WeBridge: Synthesizing Stored Procedures for Large-Scale Real-World Web Applications

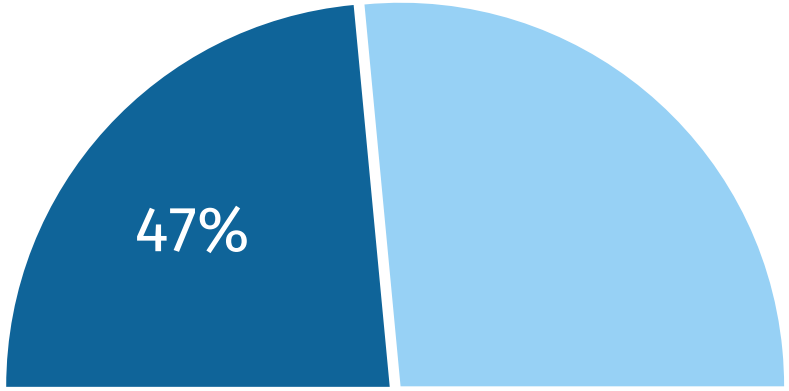
Gansen Hu, Zhaoguo Wang, **Chuzhe Tang**, Jiahuan Shen,
Zhiyuan Dong, Sheng Yao, and Haibo Chen

Institute of Parallel and Distributed Systems (IPADS),
Shanghai Jiao Tong University

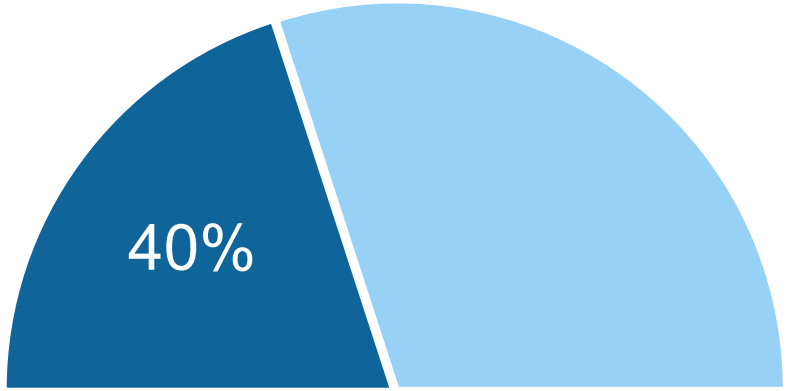
SHANGHAI JIAO TONG UNIVERSITY

IPADS
INSTITUTE OF PARALLEL AND DISTRIBUTED SYSTEMS

Latency is Critical to Web Applications



<2s page load time
expected by 47% users



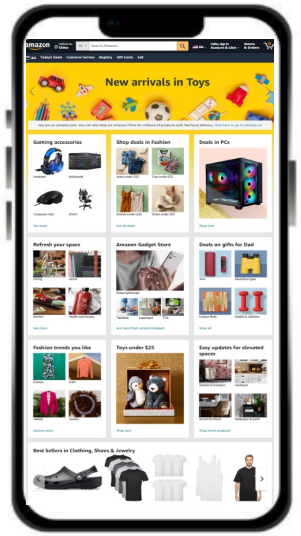
>3s page load time
causes 40% users to leave

"A 1 second page delay could potentially cost $2.5 million in lost sales every year"

* How Loading Time Affects Your Bottom Line. neilpatel.com

Web Apps Suffer from DB Round Trips

56% request processing time is spent on DB round trips!



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RT 1 `Select * From Items …`

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RT 3 `Select * From Carts …`

RT 4 `Insert Into Log Values (…)`
or
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Dynamically generated & Individually sent!

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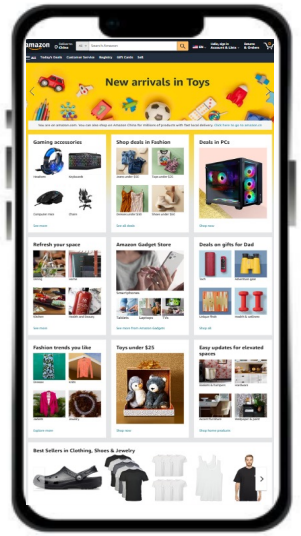

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Research Question: How to reduce DB round trips?

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Execute statements as soon as parameters become ready.

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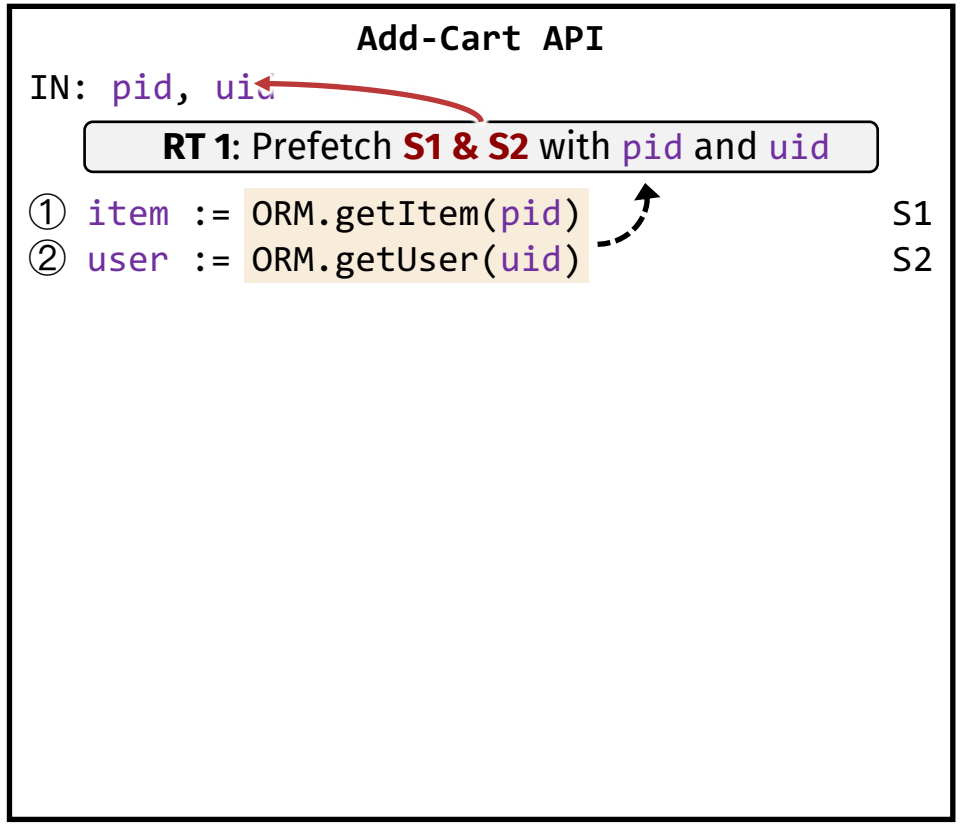

