Torturing Databases for Fun and Profit

Mai Zheng[†], Joseph Tucek[‡], Dachuan Huang[†], Feng Qin[†], Mark Lillibridge[‡]
Elizabeth S Yang[‡], Bill W Zhao[‡], Shashank Singh[†]

[†] *The Ohio State University*

[‡] *HP Labs*

database








- ACID: atomicity, consistency, isolation, and durability - even under failures

List of databases survived

Everything is broken under simulated power faults

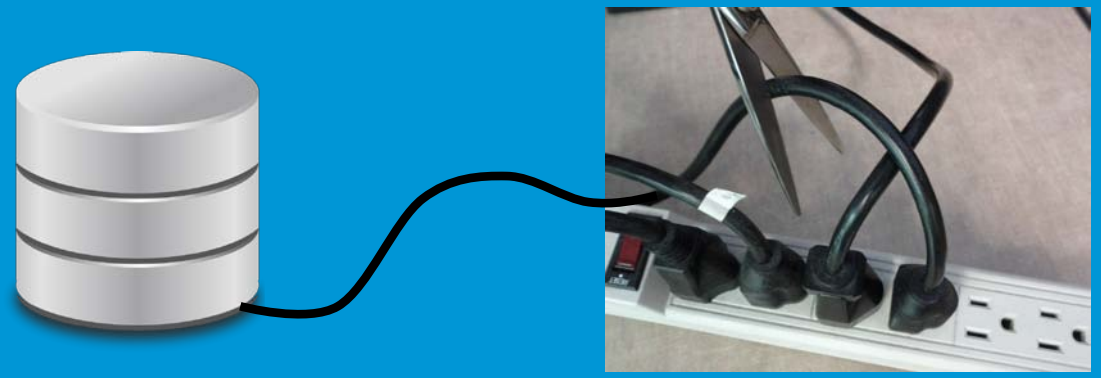
Database	File System	Workload					
		W-1	W-2	W-3	W-4.1	W-4.2	W-4.3
TokyoCabinet	ext3	D	D	D	ACD	ACD	ACD
	XFS	--	D	D	ACD	D	ACD
MariaDB	ext3	D	D	D	D	D	D
	XFS	D	D	D	D	D	D
LightningDB	ext3	--	--	--	--	--	D
	XFS	--	--	--	--	--	--
SQLite	ext3	D	D	--	D	D	D
	XFS	--	--	D	D	D	D
KVS-A	ext3	--	--	Hang	--	--	--
	XFS	--	--	--	--	--	--
SQL-A	ext3	D	D	D	D	D	D
	XFS	D	D	D	D	D	D
SQL-B	ext3	D	D	CD	CD	CD	CD
	XFS	CD	D	CD	CD	CD	CD
SQL-C	NTFS	D	D	D	D	D	D

Power faults cannot happen nowadays, right?

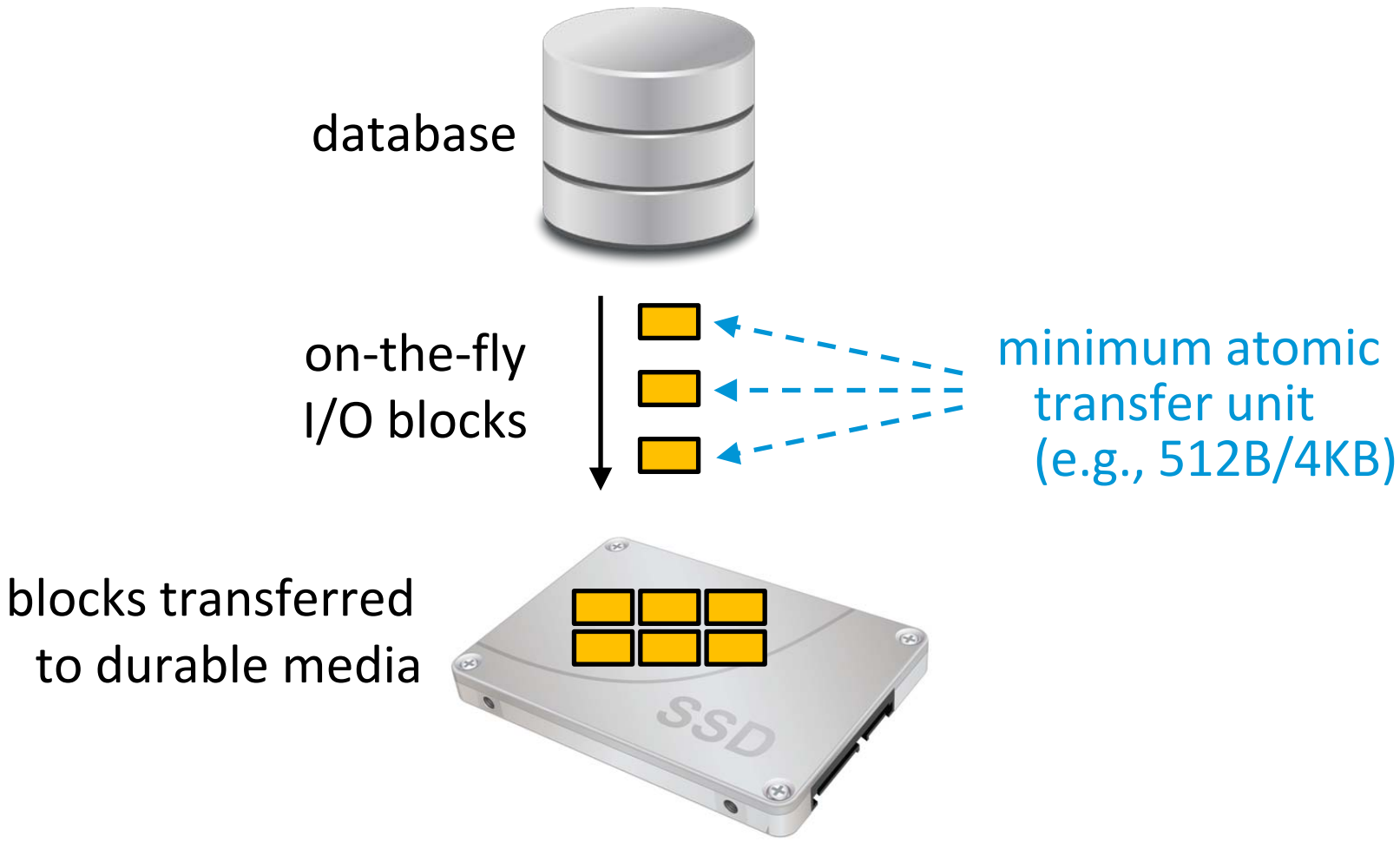

2013:"... POWER OUTAGE during Super Bowl ... because a RELAY DEVICE MALFUNCTIONED."


2014:“Internap Data Center OUTAGE Takes Down Livestream, StackExchange”
2014:“Data Center FIRE Leads to OUTAGE ...”
2014:“... ELECTRICAL FIRE took down ... primary data center... ALL POWER was OFF ...”
2013:“POWER OUTAGE knocks DreamHost customers offline ...”
2013:“ A data center POWER OUTAGE is being blamed for ...Visa downtime ...”
2013:“ A POWER OUTAGE at a key New Jersey data center ...”
2013:“... POWER OUTAGE during Super Bowl ... because a RELAY DEVICE MALFUNCTIONED.”
2012:“... HUNAM ERROR was responsible for a data center POWER OUTAGE ...”
2012:“POWER OUTAGE Hits London Data Center ...”
2012:“Amazon Data Center LOSES POWER During STORM ...”
2011:“Colocation provider Colo4 experienced a POWER OUTAGE ...”
2010:“About 3,000 servers at Montreal web host iWeb experienced an OUTAGE ...”
2010:“CAR CRASH Triggers Amazon POWER OUTAGE ...”

Database Torture 101



Fault Model: Clean termination of I/O stream



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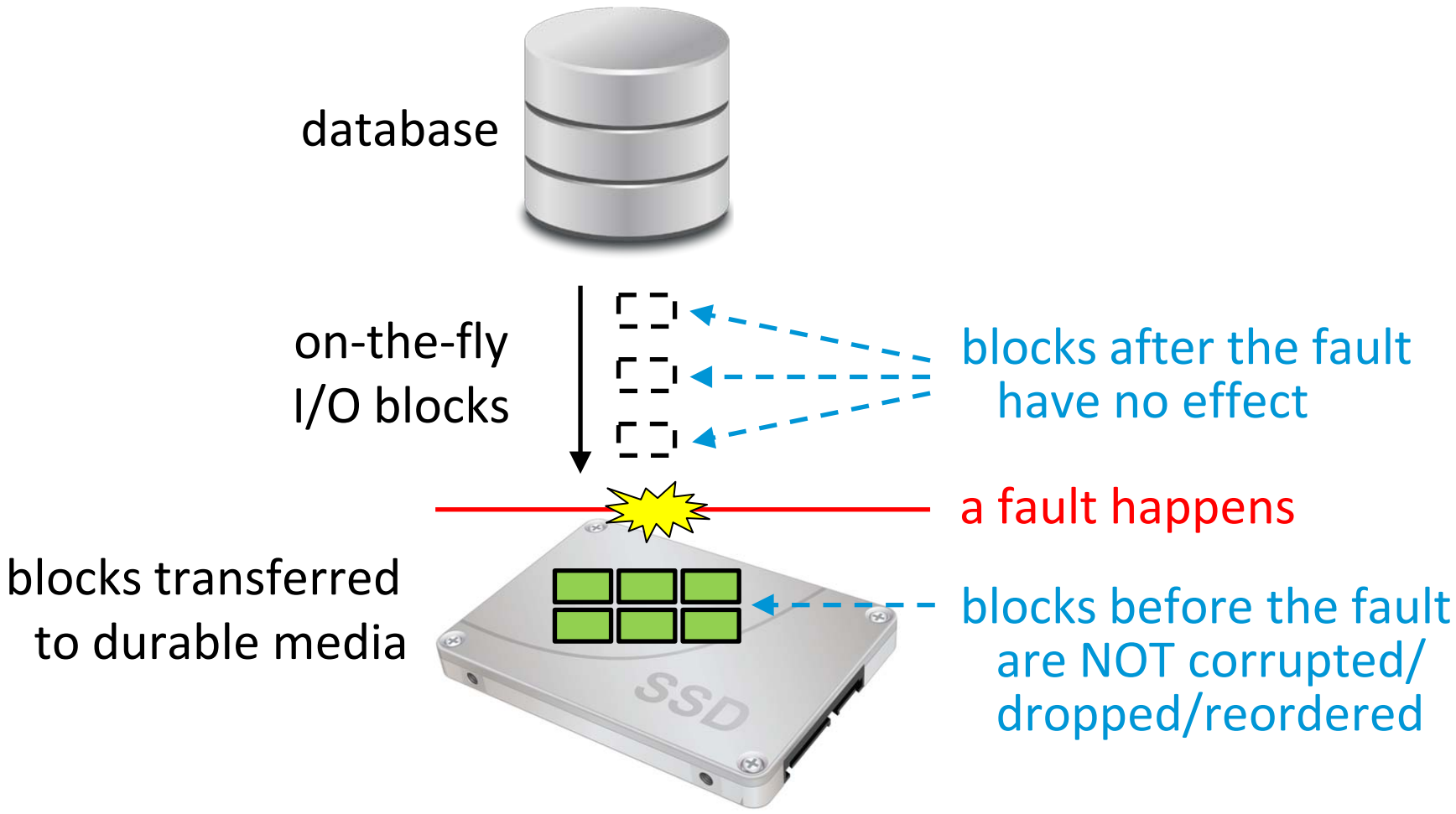
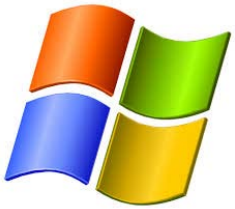


Why not introduce corruption/dropping/reordering?

- Unreasonable to require databases to handle arbitrary bad behavior introduced in the lower layers
- Simulated bad behavior w/o verification by real failures may be unrealistic
  - I/O path in kernel & device puts constraints on failure states

How do we test DBs on multiple OSes w/ high fidelity?

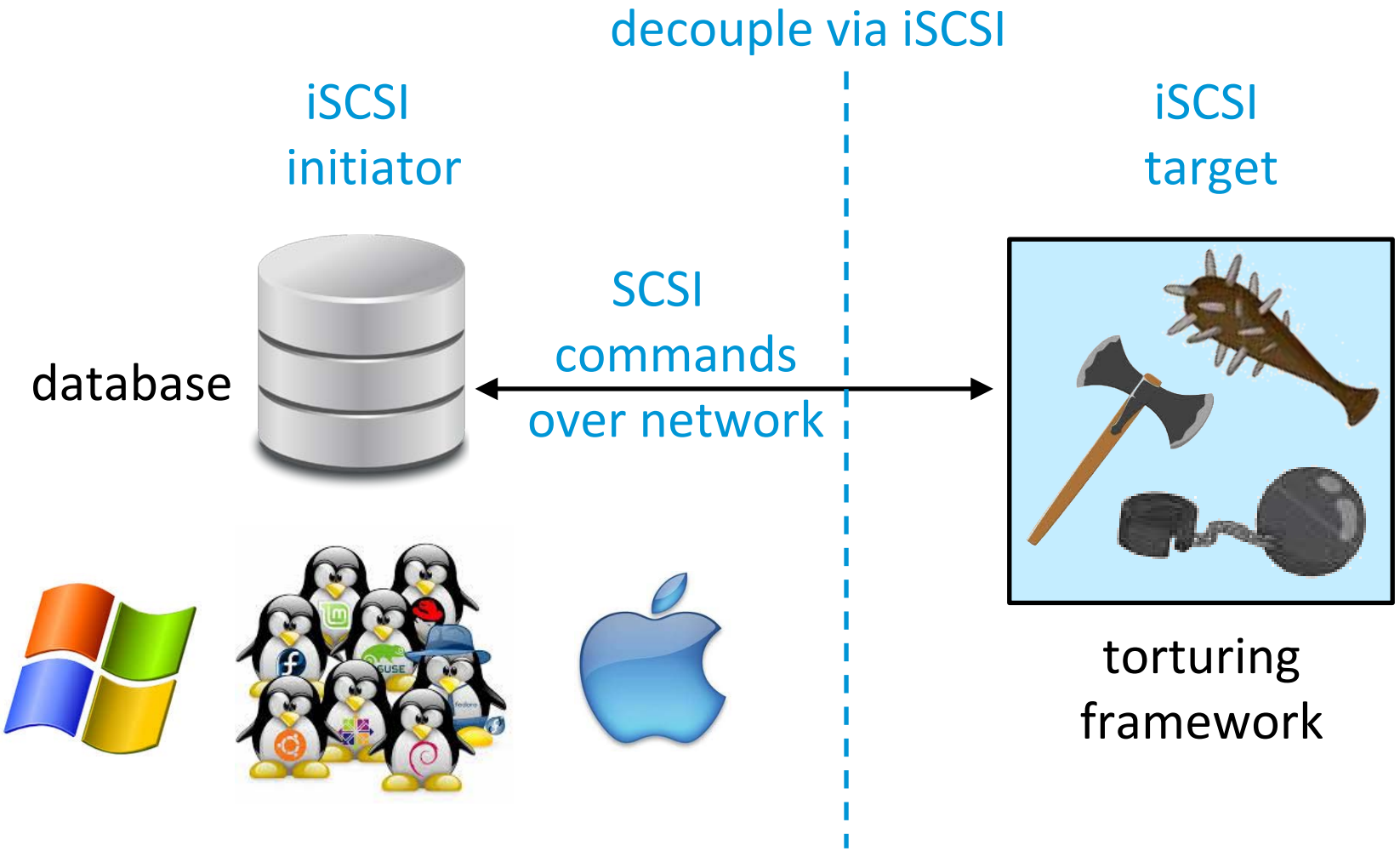
database



No disturbance on thread scheduling

No disturbance on interactions among DB, memory manager, FS, volume manager, I/O scheduler, …

How do we test DBs on multiple OSes w/ high fidelity?



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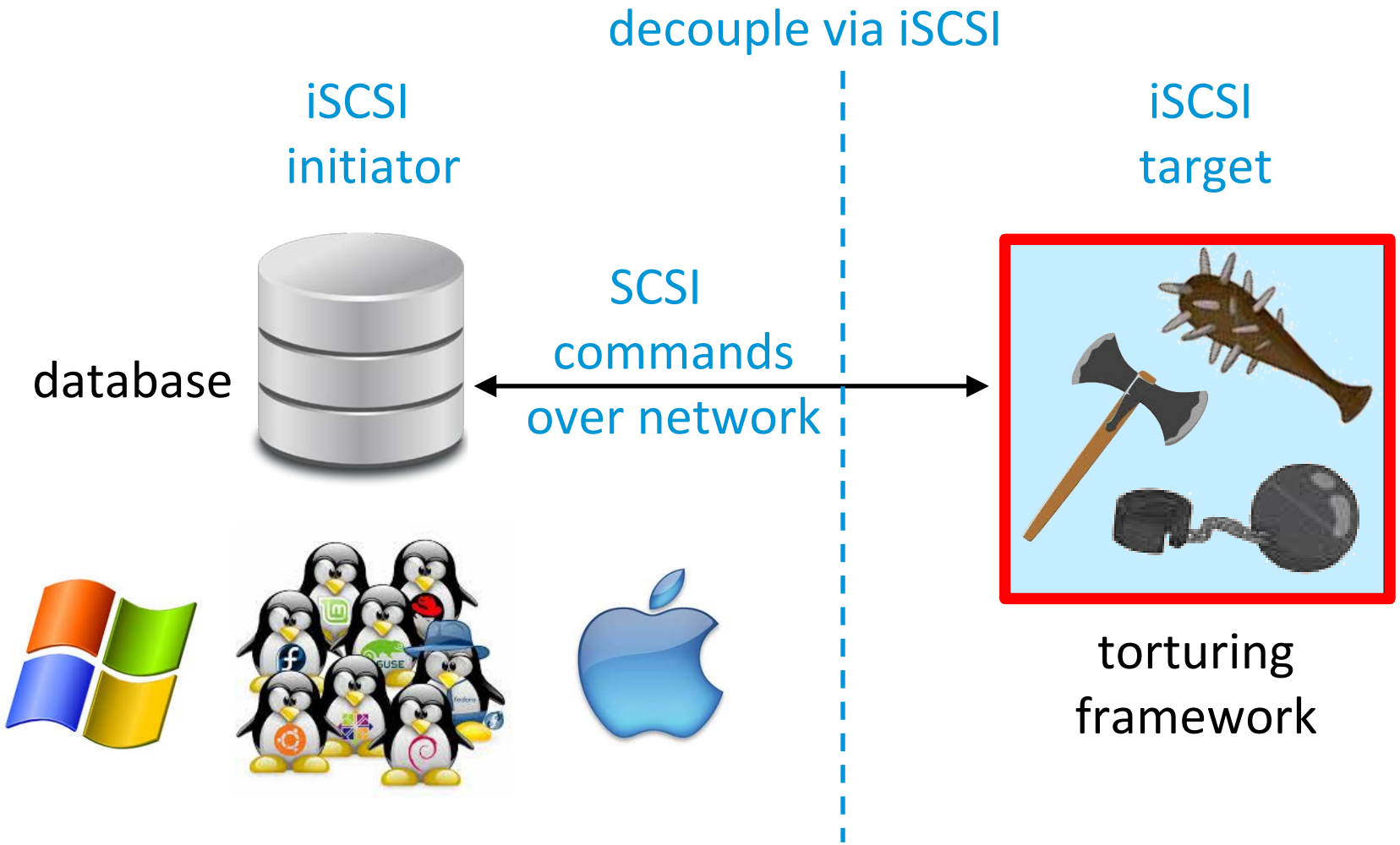
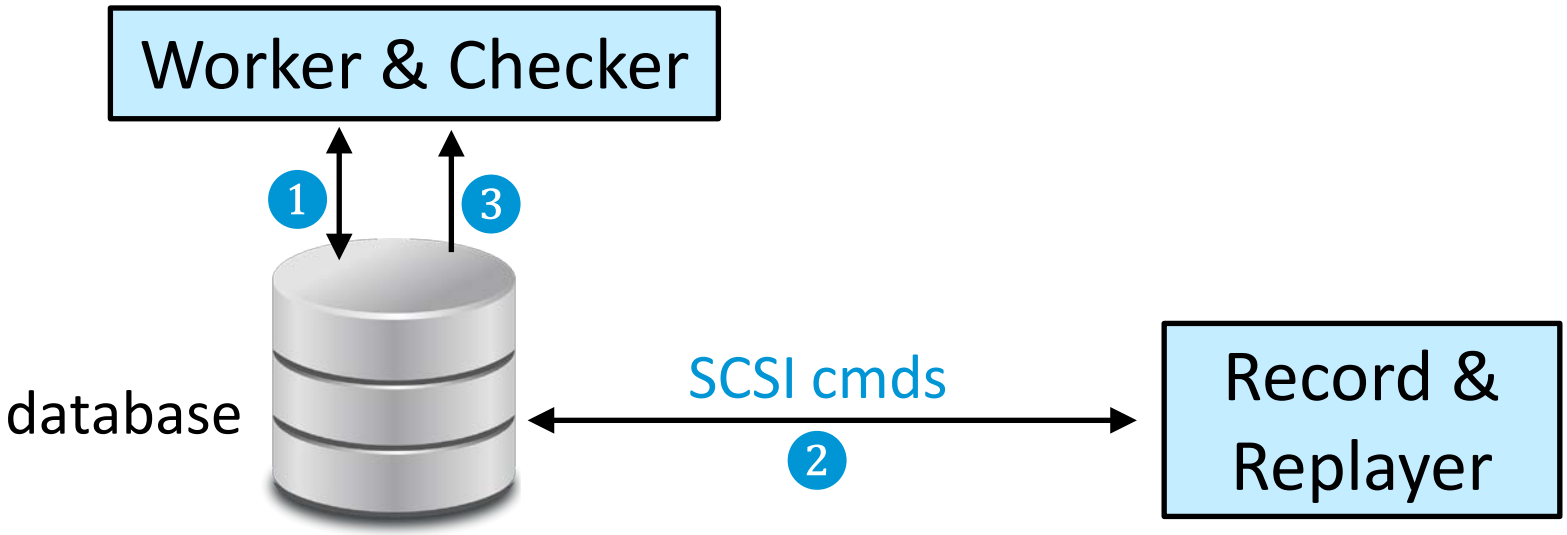


