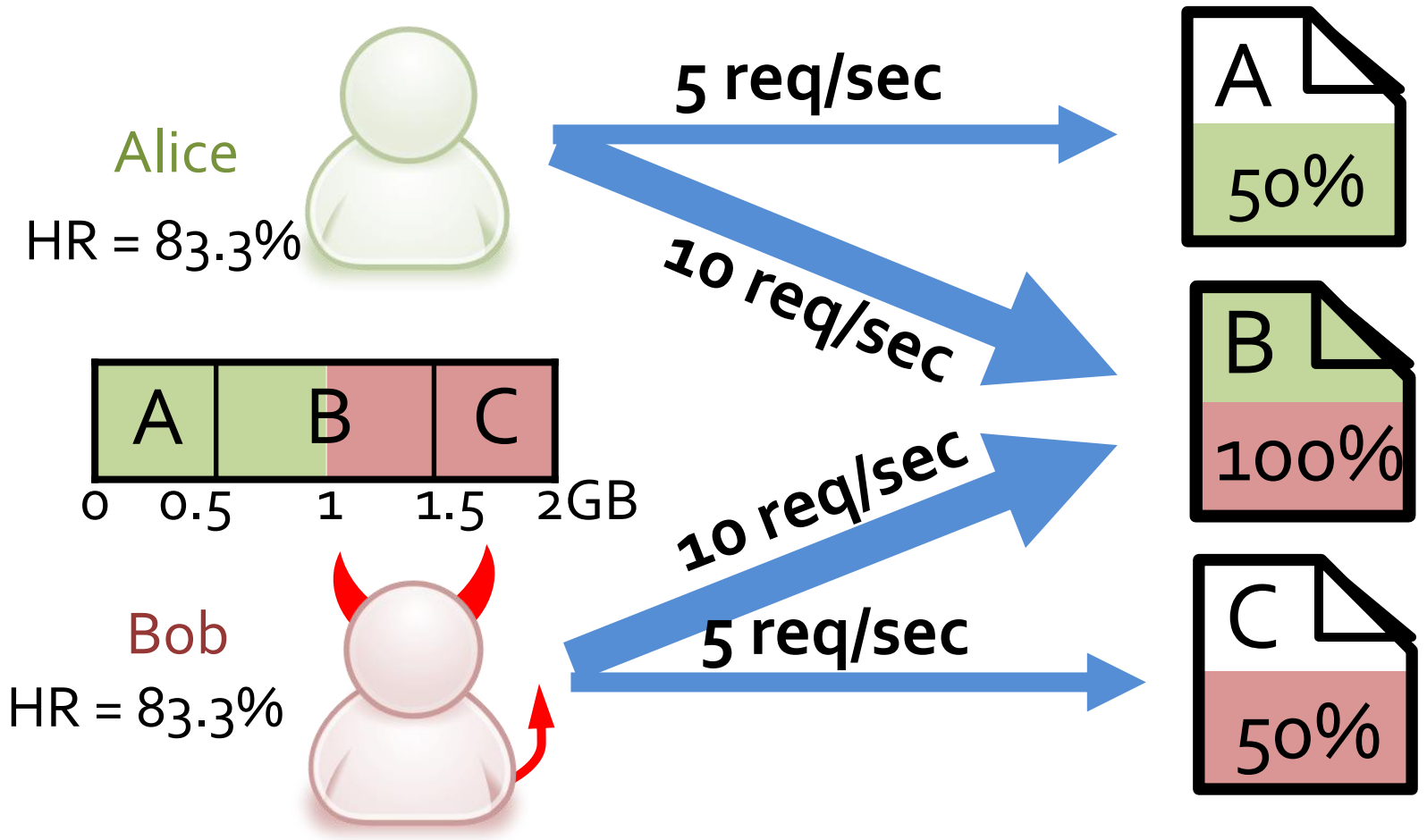

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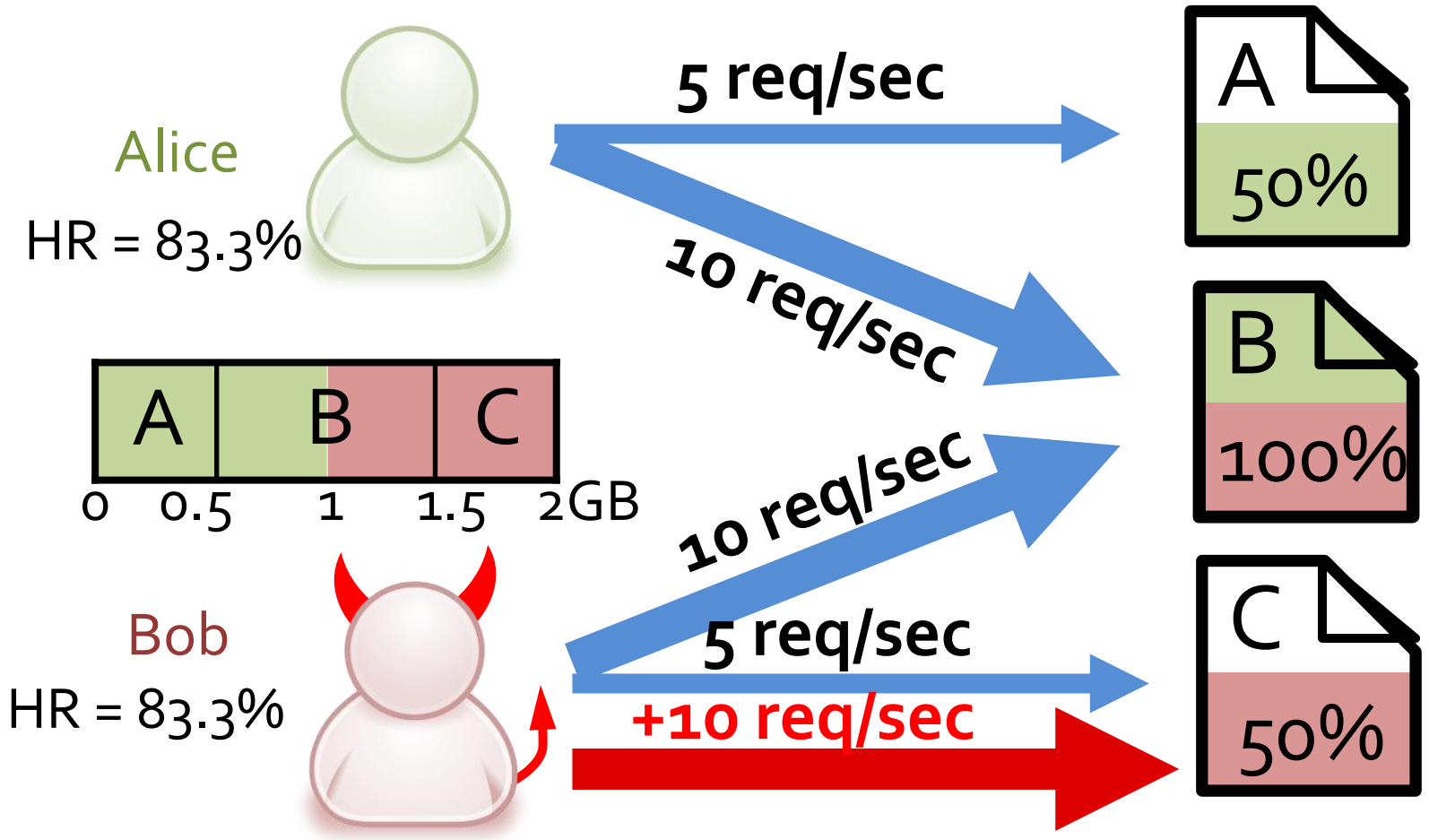

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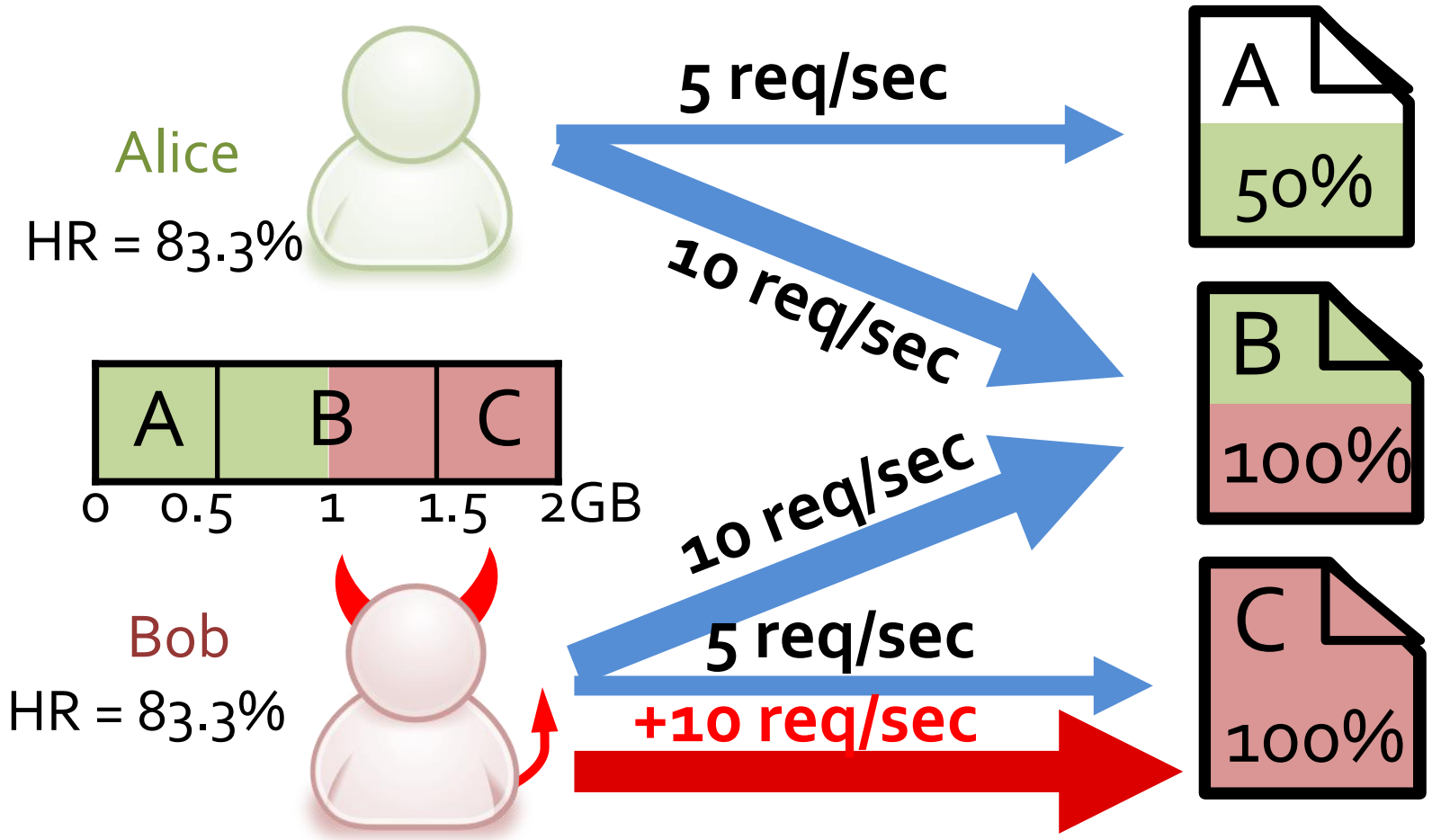

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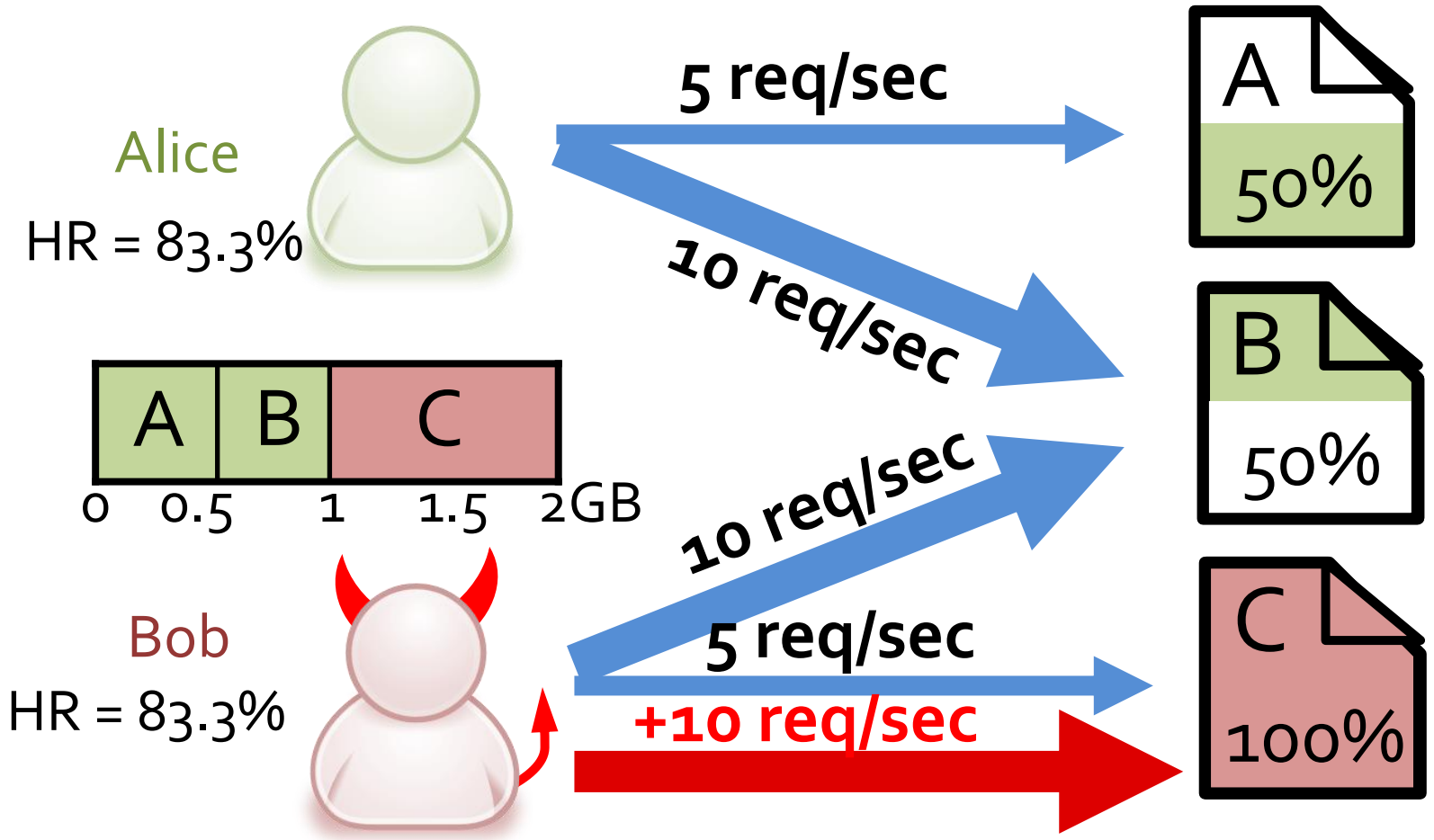