Data Dep. Control Dep. Get Results From

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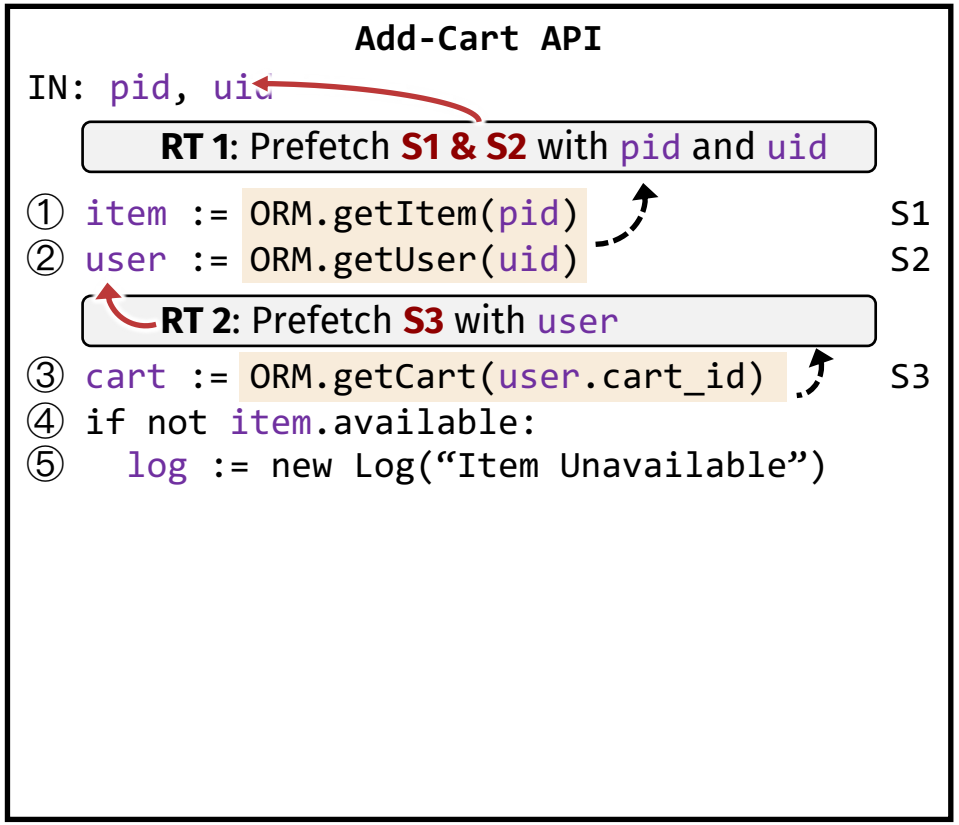

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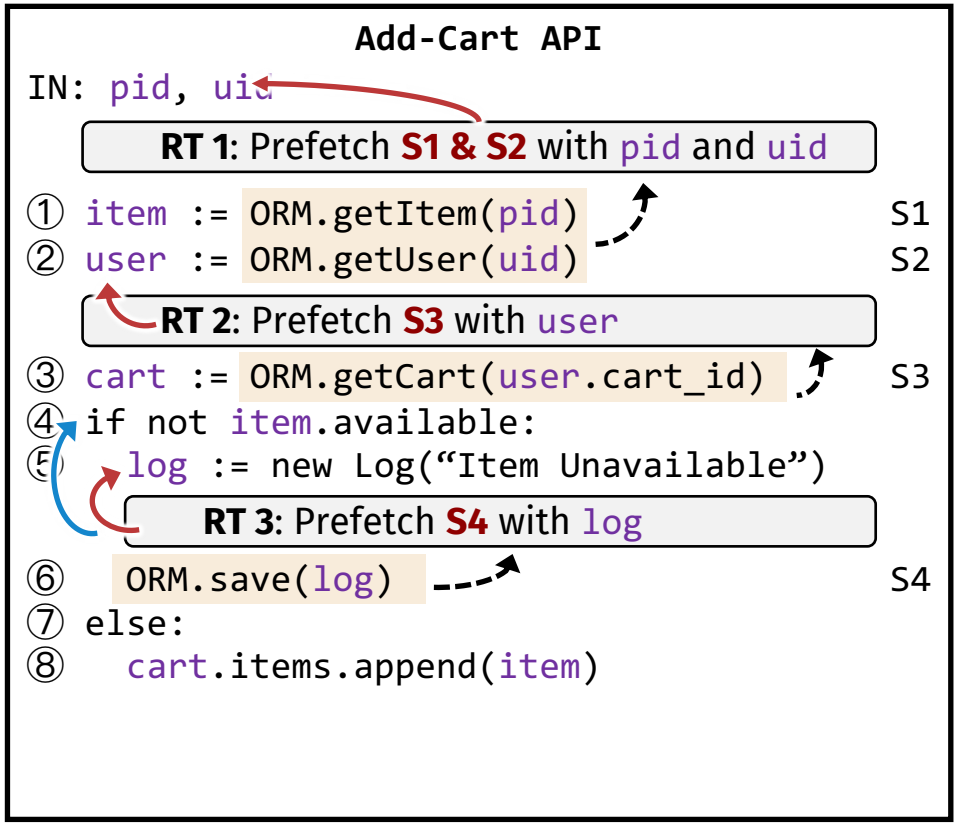

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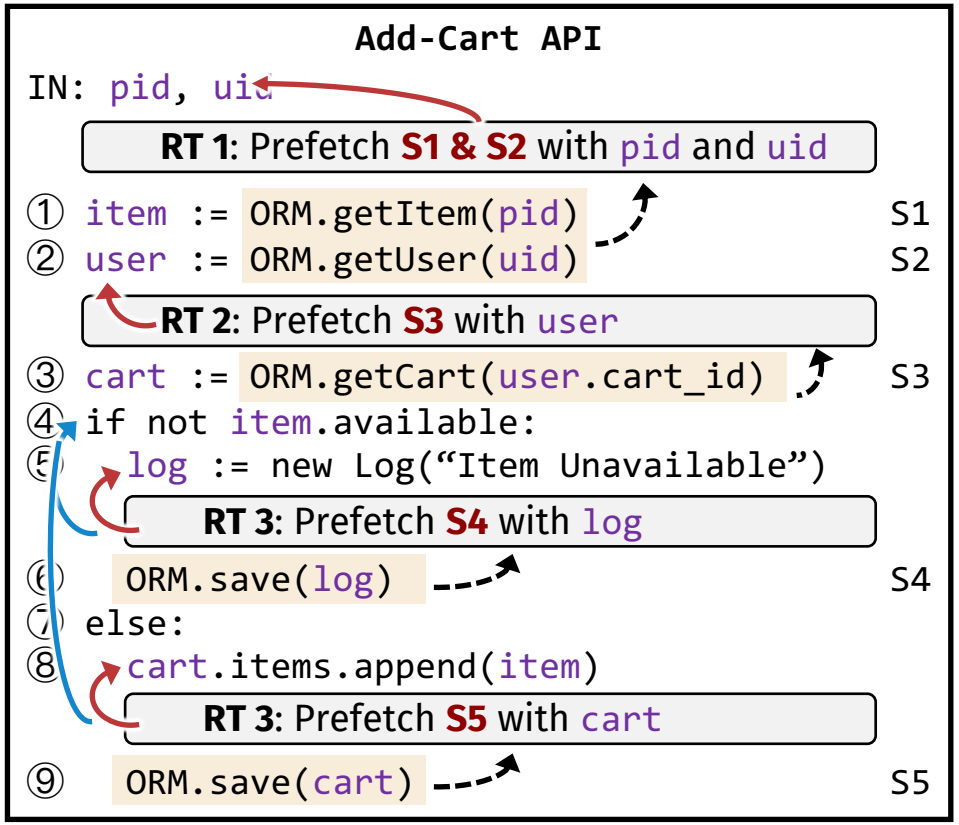