Framework Overview



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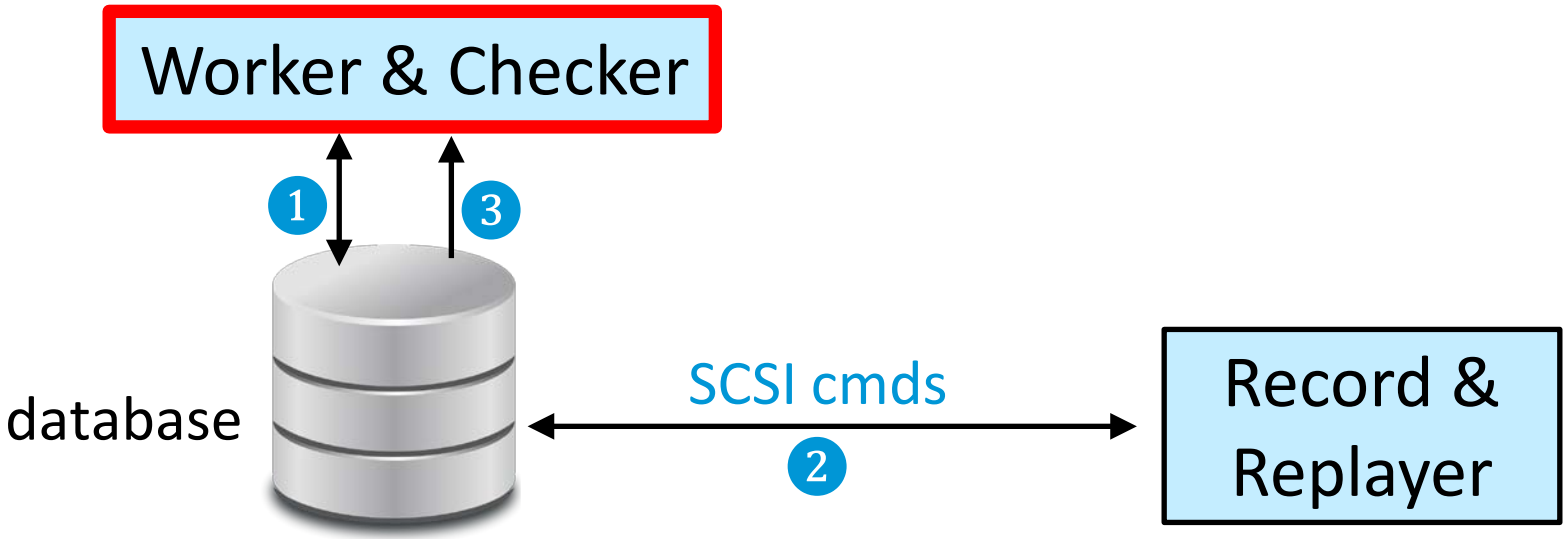
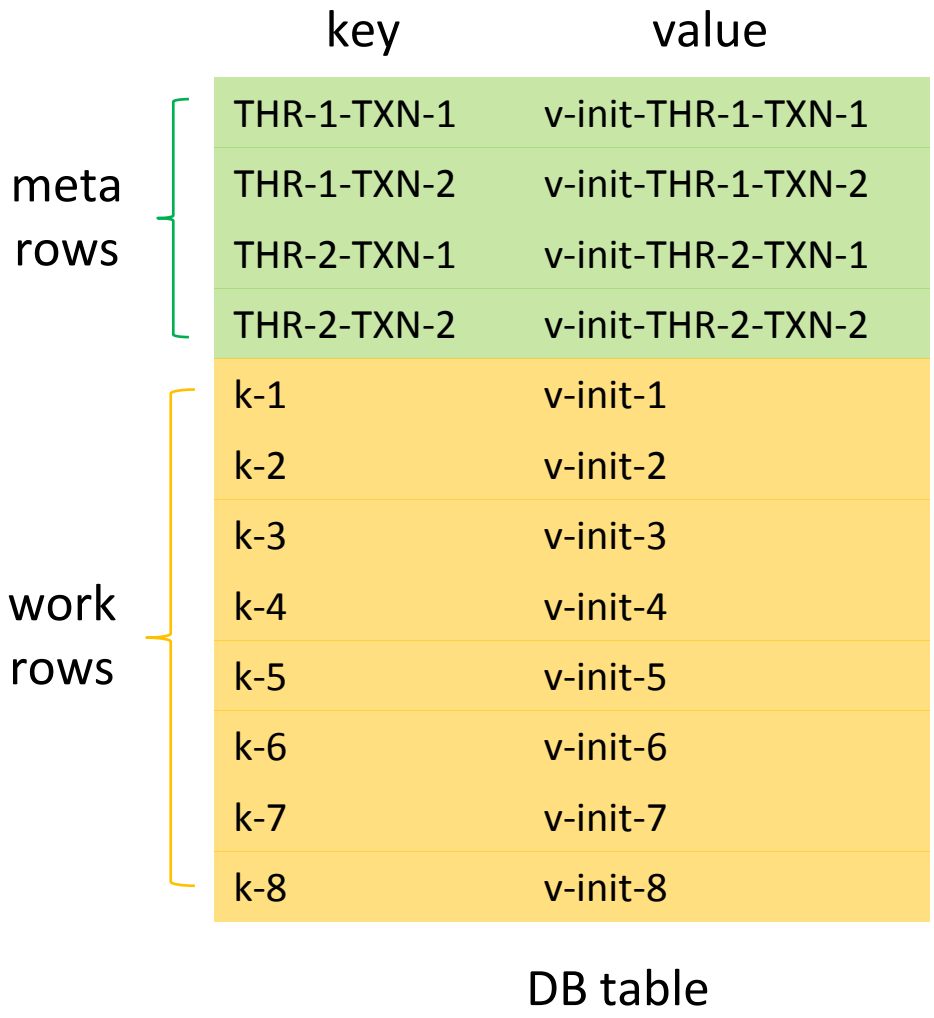


Workload Example



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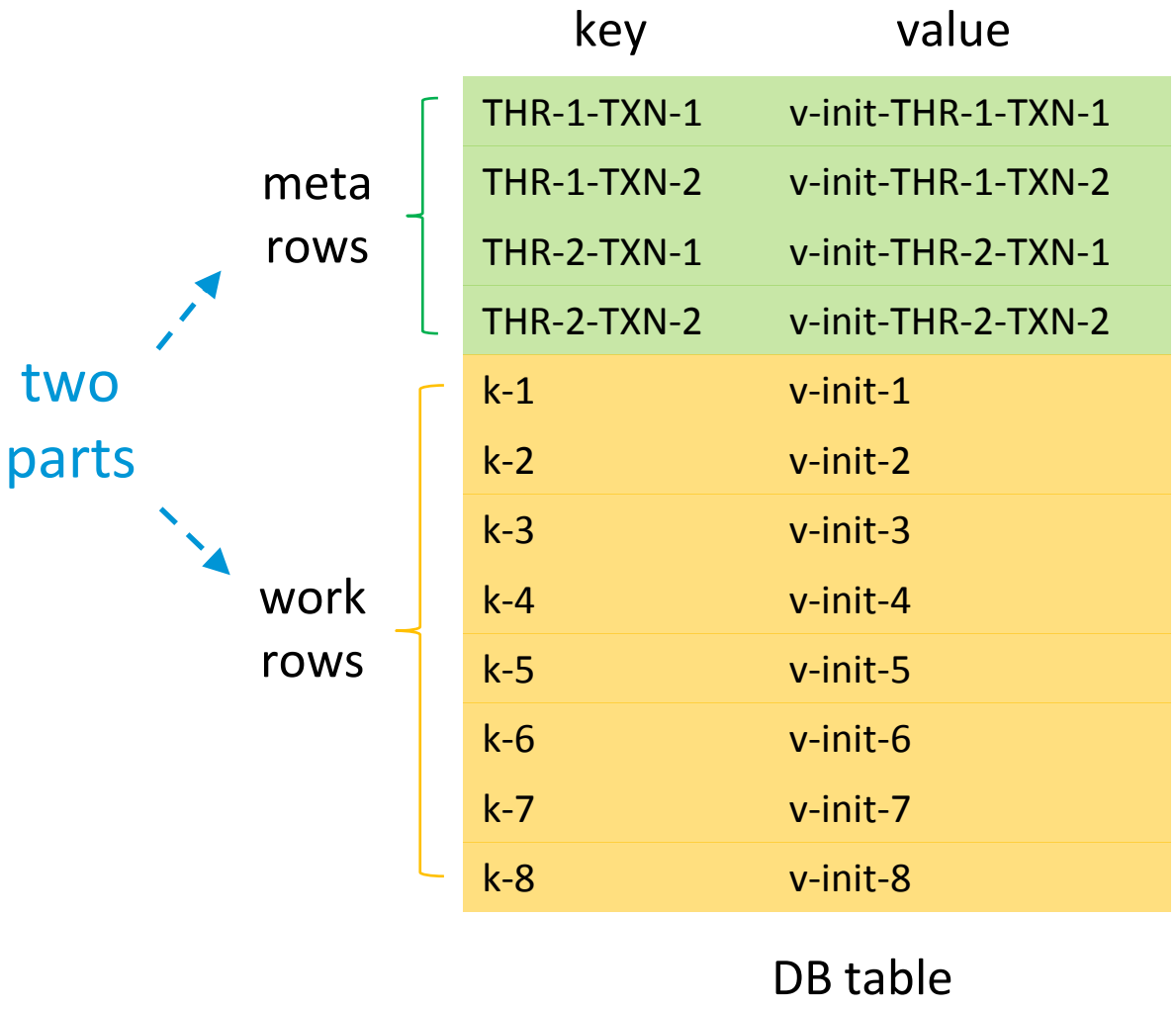
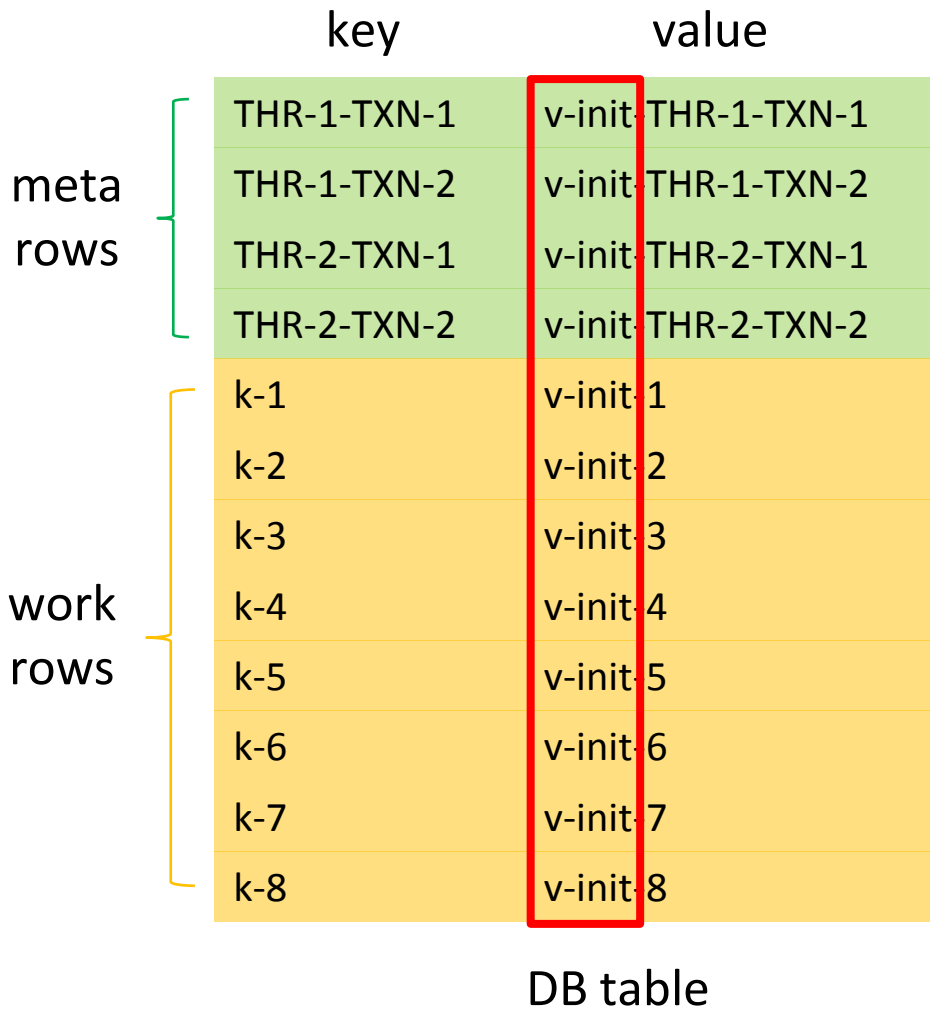
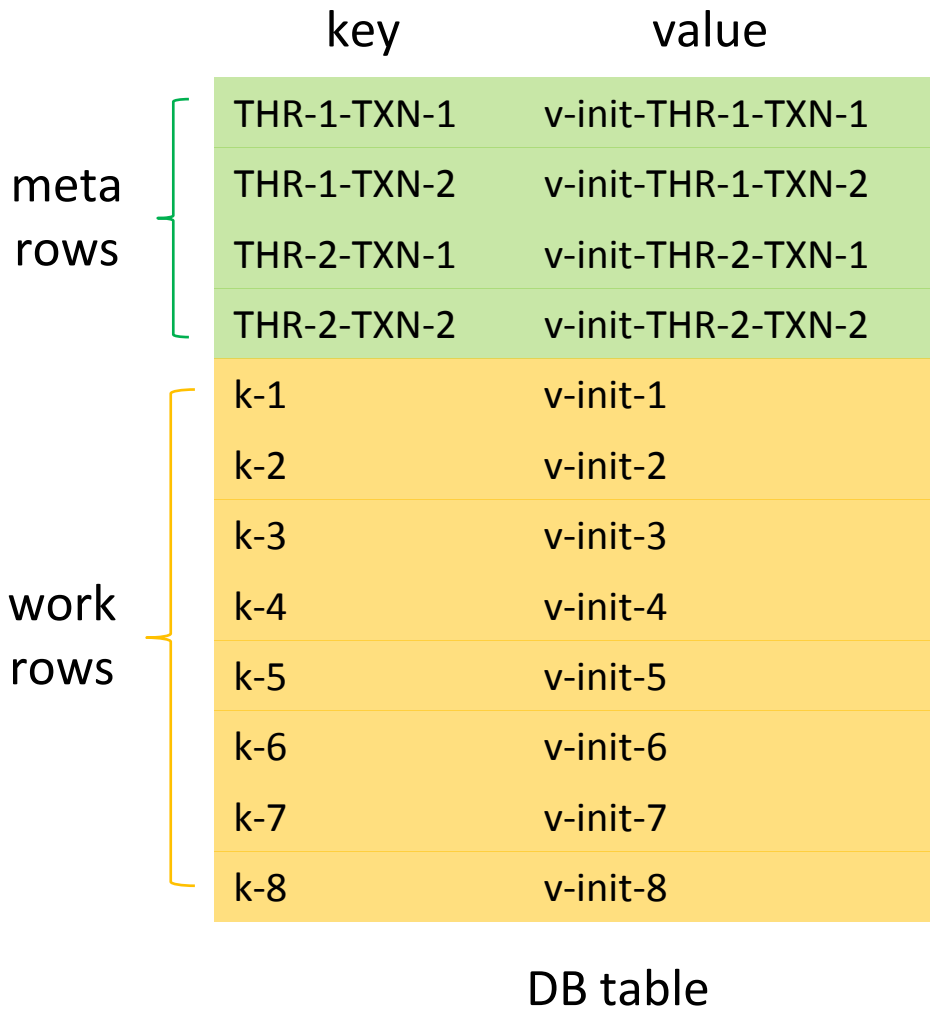


2 threads,
2 transactions
per thread

Has known initial state



Each transaction updates N random work rows + 1 meta row



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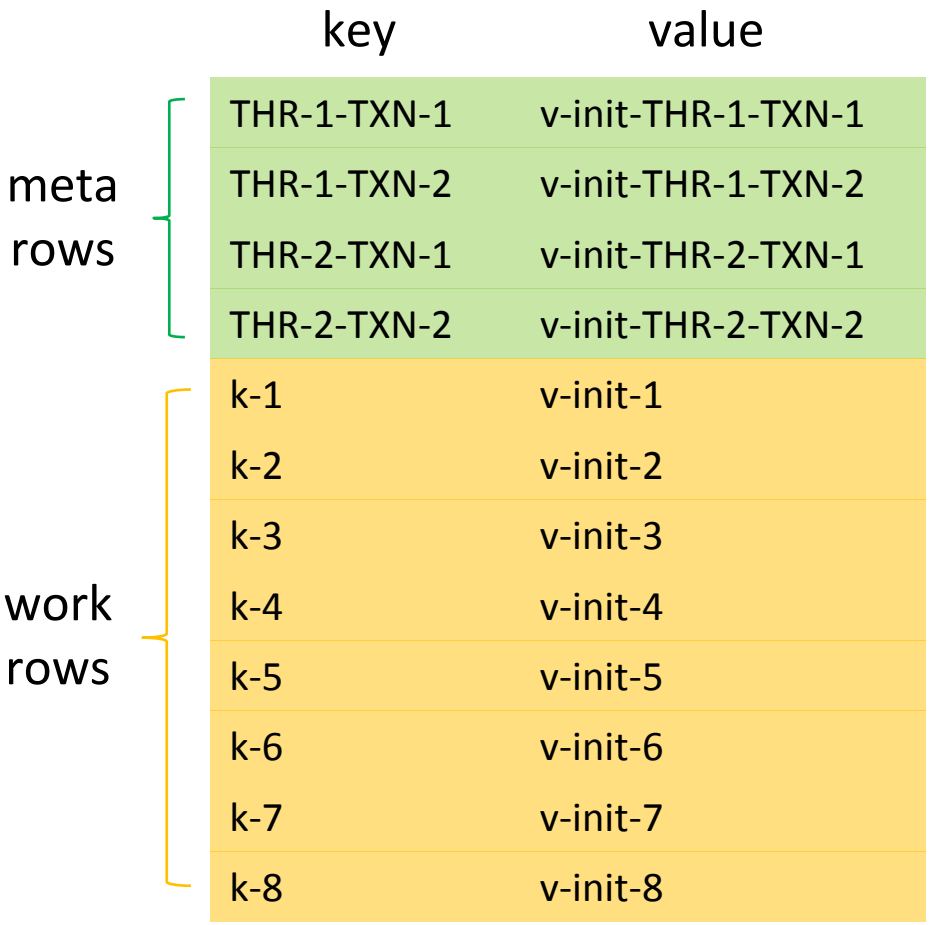
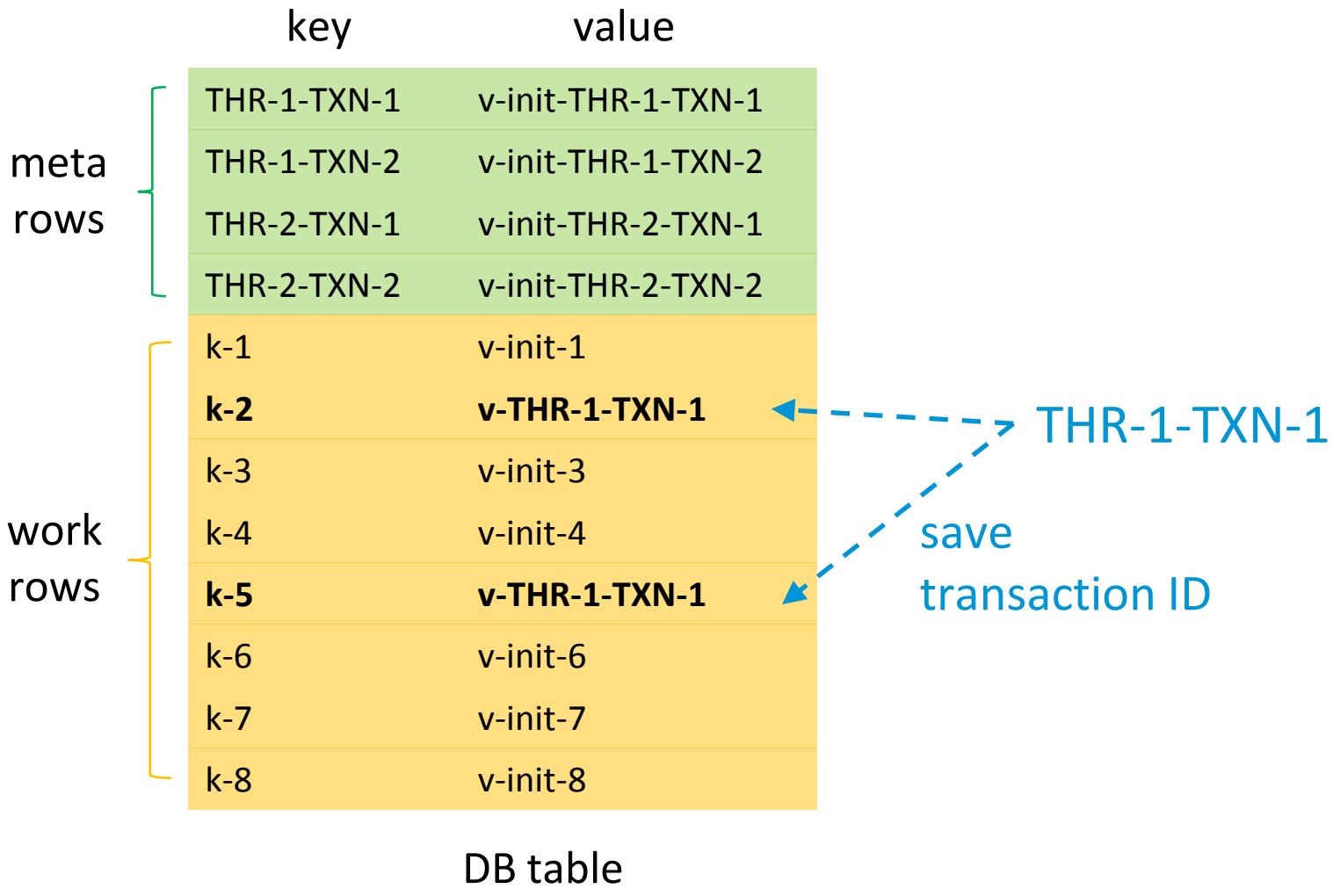


DB table

THR-1-TXN-1

Each transaction updates N random work rows + 1 meta row



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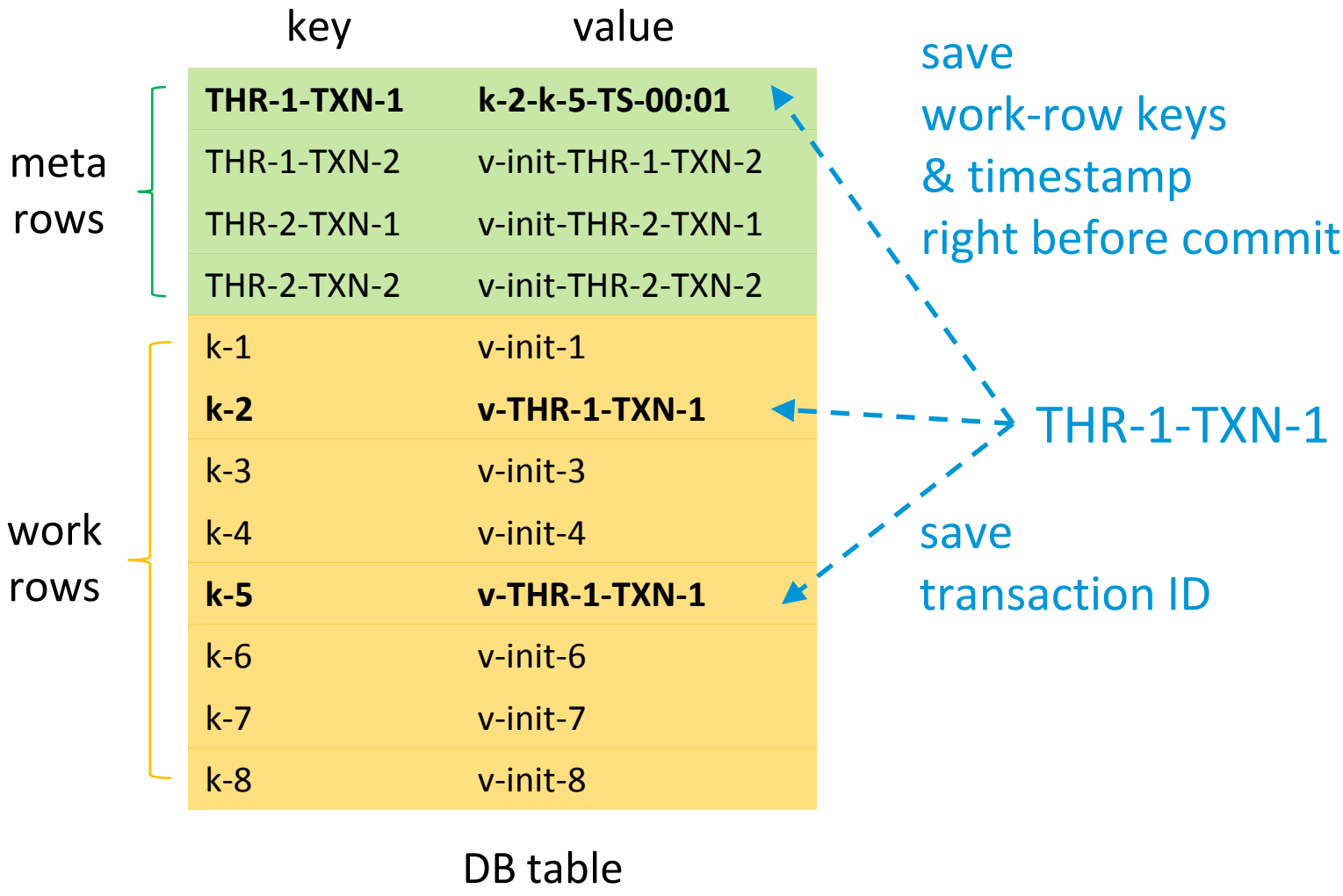
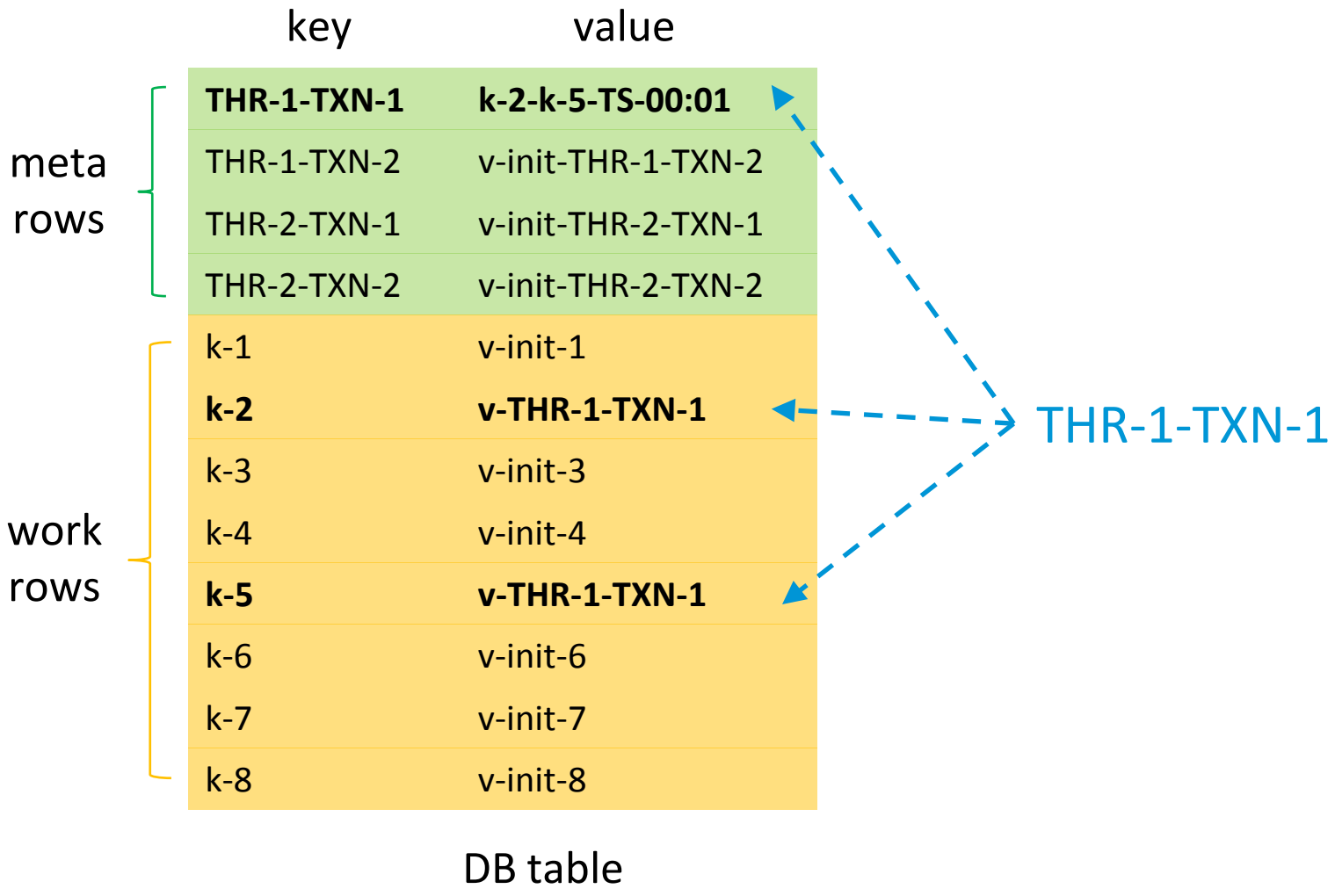


