Ad Hoc Transactions in Web Applications:
The Good, the Bad, and the Ugly

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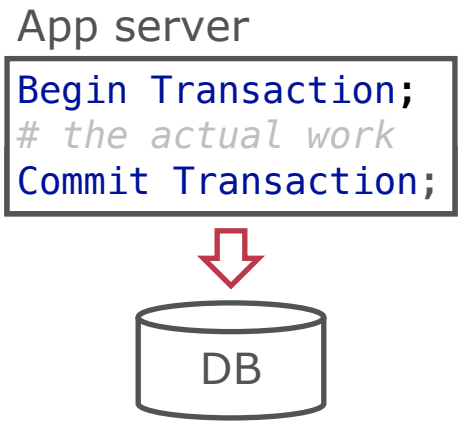
How do applications today use concurrency control?

The intuitive answer, database transactions.



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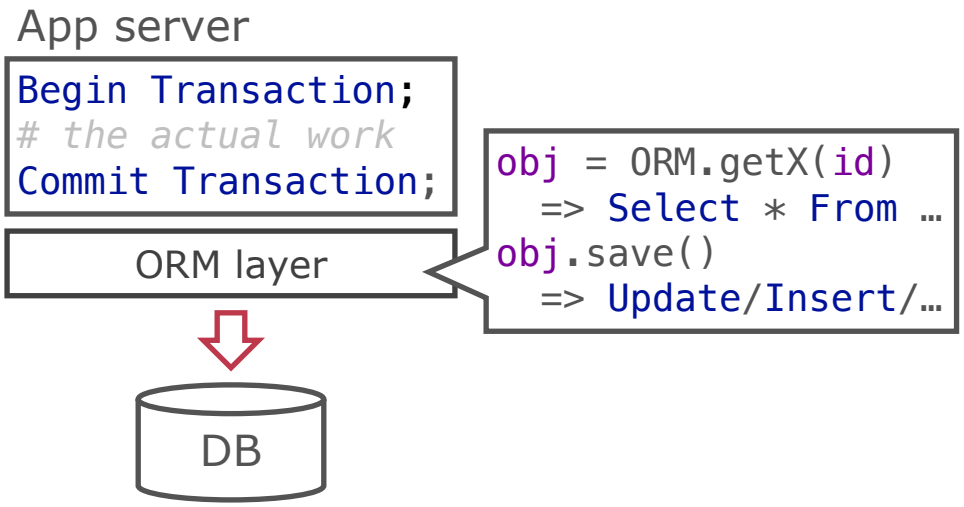


How do applications today use concurrency control?

The intuitive answer, database transactions.

Bailis et al. identified another application-level approach, invariant validation*.

- Developers specify invariants; ORMs validate them.
- E.g., uniqueness of a column's values (w/o using DB unique constraint).

*Bailis et al. Feral Concurrency Control: An Empirical Investigation of Modern Application Integrity. SIGMOD '15.

How do applications today use concurrency control?

In this study, we investigate the third approach, ad hoc transactions.

- They are the "transactions" coordinated by ad hoc constructs (e.g., locks) employed by app developers.

App server (add-cart API)

```
lock(cart_id)
# perform business logic
# use ORM to access DB
unlock(cart_id)
```