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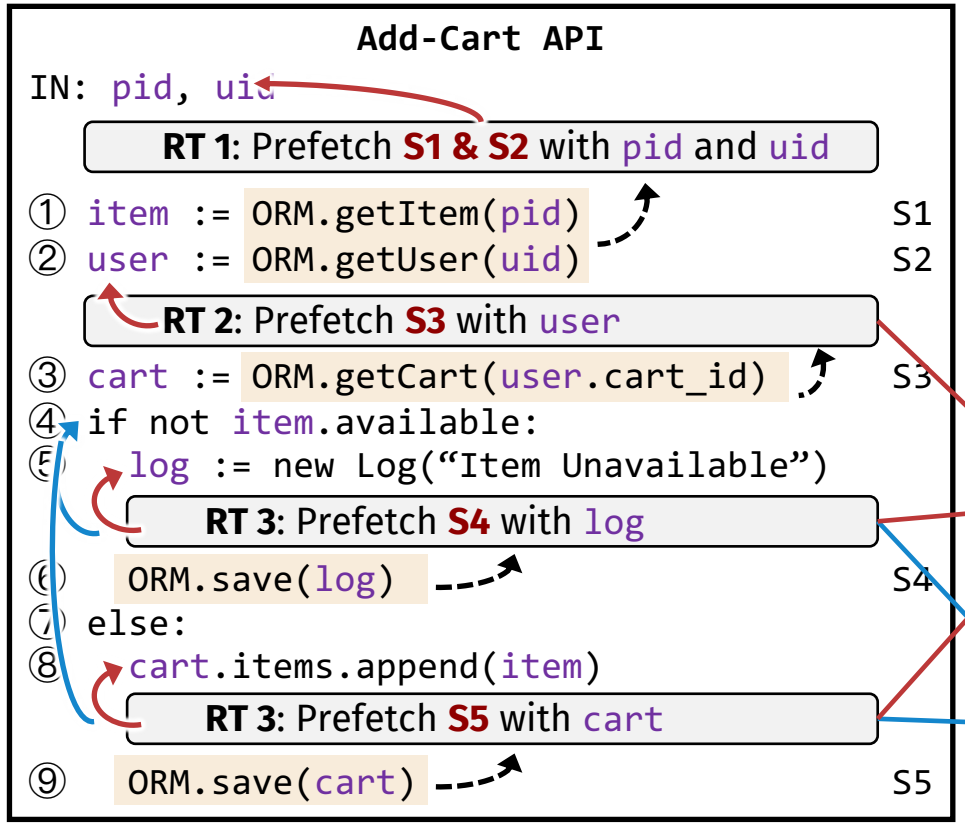

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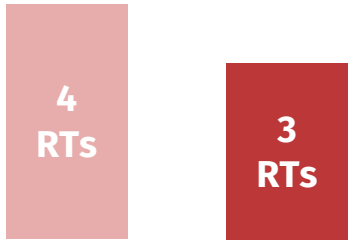
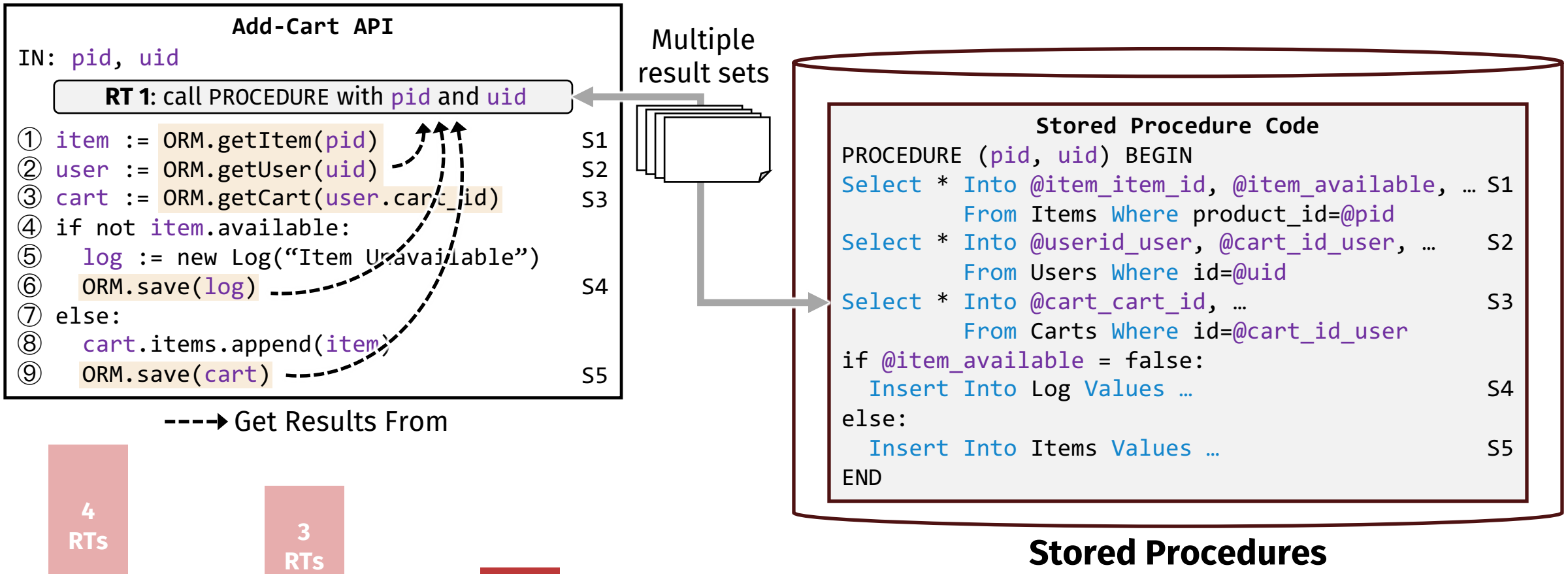


Data Dependency
Prefetching of S3 must wait until variable user is finalized.

Control Dependency
Prefetching of S4/5 must wait until branching at ④ is decided.