Fully exercise concurrency control



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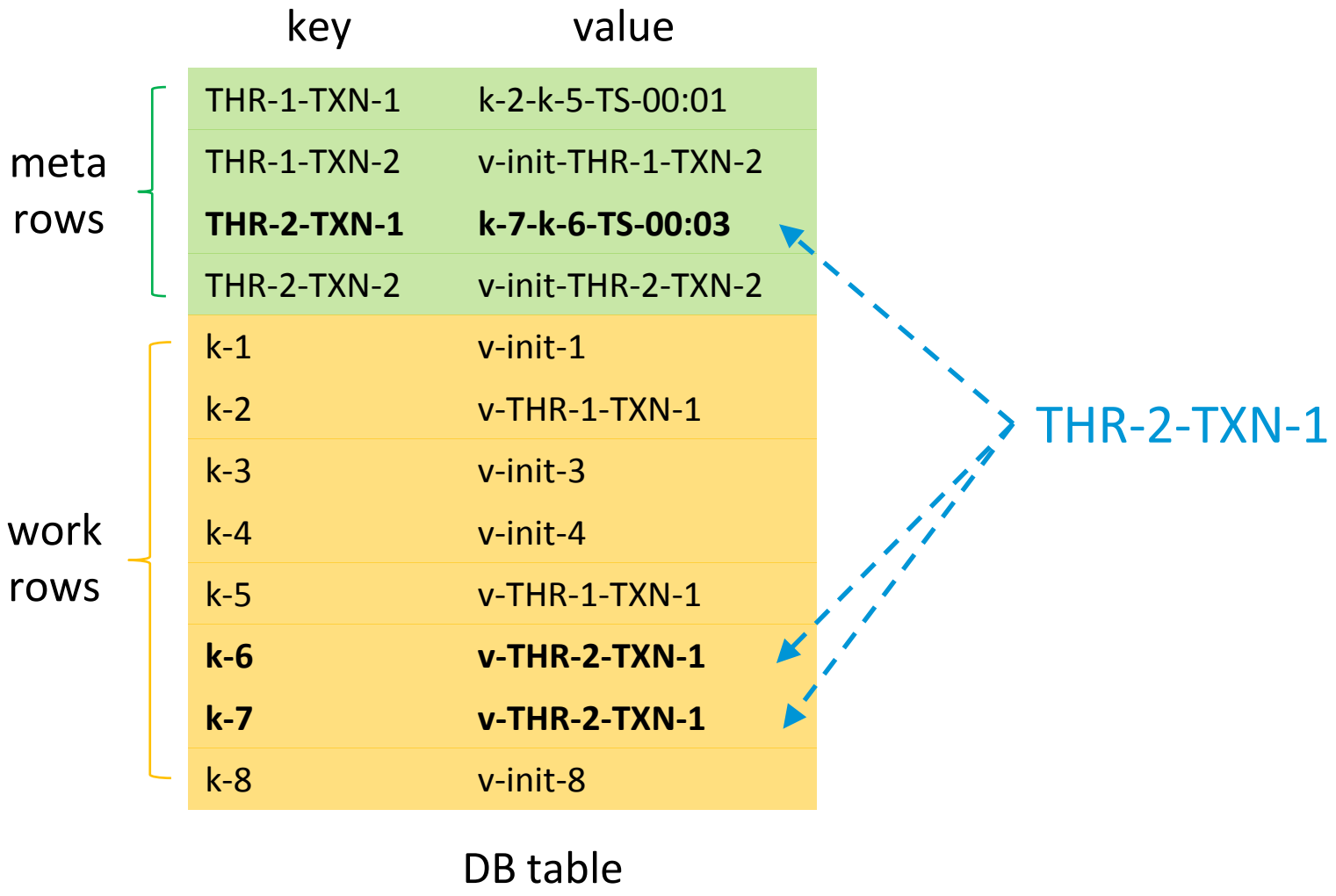

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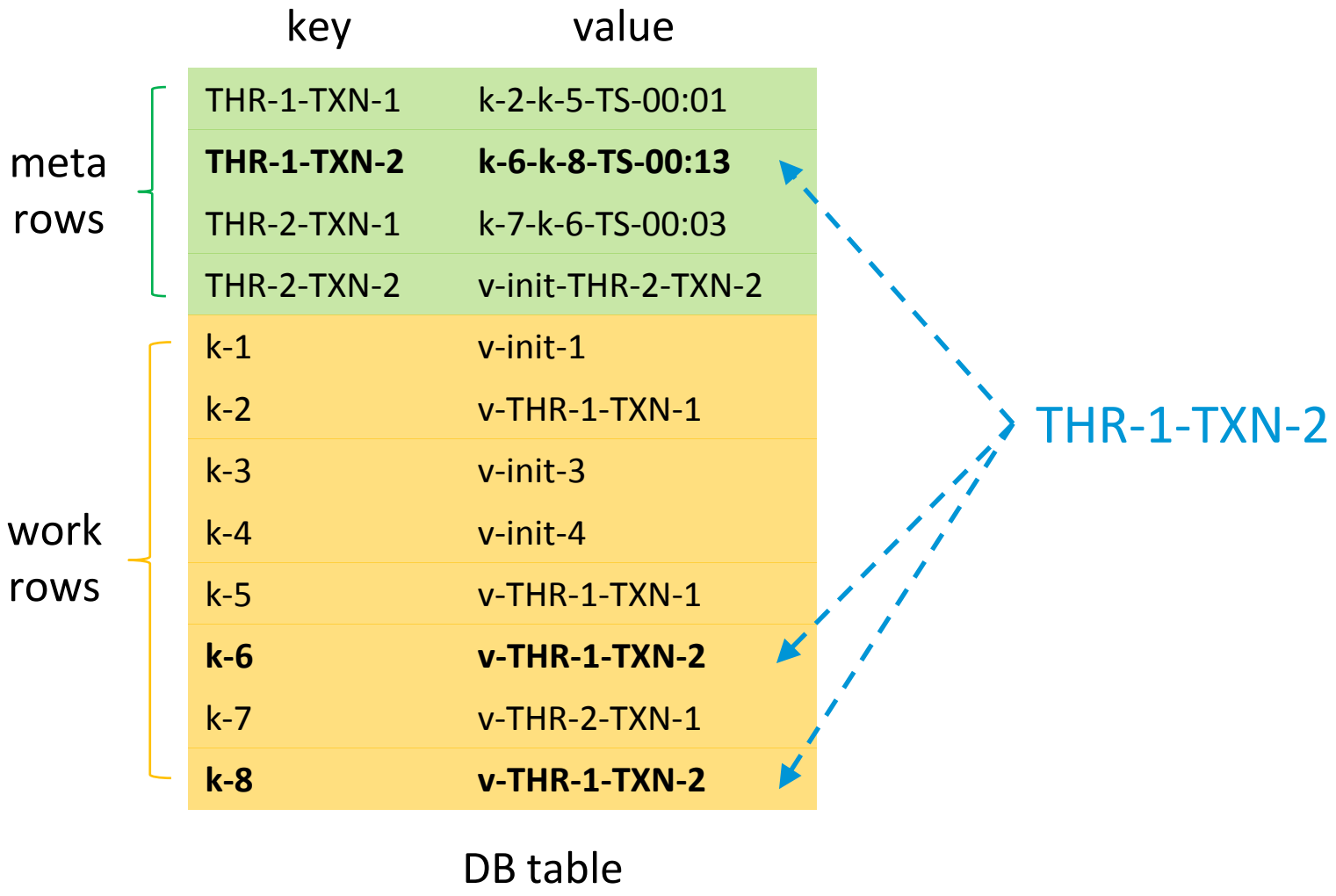

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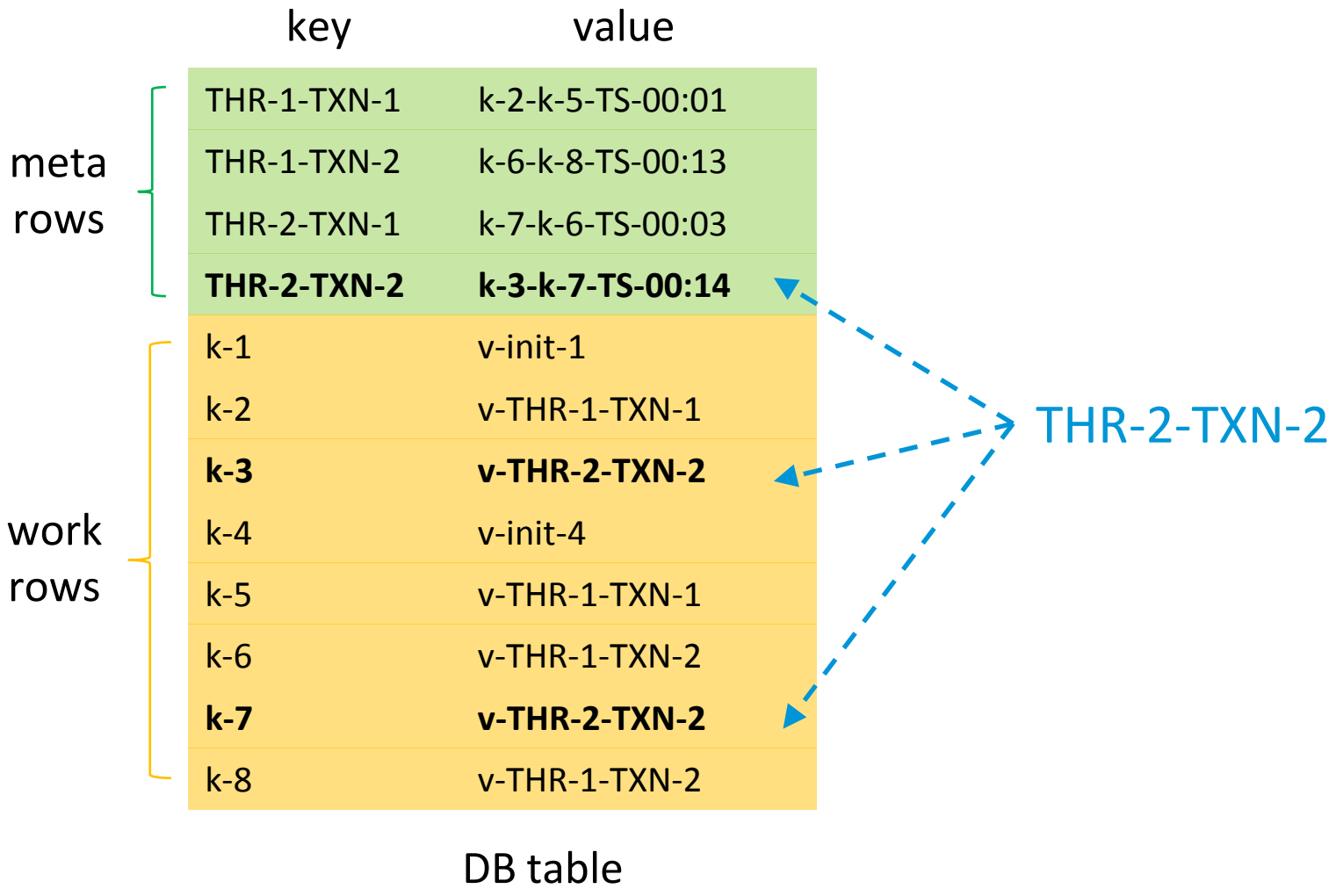
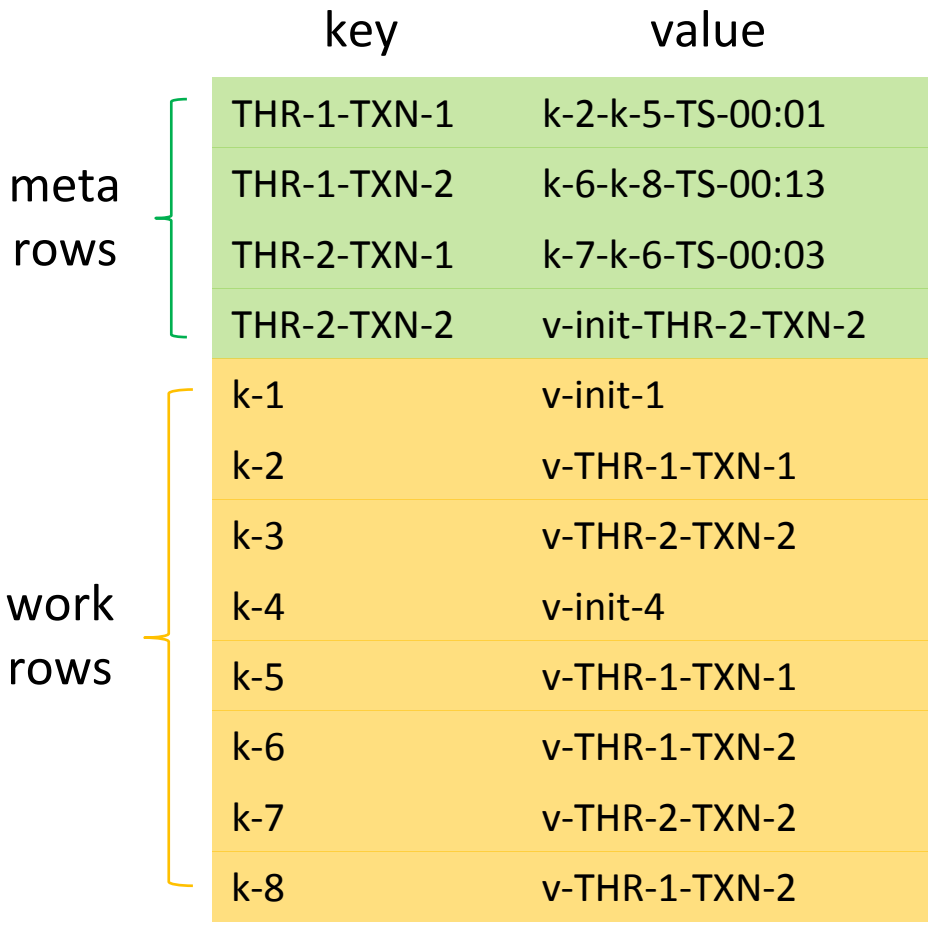


A power fault just happened during our workload ...

Is there any ACID violation after recovery?



recovered DB table

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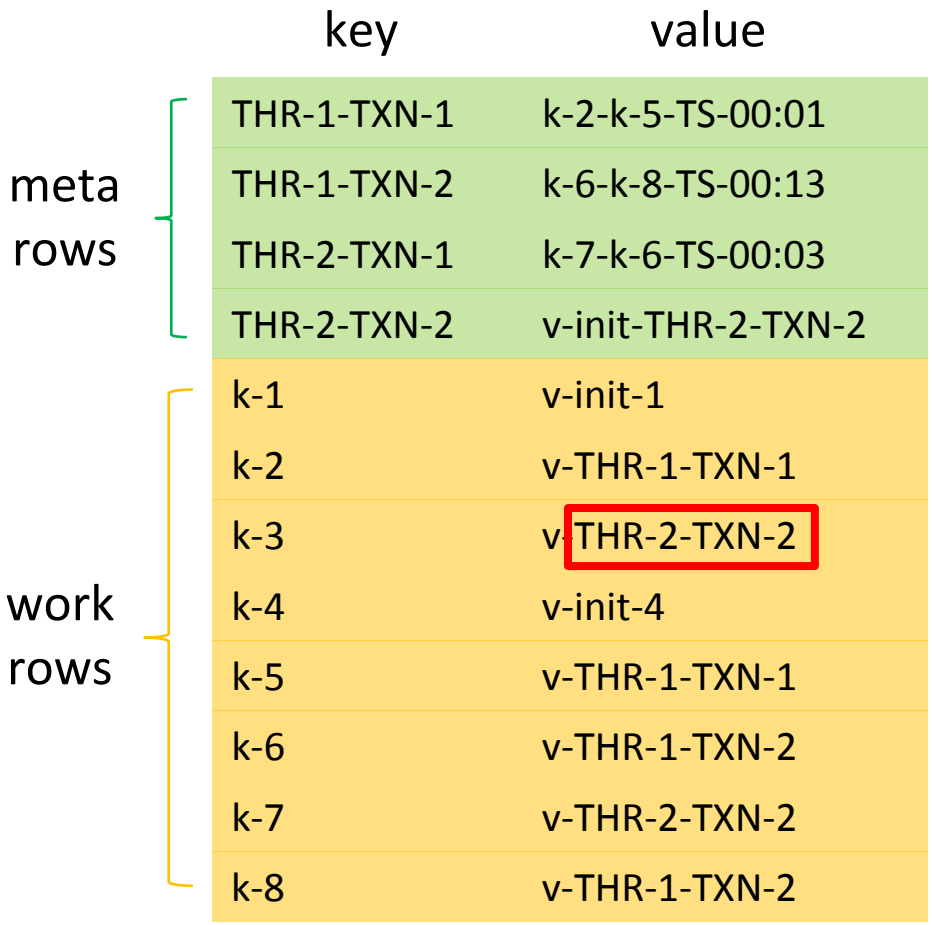

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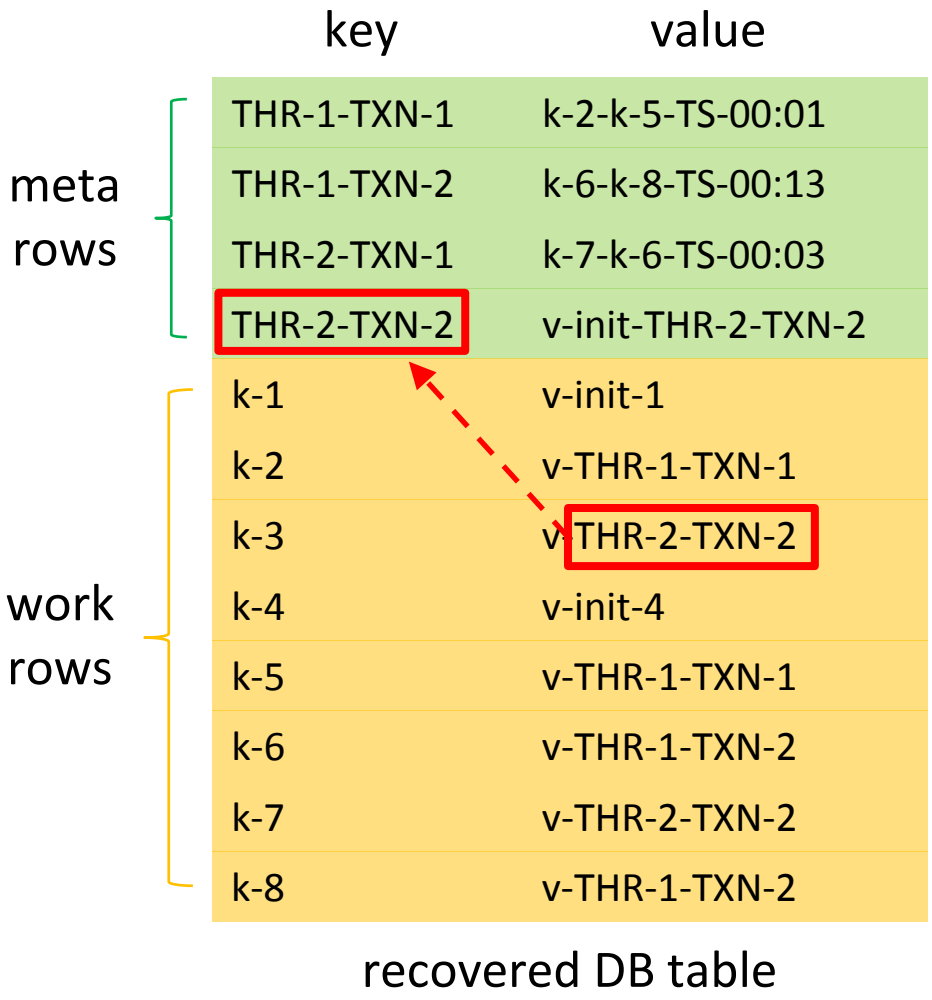