Server-side lock table

cart	locked
1	true
2	false

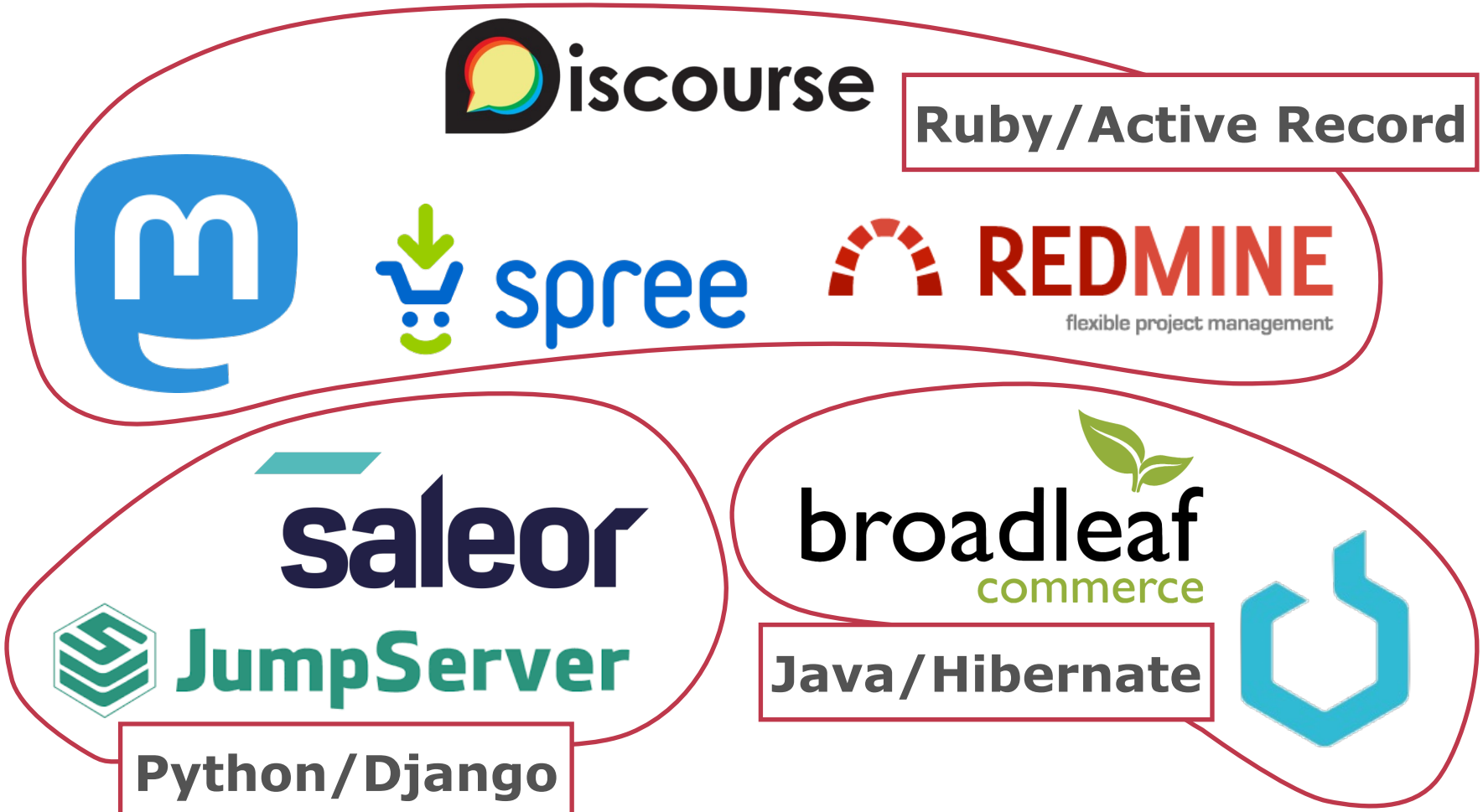
Plain `Select`/`Update`/`Insert`/`Delete` (without DB transactions)