Data Dep. Control Dep. Get Results From

Our Approach: Shipping Dependencies to DB



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Multiple result sets

Stored Procedure Code

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Select * Into @cart_cart_id, …                  S3
         From Carts Where id=@cart_id_user
if @item_available = false:
  Insert Into Log Values …                      S4
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Stored Procedures

- Can express **data dep** via local variables
- Can express **control dep** via branching commands

----→ Get Results From

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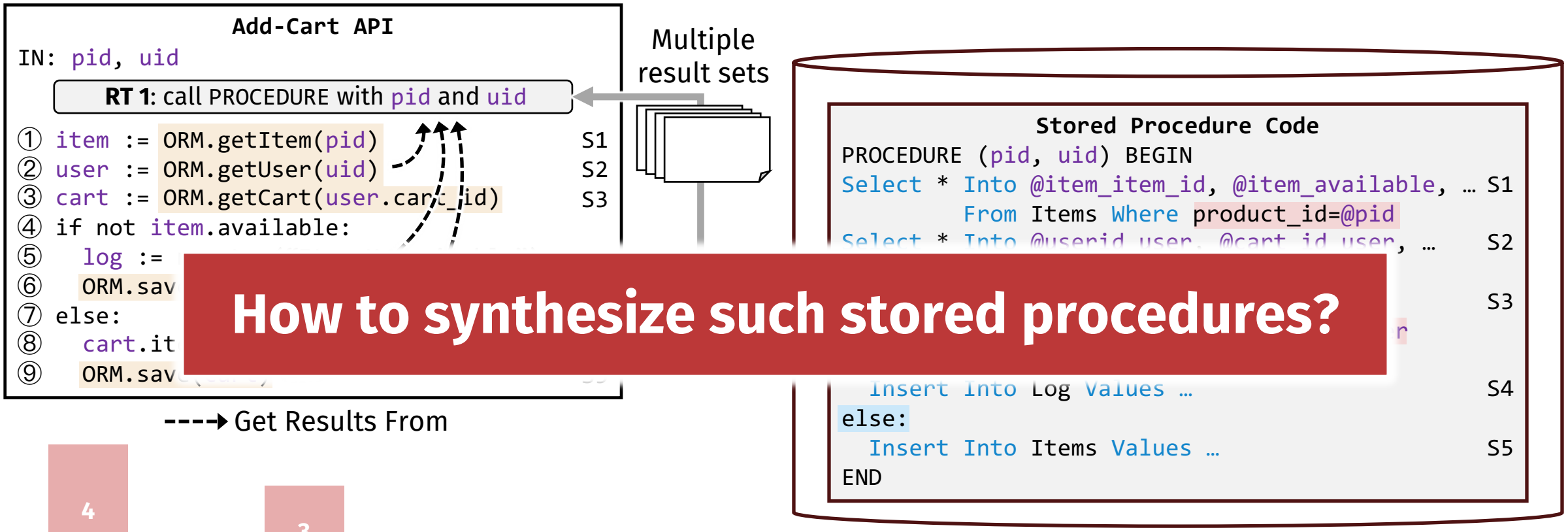

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  - The language feature that **alter program behaviors at run time** (e.g., Java's reflection), commonly used by web frameworks.

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entityManager.find(Entity.class, id)
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3. Defer `Select` until returned object is used
4. Do nothing
5. ...

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  - As a result, we **cannot statically determine** what and when SQL statements will be issued at run time.

Opportunities

- **Concolic execution (concrete + symbolic execution)**
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- **Pareto principle in program path hotness distribution**
  - Most requests are handled in a few distinct program paths.
    - In Broadleaf*, 2 hottest paths account for **96.3%** requests
  - By collecting inputs that trigger these hot paths, we can still **optimize for the most common cases**

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Key Idea

Synthesize and call stored procedures to cover hot path requests

Safely fall back to normal execution for cold path requests

Synthesizing Stored Procedures

```
IN: uid
① user := ORM.getUser(uid)                S1
② if user != null:
③   cart := ORM.getCart(user.cart_id)     S2
```

Original Code

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Original Code

```
uid:     233
S1_ret: {id:233, …}
S2_ret: /* cart obj */
```

Trace (taking `if` branch)

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Concolically Replay

SQL node (S1)

Template:	"Select … Where id={uid}"
Condition:	true
In:	uid
Out:	user

SQL node (S2)

Template:	"Select… id={user_cart_id}"
Condition:	user != null
In:	user_cart_id
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Dependency Graph

Synthesizing Stored Procedures

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Dependency Graph

Translate

```
if true:
  Select * Into @user From Users
        Where id=@uid
if @user != null:
  Select * Into @cart From Carts
        Where id=@user_cart_id
```

Stored Procedure

Integrating into Web Apps

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Interception layer

Result Buffer

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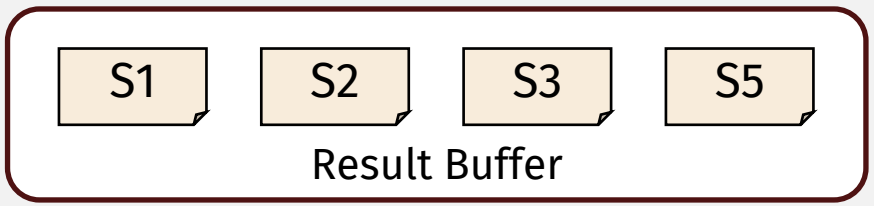

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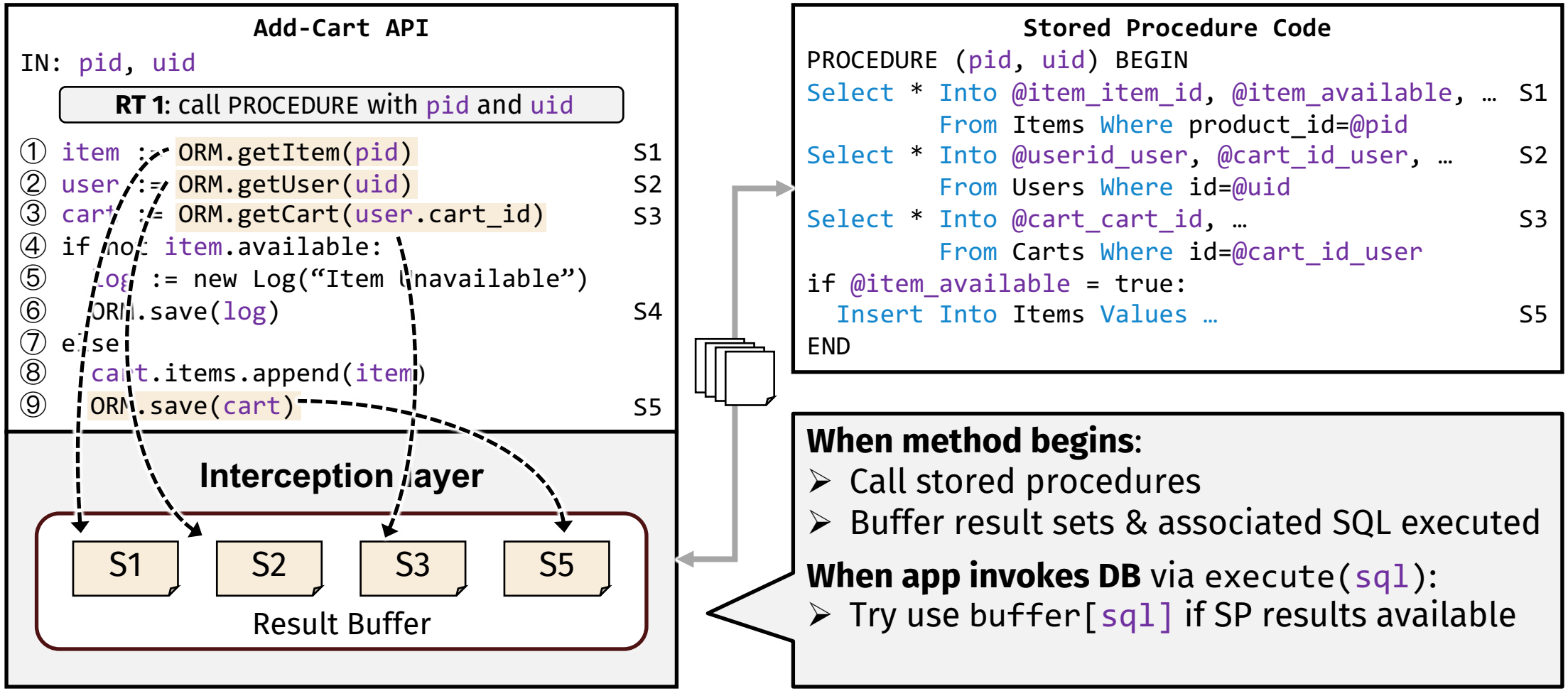