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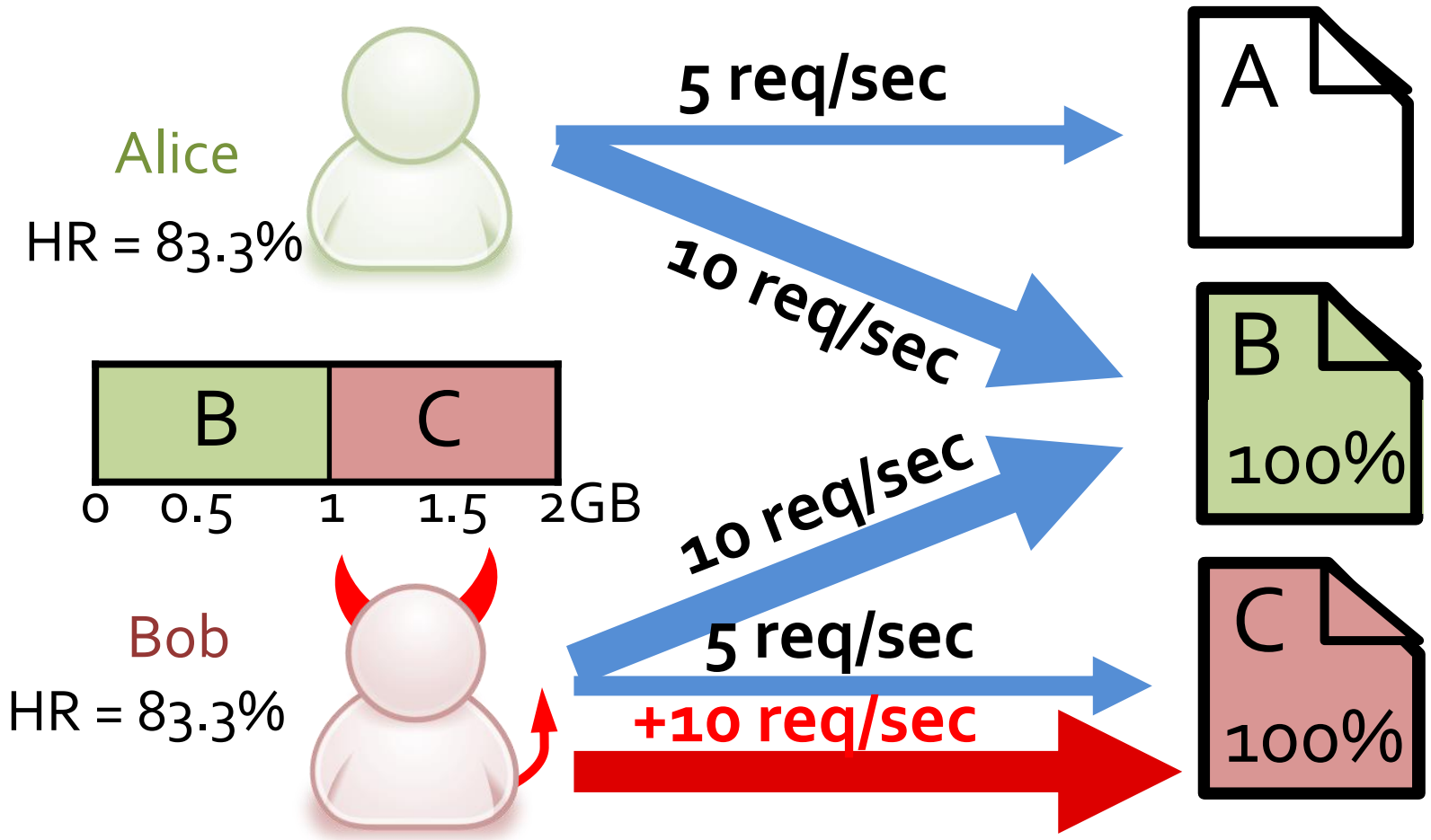

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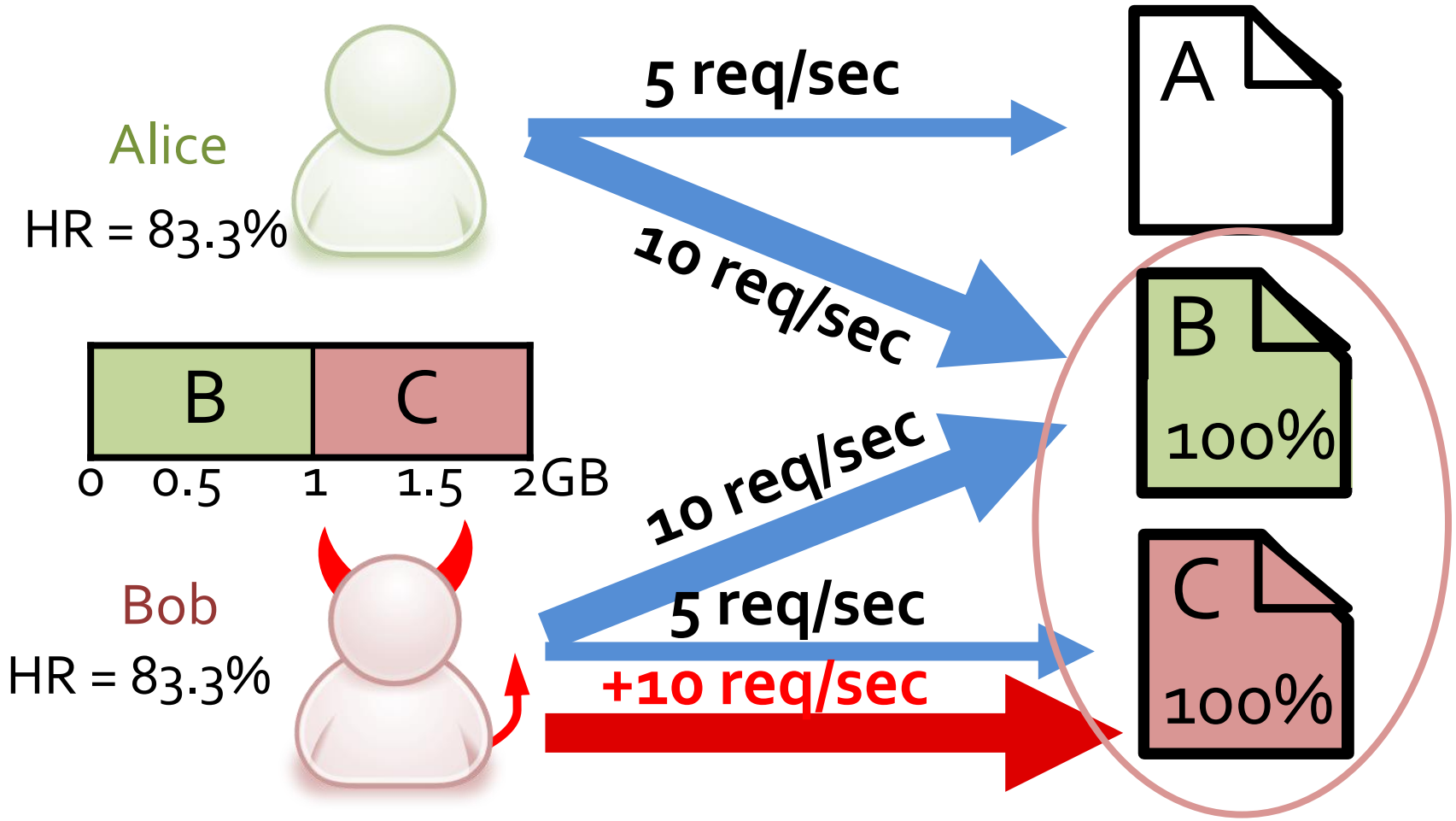
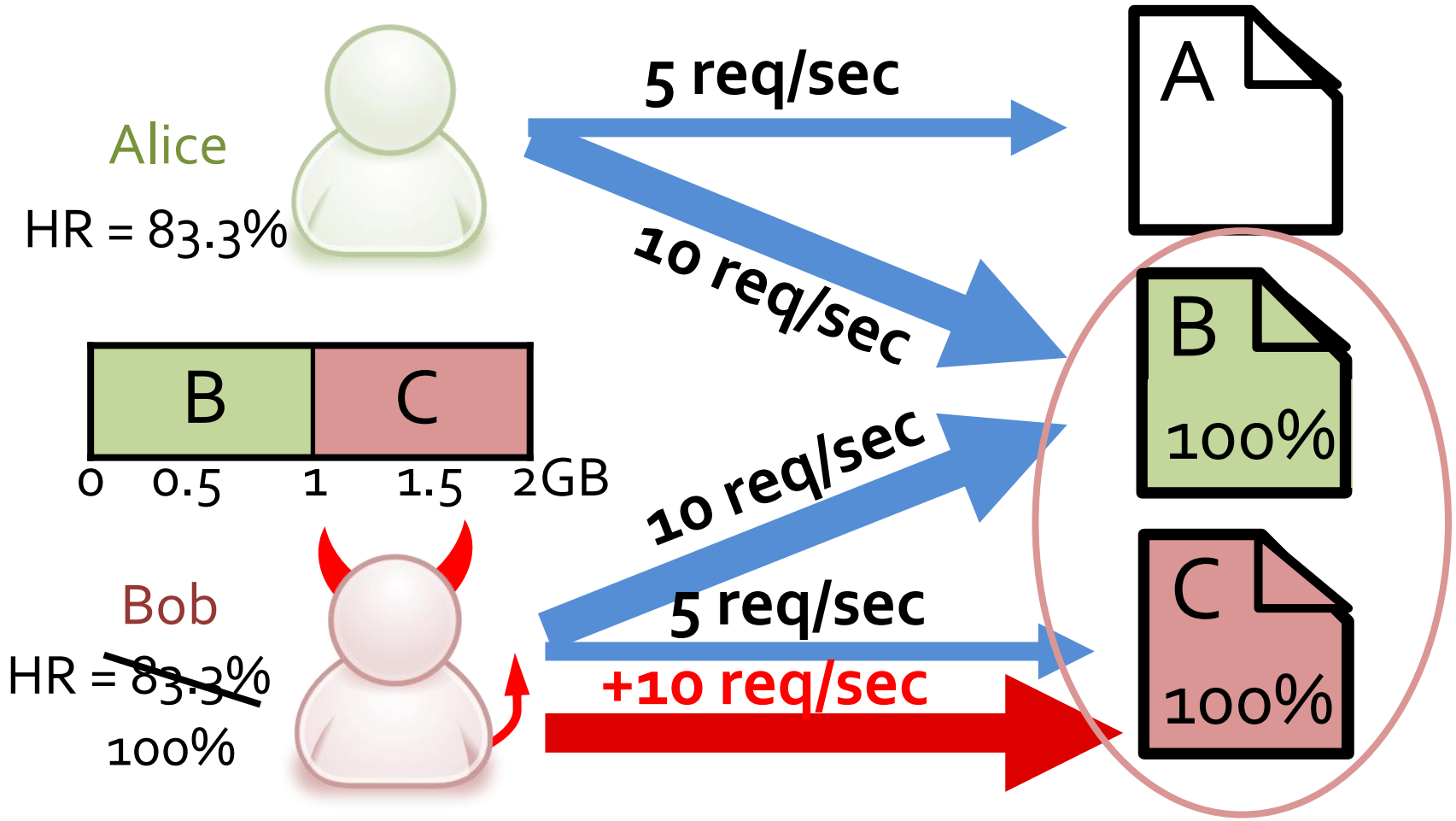


file sizes = 1GB, total cache = 2GB

An example



file sizes = 1GB, total cache = 2GB

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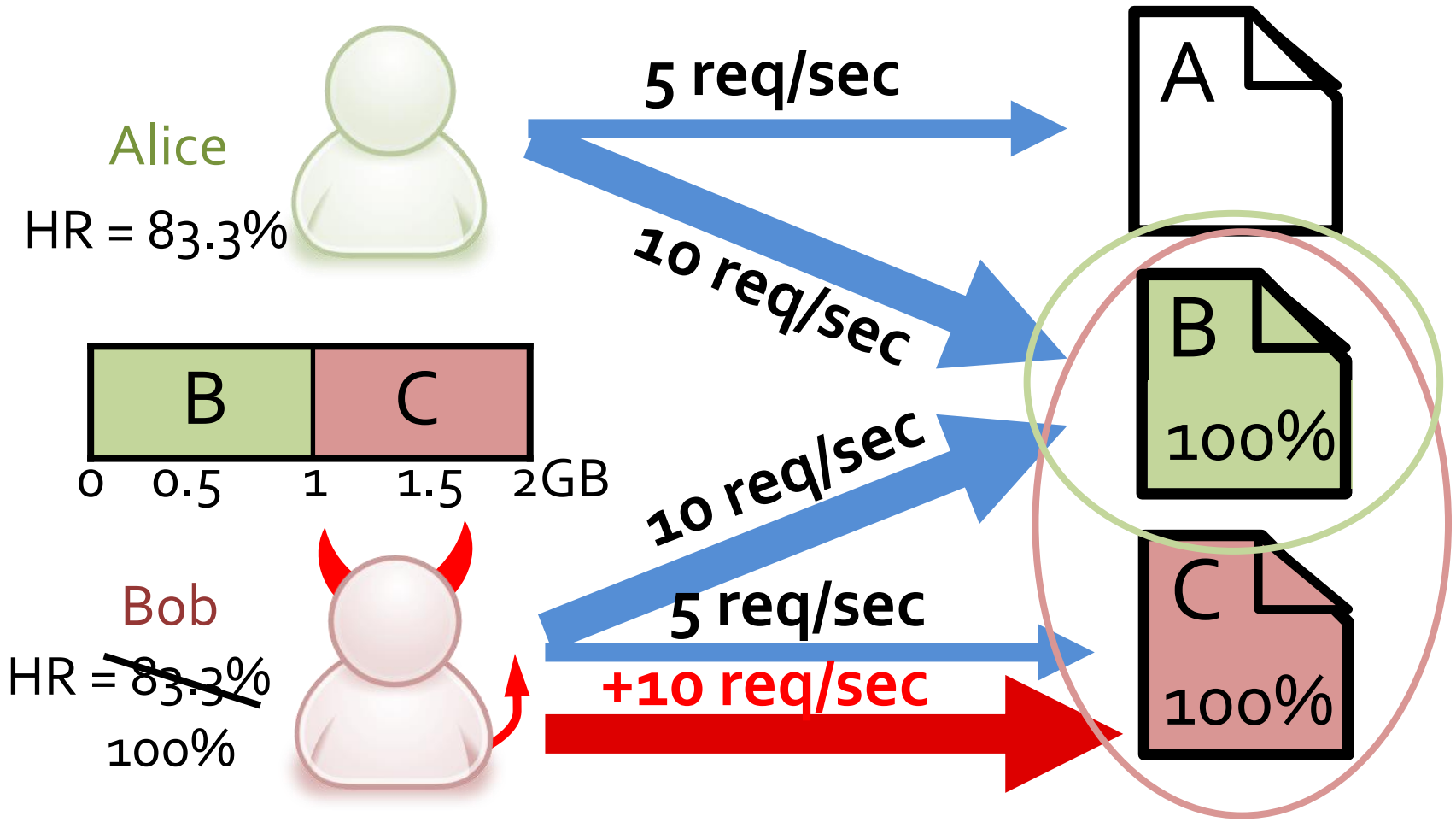

file sizes = 1GB, total cache = 2GB

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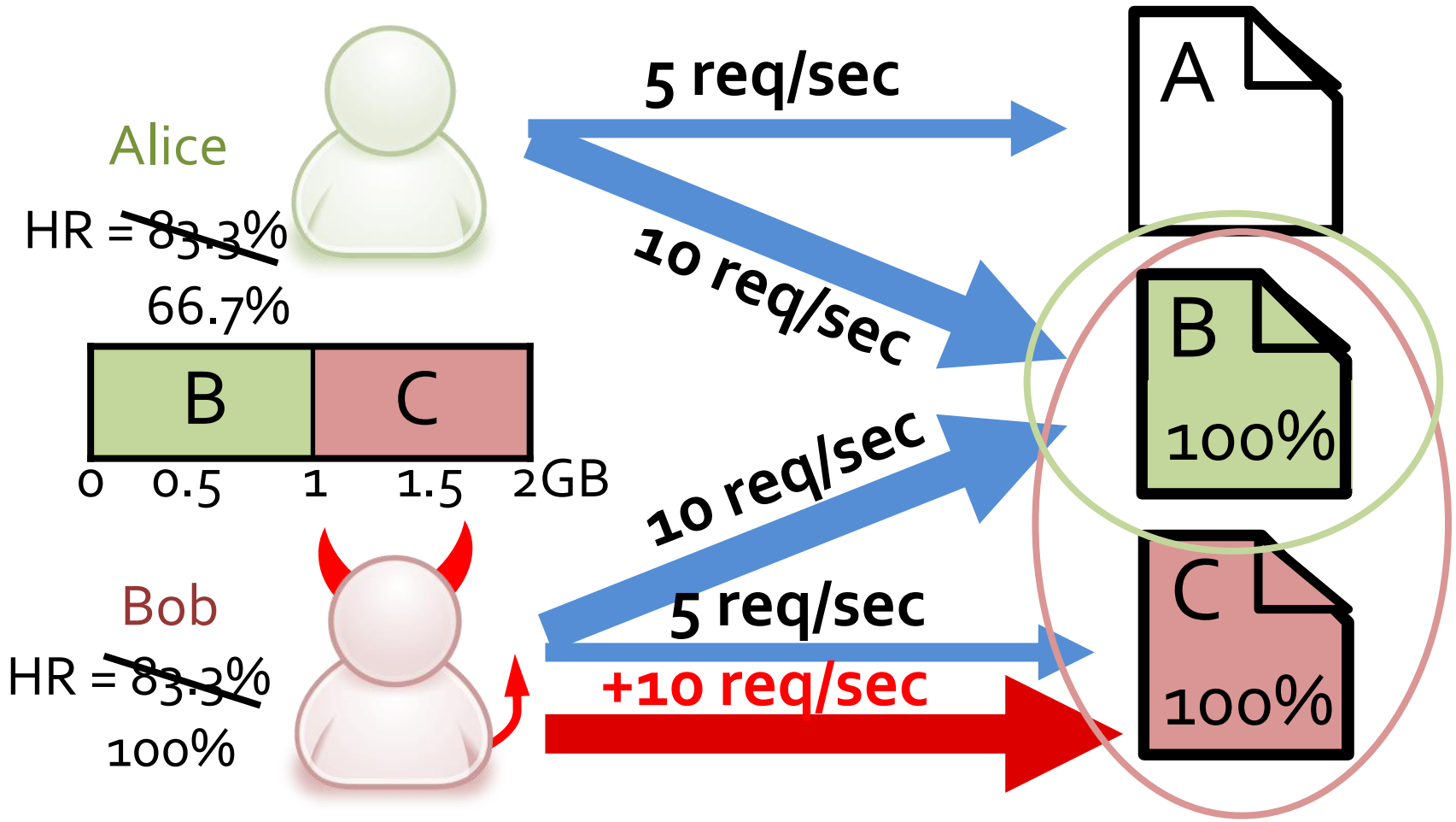