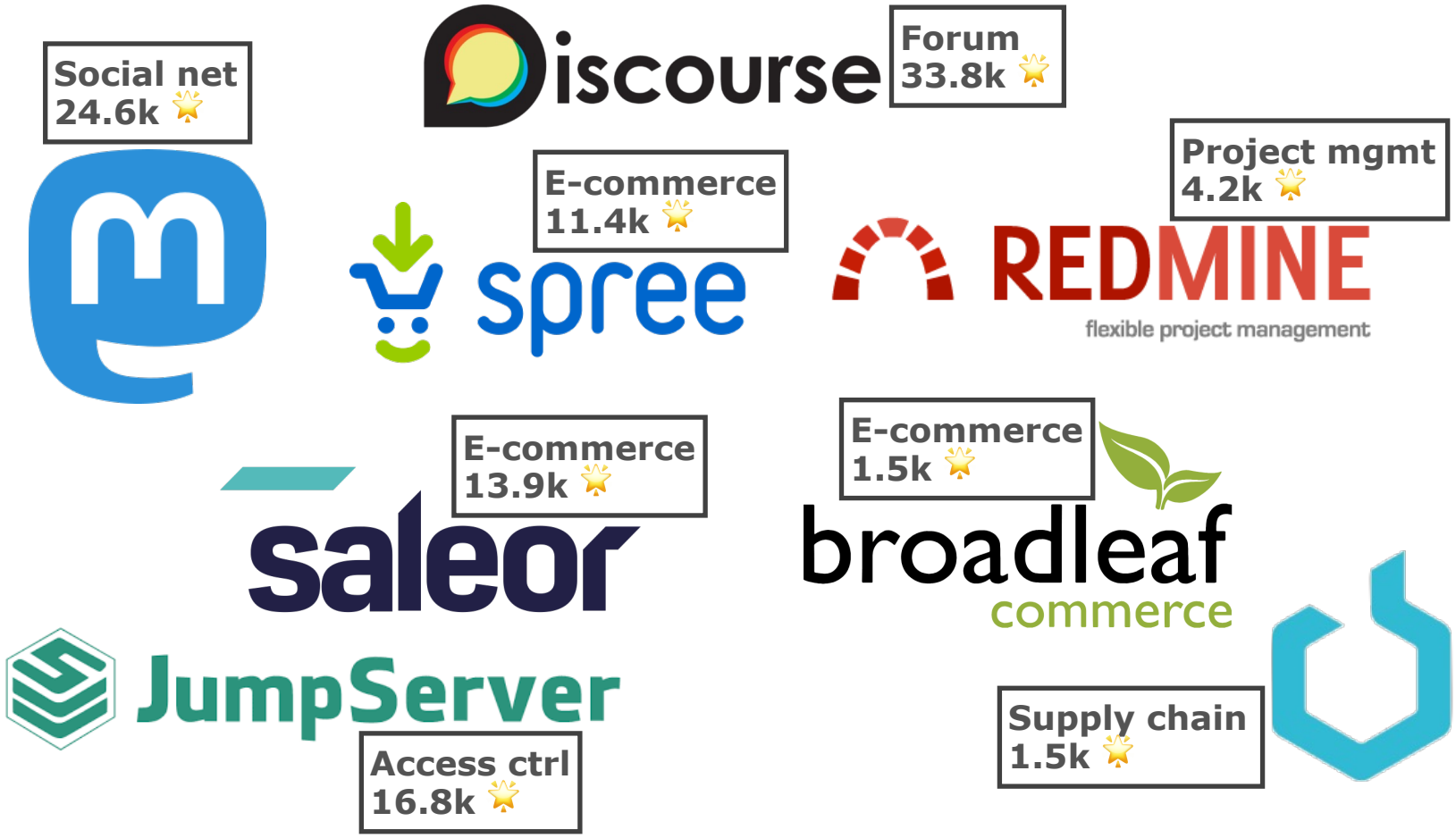
Example is simplified from the Broadleaf e-commerce application.

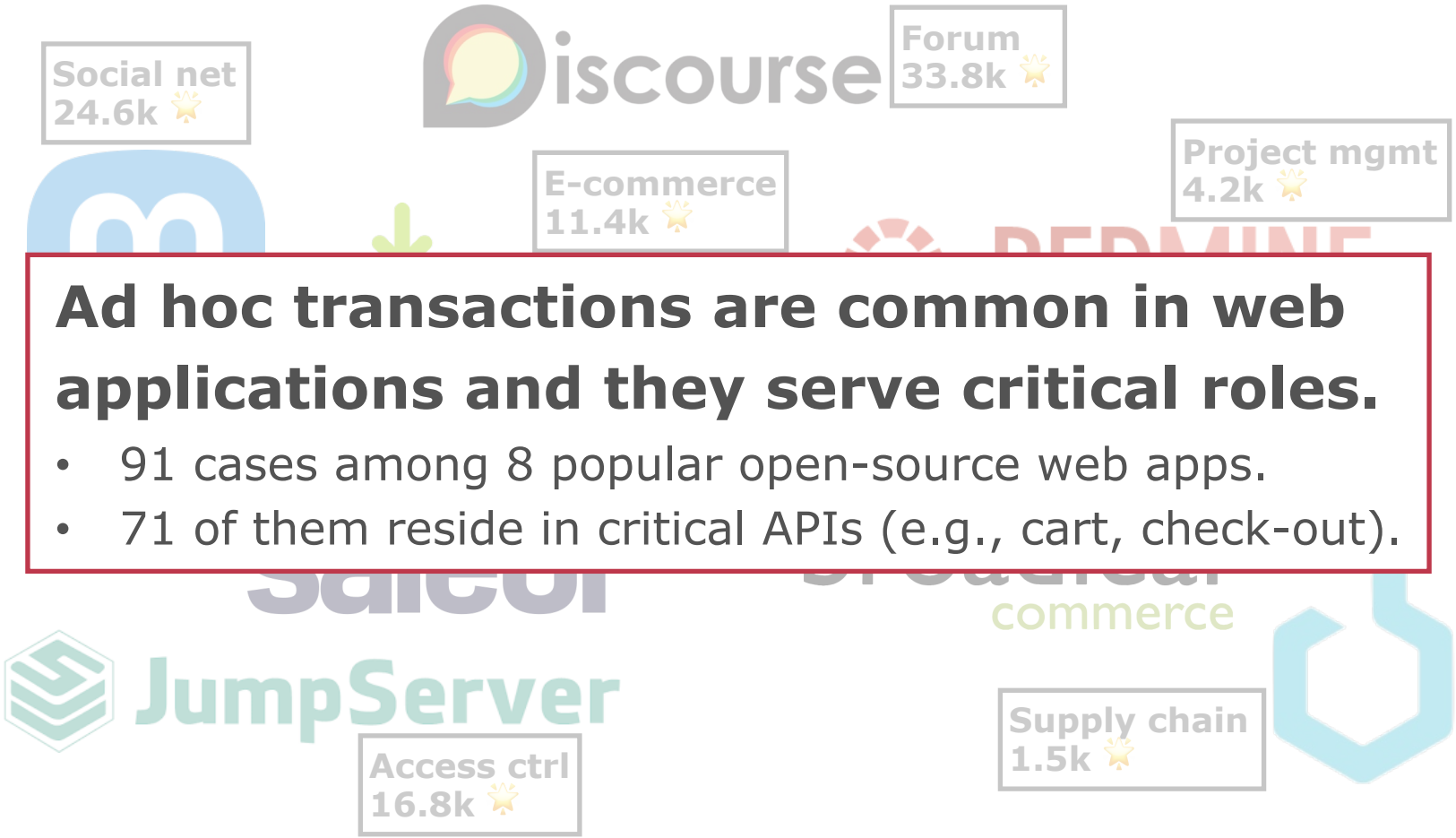
Ad hoc transactions represent the third approach