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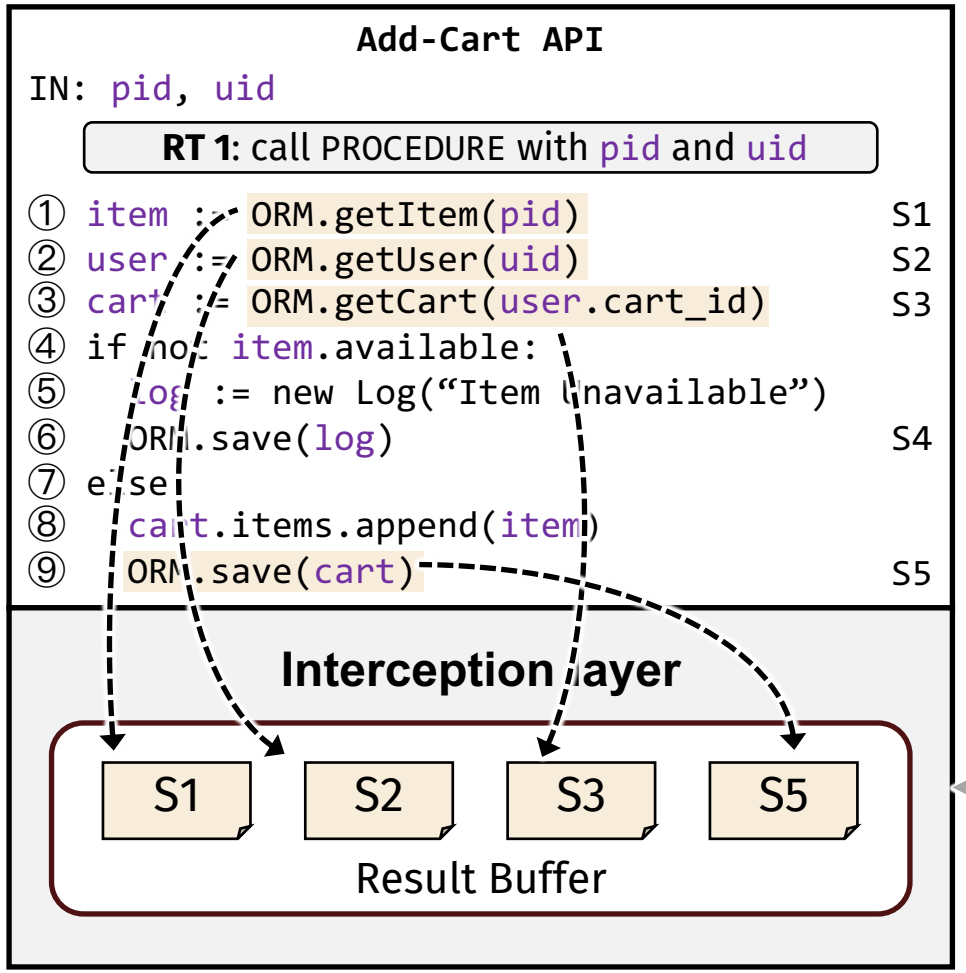

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When method begins:

- Call stored procedures
- Buffer result sets & associated SQL executed

When app invokes DB via `execute(sql)`:

- Try use `buffer[sql]` if SP results available
- On miss, send `sql` to DB & clean buffer

Handling Cold Path Requests

Add-Cart API

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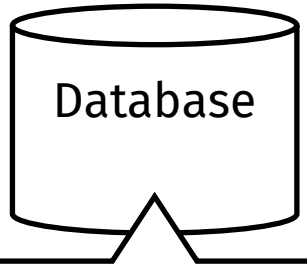

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Handling Cold Path Requests

Request adding unavailable item

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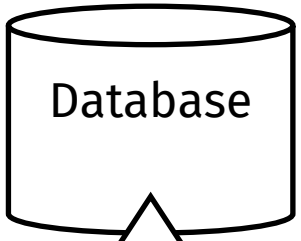