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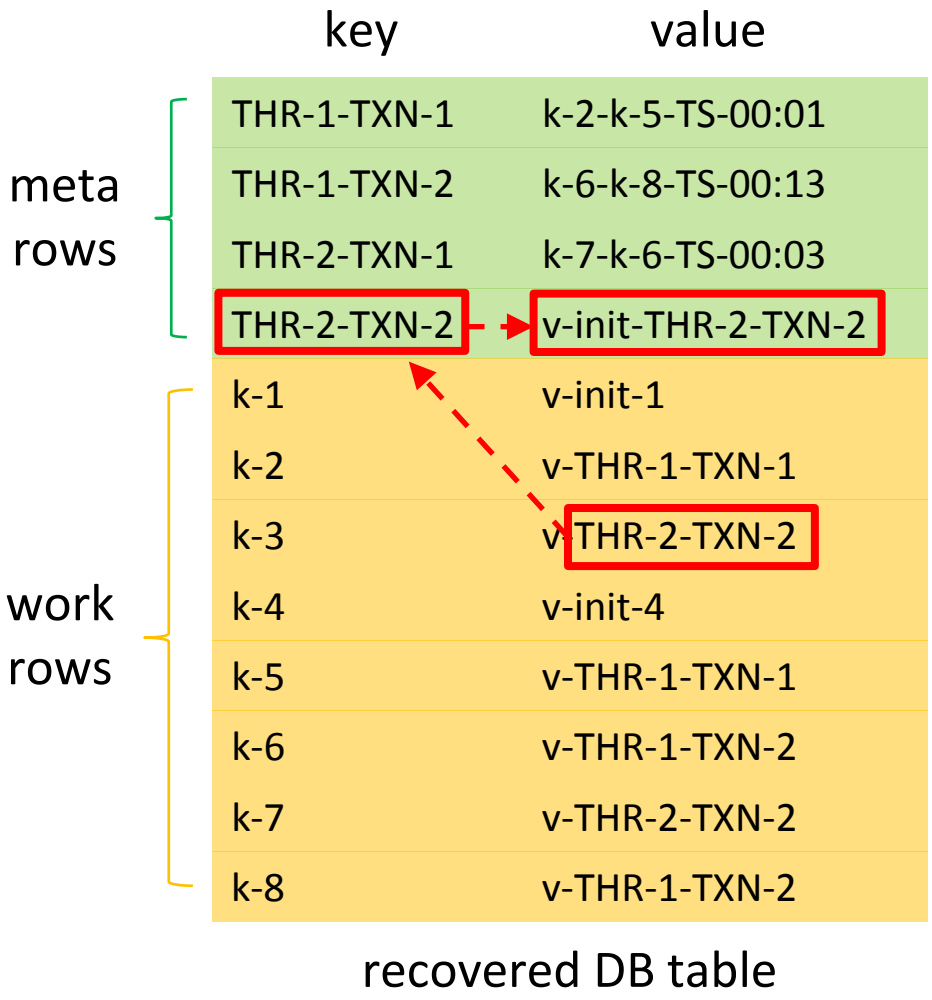

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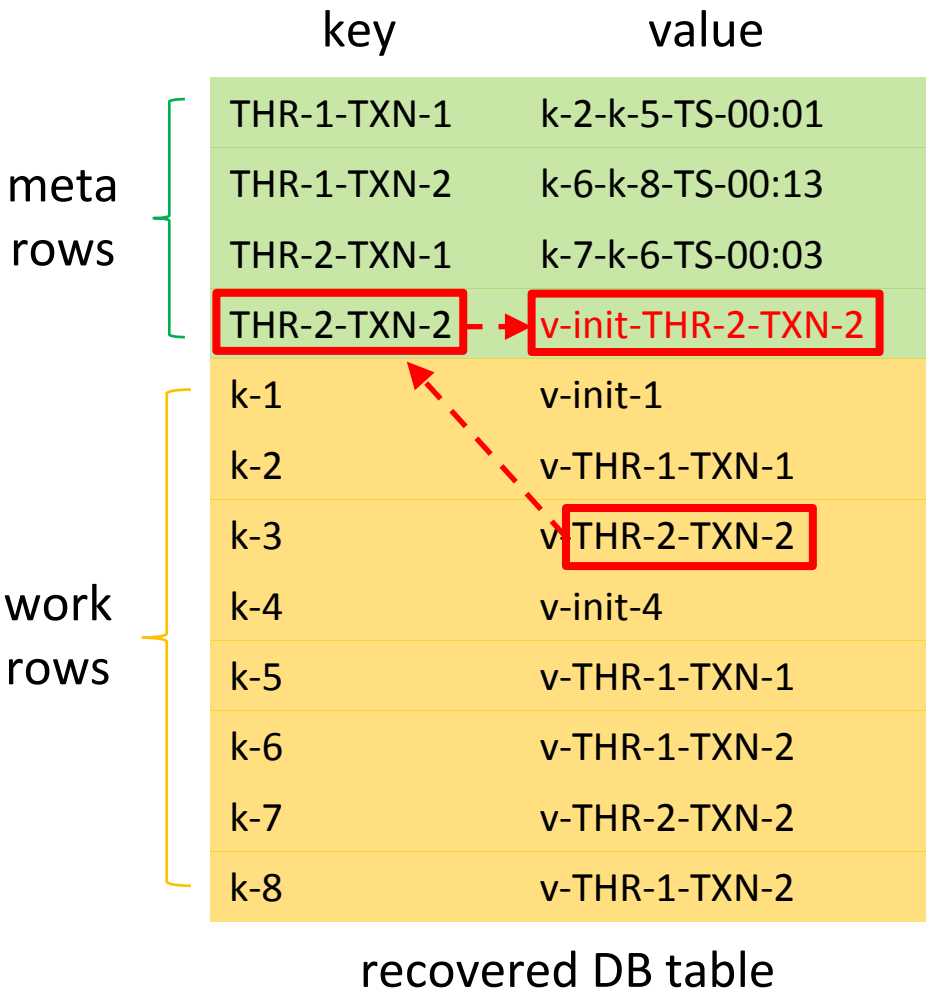
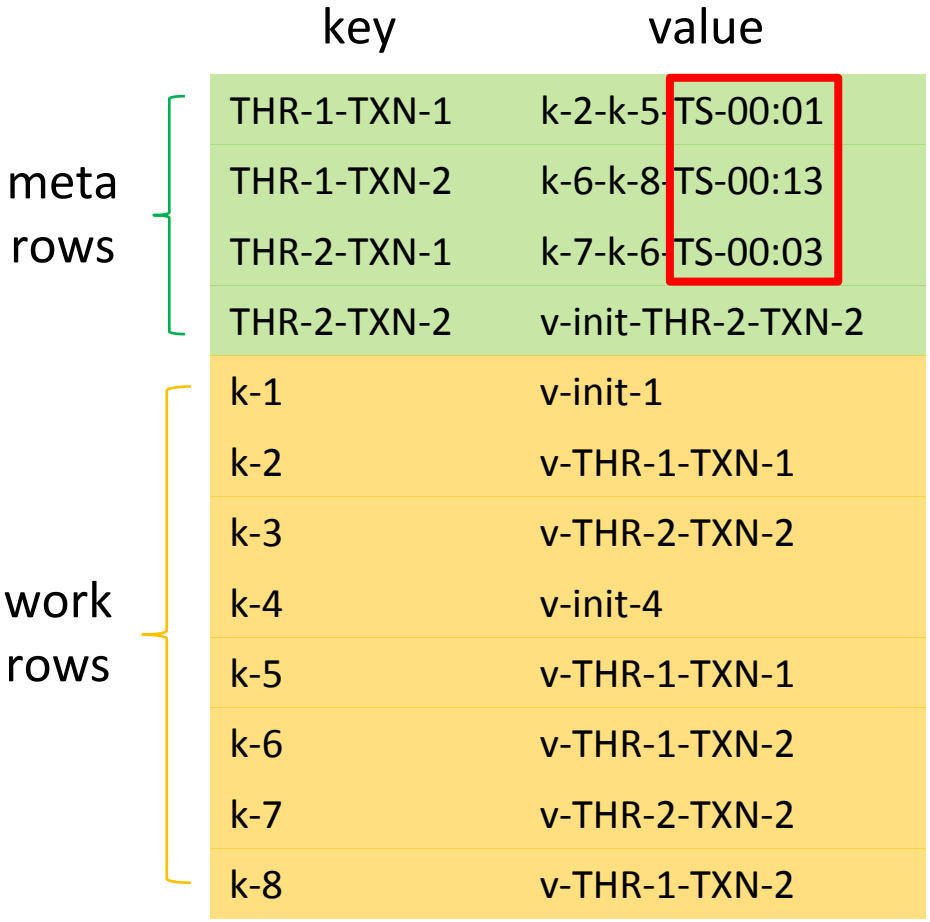


Atomicity violation!
should have been
updated w/ work rows

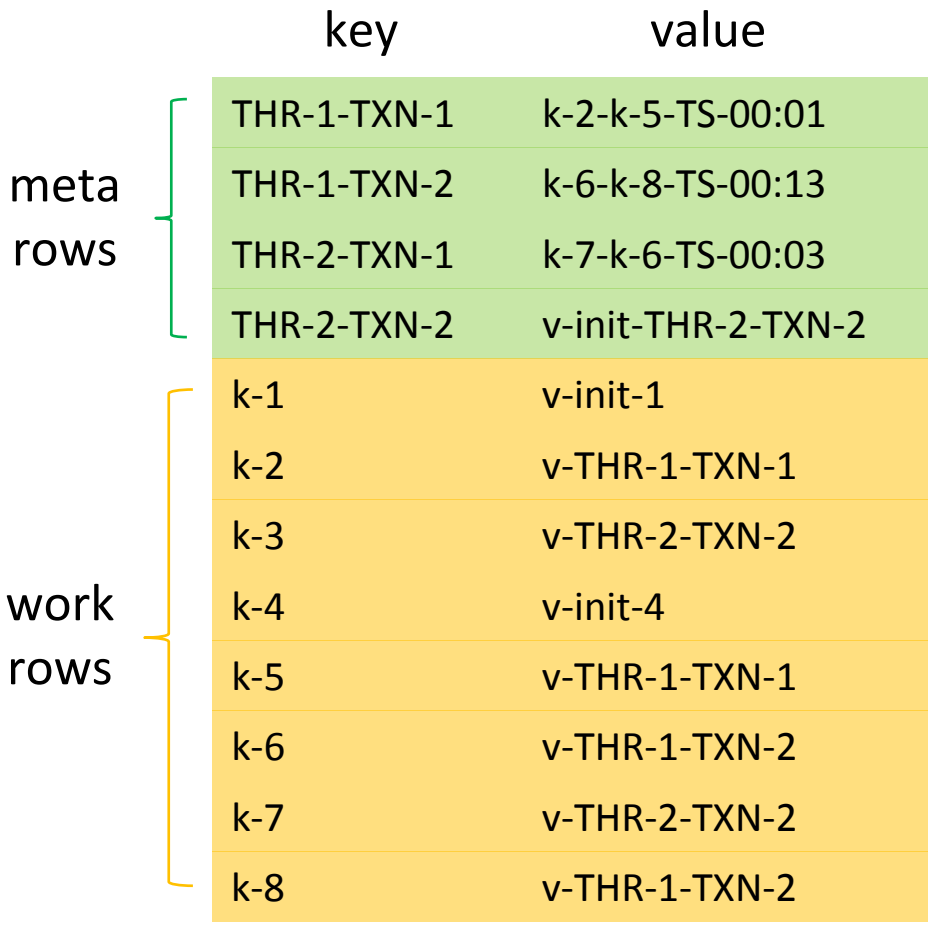
Is there any ACID violation after recovery?



recovered DB table

allow checking time & order related properties

Is there any ACID violation after recovery?



recovered DB table

More workloads & ACID checking in the paper

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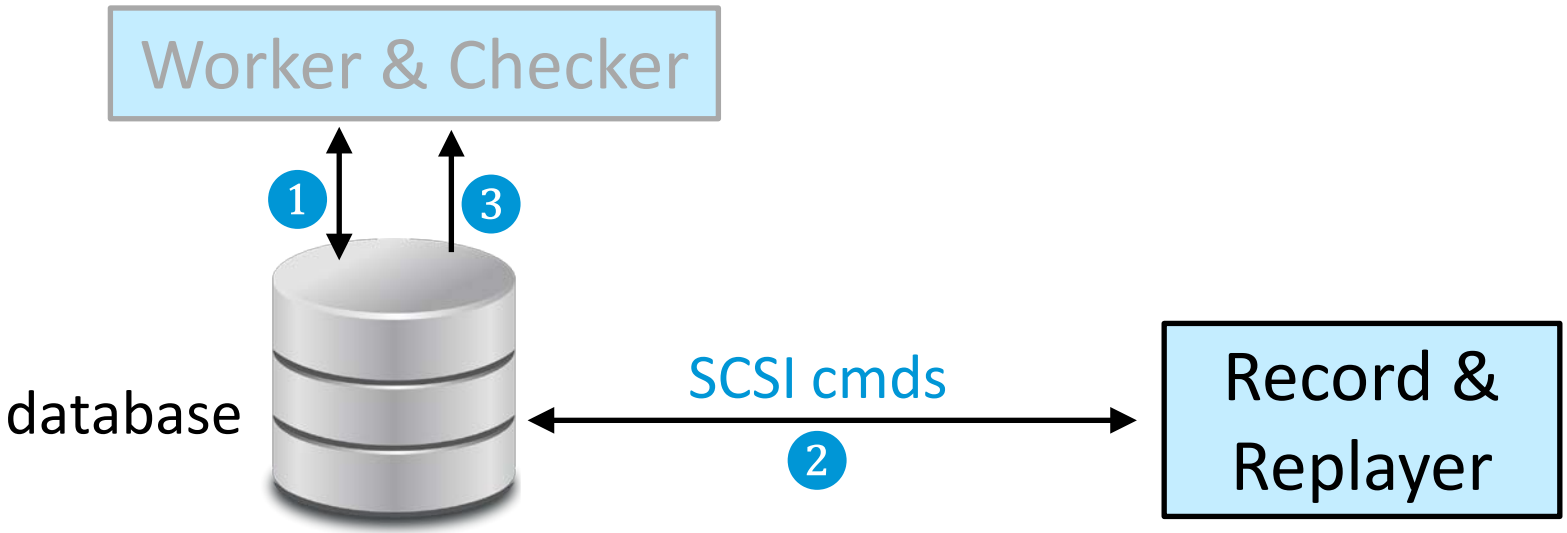

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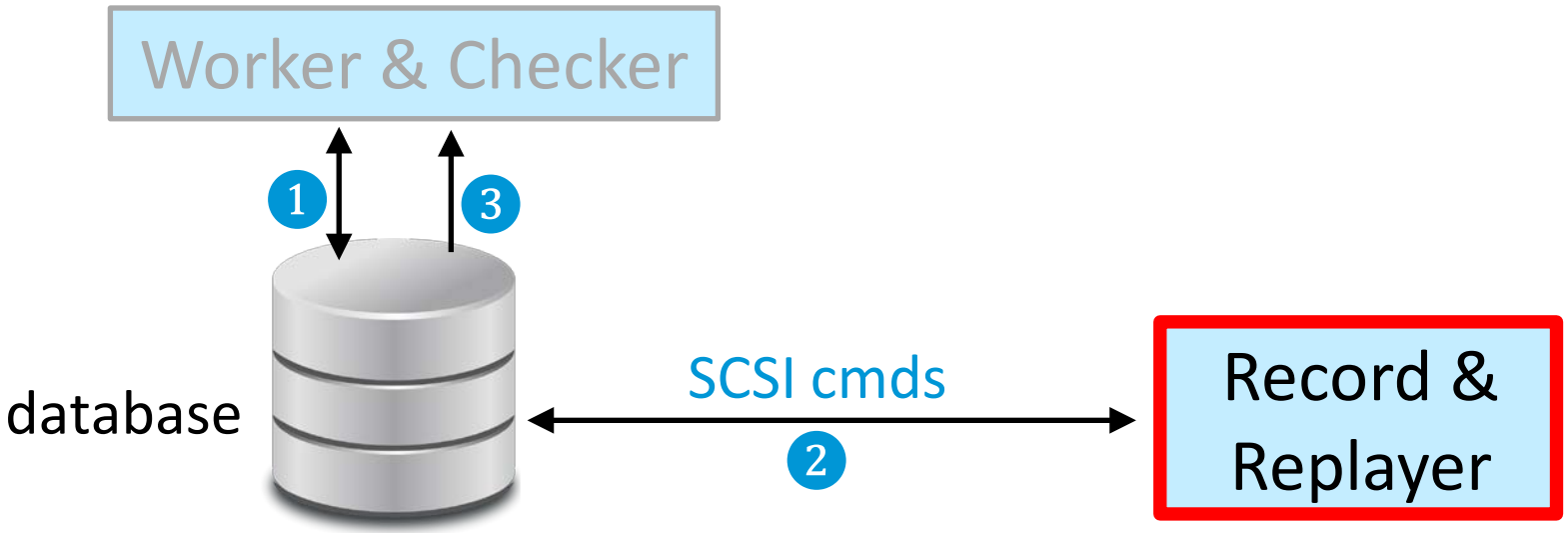
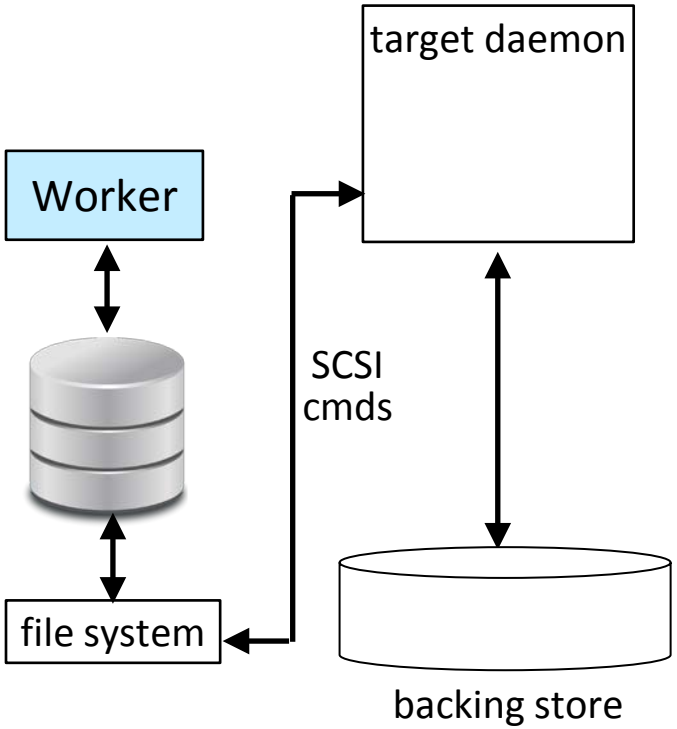


Capturing I/O trace without kernel modification



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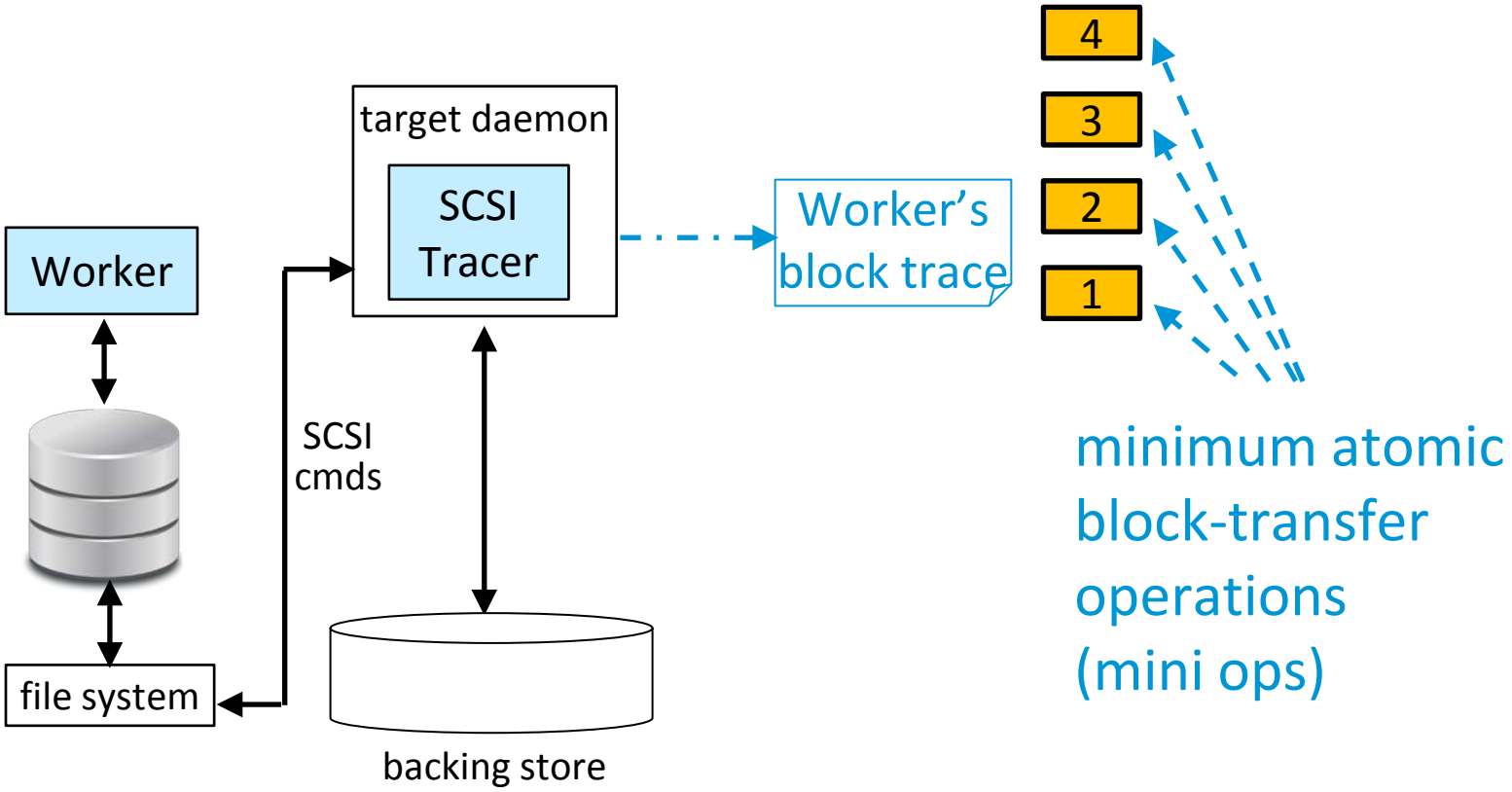
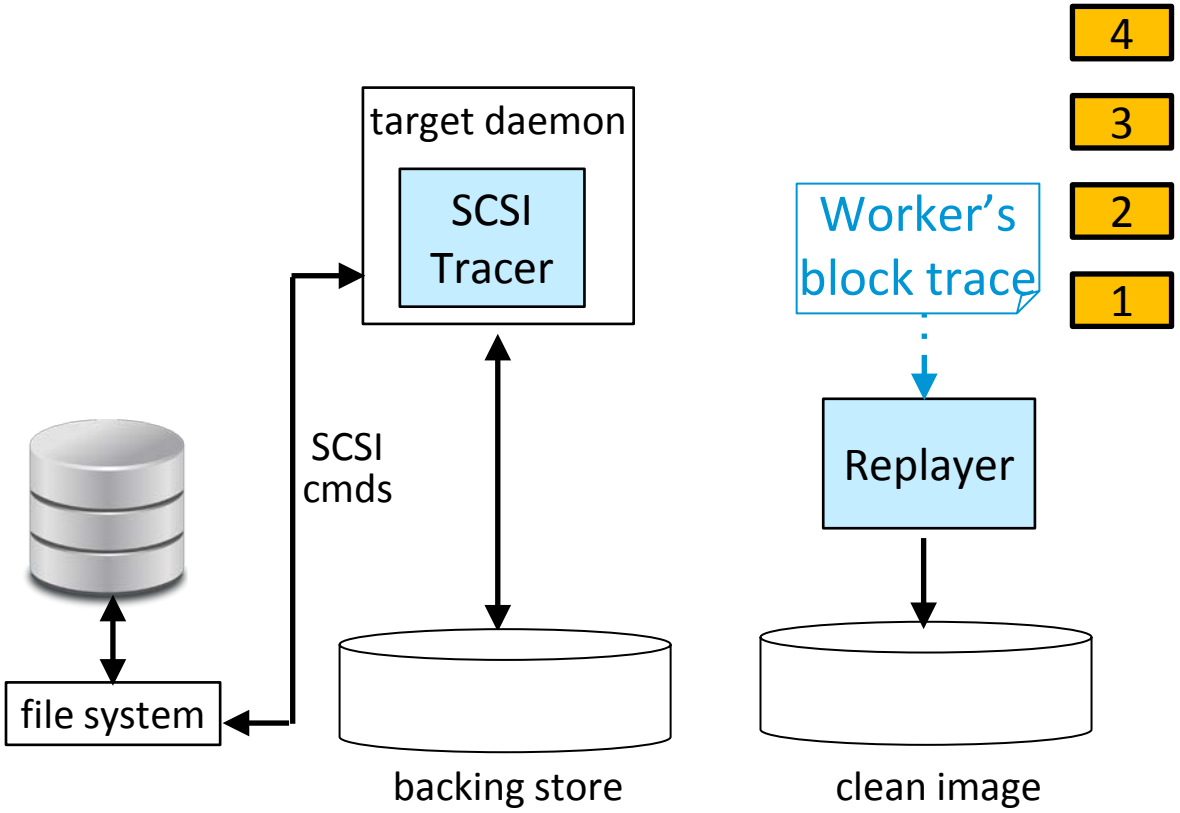