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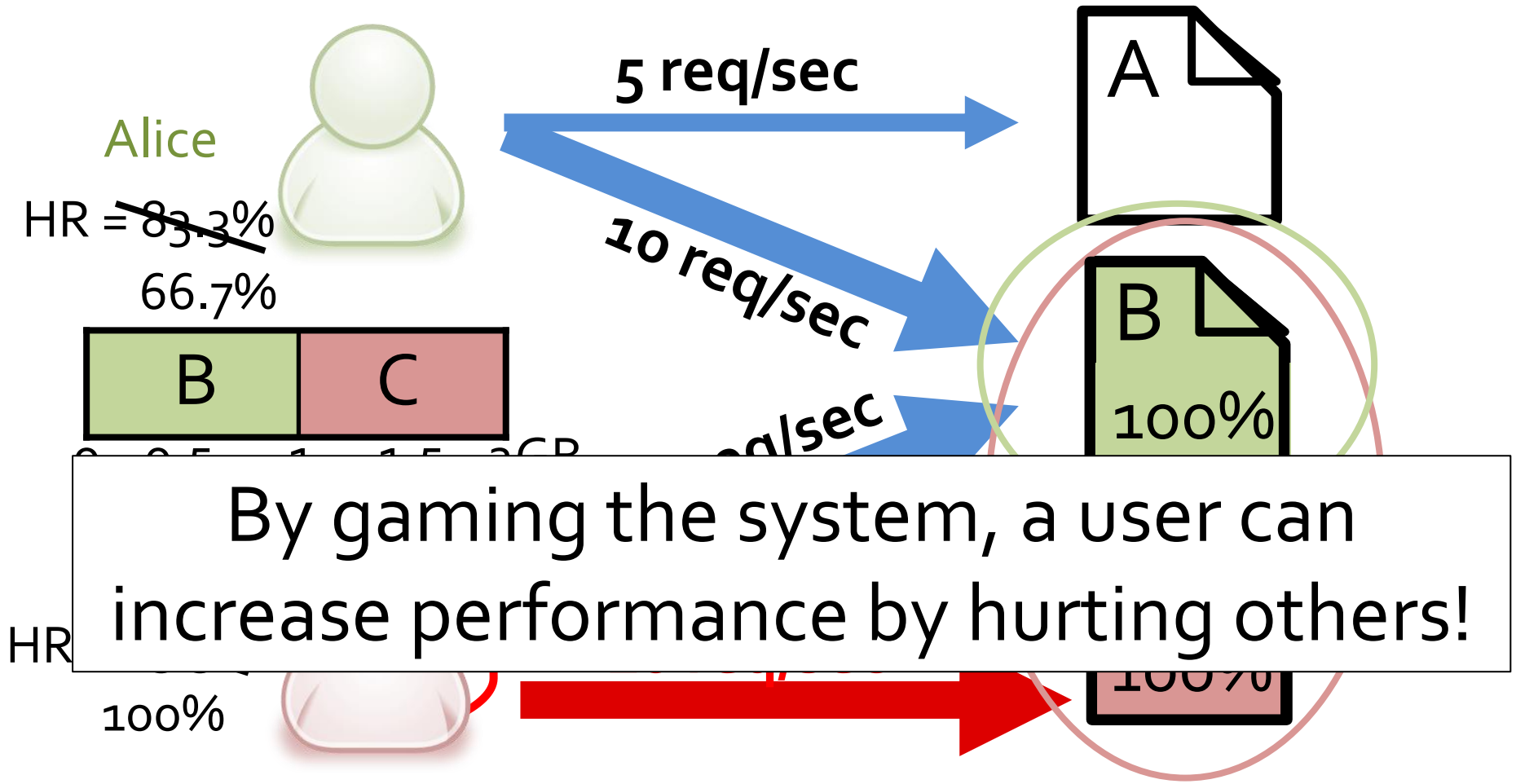

By gaming the system, a user can increase performance by hurting others!

file sizes = 1GB, total cache = 2GB

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓		✓

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	✗	✓

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	✗	✓
static allocation	✓	✓	✗

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	✗	✓
static allocation	✓	✓	✗
priority allocation	✗	✓	✓

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	✗	✓
static allocation	✓	✓	✗
priority allocation	✗	✓	✓
max-min rate	✗	✓	✗
…	…	…	…

Theorem

No allocation policy can satisfy **all three** properties!

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- Best we can do: two of three.

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  - Prevents efficient time multiplexing

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Unlike CPU or network links:

- The cost of "switching" is high
  - Cache misses go to slow storage
  - Prevents efficient time multiplexing

- Can be shared in space
  - **Shared data** can be accessed non-exclusively
  - A CPU cycle used by only one thread
  - A network link sends one packet at a time

Outline

- What properties do we want?
- Can we extend max-min to solve the problem?
- How do we solve it? (FairRide)
- How well does FairRide work in practice?

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	✗	✓
static allocation	✓	✓	✗
priority allocation	✗	✓	✓
max-min rate	✗	✓	✗

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	✗	✓
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FairRide			

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FairRide	✓	✓	

Properties

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max-min fairness	✓	✗	✓
static allocation	✓	✓	✗
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max-min rate	✗	✓	✗
FairRide	✓	✓	Near-optimal

FairRide

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- Starts with max-min fairness
  - Allocate 1/n to each user
  - Split "cost" of shared files equally among shared users

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- Only difference:

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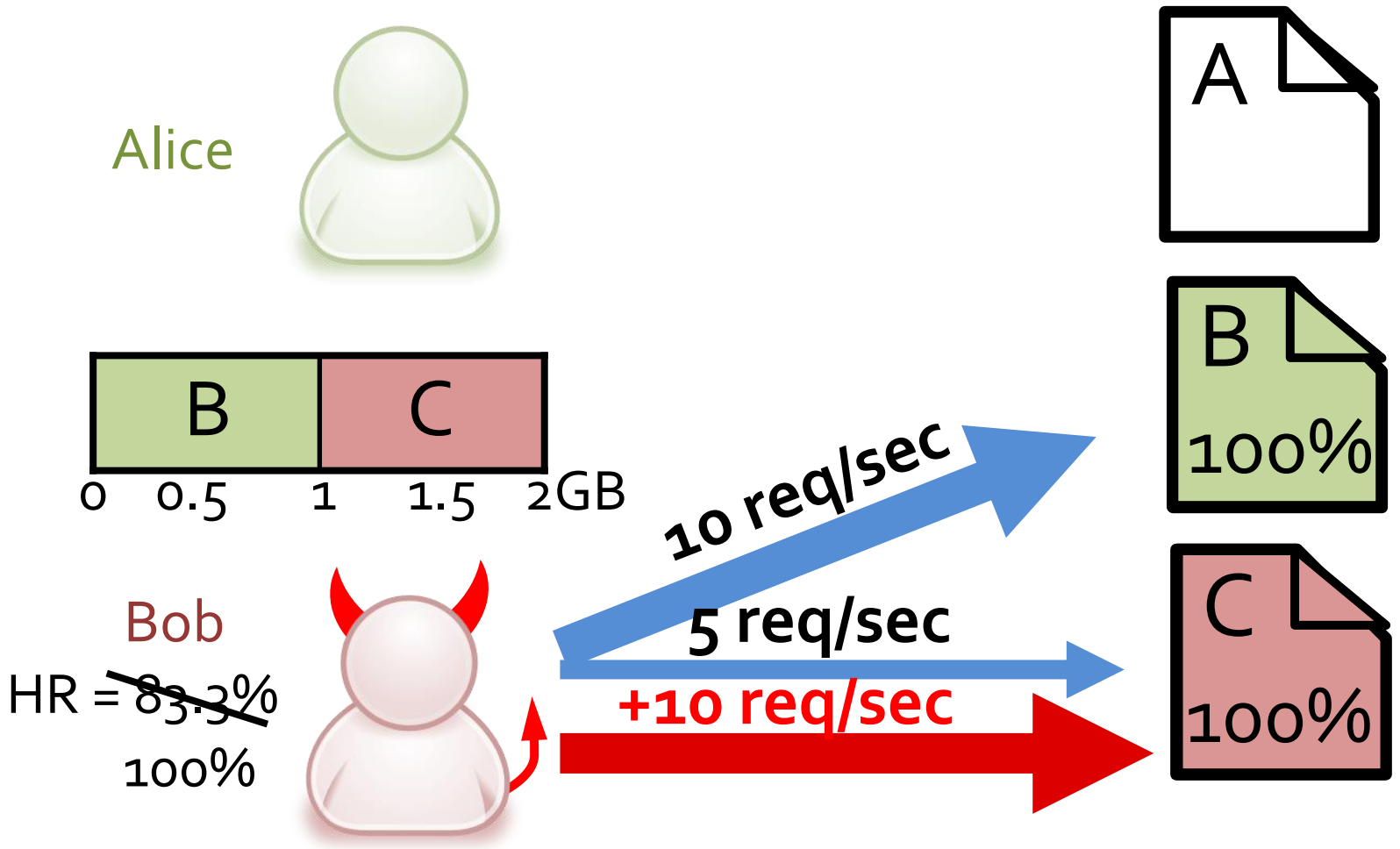
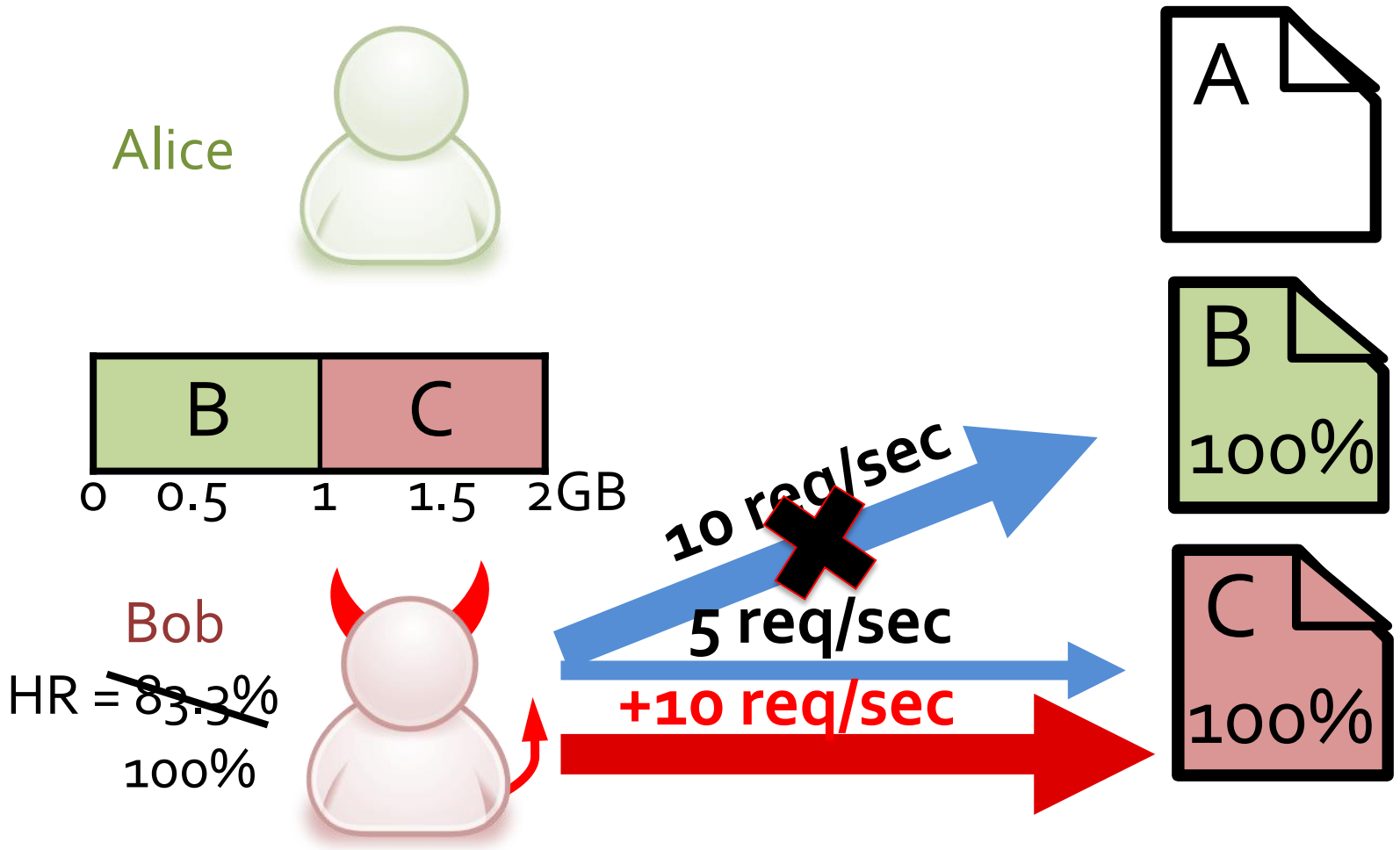
- Probabilistic blocking: with some probability
  - Implemented with delaying

FairRide: Blocking



FairRide: Blocking



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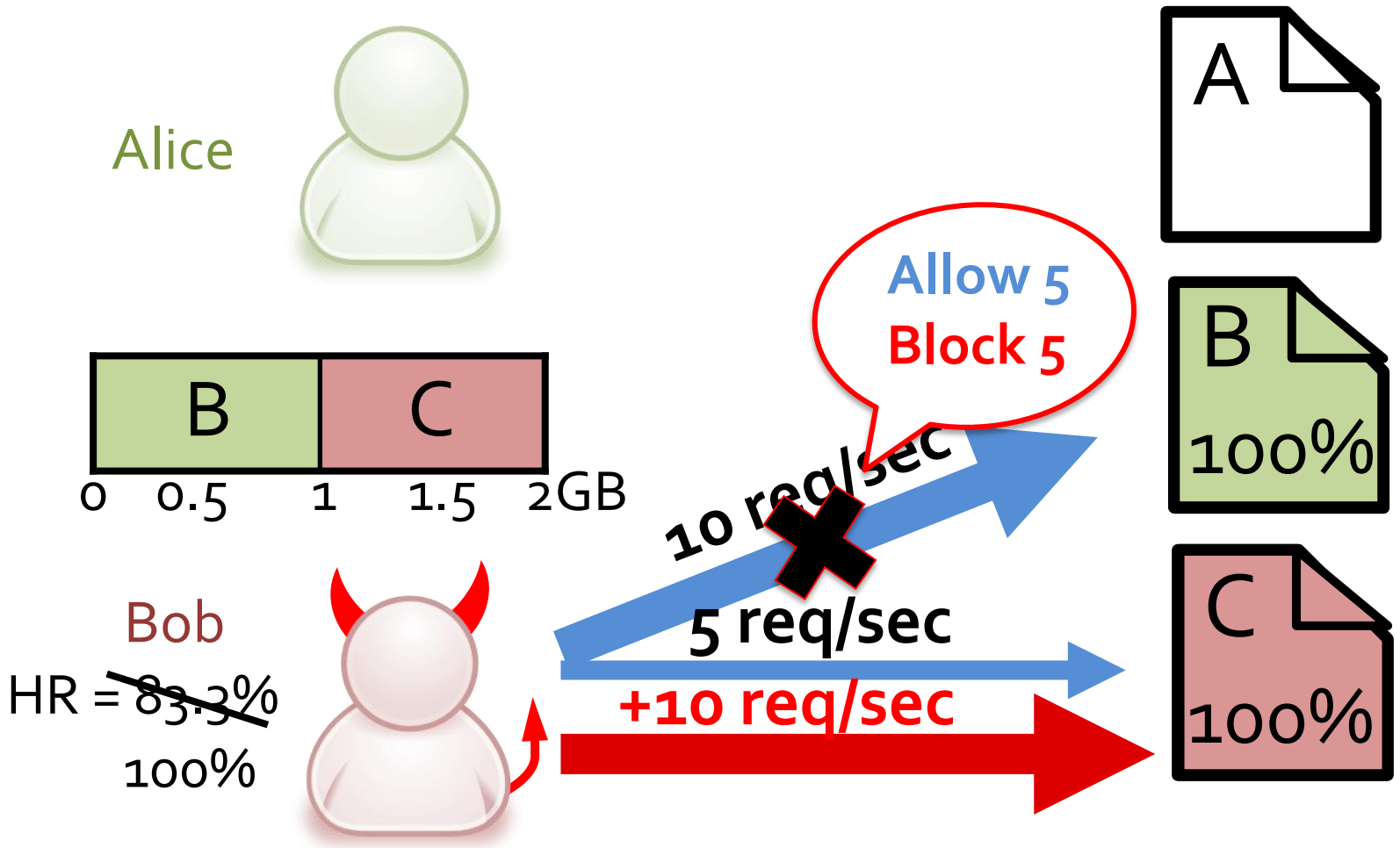