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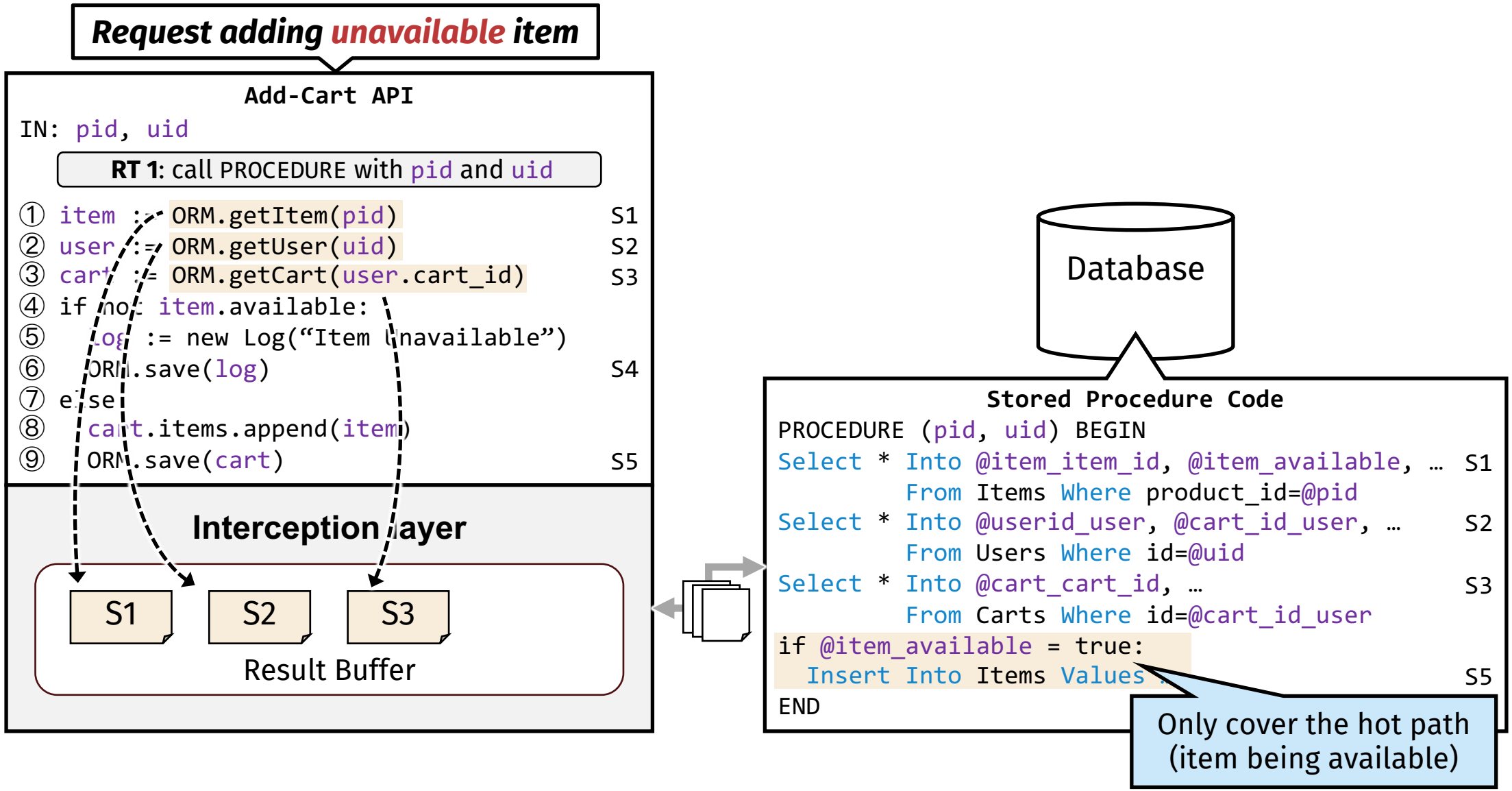
Only cover the hot path (item being available)

Handling Cold Path Requests



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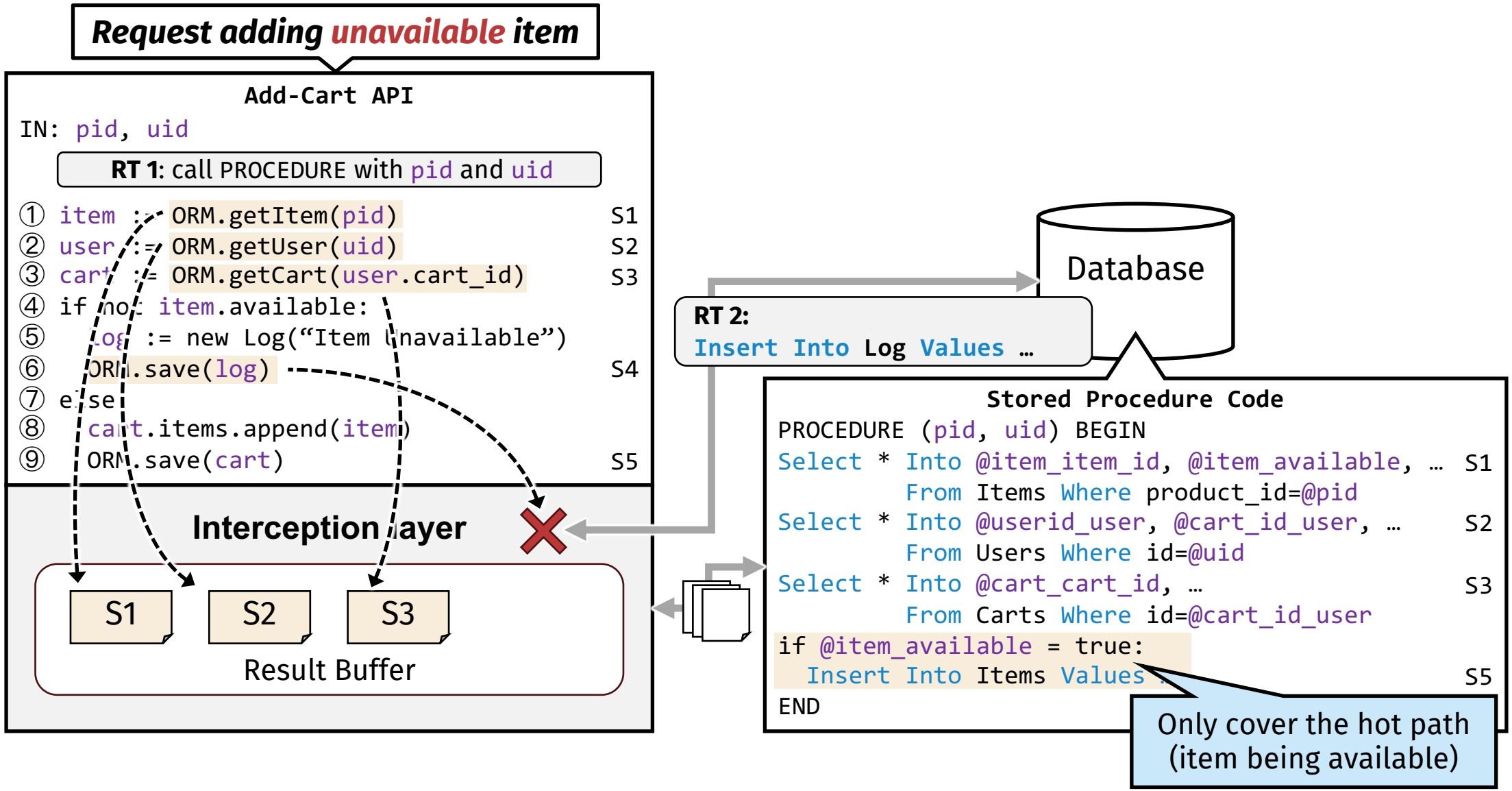
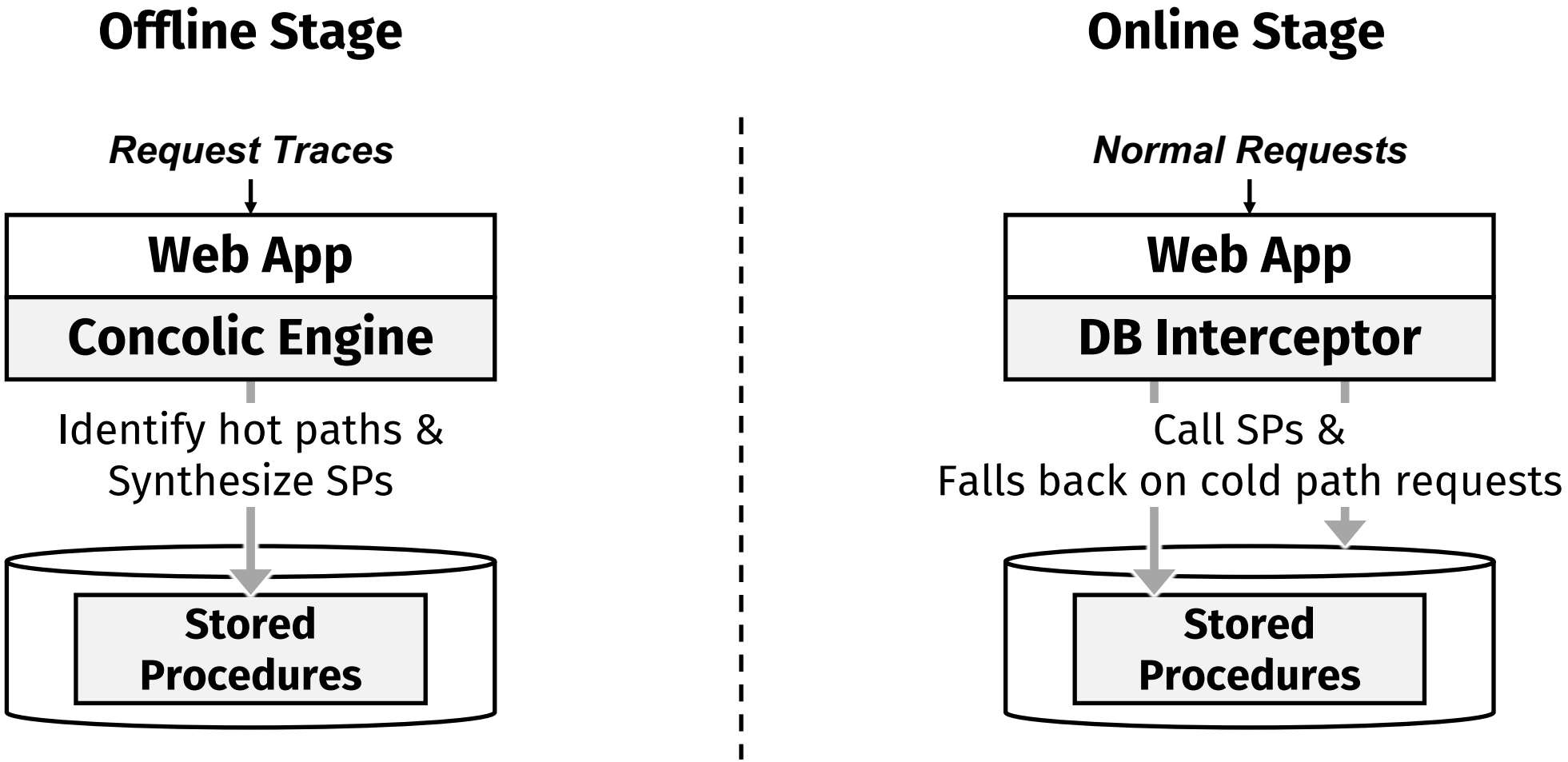