	Database transactions	**Invariant validation**	**Ad hoc transactions**
WHAT is protected?	Business logic snippets	Invariants on Database rows	Business logic snippets
WHO conducts the protection?	Database CC	ORMs	Developers

What is the state of the practice?


Discourse
Ruby/Active Record
spree
REDMINE
flexible project management
saleor
JumpServer
Python/Django
broadleaf
commerce
Java/Hibernate


Social net
24.6k
Forum
33.8k
Discourse
Project mgmt
4.2k
E-commerce
11.4k
spree
REDMINE
flexible project management
E-commerce
13.9k
saleor
E-commerce
1.5k
broadleaf
commerce
JumpServer
Access ctrl
16.8k
Supply chain
1.5k



Ad hoc transactions are common in web applications and they serve critical roles.

- 91 cases among 8 popular open-source web apps.
- 71 of them reside in critical APIs (e.g., cart, check-out).

In the rest of this talk

Answer the following questions.

- **How do ad hoc transactions look like?**
  They look diverse in many aspects.
- **Are they correct?**
  More than half are incorrect.
- **Do they perform well?**
  They sometimes outperform DB transactions.

Discuss the implications.

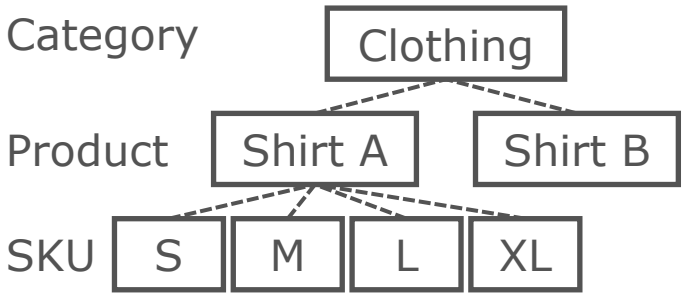
Ad hoc transactions have diverse semantics

They can coordinate DB operations partially.

- 22/91 cases coordinate partially.

```
lock(sku_id)
sku = ORM.getSku(sku_id)
if sku.qty > want:
  sku.qty -= want
  sku.save()
unlock(sku_id)
```

```
Update sku.qty                    # SKUs table
Update sku.prod.update_time       # Products table
for category in sku.prod.cats:
  Update category.update_time # Categories table
```



Example is simplified from the Spree e-commerce application.

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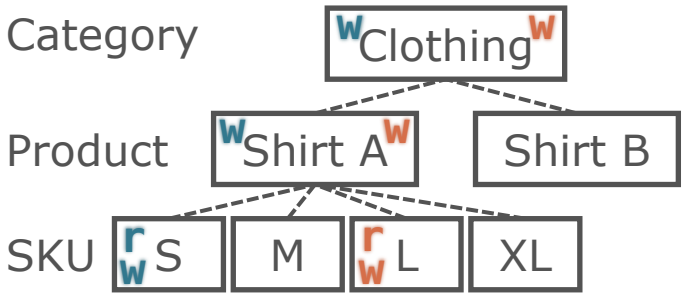