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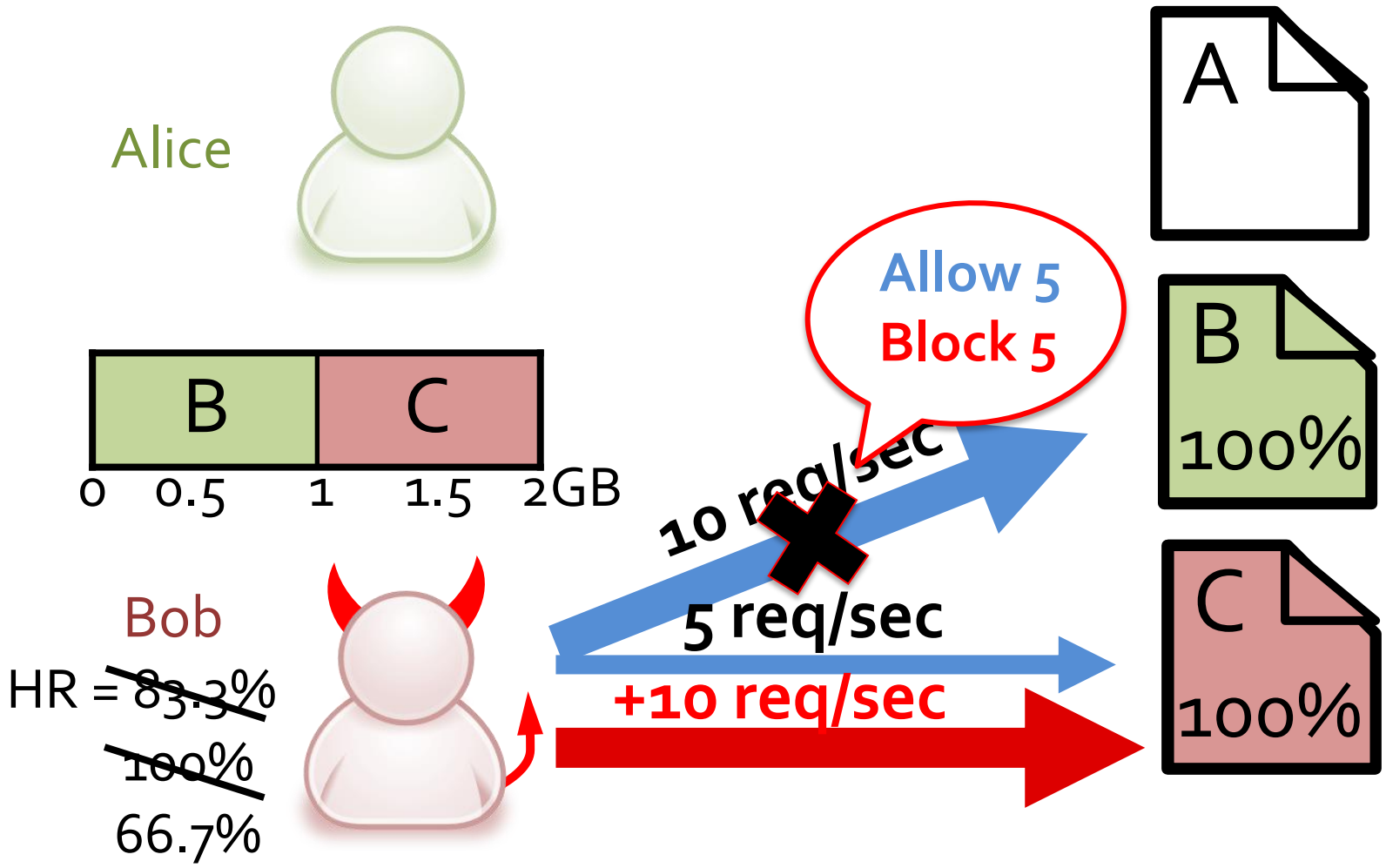
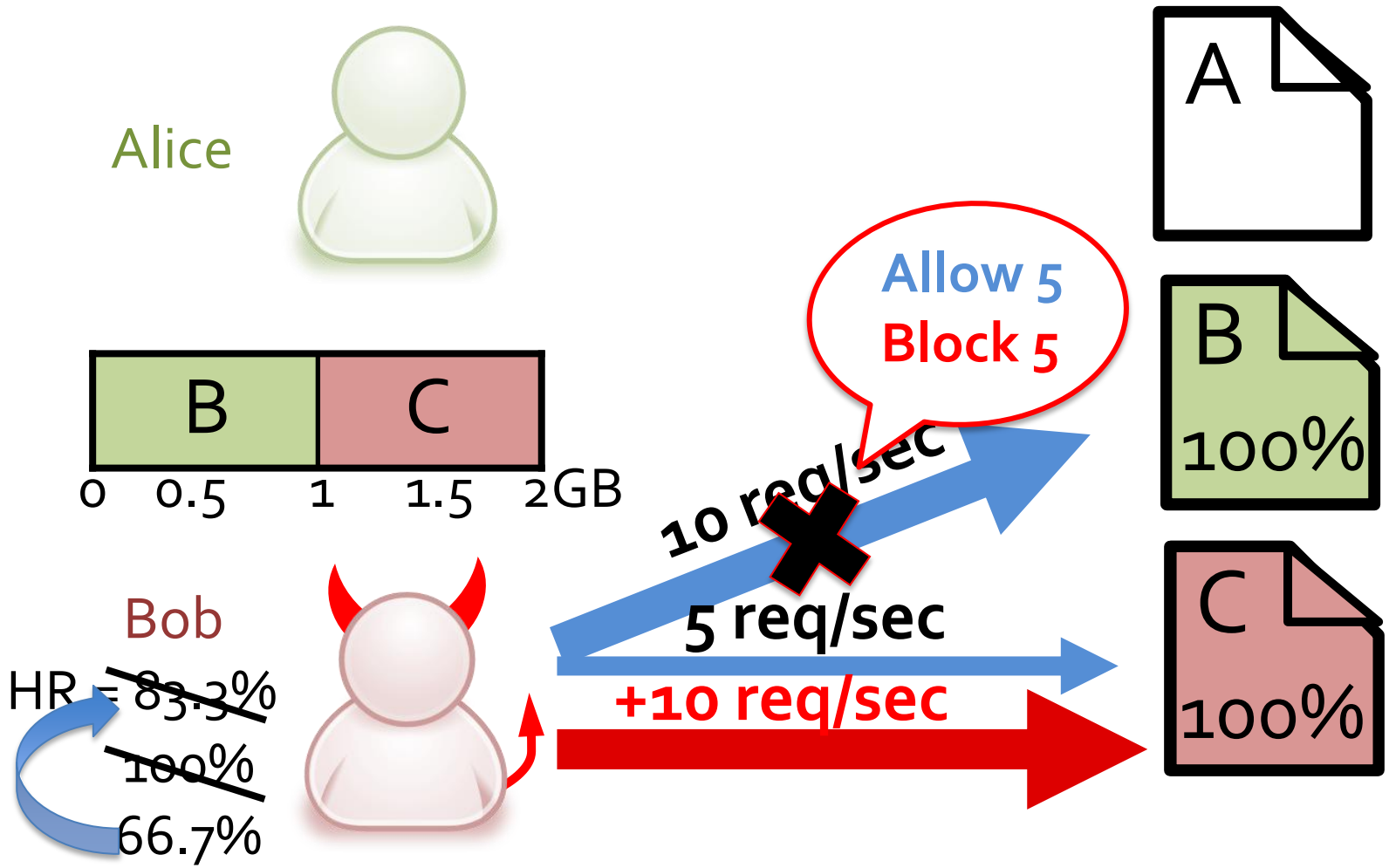
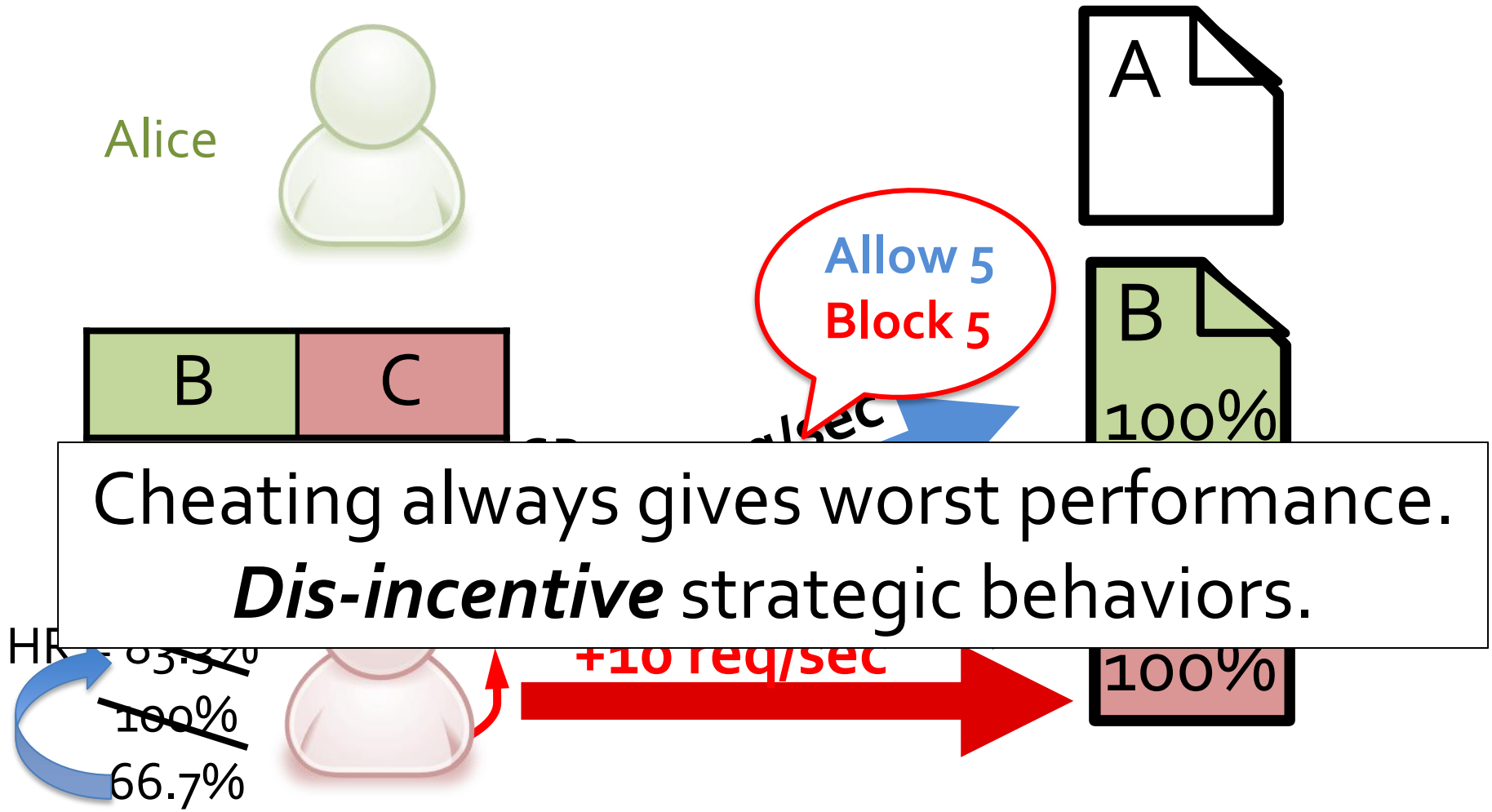


FairRide: Blocking



FairRide: Blocking



Cheating always gives worst performance.

Dis-incentive strategic behaviors.

Probabilistic blocking

Probabilistic blocking

- FairRide blocks a user with ***p(nj) = 1/(nj+1)*** probability
  - *nj* is number of other users caching file *j*
  - e.g., p(1)=50%, p(4)=20%

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- The best you can do in a general case
  - **Less blocking does not prevent cheating**

Properties

	Isolation Guarantee	Strategy Proofness	Pareto Efficiency
max-min fairness	✓	✗	✓
static allocation	✓	✓	✗
priority allocation	✗	✓	✓
max-min rate	✗	✓	✗
FairRide	✓	✓	Near-optimal

Strategy-proofness vs. Pareto-efficiency

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- More efficient when user cheats
  - Minimal impact on efficiency when no user cheats

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  - The latter is small *insurance* for the former

Strategy-proofness vs. Pareto-efficiency

- More efficient when user cheats
  - Minimal impact on efficiency when no user cheats
- Cost of cheating vs. cost of blocking/delaying
  - The latter is small *insurance* for the former
- Strategy-proofness makes the system stable

Outline

- What properties do we want?
- Can we extend max-min to solve the problem?
- How do we solve it? (FairRide)
- How well does FairRide work in practice?

Evaluation

- Implemented in Alluxio (formerly Tachyon)

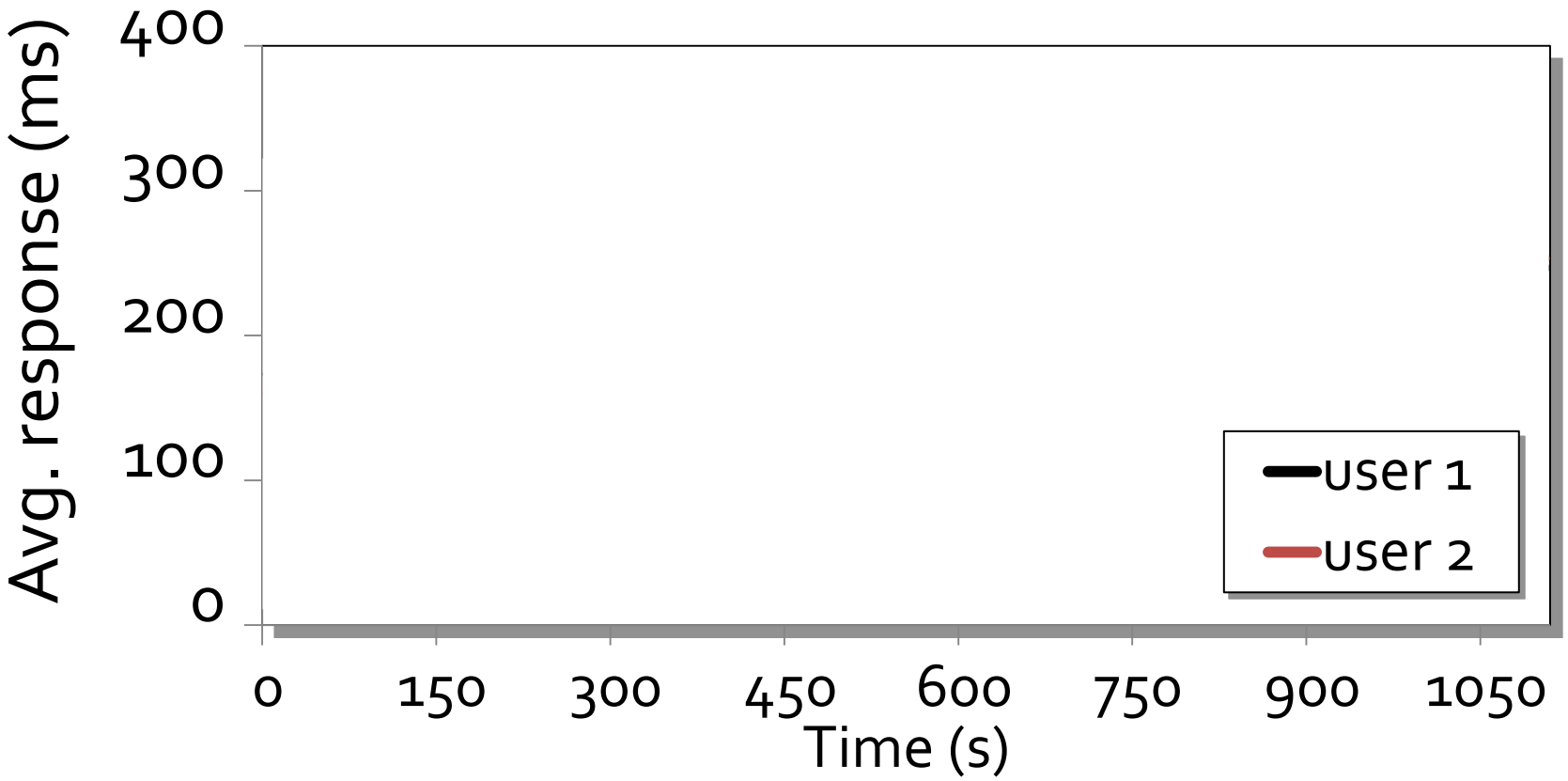
- FairRide: delay a request as if blocked
- Compared with max-min fairness.

- Benchmarked with TPC-H, YCSB, Facebook workloads.

Evaluation

- Does FairRide prevent cheating?
- What is the cost of FairRide?
- How does it perform end-to-end?