Constructing a post-fault disk image



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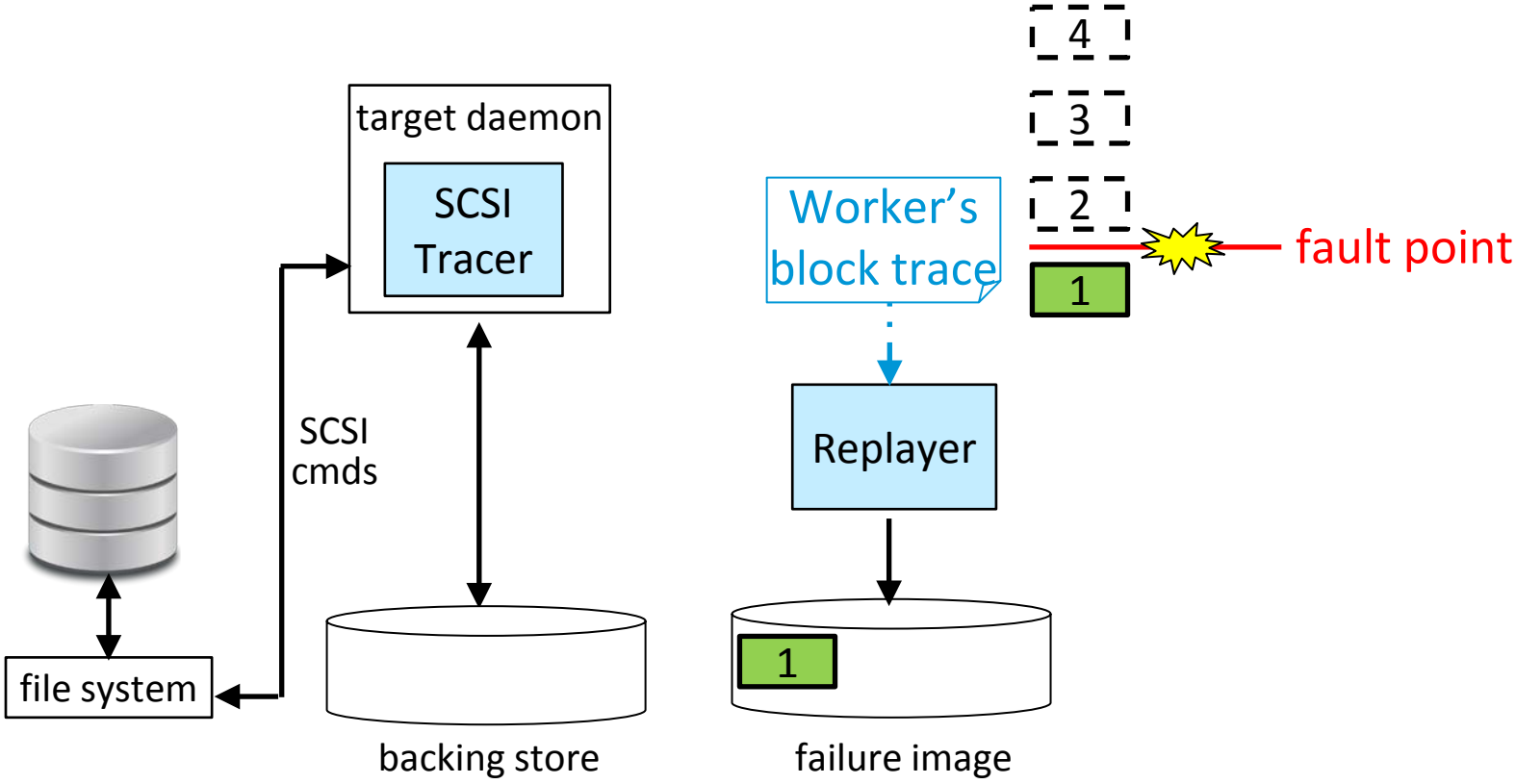
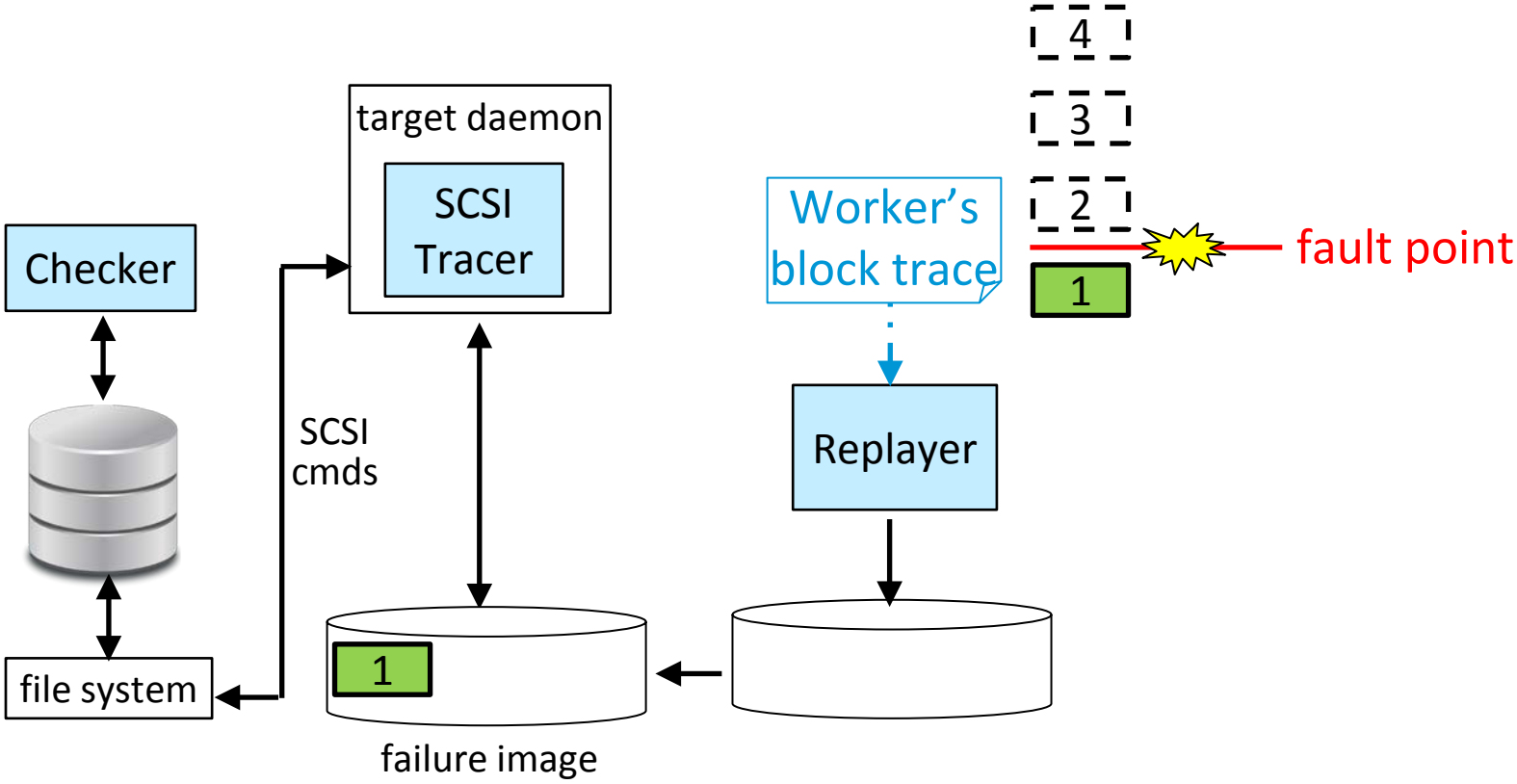


Checking the post-fault DB



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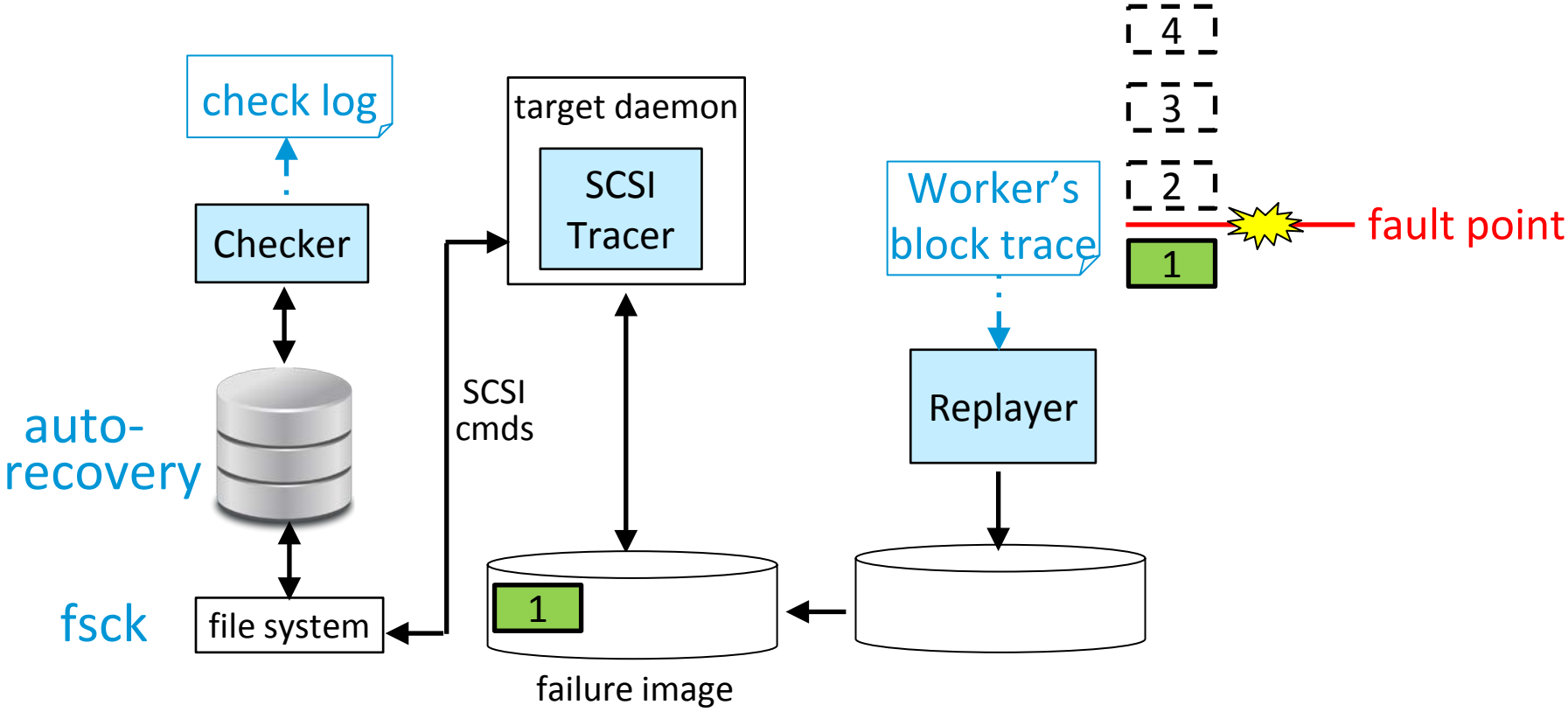
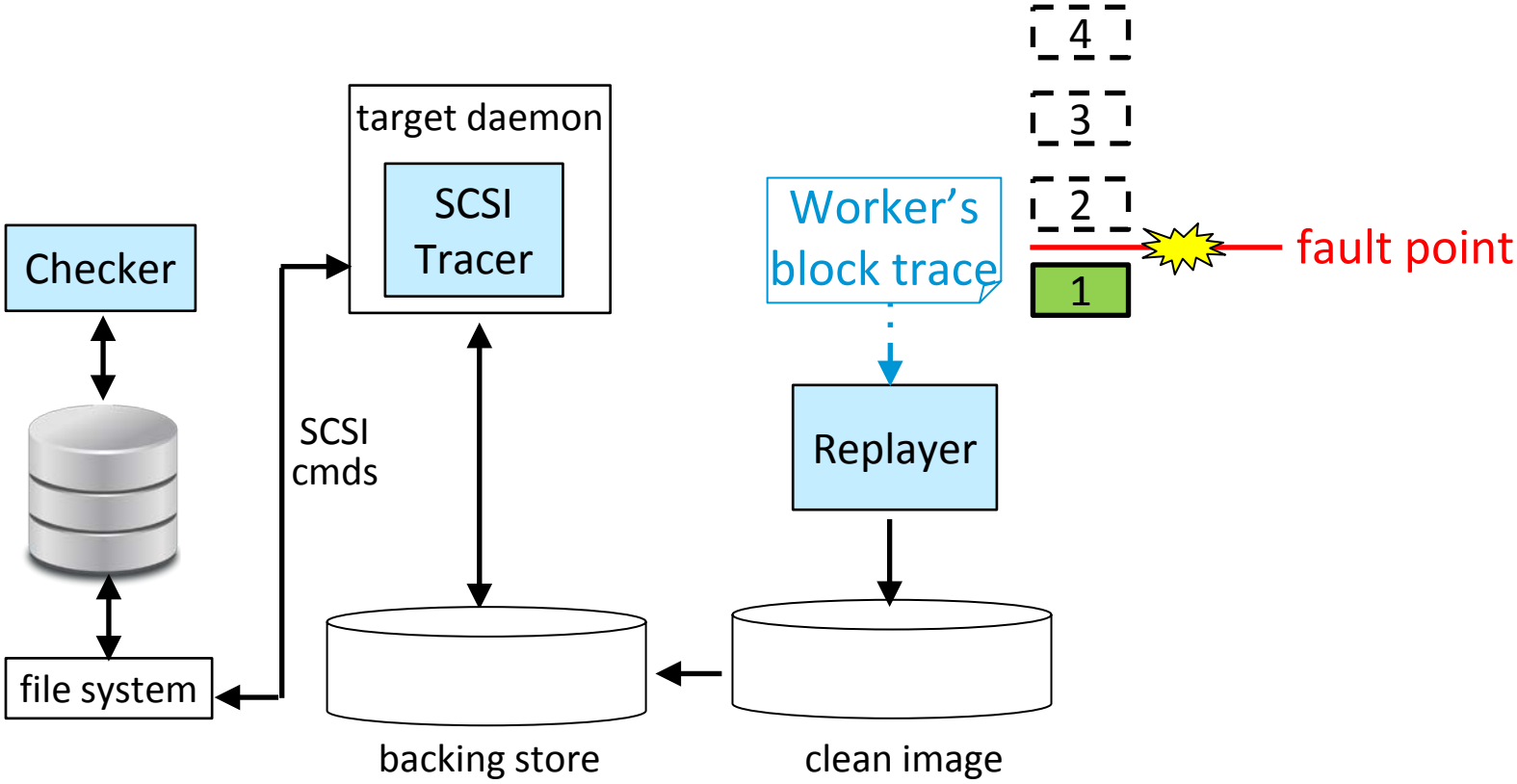


Testing different fault points easily



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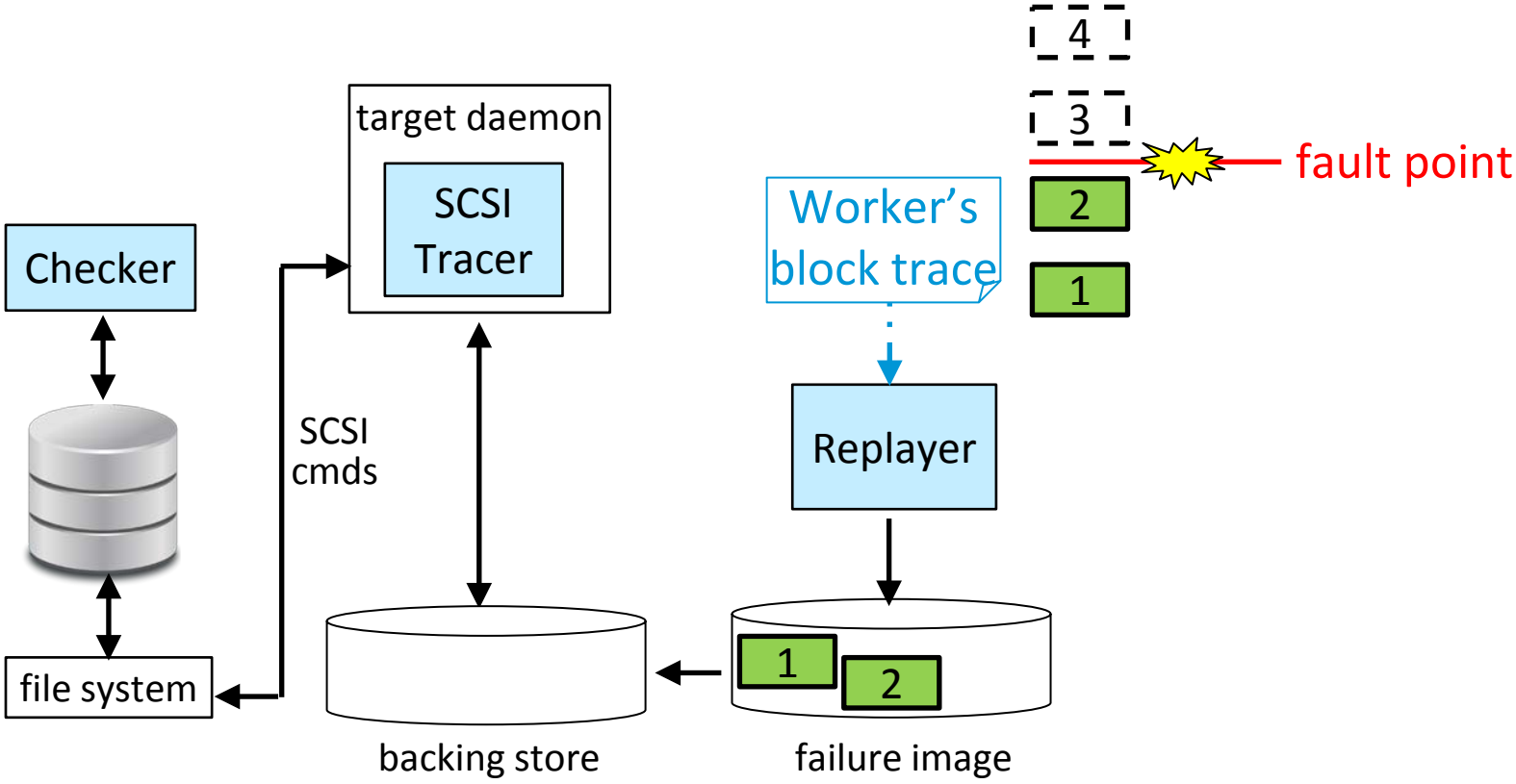

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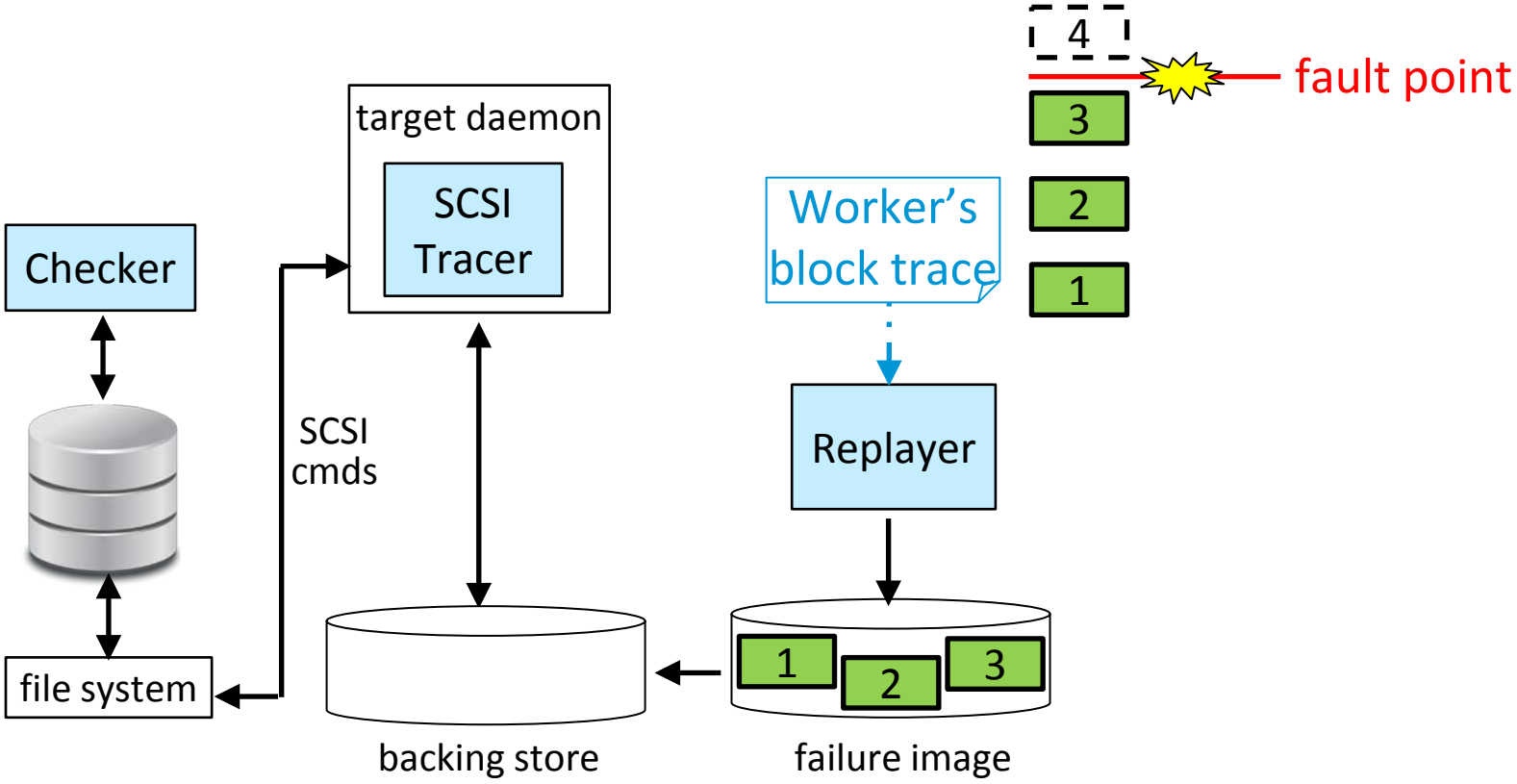
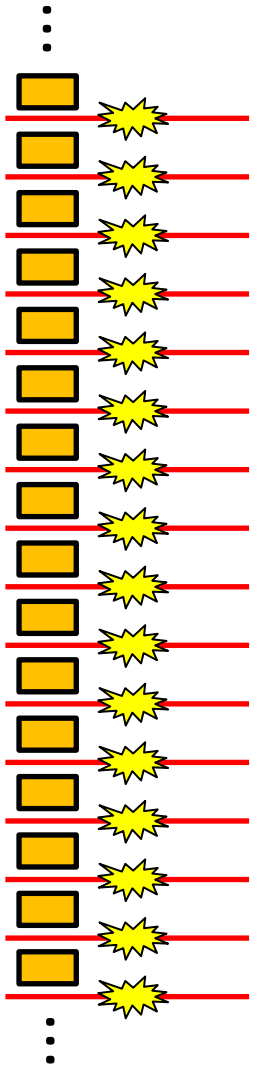


The framework is not good enough

- Sometimes need several days
  - too many mini operations, too many potential fault points