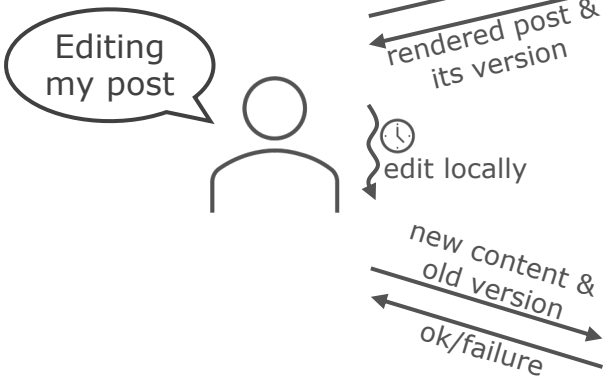
User 1 buys a small shirt A
User 2 buys a large shirt A
Only SKU ops are serialized!

Example is simplified from the Spree e-commerce application.

Ad hoc transactions have diverse semantics

Their coordination can span many requests.

- 10/91 cases coordinate across multiple requests.




```
Begin Transaction
post = ORM.getPost(post_id)
return render(post)
```

```
lock(post_id)
current = ORM.getPost(post_id)
if current.ver != prev_version:
  current.content = new_content
  current.ver += 1
  current.save()
Commit Transaction
```

Example is simplified from the Discourse forum application.

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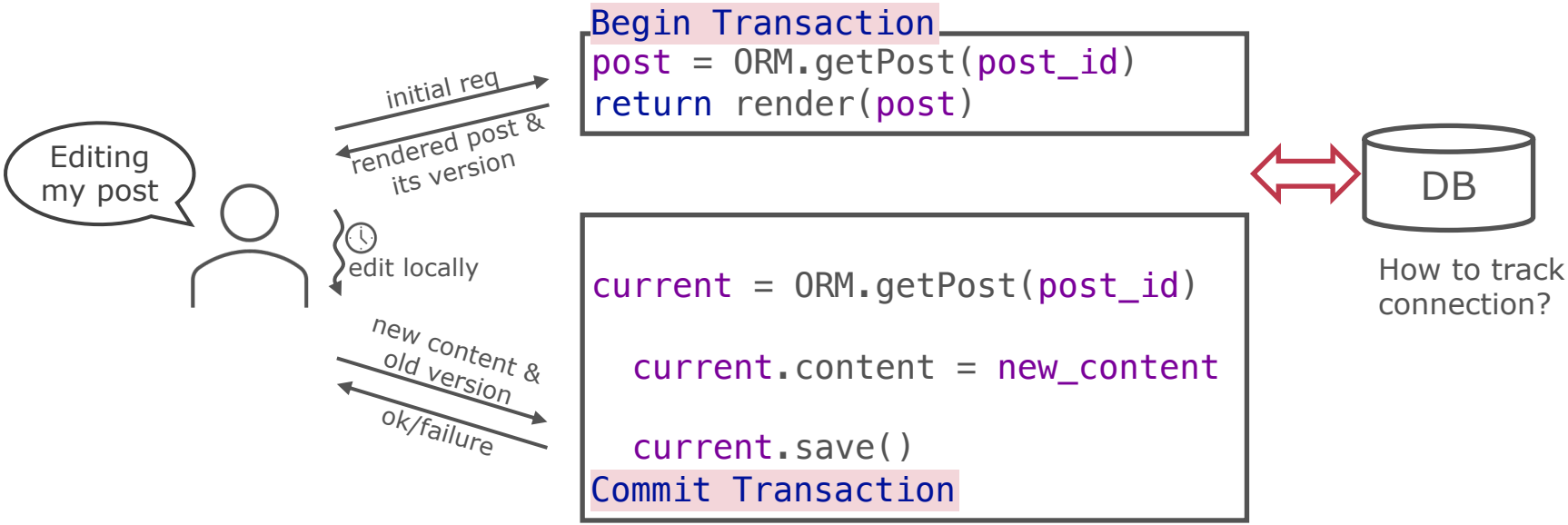