System Overview



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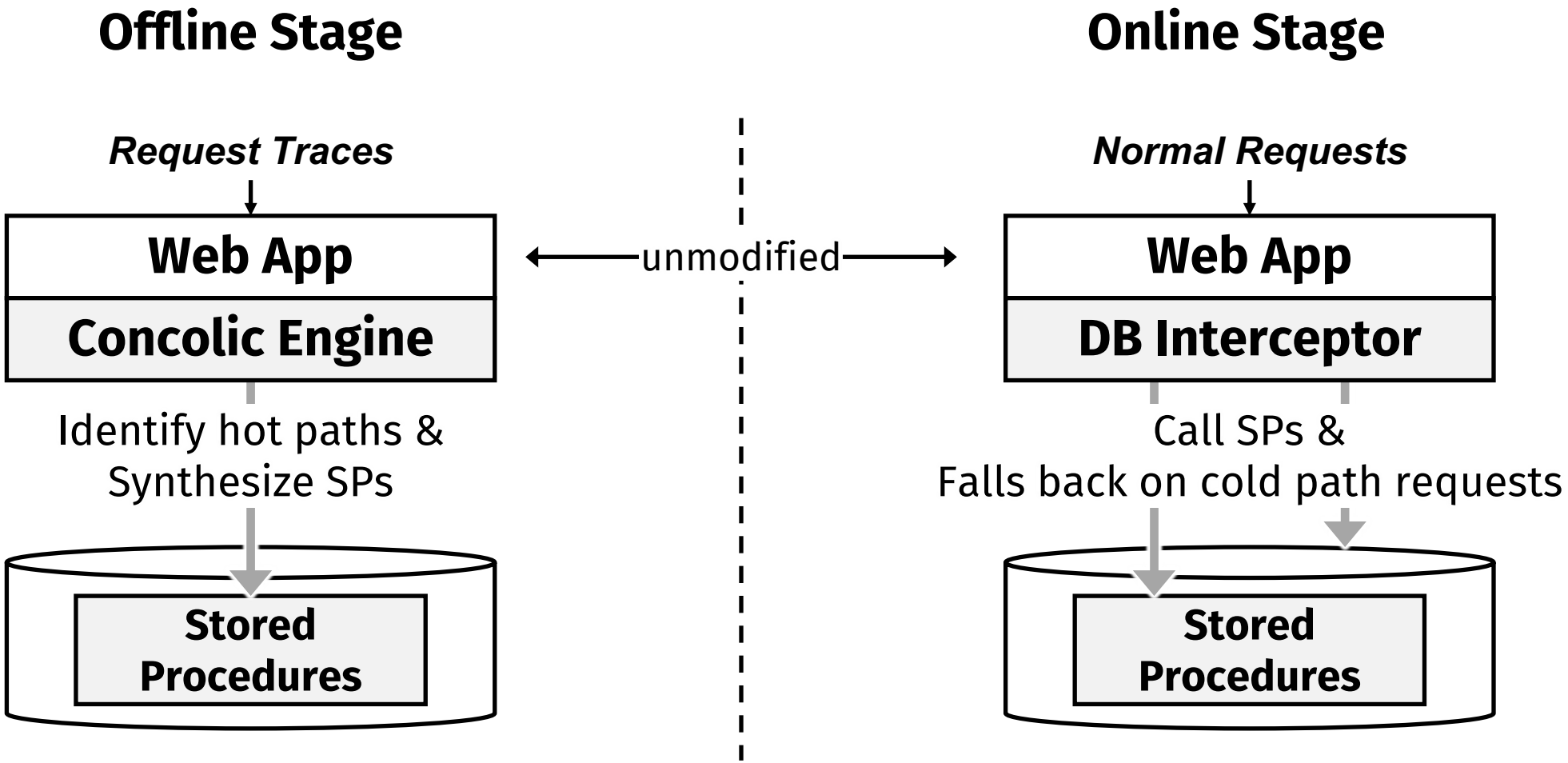
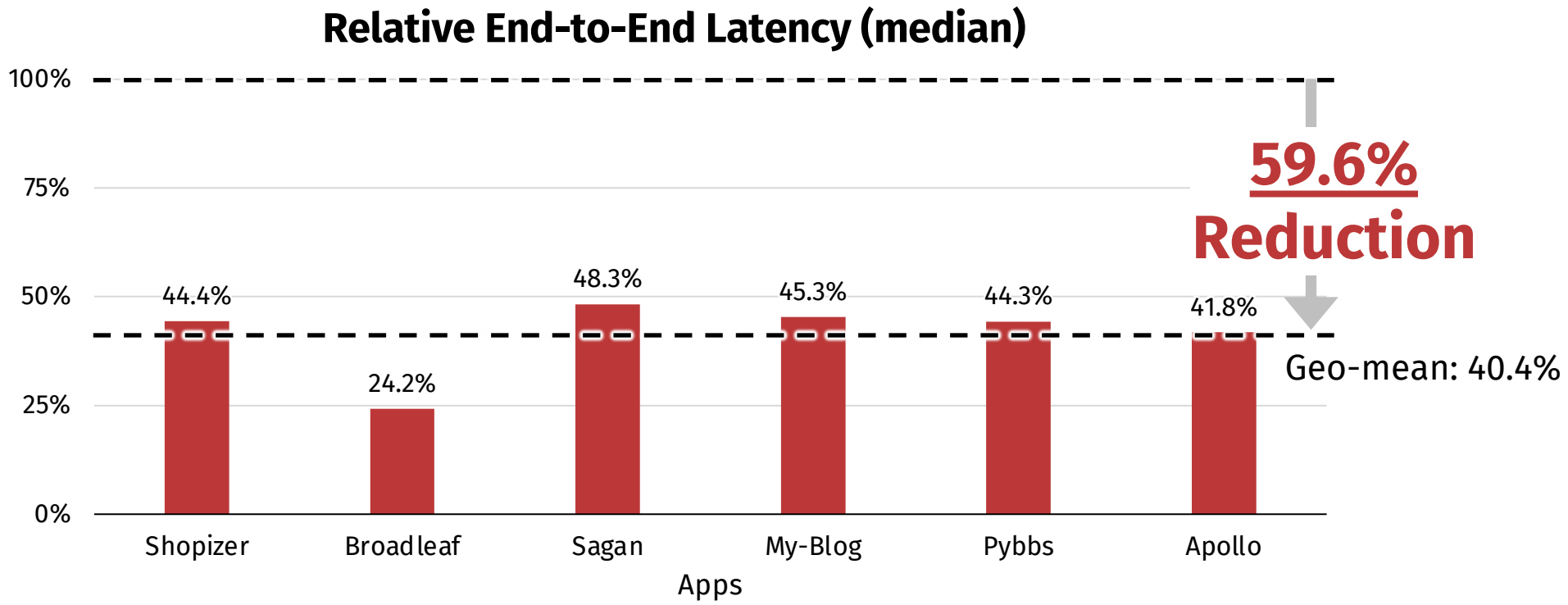