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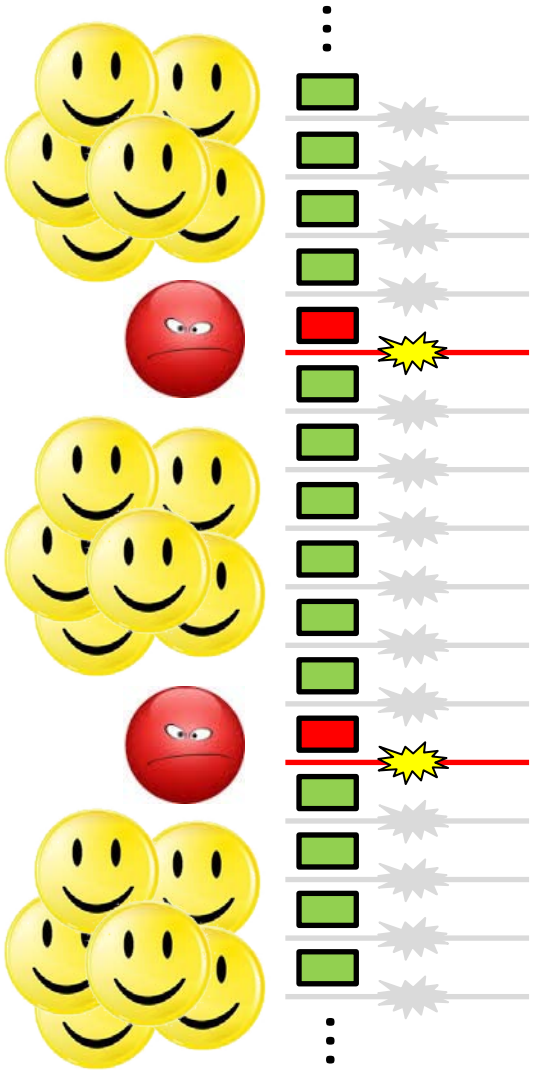
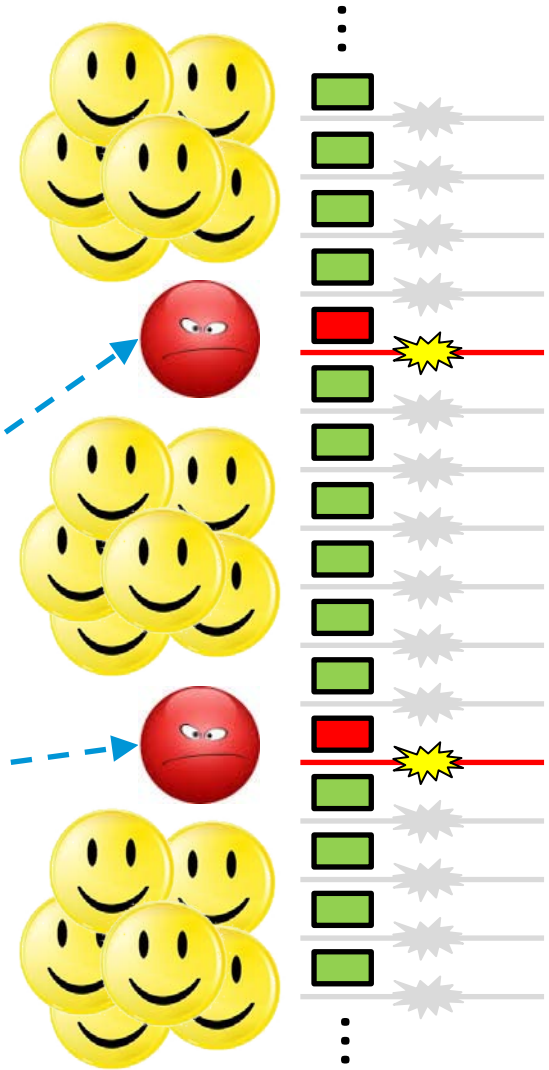
- We tried sampling
  - but only a few fault points trigger ACID violations



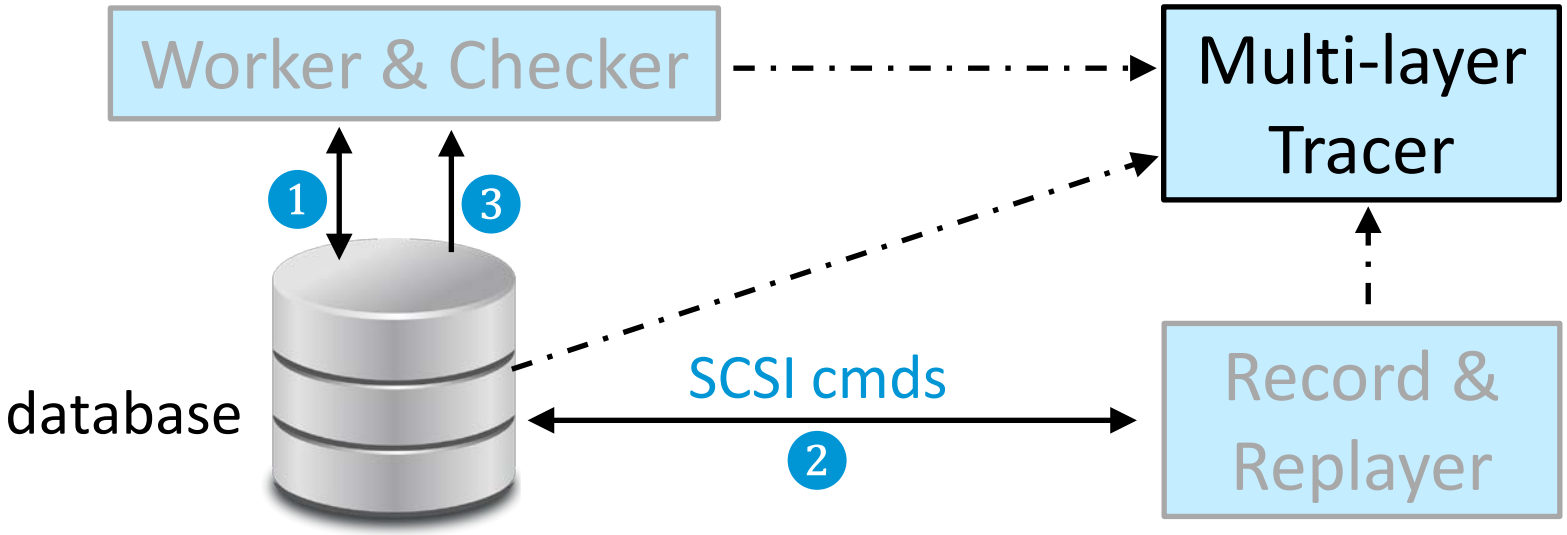
The framework is not good enough

- Sometimes need several days
  - too many mini operations, too many potential fault points
- We tried sampling
  - but only a few fault points trigger ACID violations
- Don’t know why



Enhanced Design

Framework Overview



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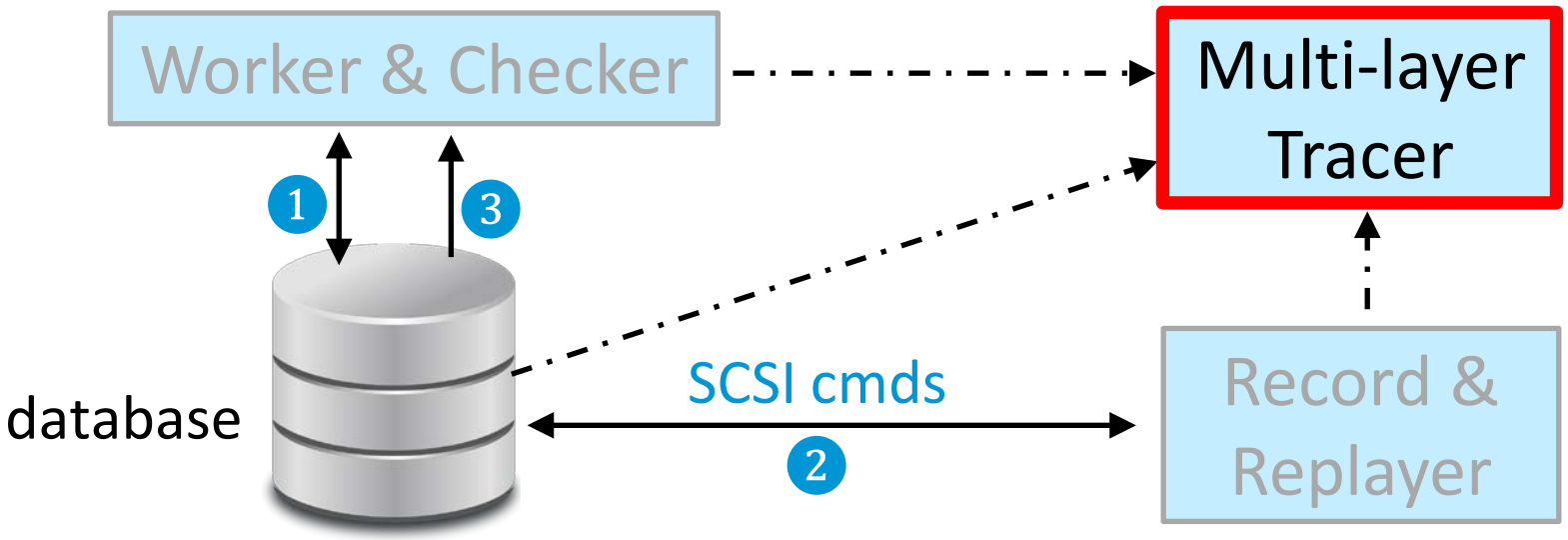
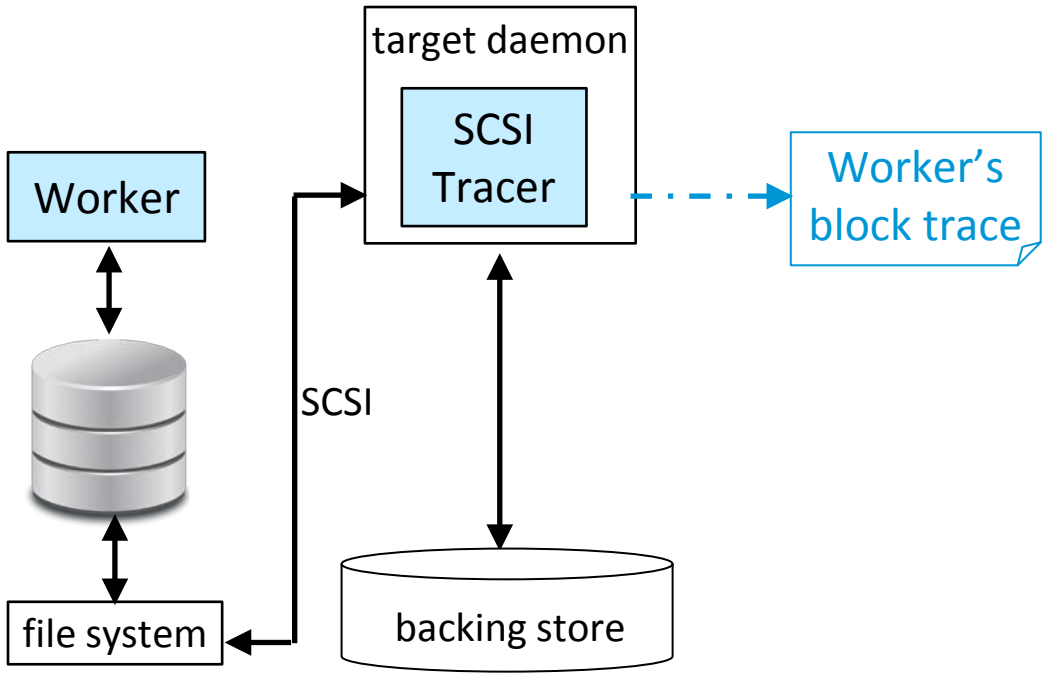


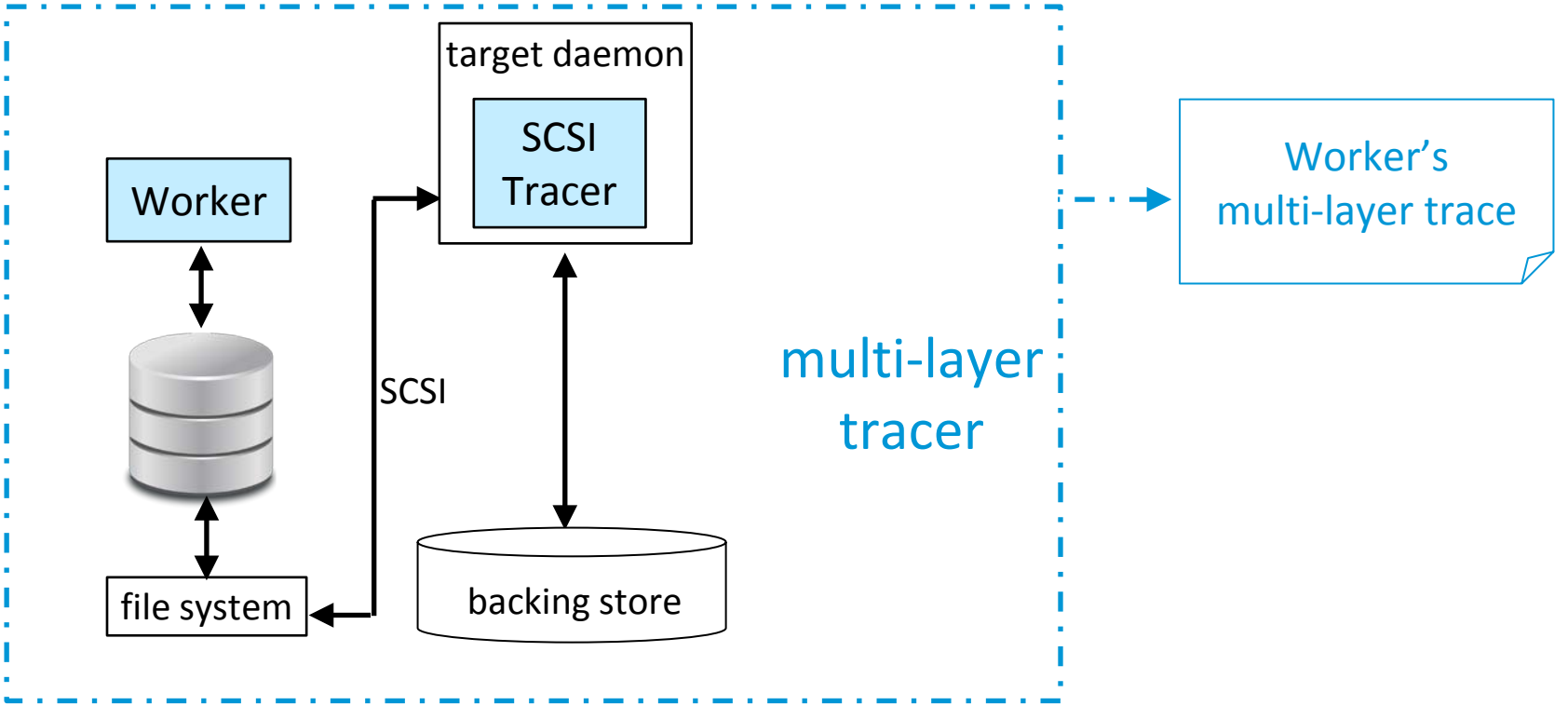
Original trace provides little semantics

op#	content	LBA
1	0a080101 ...	1012
2	0a080001 ...	6541
3	98393bc0 ...	9598
4	00000100 ...	9602



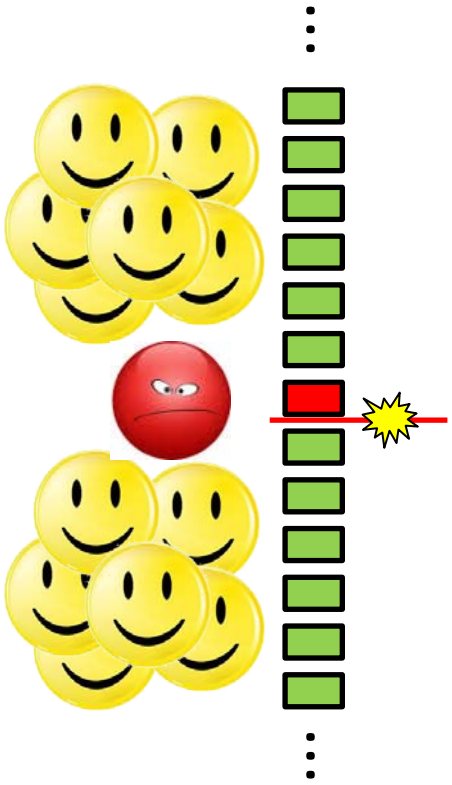
Enhancing w/ more context

op#	content	LBA	timestamp	SCSI cmd#	file	syscall
1	0a080101 ...	1012	139...013065	1	x.db	msync(x.db)
2	0a080001 ...	6541	139...210438	2	x.log	fsync(x.log)
3	98393bc0 ...	9598	139...355253	3	fs-j	fsync(x.log)
4	00000100 ...	9602	139...506097	3	fs-j	fsync(x.log)



What makes some fault points special?

Checking result



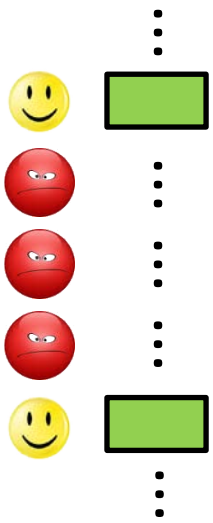
Worker's multi-layer trace

op#	content	LBA	ts	cmd#	file	syscall
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	**…**	**…**	**…**	**…**	**…**	**…**
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…

anything special?

5 patterns found from 2 databases

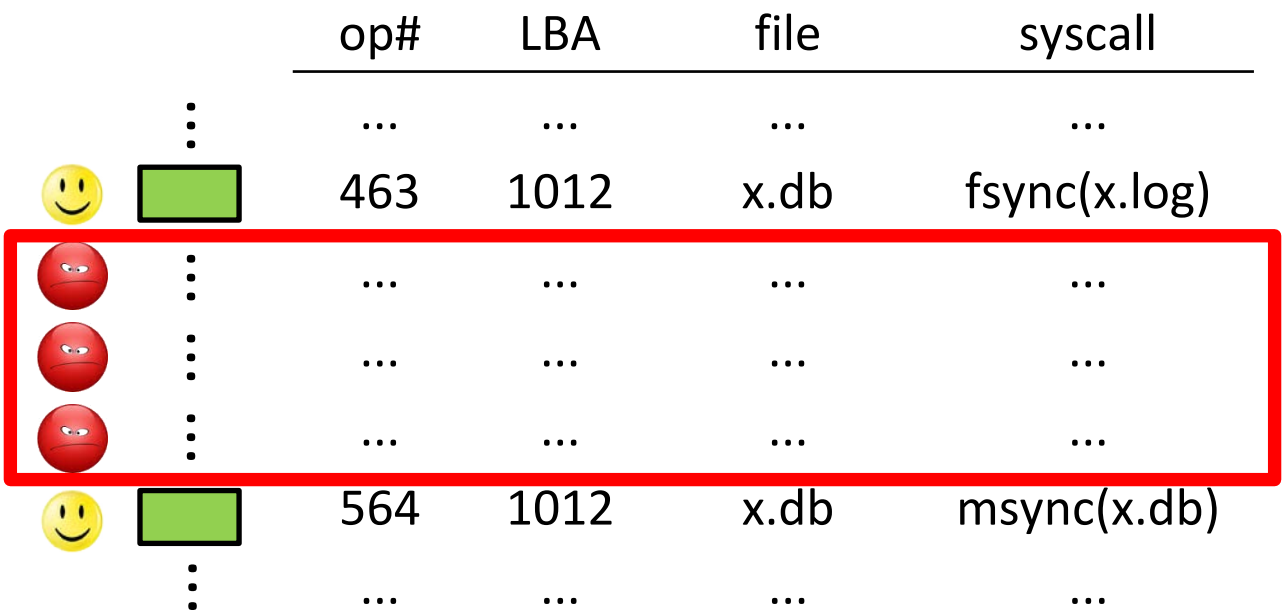
- MMAP_p : unintended update to mmap'ed blocks



op#	LBA	file	syscall
…	…	…	…
463	1012	x.db	fsync(x.log)
…	…	…	…
…	…	…	…
…	…	…	…
564	1012	x.db	msync(x.db)
…	…	…	…

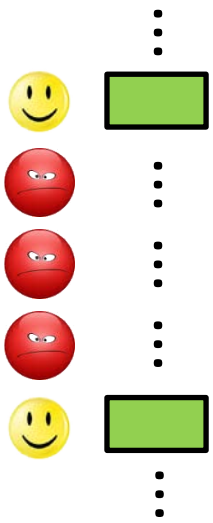
5 patterns found from 2 databases

- MMAP_p : unintended update to mmap'ed blocks



5 patterns found from 2 databases

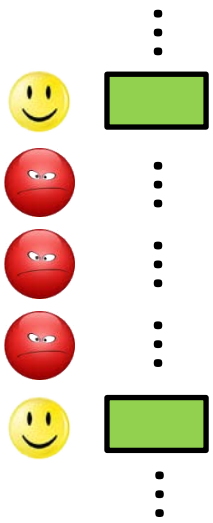
- $MMAP_p$: unintended update to mmap'ed blocks



op#	LBA	file	syscall	
…	…	…	…	
463	1012	x.db	fsync(x.log)	
…	…	…	…	
…	…	…	…	
…	…	…	…	
564	1012	x.db	msync(x.db)	intended
…	…	…	…	

5 patterns found from 2 databases

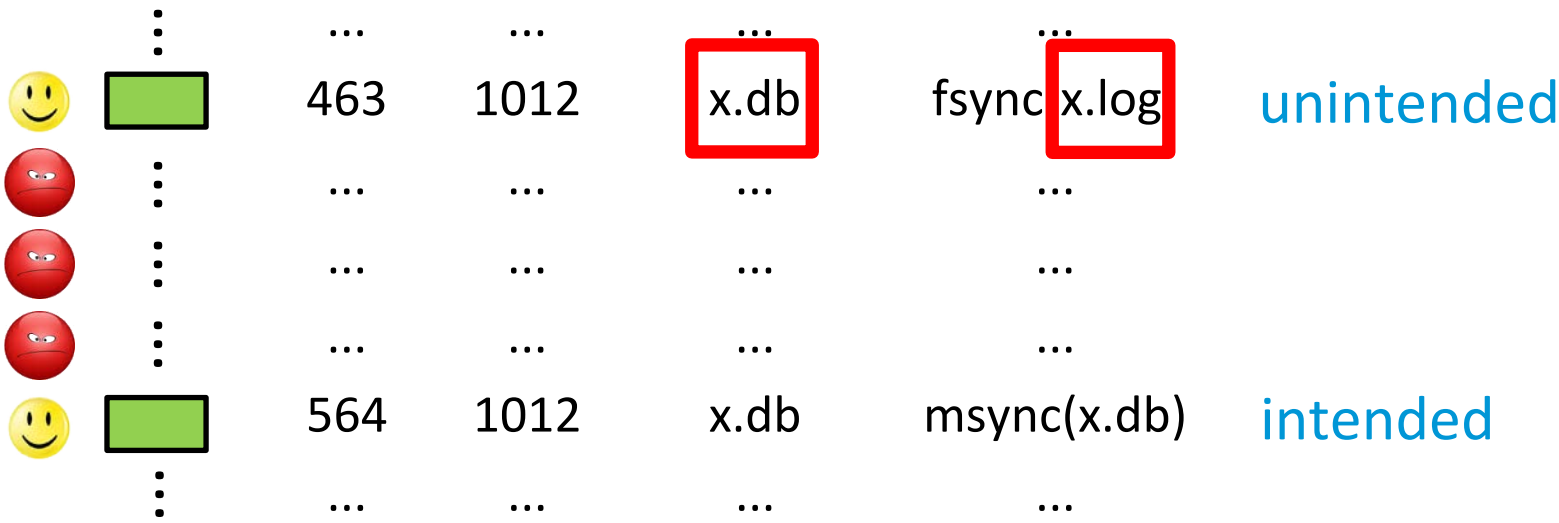
- $MMAP_p$: unintended update to mmap'ed blocks



op#	LBA	file	syscall	
…	…	…	…	
463	1012	x.db	fsync(x.log)	
…	…	…	…	
…	…	…	…	
…	…	…	…	
564	1012	x.db	msync(x.db)	intended
…	…	…	…	