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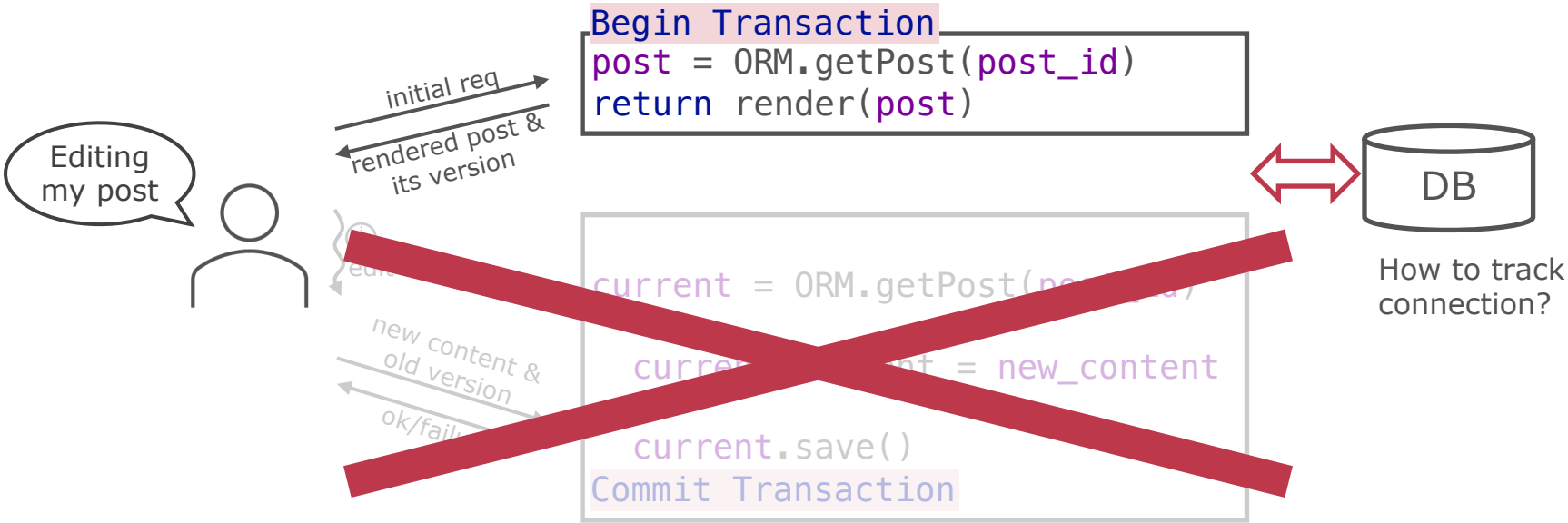

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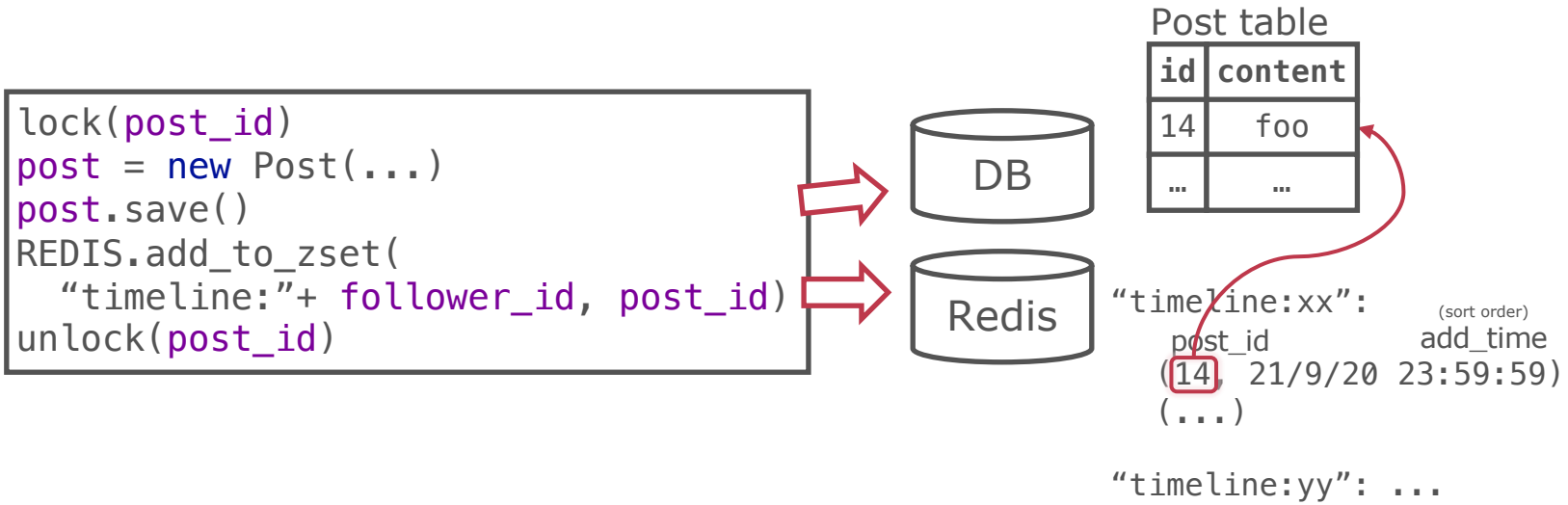
Ad hoc transactions have diverse semantics

They can also coordinate non-DB operations.