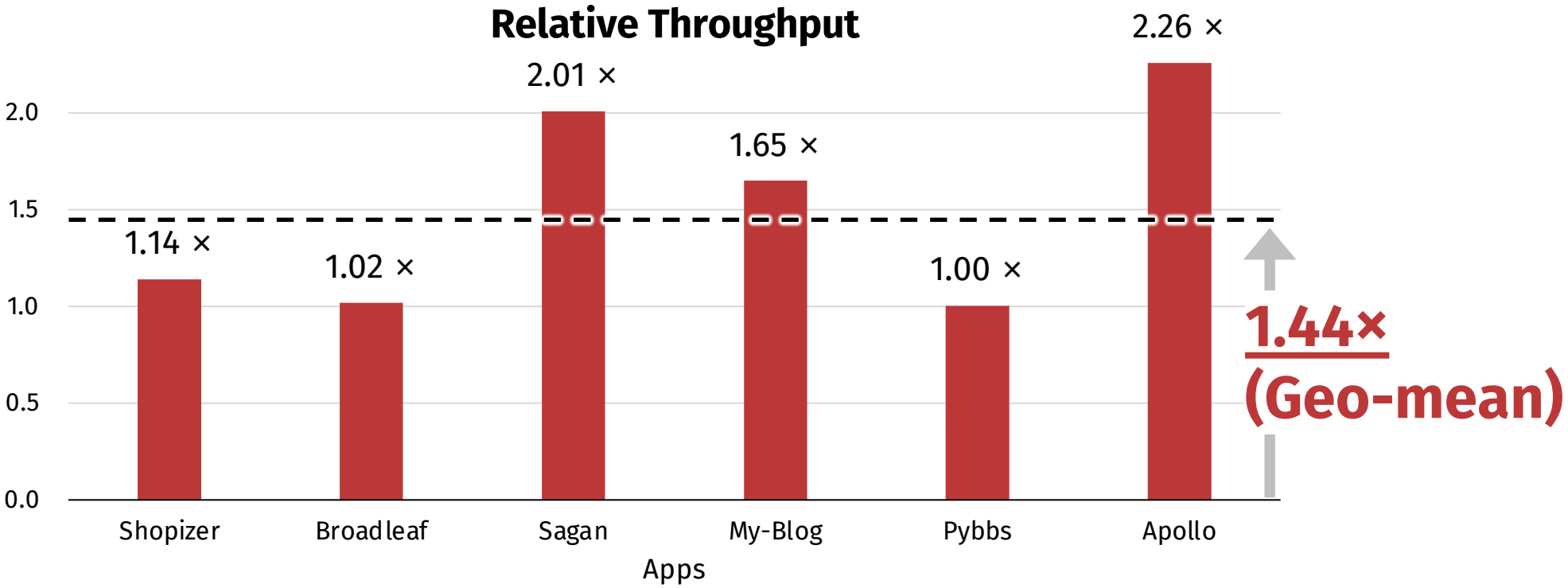
Evaluation: Latency

- **Over 6 open-source apps with realistic workloads. (6.8k ★/app)**
- **WeBridge achieves 59.6% end-to-end latency reduction.**



Evaluation: Throughput

- **WeBridge can also increase near half throughput, by**
  - Avoid DB repeatedly parsing interactive statements; and
  - Shorten lock-holding time of conflicting transactions



Summary and Q/A

- **WeBridge synthesize stored procedures to pre-execute SQL statements to reduce DB round trips.**
- **Using concolic execution, data & control dependencies are accurately shipped to DB.**
- **For end-users, WeBridge reduces 59.6% latency and achieves 1.44× relative throughput.**

- **Check out our paper and source code!**
  - Design details; optimizations; correctness proof, etc.

Paper

Code