Cheating under Max-min fairness



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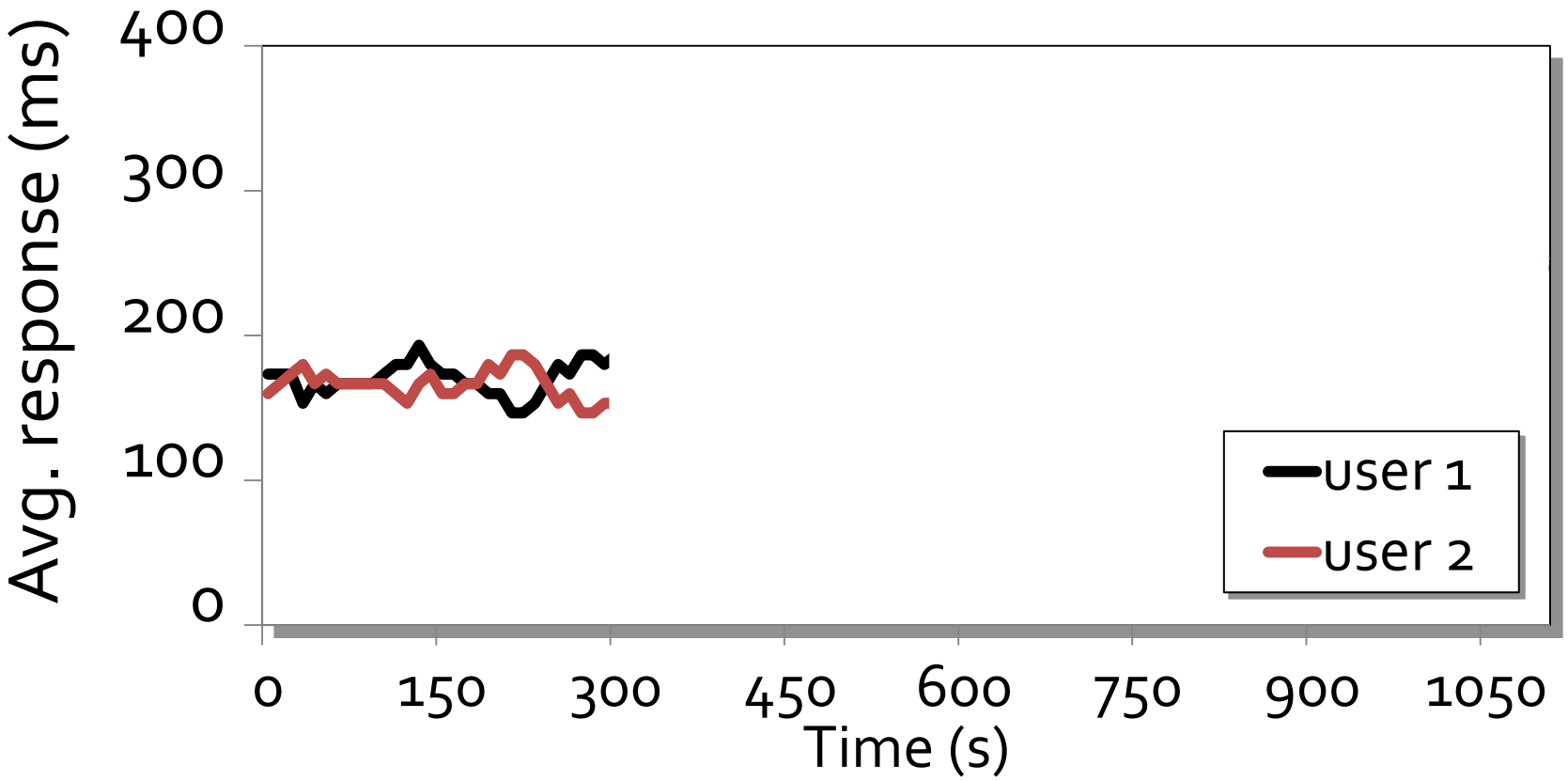

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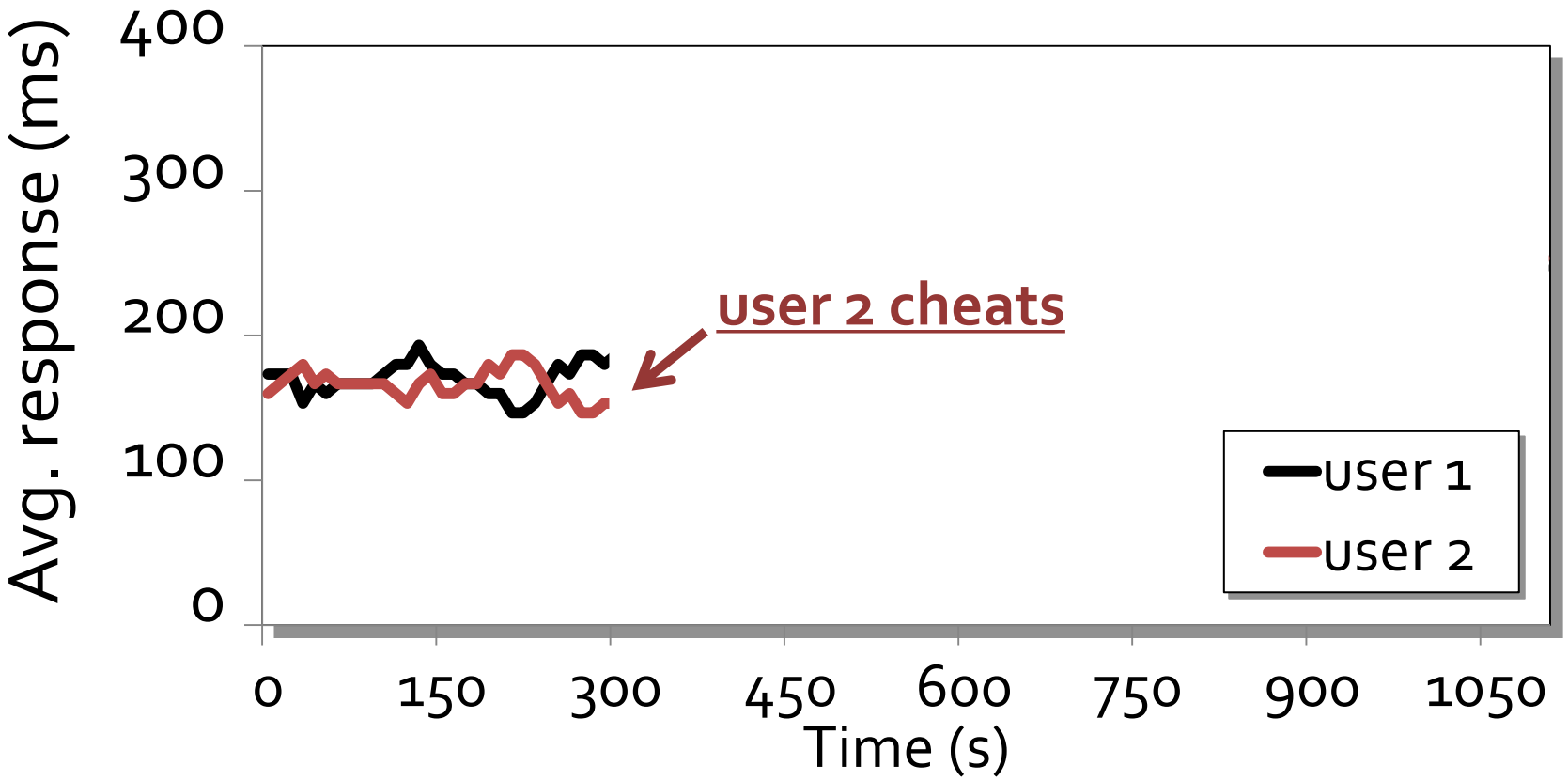
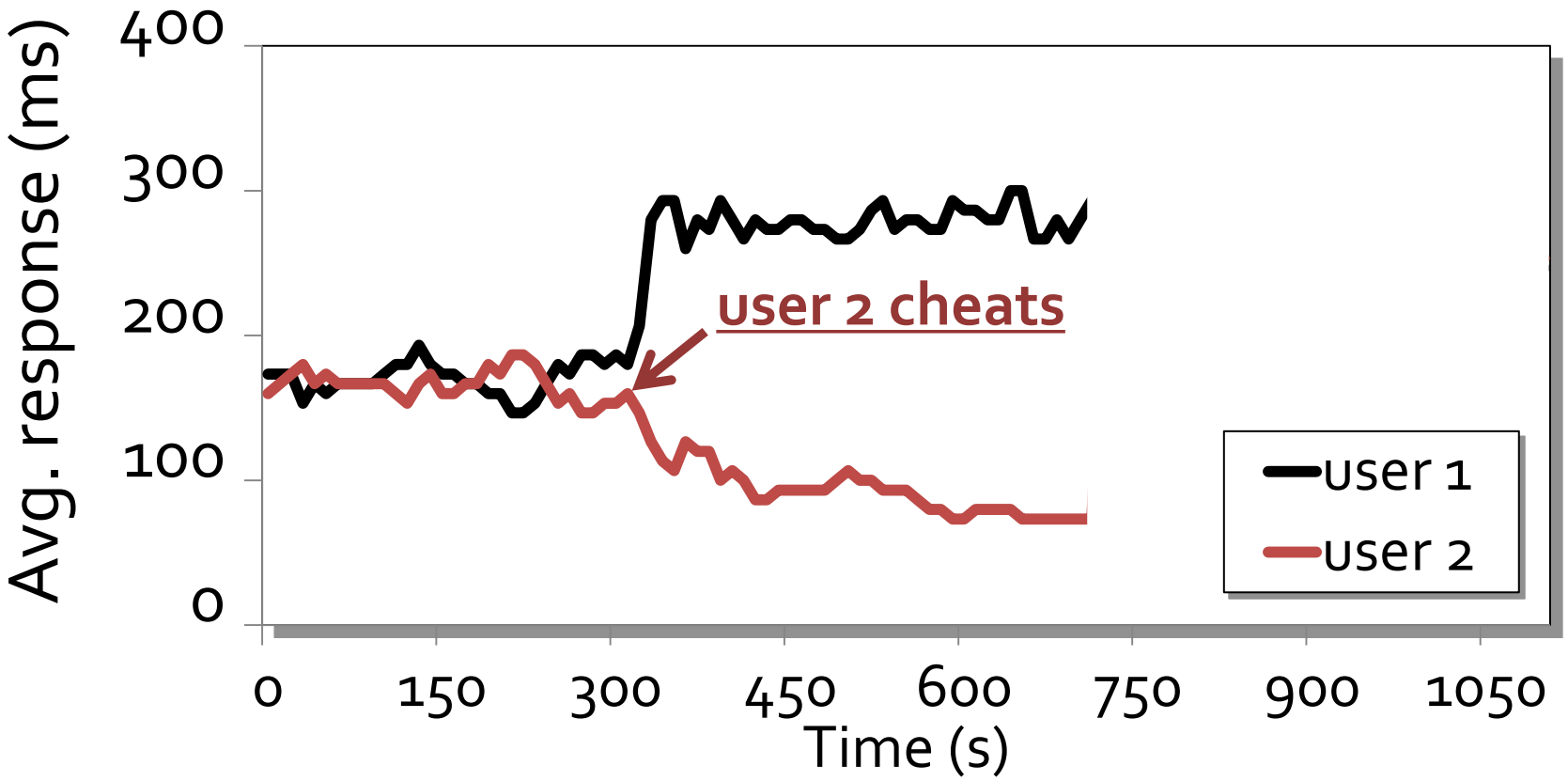
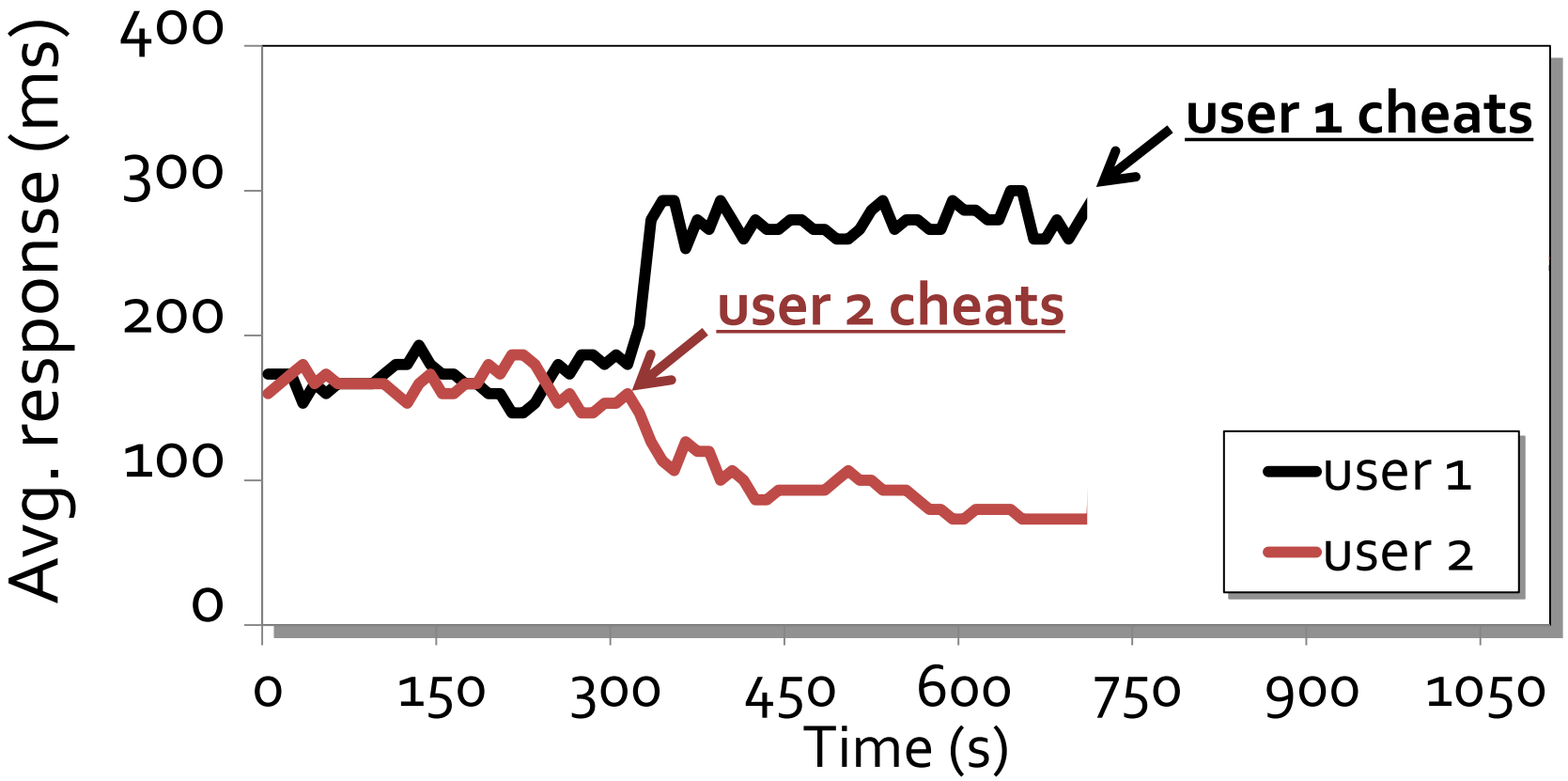