- 8/91 cases handle non-DB operations.



Example is simplified from the Mastodon social network application.

Ad hoc transactions have diverse implementations

They use either locks or validation procedures for coordination.

For locks, there are 7 different implementations among 8 applications.

- 2 implementations reuse existing locking facilities.

```
store = loadStoreInfo(...)
synchronized(store) # Java keyword
  { /* perform work here */ }
```

Example is simplified from the SCM Suite supply chain management application.

Ad hoc transactions have diverse implementations

They use either locks or validation procedures for coordination.

For locks, there are 7 different implementations among 8 applications.

- 2 implementations reuse existing locking facilities.
- 2 implementations store lock information in Redis.

```
REDIS.set_if_not_exist(lock_key)
# perform work here
REDIS.delete(lock_key)
```

Redis

lock_key	value
“post66”	{owner :xx, expire:yy}
…	…

Example is simplified from the Mastodon social network application.

Ad hoc transactions have diverse implementations

They use either locks or validation procedures for coordination.

For locks, there are 7 different implementations among 8 applications.

- 2 implementations reuse existing locking facilities.
- 2 implementations store lock information in Redis.
- 1 implementation stores lock information in DB tables.
- 2 implementations store lock information in application runtime containers (e.g., Java’s ConcurrentHashMap).

Ad hoc transactions have diverse implementations

They use either locks or validation procedures for coordination.

For locks, there are 7 different implementations among 8 applications.

For validation procedures, there are also 2 categories.

- ORMs can generate some according to annotations. (4 apps)
- Developers also implement the others from scratch. (3 apps)
  - They need to ensure the check-and-update atomicity.

How do ad hoc transactions look like?

They have diverse semantics.

- Partial coordination.
- Multi-request coordination.
- Coordinating non-DB operations.

They have diverse implementations.

- 7 for locks and 2 for validation.

They coordinate at diverse granularity.

- Customized with developers' domain knowledge.
- Either coarser or finer than DB transactions.

They handle failure differently.

- Usually simpler than DB transactions.

Are ad hoc transactions correct?

69 correctness issues are found in 53 cases.*

- 33 cases' issues are confirmed by developers.

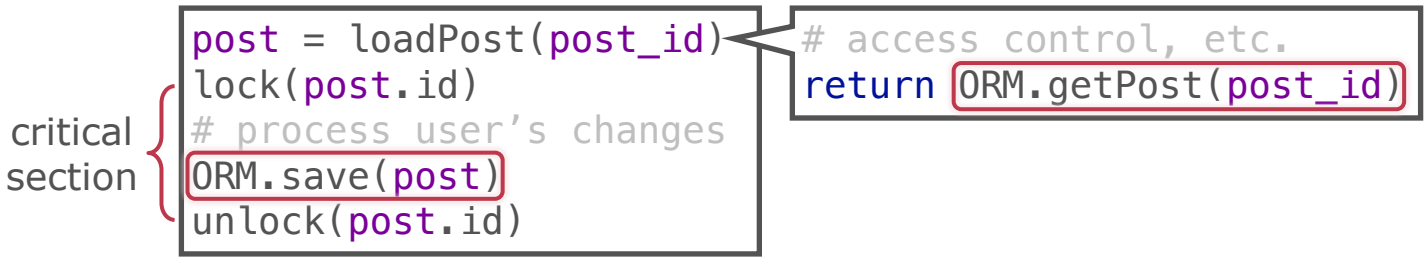
We consider 28 of them severe.

App.	Known severe consequences	Cases
Discourse	Overwritten post contents, page rendering failure, excessive notifications.	6
Mastodon	Showing deleted posts, corrupted account info., incorrect polls.	4
Spree	Overcharging, inconsistent stock level, inconsistent order status, selling discontinued products.	9
Broadleaf	Promotion overuse, inconsistent stock level, inconsistent order status, overselling.	6
Saleor	Overcharging.	3

*Some cases suffer from multiple issues.

Majority of issues stem from wrong locking/validation primitives

36/65 lock-based ad hoc transactions wrongly implement or use locking primitives.



Example is simplified from the Discourse forum application.

Majority of issues stem from wrong locking/validation primitives

36/65 lock-based ad hoc transactions wrongly implement or use locking primitives.