5 patterns found from 2 databases

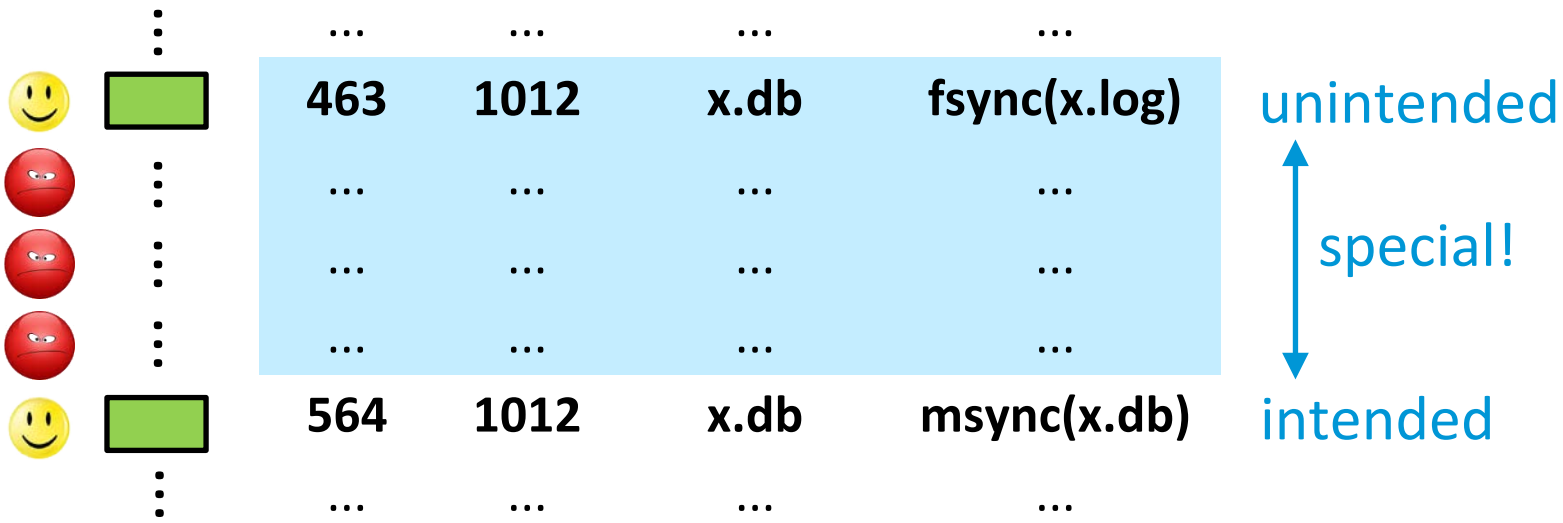
- $MMAP_p$: unintended update to mmap'ed blocks



implicit flush of dirty blocks by kernel or FS under heavy transactions

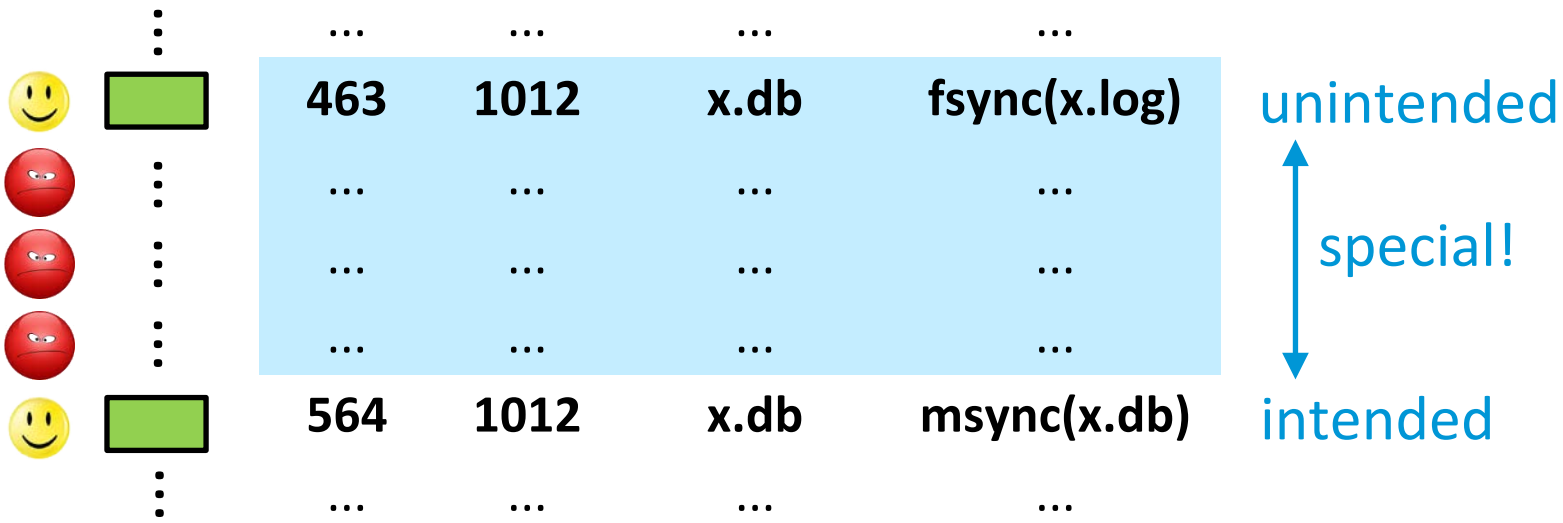
5 patterns found from 2 databases

- $MMAP_p$: unintended update to mmap'ed blocks



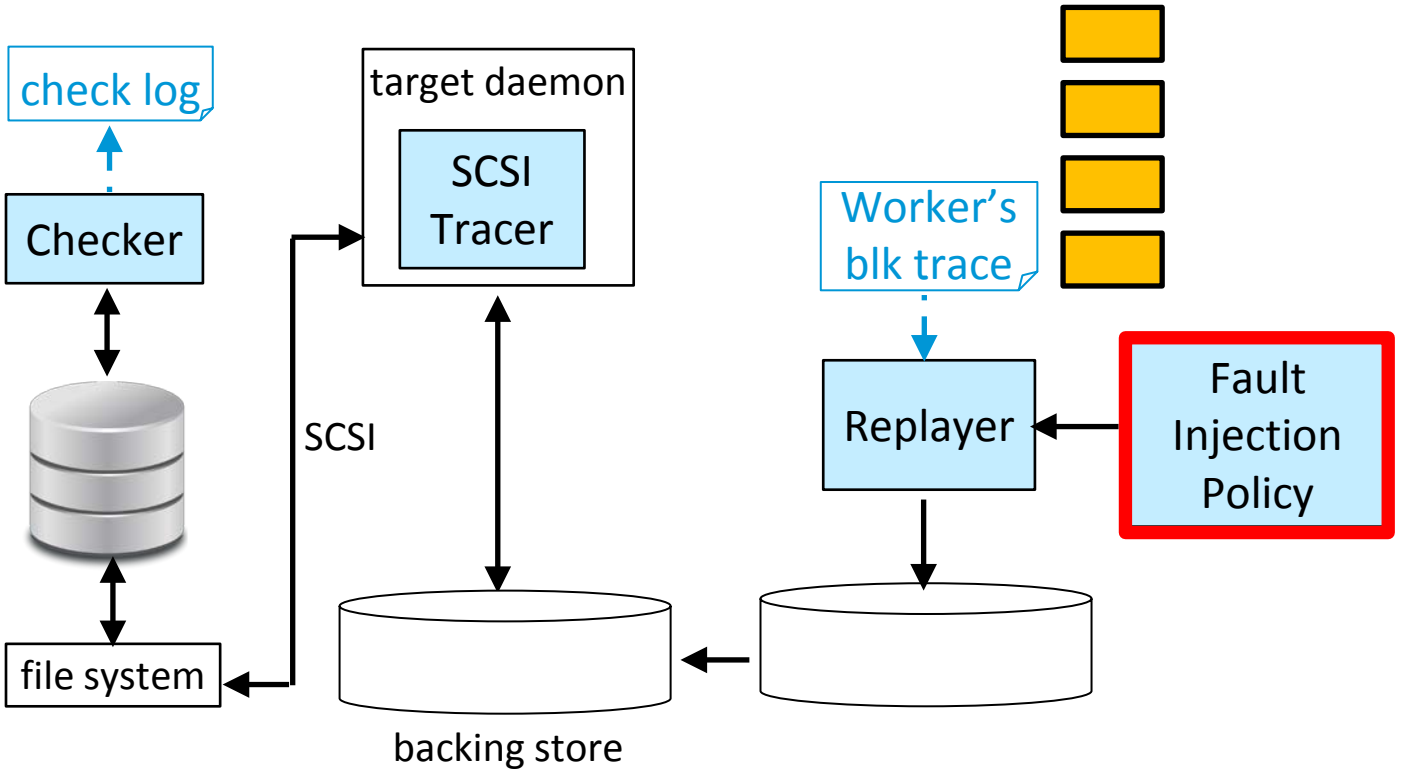
5 patterns found from 2 databases

- $MMAP_p$: unintended update to mmap'ed blocks



- Four more patterns: REP_p , $JUMP_p$, $HEAD_p$, $TRAN_p$

Add fault injection policy to determine where to inject faults



Alternative to Exhaustive: Pattern-based Ranking

Worker's multi-layer trace

op#	LBA	cmd#	file	syscall	
1	348	1	x.db	msyc(x.db)	1
2	352	2	x.log	fsync(x.log)	2
3	356	2	x.log	fsync(x.log)	3
4	360	2	x.log	fsync(x.log)	4
5	364	2	x.log	fsync(x.log)	5
6	370	3	x.log	fsync(x.log)	6
7	348	4	x.db	fsync(x.log)	7
8	906	5	fs-j	fsync(x.log)	8

Scoreboard

$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score

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Worker's multi-layer trace

op#	LBA	cmd#	file	syscall
1	348	1	x.db	msyc(x.db)
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4	360	2	x.log	fsync(x.log)
5	364	2	x.log	fsync(x.log)
6	370	3	x.log	fsync(x.log)
7	348	4	x.db	fsync(x.log)
8	906	5	fs-j	fsync(x.log)

Scoreboard

	$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score
1	0					
2	0					
3	0					
4	0					
5	0					
6	0					
7	1					
8	1					

Alternative to Exhaustive: Pattern-based Ranking

Worker's multi-layer trace

op#	LBA	cmd#	file	syscall
1	348	1	x.db	msyc(x.db)
2	352	2	x.log	fsync(x.log)
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5	364	2	x.log	fsync(x.log)
6	370	3	x.log	fsync(x.log)
7	348	4	x.db	fsync(x.log)
8	906	5	fs-j	fsync(x.log)

Scoreboard

	$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score
1	0	1				
2	0	0				
3	0	0				
4	0	0				
5	0	0				
6	0	0				
7	1	1				
8	1	0				

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Worker's multi-layer trace

op#	LBA	cmd#	file	syscall
1	348	1	x.db	msyc(x.db)
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5	364	2	x.log	fsync(x.log)
6	370	3	x.log	fsync(x.log)
7	348	4	x.db	fsync(x.log)
8	906	5	fs-j	fsync(x.log)

Scoreboard

	$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score
1	0	1	0			
2	0	0	0			
3	0	0	0			
4	0	0	0			
5	0	0	0			
6	0	0	1			
7	1	1	1			
8	1	0	1			

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op#	LBA	cmd#	file	syscall
1	348	1	x.db	msyc(x.db)
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Scoreboard

	$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score
1	0	1	0	0		
2	0	0	0	1		
3	0	0	0	0		
4	0	0	0	0		
5	0	0	0	0		
6	0	0	1	0		
7	1	1	1	0		
8	1	0	1	0		

Alternative to Exhaustive: Pattern-based Ranking

Worker's multi-layer trace

op#	LBA	cmd#	file	syscall
1	348	1	x.db	msyc(x.db)
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8	906	5	fs-j	fsync(x.log)

Scoreboard

	$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score
1	0	1	0	0	1	
2	0	0	0	1	1	
3	0	0	0	0	0	
4	0	0	0	0	0	
5	0	0	0	0	0	
6	0	0	1	0	1	
7	1	1	1	0	1	
8	1	0	1	0	1	

Alternative to Exhaustive: Pattern-based Ranking

Worker's multi-layer trace

op#	LBA	cmd#	file	syscall
1	348	1	x.db	msyc(x.db)
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7	348	4	x.db	fsync(x.log)
8	906	5	fs-j	fsync(x.log)

Scoreboard

	$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score
1	0	1	0	0	1	**2**
2	0	0	0	1	1	**2**
3	0	0	0	0	0	**0**
4	0	0	0	0	0	**0**
5	0	0	0	0	0	**0**
6	0	0	1	0	1	**2**
7	1	1	1	0	1	**4**
8	1	0	1	0	1	**3**

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Worker's multi-layer trace

op#	LBA	cmd#	file	syscall	
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Scoreboard

	$MMAP_p$	REP_p	$JUMP_p$	$HEAD_p$	$TRAN_p$	total score
1	0	1	0	0	1	**2**
2	0	0	0	1	1	**2**
3	0	0	0	0	0	**0**
4	0	0	0	0	0	**0**
5	0	0	0	0	0	**0**
6	0	0	1	0	1	**2**
7	1	1	1	0	1	**4**
8	1	0	1	0	1	**3**

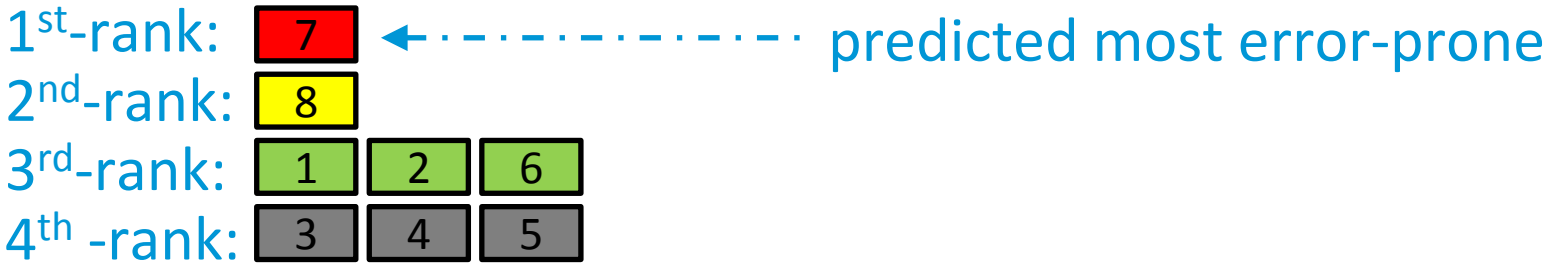
1st-rank: 7 ← predicted most error-prone

2nd-rank: 8

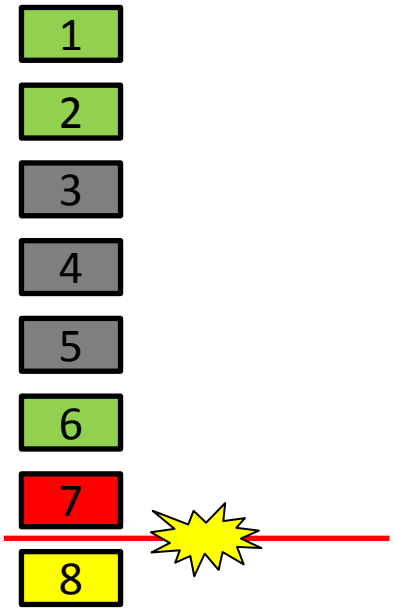
3rd-rank: 1 2 6

4th -rank: 3 4 5

Alternative to Exhaustive: Pattern-based Ranking



Alternative to Exhaustive: Pattern-based Ranking



1st-rank: 7 ← predicted most error-prone

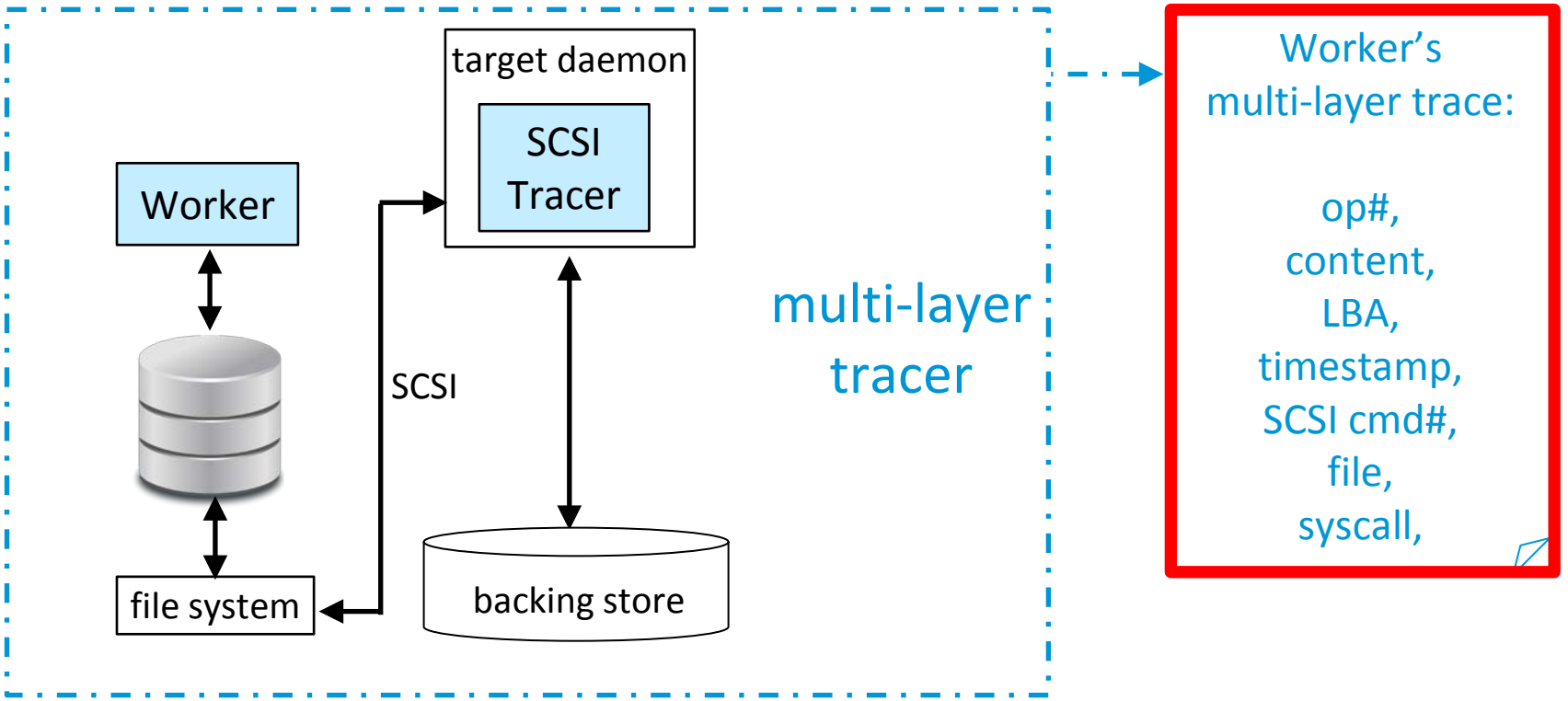
2nd-rank: 8

3rd-rank: 1 2 6

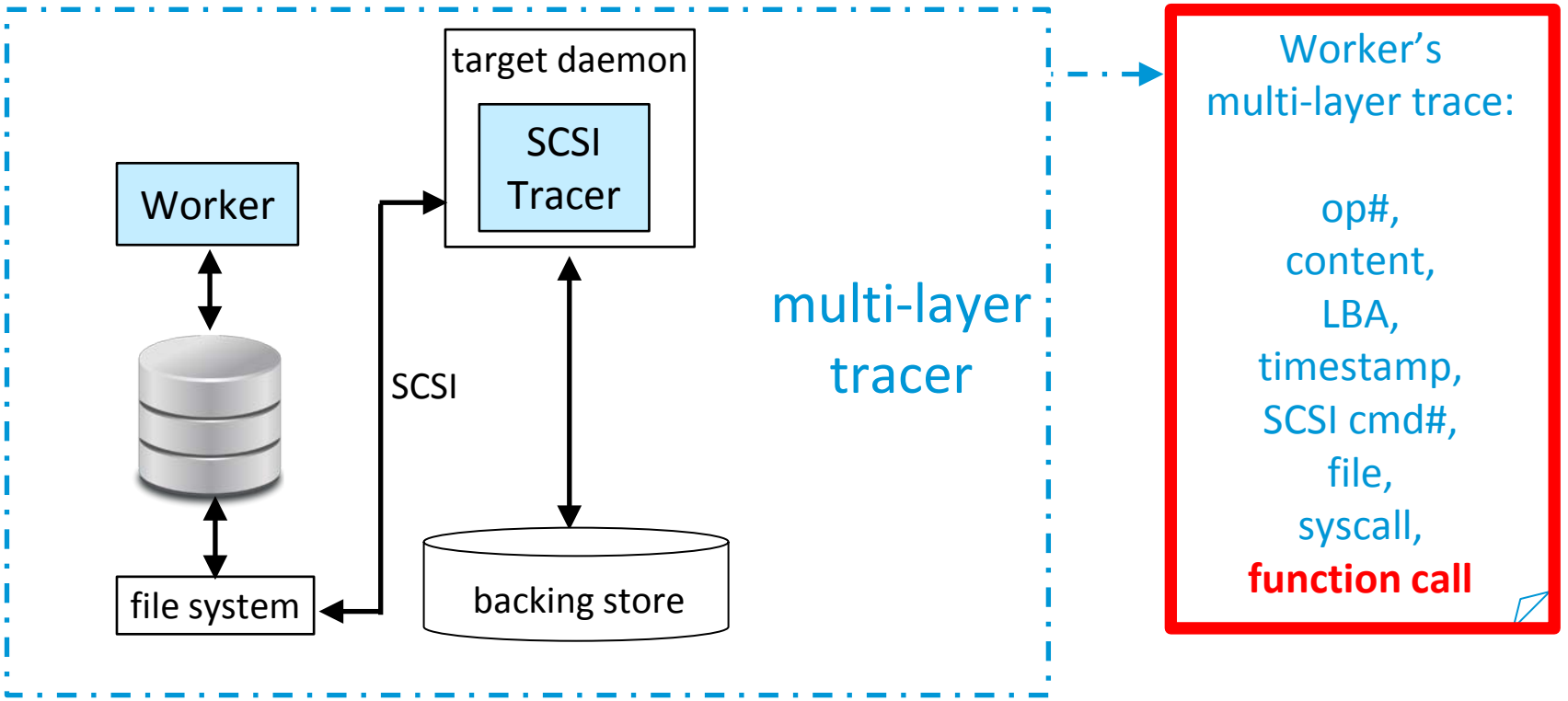
4th -rank: 3 4 5

Diagnosis Support

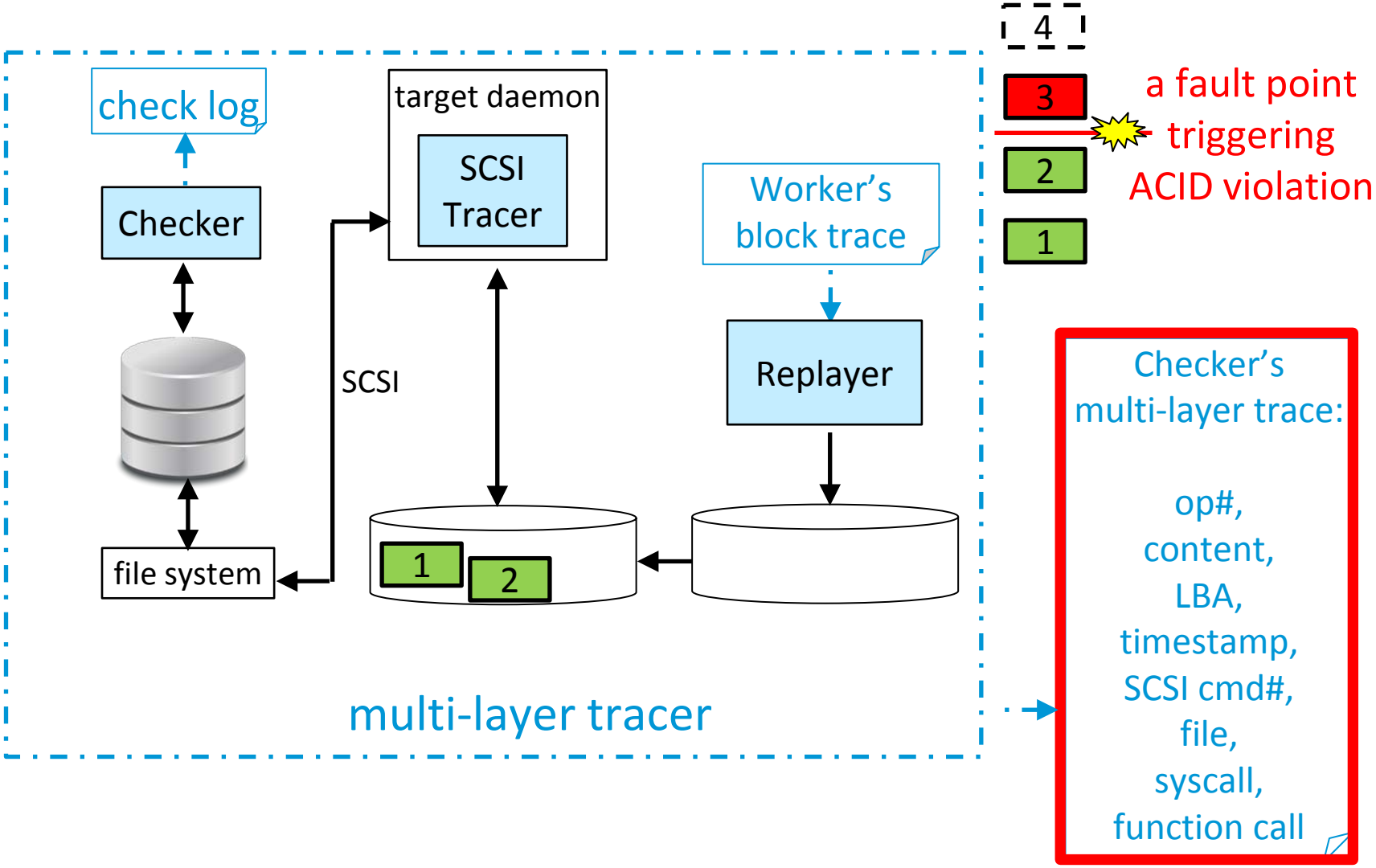
Worker's multi-layer trace helps understand what happened at fault time