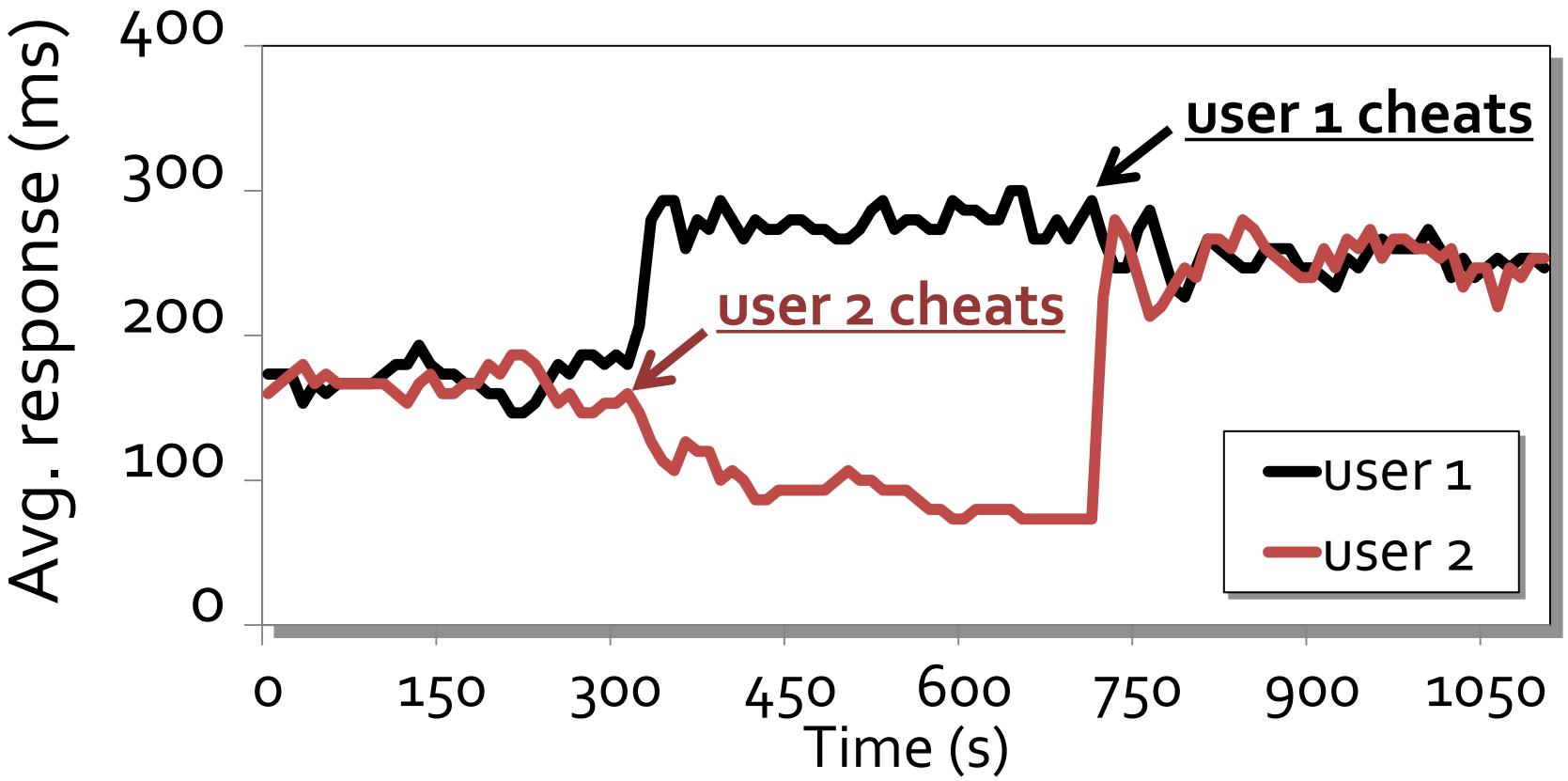
Cheating under Max-min fairness



Cheating under Max-min fairness



Cheating under Max-min fairness



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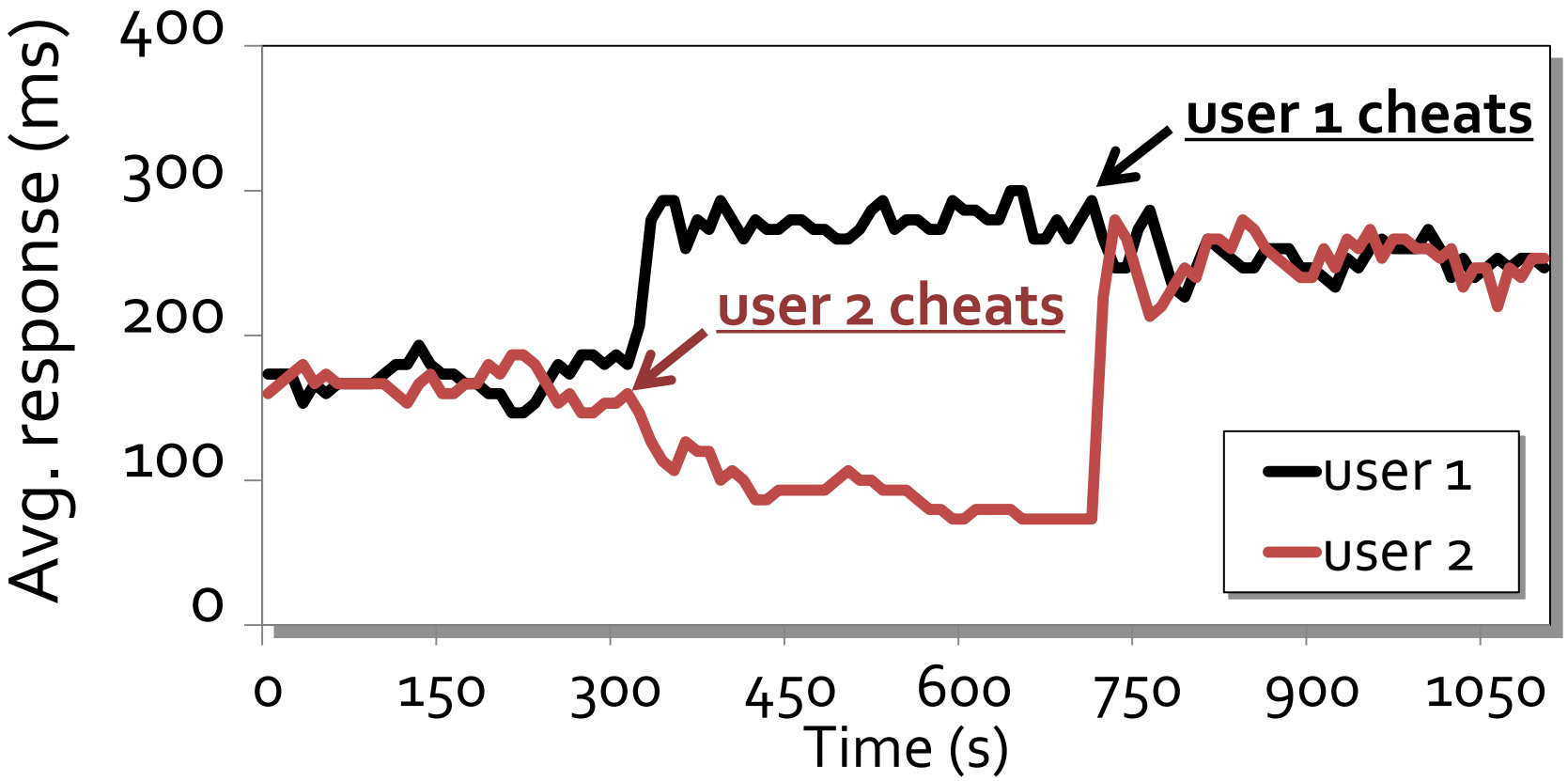
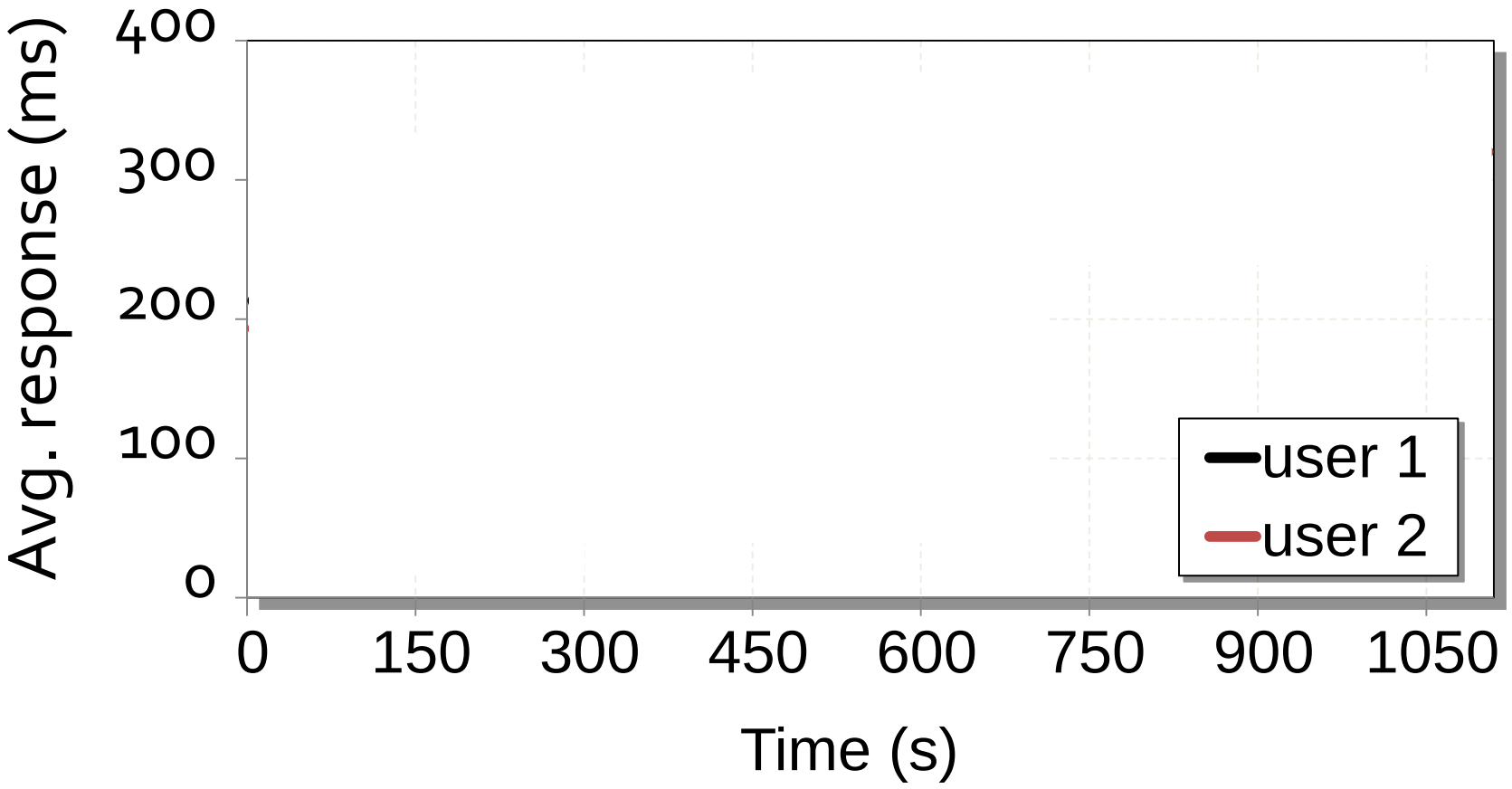
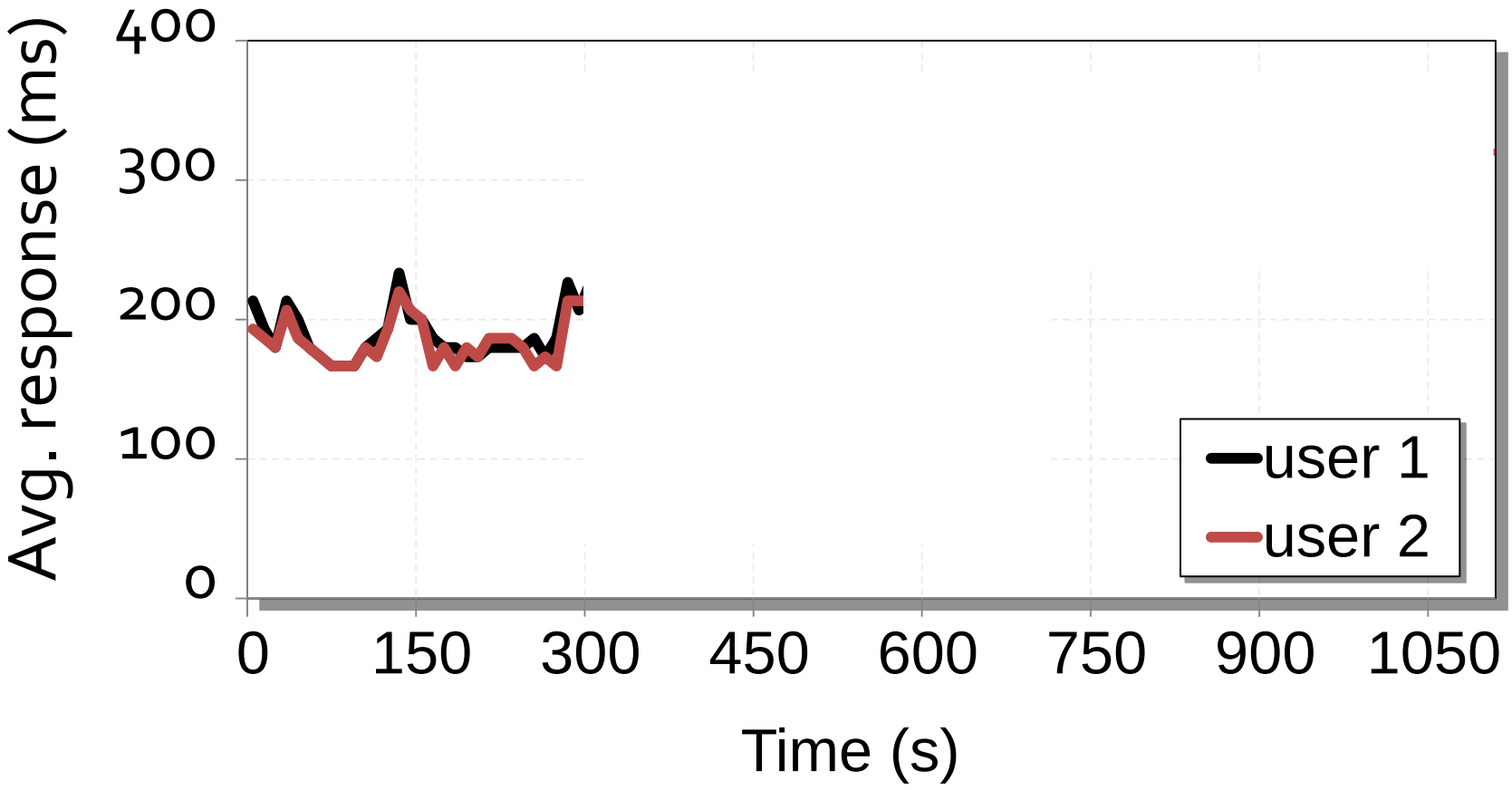


Cheating can greatly hurt user performance.