11/26 validation-based ad hoc transactions failed to ensure check-and-update atomicity.

```
ORM.transaction:
  ok = MiniSql.query(
    Update Posts Set version=version+1
    Where id=id And version=version)
  if not ok:
    ORM.abort_transaction()
  # perform updates here
```

Majority of issues stem from wrong locking/validation primitives

36/65 lock-based ad hoc transactions wrongly implement or use locking primitives.

11/26 validation-based ad hoc transactions failed to ensure check-and-update atomicity.

```
ORM.transaction:
  ok = MiniSql.query(
    Update Posts Set version=version+1
    Where id=id
  if not ok:
    ORM.abort_transaction()
  # perform updates here
```

MiniSql is independent of the ORM, thus issuing Update outside of the DB transaction.

Developers sometimes wrongly employ ad hoc transactions

16 issues are caused by incorrect scopes.

- Developers might omit critical operations from coordination in existing ad hoc transactions. (11 cases)
- Developers might forget to employ ad hoc transactions for conflicting procedures. (5 cases)

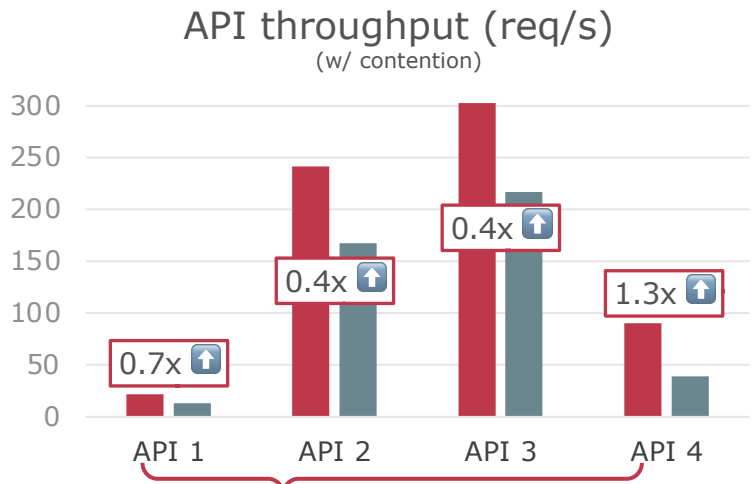
4 issues are caused by incorrect failure handling.

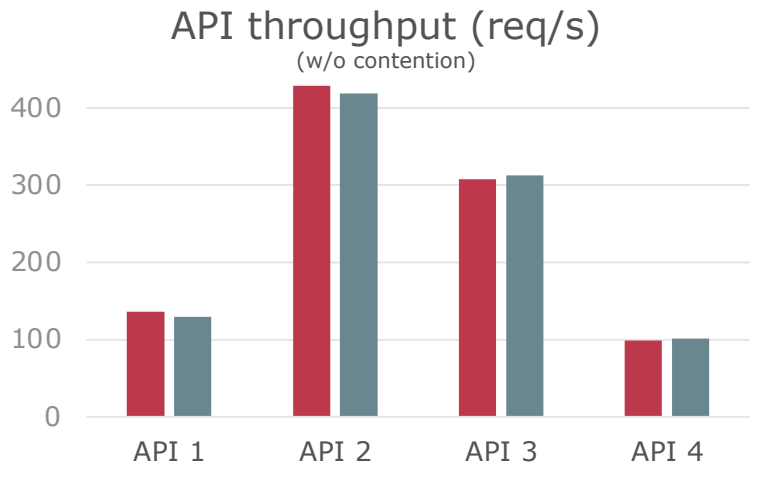
- E.g., crash during ad hoc transactions introduce invalid intermediate states that cause user blocking after reboot.

Do ad hoc transactions perform well?

We deployed the applications and evaluated a subset of APIs with synthetic workloads.

- In comparison with codebase modified to use DB transactions.





Study summary

How do ad hoc transactions look like?

- They look diverse in semantics, implementation, coordination granularities, and failure handling.

Are they correct?

- More than half are incorrect; many issues are severe.

Do they perform well?

- They can outperform DB transactions under contention.

What does it imply?

Why do developers not use DB transactions?

- DB transactions lack important functionalities/properties?
- DB transactions need better integration with applications?
- Or applications are fine with relaxed ACID semantics?

What should we do?

- Further investigate why developers use ad hoc transactions.
- Explore new concurrency abstraction to better suit applications today.
- Build tools to improve existing applications that rely on ad hoc transactions.

Conclusion

Ad hoc transactions are a common approach to concurrency control in web applications.

- They have unique and diverse characteristics in their design and implementation.
- They usually have correctness issues due to their ad hoc nature.
- They have the potential to improve application performance in specific cases.

Their existence presents great opportunities for improving real-world DB applications.