Add function-call tracing to disclose more semantics for diagnosis



Enable same tracing during checking to see why recovery didn't work



Results

Experimental Environment

- 8 databases
  - Open-source: TokyoCabinet, MariaDB, LightningDB, SQLite
  - Commercial: KVS-A, SQL-A, SQL-B, SQL-C
- 4 workloads
- 3 file systems
  - ext3, XFS, NTFS
- Several operating systems
  - Linux: RHEL 6, Debian6, Ubuntu 12 LTS
  - Windows 7 Enterprise

Not a single DB can survive all tests

DB	FS	W-1	W-2	W-3	W-4.1	W-4.2	W-4.3	A	C	I	D
TokyoCabinet	ext3	D	D	D	ACD	ACD	ACD	0.15%	0.14%	0	16.05%
	XFS	--	D	D	ACD	D	ACD	<0.01%	0.01%	0	4.38%
MariaDB	ext3	D	D	D	D	D	D	0	0	0	1.36%
	XFS	D	D	D	D	D	D	0	0	0	0.49%
LightningDB	ext3	--	--	--	--	--	D	0	0	0	0.05%
	XFS	--	--	--	--	--	--	0	0	0	0
SQLite	ext3	D	D	--	D	D	D	0	0	0	19.15%
	XFS	--	--	D	D	D	D	0	0	0	10.60%
KVS-A	ext3	--	--	Hang	--	--	--	0	0	0	0
	XFS	--	--	--	--	--	--	0	0	0	0
SQL-A	ext3	D	D	D	D	D	D	0	0	0	3.31%
	XFS	D	D	D	D	D	D	0	0	0	0.92%
SQL-B	ext3	D	D	CD	CD	CD	CD	0	8.96%	0	3.24%
	XFS	CD	D	CD	CD	CD	CD	0	7.77%	0	3.90%
SQL-C	NTFS	D	D	D	D	D	D	0	0	0	8.08%

Durability violation is most common

DB	FS	W-1	W-2	W-3	W-4.1	W-4.2	W-4.3	A	C	I	D
TokyoCabinet	ext3	D	D	D	ACD	ACD	ACD	0.15%	0.14%	0	16.05%
	XFS	--	D	D	ACD	D	ACD	<0.01%	0.01%	0	4.38%
MariaDB	ext3	D	D	D	D	D	D	0	0	0	1.36%
	XFS	D	D	D	D	D	D	0	0	0	0.49%
LightningDB	ext3	--	--	--	--	--	D	0	0	0	0.05%
	XFS	--	--	--	--	--	--	0	0	0	0
SQLite	ext3	D	D	--	D	D	D	0	0	0	19.15%
	XFS	--	--	D	D	D	D	0	0	0	10.60%
KVS-A	ext3	--	--	Hang	--	--	--	0	0	0	0
	XFS	--	--	--	--	--	--	0	0	0	0
SQL-A	ext3	D	D	D	D	D	D	0	0	0	3.31%
	XFS	D	D	D	D	D	D	0	0	0	0.92%
SQL-B	ext3	D	D	CD	CD	CD	CD	0	8.96%	0	3.24%
	XFS	CD	D	CD	CD	CD	CD	0	7.77%	0	3.90%
SQL-C	NTFS	D	D	D	D	D	D	0	0	0	8.08%

Some violations are difficult to trigger

DB	FS	W-1	W-2	W-3	W-4.1	W-4.2	W-4.3	A	C	I	D
TokyoCabinet	ext3	D	D	D	ACD	ACD	ACD	0.15%	0.14%	0	16.05%
	XFS	--	D	D	ACD	D	ACD	<0.01%	0.01%	0	4.38%
MariaDB	ext3	D	D	D	D	D	D	0	0	0	1.36%
	XFS	D	D	D	D	D	D	0	0	0	0.49%
LightningDB	ext3	--	--	--	--	--	D	0	0	0	0.05%
	XFS	--	--	--	--	--	--	0	0	0	0
SQLite	ext3	D	D	--	D	D	D	0	0	0	19.15%
	XFS	--	--	D	D	D	D	0	0	0	10.60%
KVS-A	ext3	--	--	Hang	--	--	--	0	0	0	0
	XFS	--	--	--	--	--	--	0	0	0	0
SQL-A	ext3	D	D	D	D	D	D	0	0	0	3.31%
	XFS	D	D	D	D	D	D	0	0	0	0.92%
SQL-B	ext3	D	D	CD	CD	CD	CD	0	8.96%	0	3.24%
	XFS	CD	D	CD	CD	CD	CD	0	7.77%	0	3.90%
SQL-C	NTFS	D	D	D	D	D	D	0	0	0	8.08%

Some violations are difficult to trigger

DB	FS	W-1	W-2	W-3	W-4.1	W-4.2	W-4.3	A	C	I	D
TokyoCabinet	ext3	D	D	D	ACD	ACD	ACD	0.15%	0.14%	0	16.05%
	XFS	--	D	D	ACD	D	ACD	<0.01%	0.01%	0	4.38%
MariaDB	ext3	D	D	D	D	D	D	0	0	0	1.36%
	XFS	D	D	D	D	D	D	0	0	0	0.49%
LightningDB	ext3	--	--	--	--	--	D	0	0	0	0.05%
	XFS	--	--	--	--	--	--	0	0	0	0
SQLite	ext3	D	D	--	D	D	D	0	0	0	19.15%
	XFS	--	--	D	D	D	D	0	0	0	10.60%
KVS-A	ext3	--	--	Hang	--	--	--	0	0	0	0
	XFS	--	--	--	--	--	--	0	0	0	0
SQL-A	ext3	D	D	D	D	D	D	0	0	0	3.31%
	XFS	D	D	D	D	D	D	0	0	0	0.92%
SQL-B	ext3	D	D	CD	CD	CD	CD	0	8.96%	0	3.24%
	XFS	CD	D	CD	CD	CD	CD	0	7.77%	0	3.90%
SQL-C	NTFS	D	D	D	D	D	D	0	0	0	8.08%

Case Study: A TokyoCabinet Bug

- Failure symptoms

  faults injected in a region of operations cause:

  - A violation: a transaction is partially committed

  - D violation: some rows are irretrievable

  - C violation: retrievable rows by range query and point queries are different

Case Study: A TokyoCabinet Bug

Why recovery didn't work?

```
...
tchdbopenimpl(x.tcb)
...
open(x.tcb) = 3
read(x.tcb) = 256
//op#, LBA,  content, file
op#1, 480, ...100..., x.tcb

tcbdbget()
...
```

Checker's trace when ACID violations were found

```
...
tchdbopenimpl(x.tcb)
...
open(x.tcb) = 3
read(x.tcb) = 256
//op#, LBA,  content, file
op#1, 480, ...101..., x.tcb
tchdbwalrestore()
tcbdbget()
...
```

Checker's trace when no violation was found

Delta Debugging
[Zeller, SIGSOFT'02/FSE-10]

Case Study: A TokyoCabinet Bug

Why recovery didn't work?

```
...
tchdbopenimpl(x.tcb)
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//op#, LBA,  content, file
op#1, 480, ...100..., x.tcb
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tcbdbget()
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op#1, 480, ...101..., x.tcb
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read(x.tcb) = 256
//op#, LBA,  content, file
op#1, 480, ...101..., x.tcb
tchdbwalrestore()
tcbdbget()
...
```

Checker's trace when no violation was found

Delta Debugging
[Zeller, SIGSOFT'02/FSE-10]

Case Study: A TokyoCabinet Bug

What happened at fault time?

Worker's trace
around the bug-triggering
fault points op#30–#90

```
...
mmap(8192, x.tcb, 0)
...
fsync(x.tcb.wal)
//op#,  LBA,  content, file,          syscall
op#26, 630, ....., x.tcb.wal, fsync(x.tcb.wal)
op#27, 960, ....., fs-j ,          fsync(x.tcb.wal)
op#28, 964, ....., fs-j ,          fsync(x.tcb.wal)
op#29, 480, ...100..., x.tcb ,     fsync(x.tcb.wal)
...
msync(x.tcb)
 //op#, LBA,  content, file, syscall
op#91, 480, ..101..., x.tcb, msync(x.tcb)
...
```

Why recovery didn't work?

```
...
tchdbopenimpl(x.tcb)
...
open(x.tcb) = 3
read(x.tcb) = 256
//op#, LBA,  content, file
op#1, 480, ...100..., x.tcb
//no tchdbwalrestore()
tcbdbget()
...
```

```
...
tchdbopenimpl(x.tcb)
...
open(x.tcb) = 3
read(x.tcb) = 256
//op#, LBA,  content, file
op#1, 480, ...101..., x.tcb
tchdbwalrestore()
tcbdbget()
...
```

Case Study: A TokyoCabinet Bug

What happened at fault time?

Worker's trace
around the bug-triggering
fault points op#30–#90

```
...
mmap(8192, x.tcb, 0)
...
fsync(x.tcb.wal)
//op#,  LBA,  content, file,        syscall
op#26, 630, ....., x.tcb.wal, fsync(x.tcb.wal)
op#27, 960, ....., fs-j ,         fsync(x.tcb.wal)
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op#29, 480, ...100..., x.tcb ,    fsync(x.tcb.wal)
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msync(x.tcb)
 //op#, LBA,  content, file, syscall
op#91, 480, ...101..., x.tcb, msync(x.tcb)
...
```

Why recovery didn't work?

```
...
tchdbopenimpl(x.tcb)
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Case Study: A TokyoCabinet Bug

What happened at fault time?

Worker's trace
around the bug-triggering
fault points op#30–#90

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mmap(8192, x.tcb, 0)
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← – – Intended update

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← – – Unintended update!

← – – Intended update

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Case Study: A TokyoCabinet Bug

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tcbdbget()
...
```
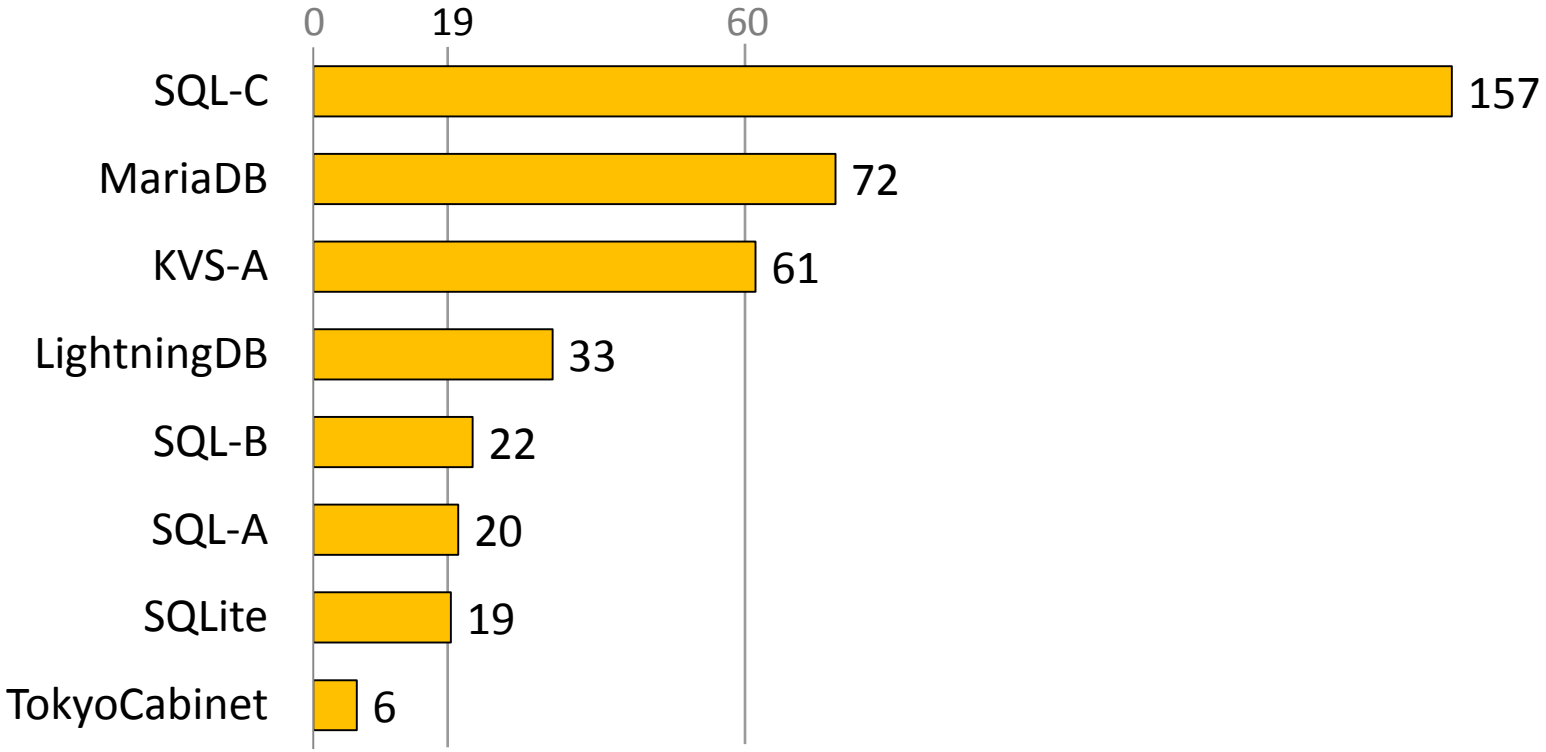

One solution:
Failure-atomic msync()
[Park *et.al.*, EuroSys'13]

Patterns reduce required test points greatly while achieving similar coverage



reduction factor =

$$\frac{\#\ of\ test\ points\ under\ exhaustive\ policy}{\#\ of\ test\ points\ under\ pattern\ policy}$$

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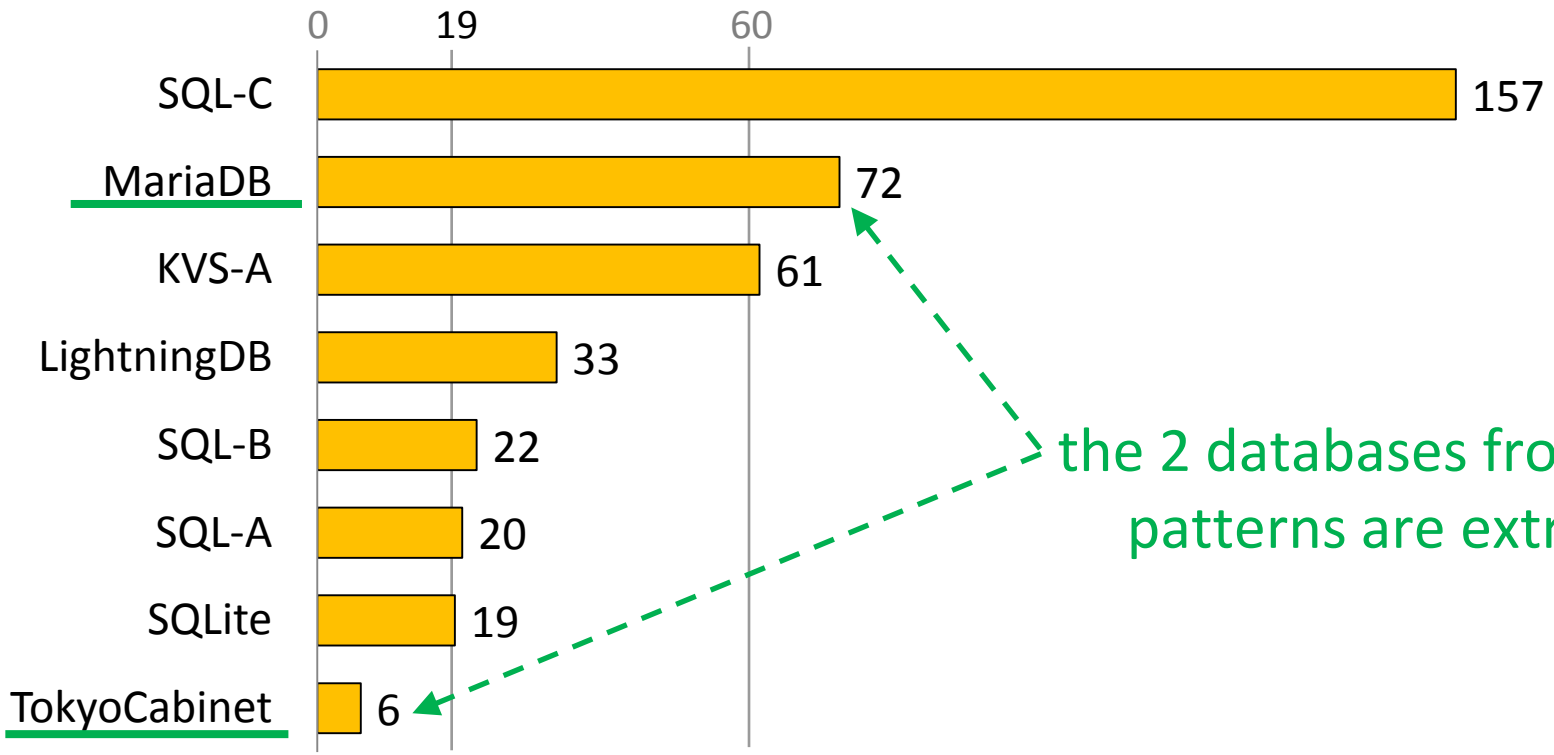

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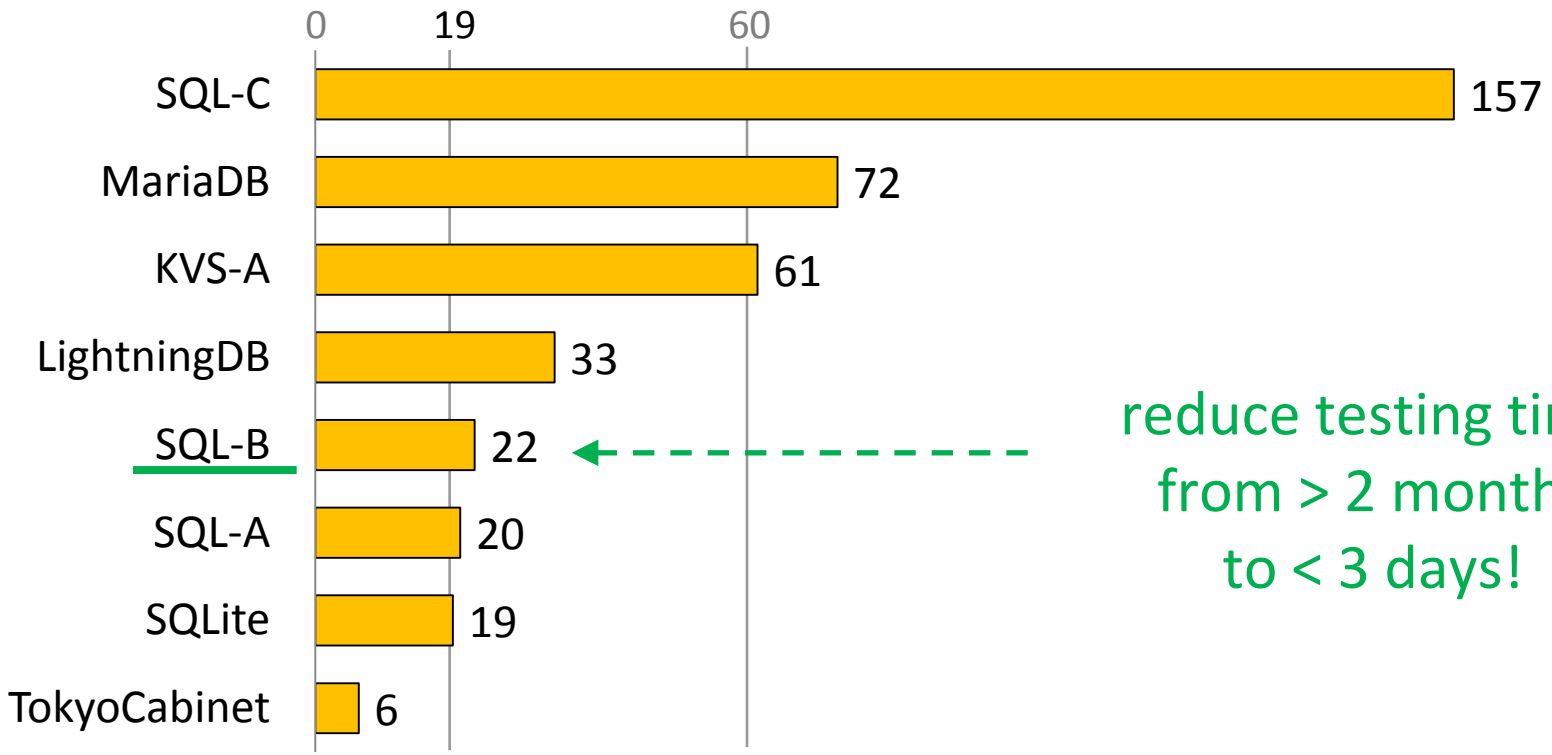

reduce testing time from > 2 months to < 3 days!

reduction factor =

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Conclusions & Future Work

- A wake-up call

  - traditional testing methodology may not be enough for today's complex storage systems

  - thorough testing requires purpose-built workloads and intelligent fault injection techniques

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  - traditional testing methodology may not be enough for today's complex storage systems

  - thorough testing requires purpose-built workloads and intelligent fault injection techniques

- Different layers in OS can help in different ways

  - iSCSI: fault injection w/ high portability & high fidelity

  - LBA & syscall: generic behavior patterns

  - combined multi-layer info: clear whole picture of complicated scenarios

Conclusions & Future Work

- We should bridge the gaps of understanding/assumptions!

between
DB & OS

between
User & DB

Conclusions & Future Work

- We should bridge the gaps of understanding/assumptions!

Pop Quiz: true or false?

between DB & OS	“mmap'ed files are not updated until msync()”	
	“file-length update are persistent after fdatasync()”	
between User & DB	“durability is provided by the default configuration”	
	“transactions are durable after COMMIT”	

Conclusions & Future Work

- We should bridge the gaps of understanding/assumptions!

Pop Quiz: true or false?

between DB & OS	“mmap'ed files are not updated until msync()”	false
	“file-length update are persistent after fdatasync()”	
between User & DB	“durability is provided by the default configuration”	
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Conclusions & Future Work

- We should bridge the gaps of understanding/assumptions!

Pop Quiz: true or false?

between DB & OS	“mmap'ed files are not updated until msync()”	false
	“file-length update are persistent after fdatasync()”	depends!
between User & DB	“durability is provided by the default configuration”	depends!
	“transactions are durable after COMMIT”	depends!

Conclusions & Future Work

- We should bridge the gaps of understanding/assumptions!

Pop Quiz: true or false?

between DB & OS	“mmap'ed files are not updated until msync()”	false
	“file-length update are persistent after fdatasync()”	depends!
between User & DB	“durability is provided by the default configuration”	depends!
	“transactions are durable after COMMIT”	depends!

Thank you!