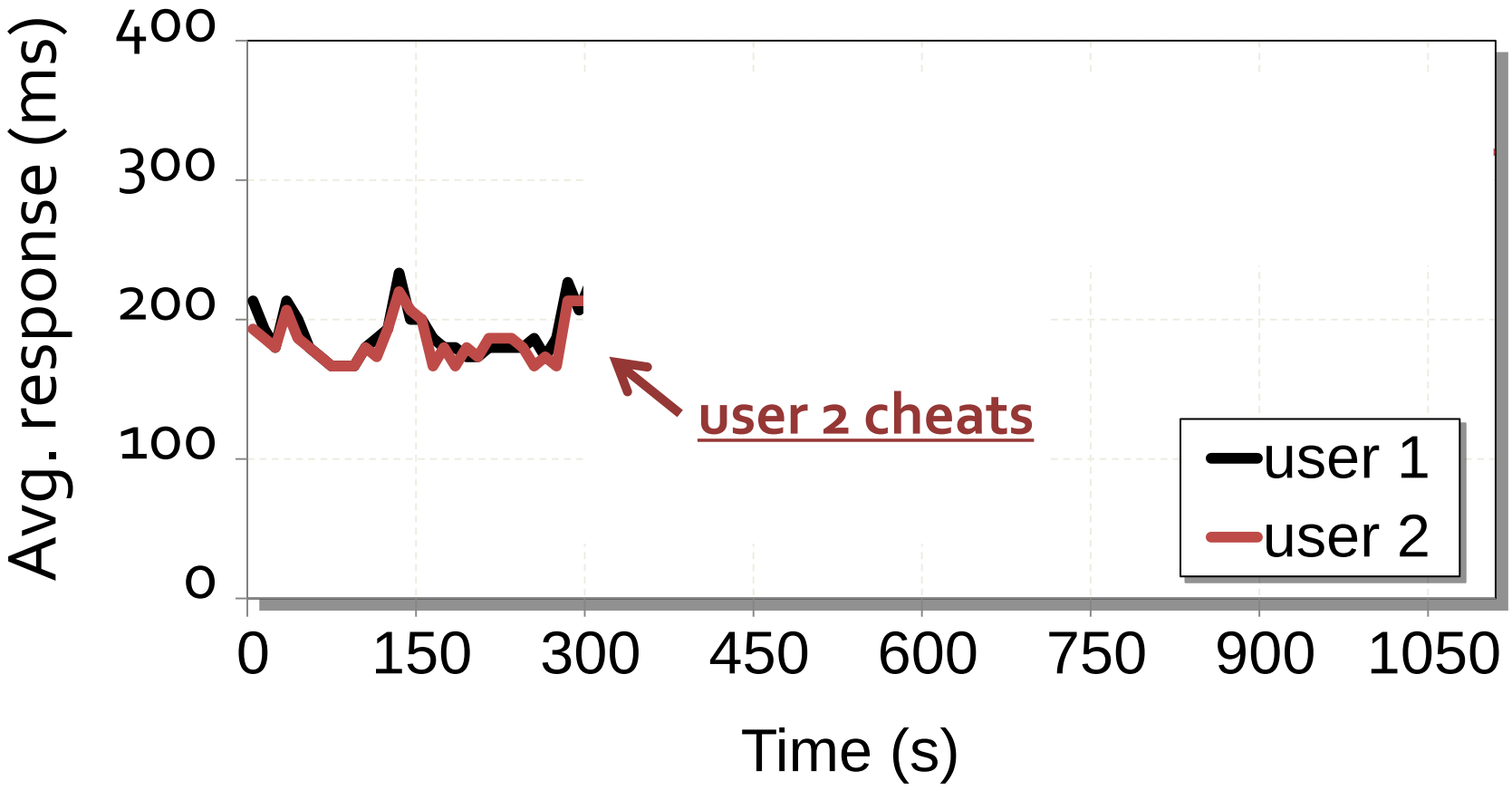
Cheating under FairRide



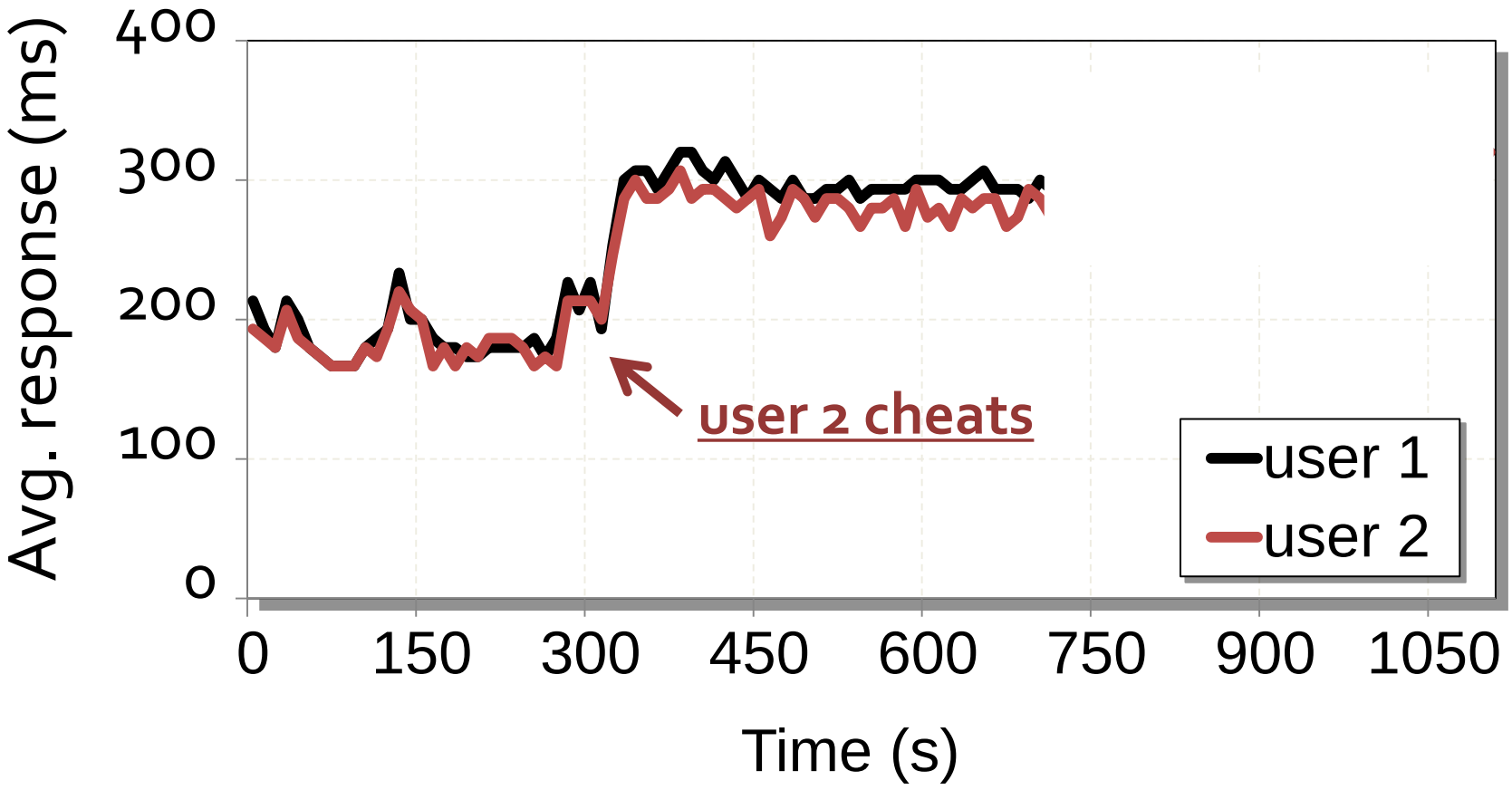
Cheating under FairRide



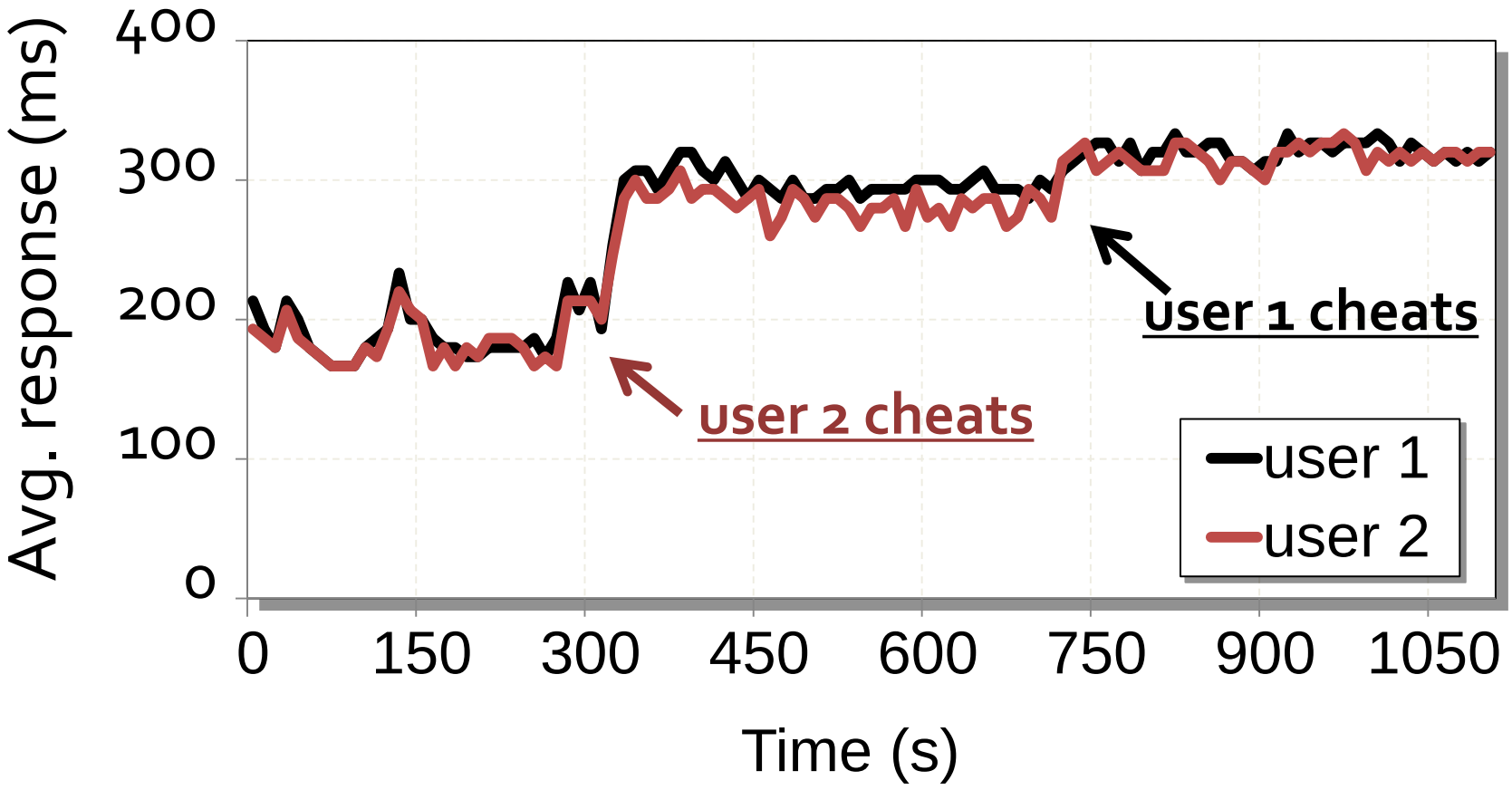
Cheating under FairRide



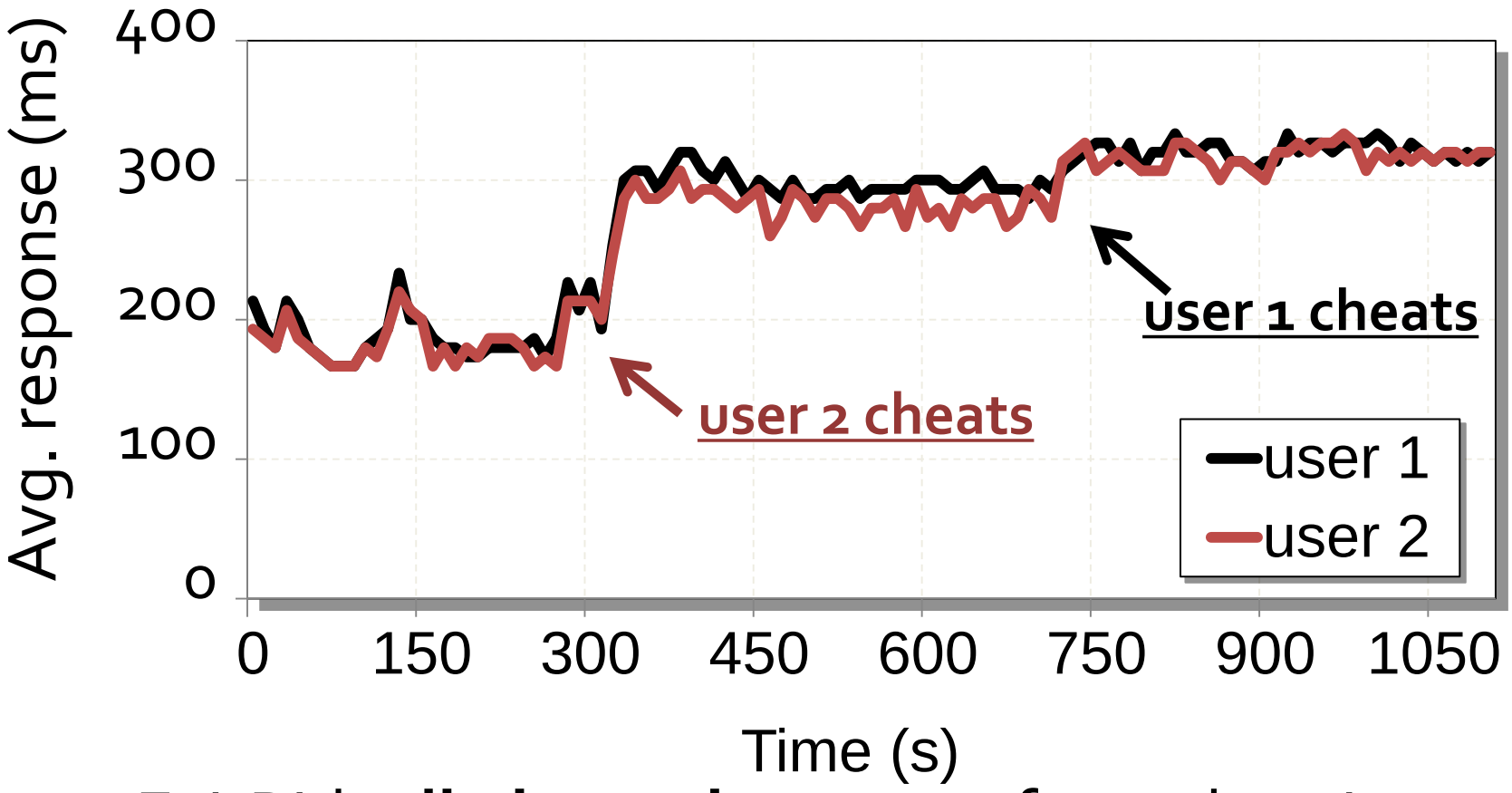
Cheating under FairRide



Cheating under FairRide

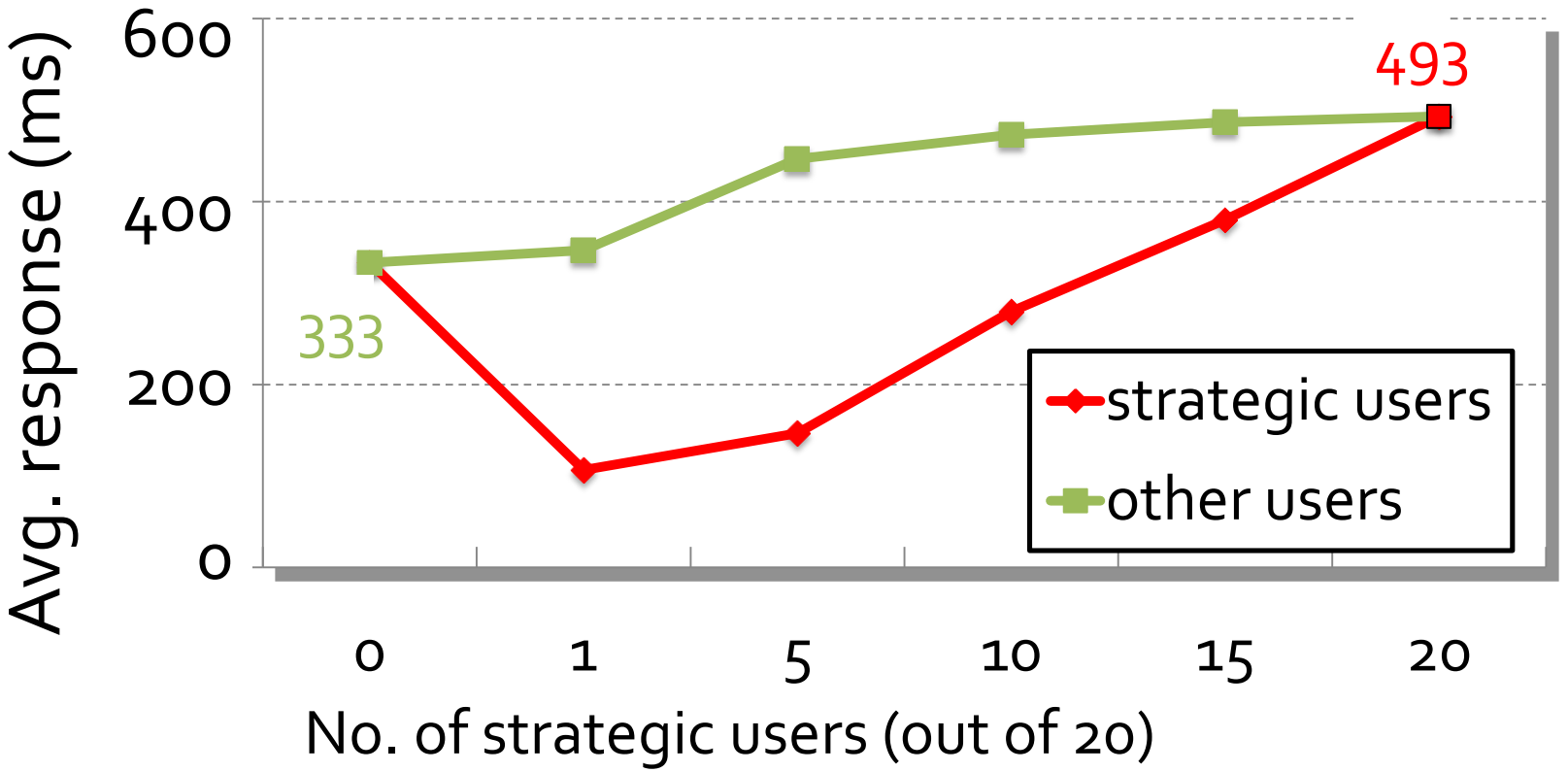


Cheating under FairRide

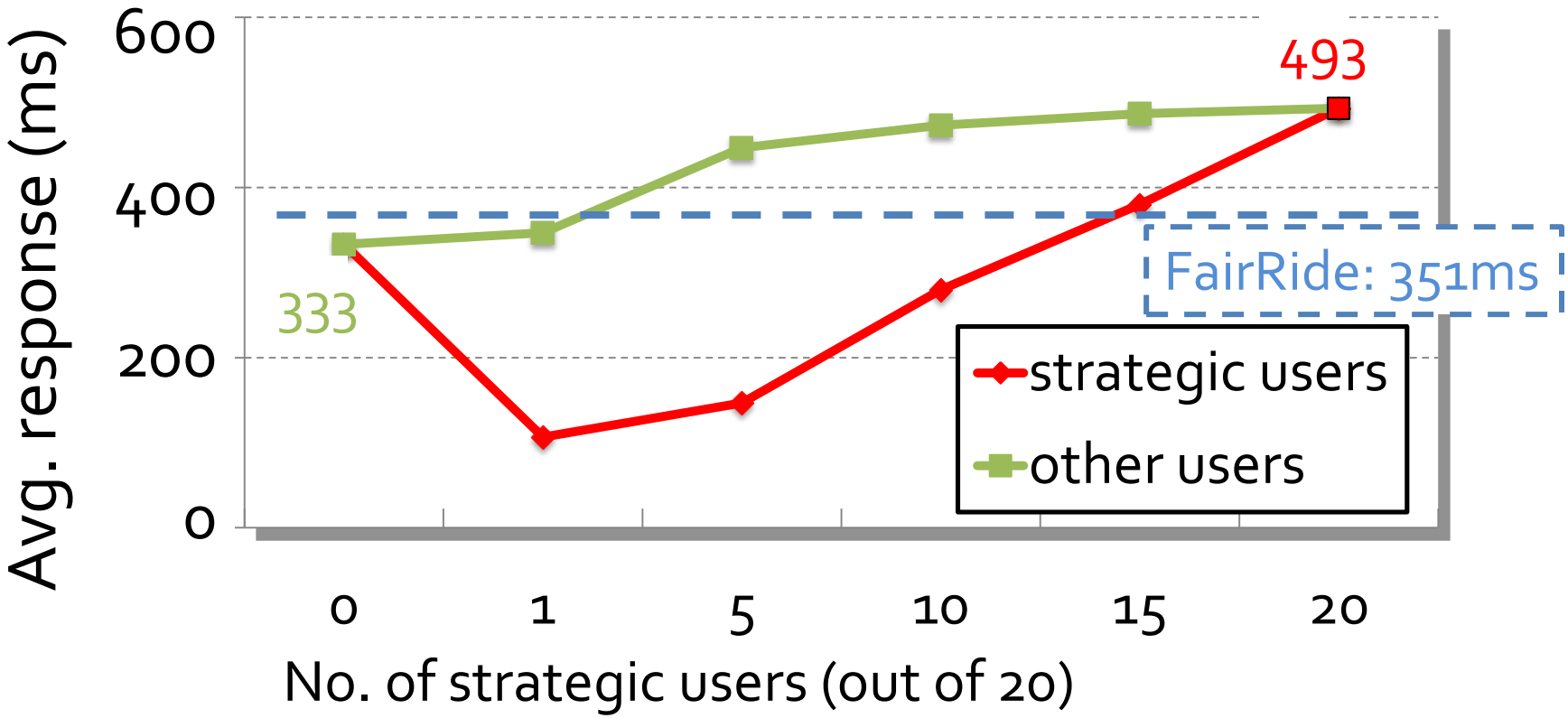


FairRide **dis-incentives** users from cheating.

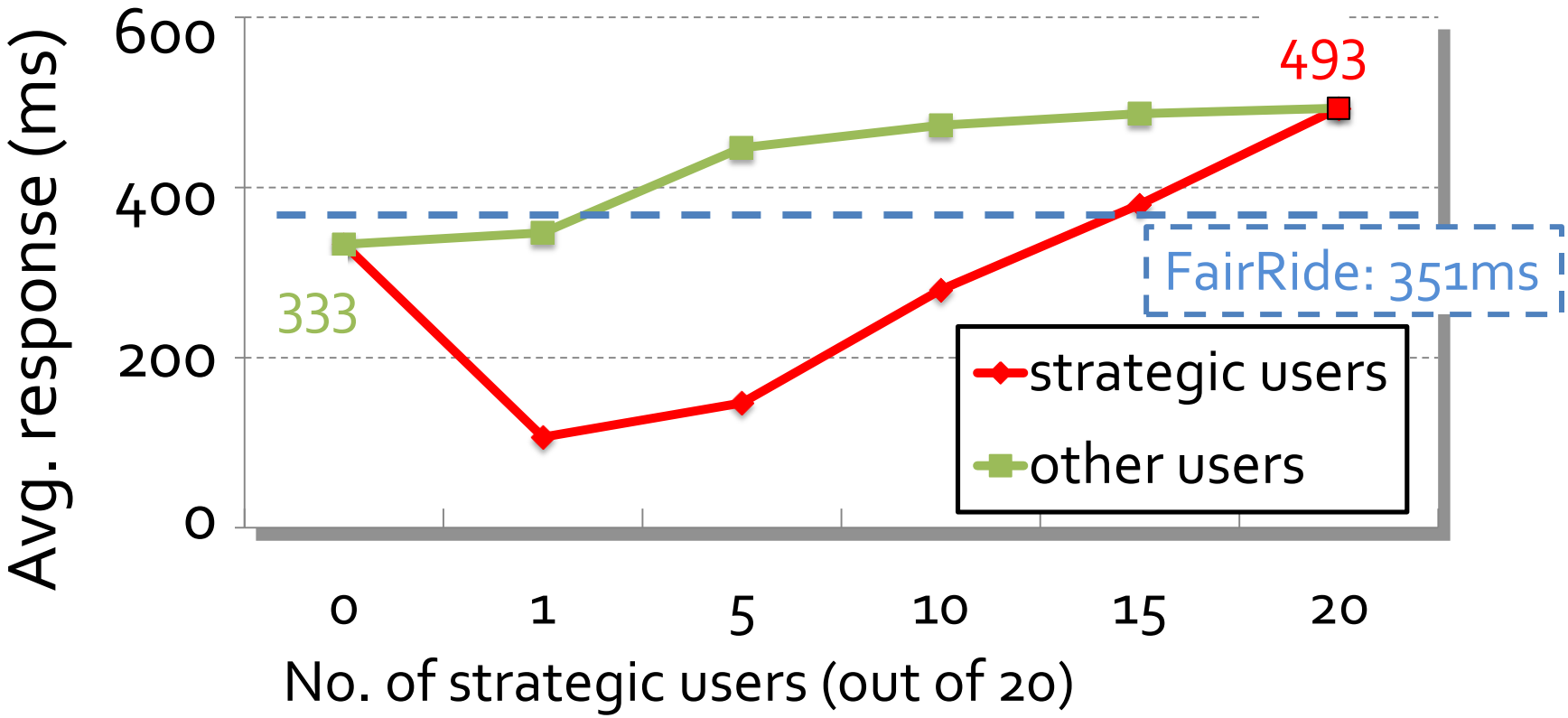
Many users


Avg. response (ms)
600
400
200
0
493
333
strategic users
other users
0
1
5
10
15
20
No. of strategic users (out of 20)

Many users


Avg. response (ms)
600
400
200
0
493
333
FairRide: 351ms
strategic users
other users
0
1
5
10
15
20
No. of strategic users (out of 20)

Many users


Avg. response (ms)
600
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FairRide: 351ms
strategic users
other users
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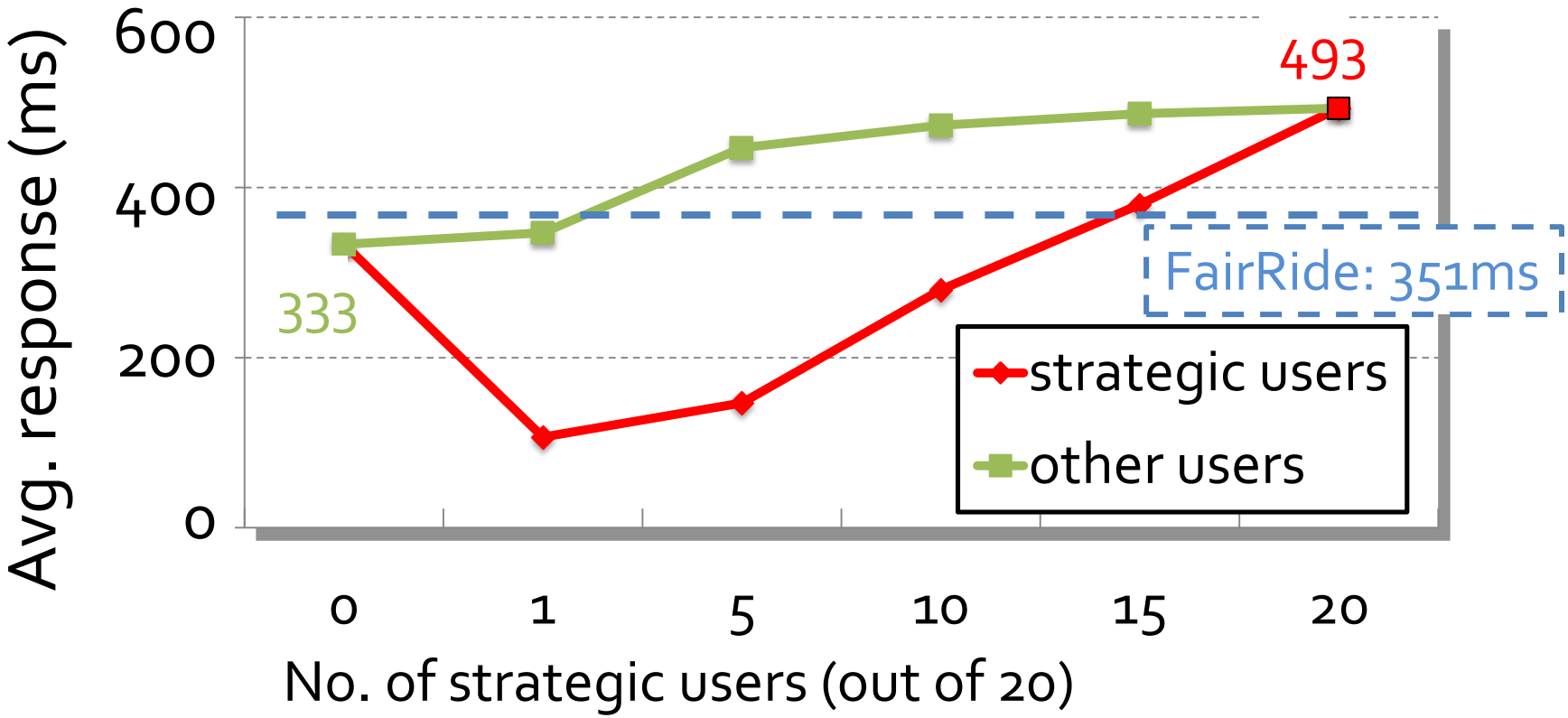
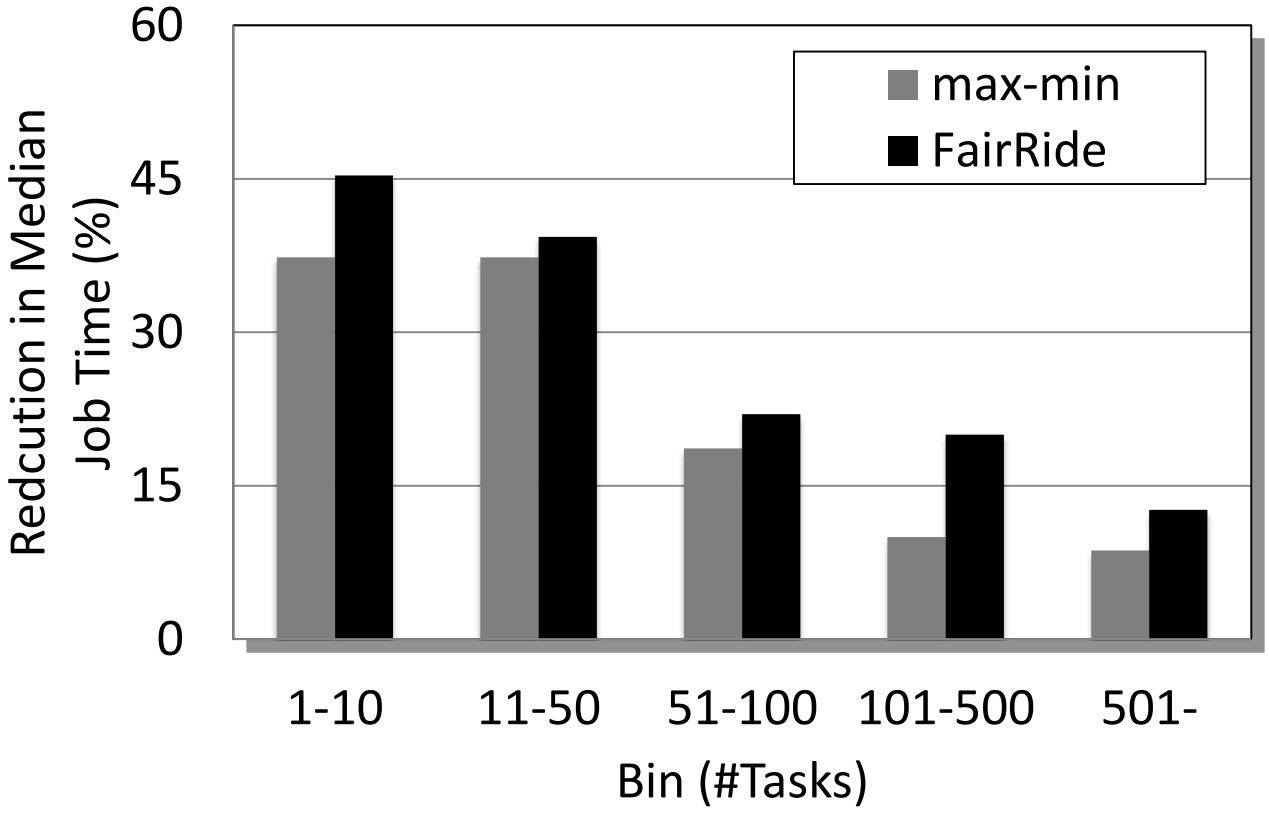
Many users

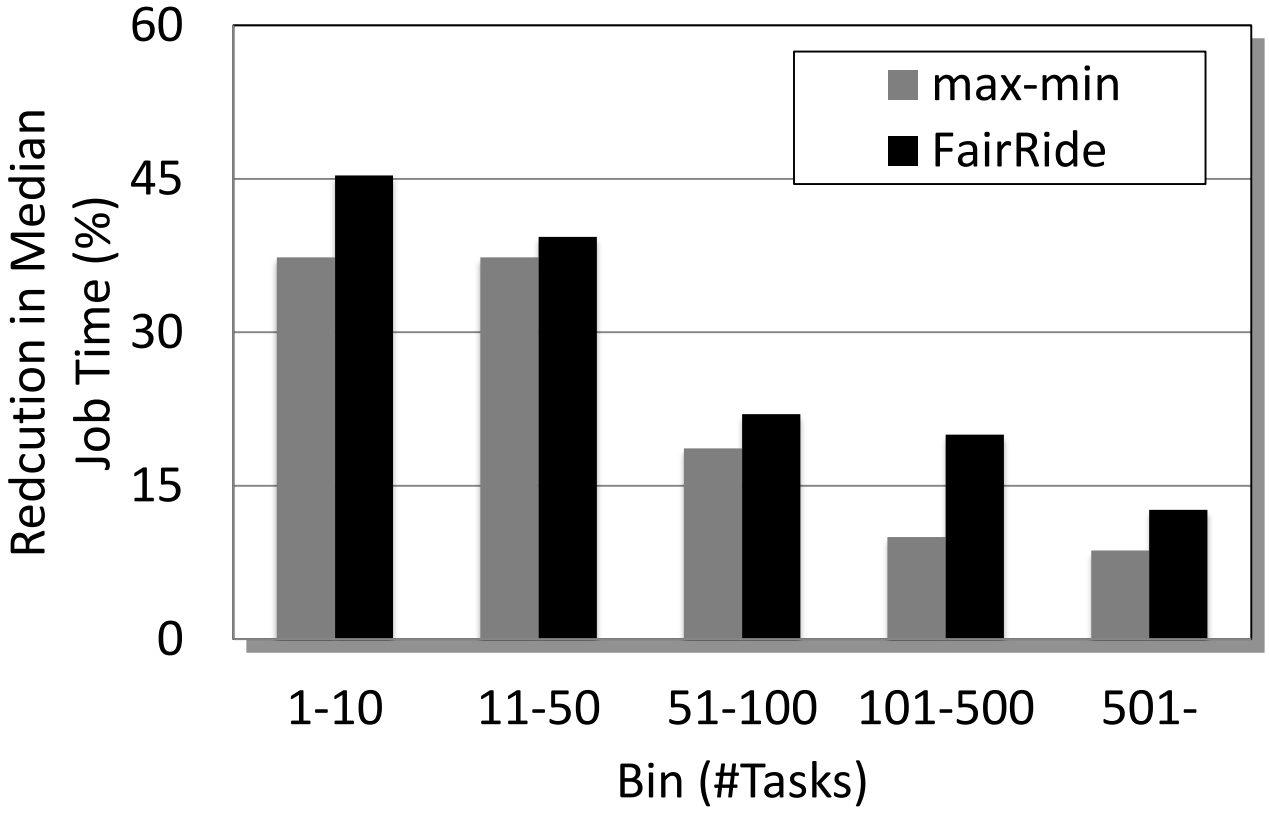


FairRide has minimal loss.

Facebook experiments



Facebook experiments



FairRide outperforms max-min fairness by 29%

Conclusion

- No policy can satisfy all desirable properties:
  - Isolation guarantee
  - Strategy proofness
  - Pareto efficiency

Conclusion

- No policy can satisfy all desirable properties:
  - Isolation guarantee
  - Strategy proofness
  - Pareto efficiency
- FairRide:isolation guarantee and strategy-proofness through ***probabilistic blocking***.
  - Outperforms static allocation and other sharing policies when users cheat.
  - Achieves this with least overhead