Automating the Choice of Consistency Levels in Replicated Systems

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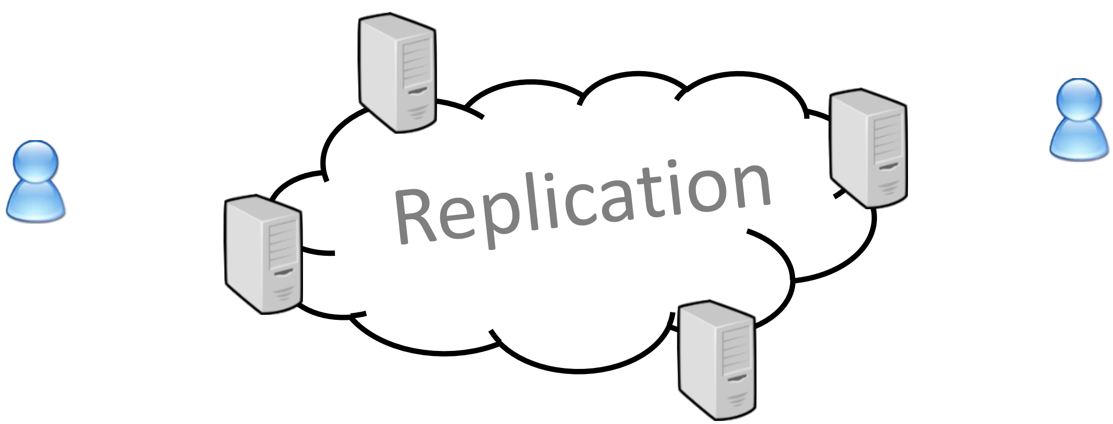
RedBlue Consistency [OSDI'12]

Builds replicated systems that are fast



RedBlue Consistency [OSDI'12]

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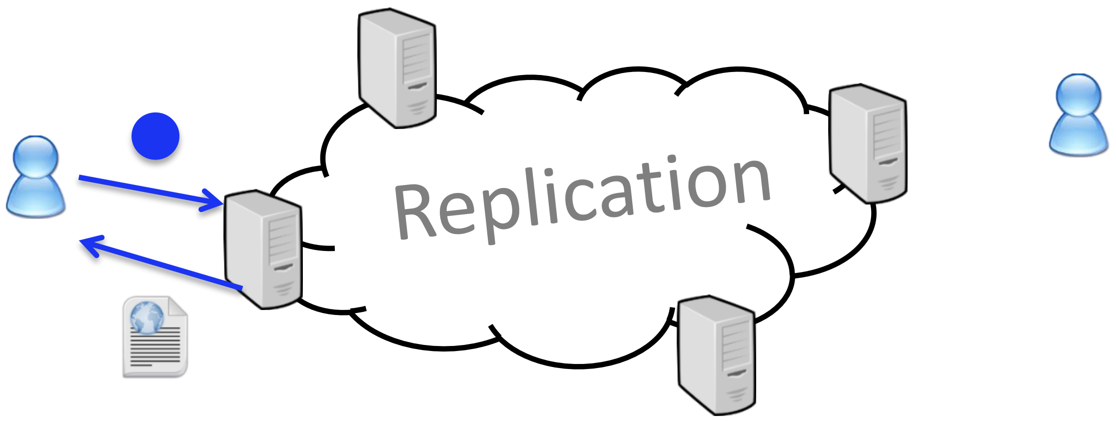
Blue ops: local, fast, weakly consistent



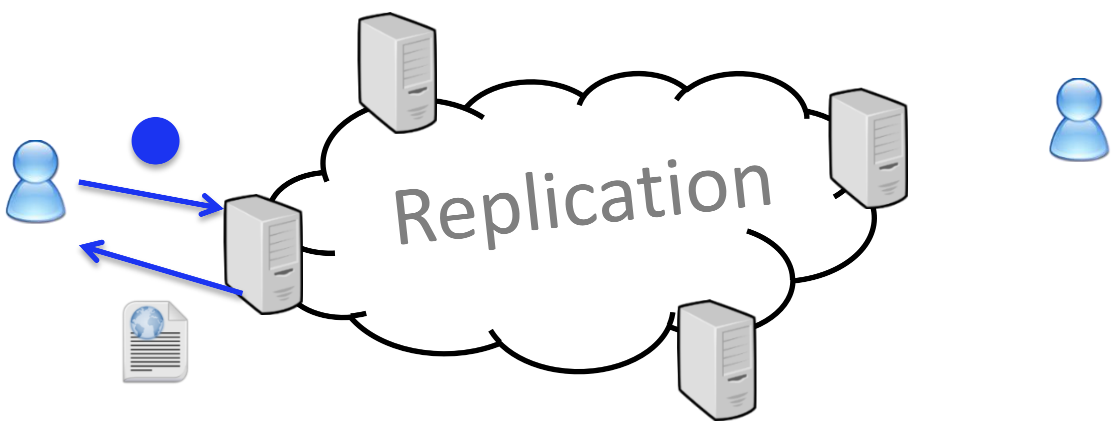
RedBlue Consistency [OSDI'12]

Builds replicated systems that are fast and correct

State convergence

Invariant preservation

Blue ops: local, fast, weakly consistent



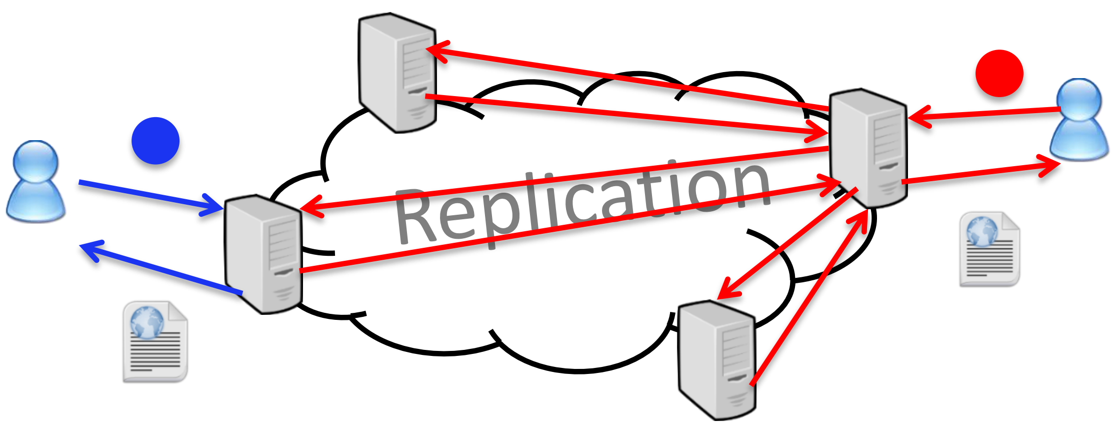
RedBlue Consistency [OSDI'12]

Builds replicated systems that are fast and correct

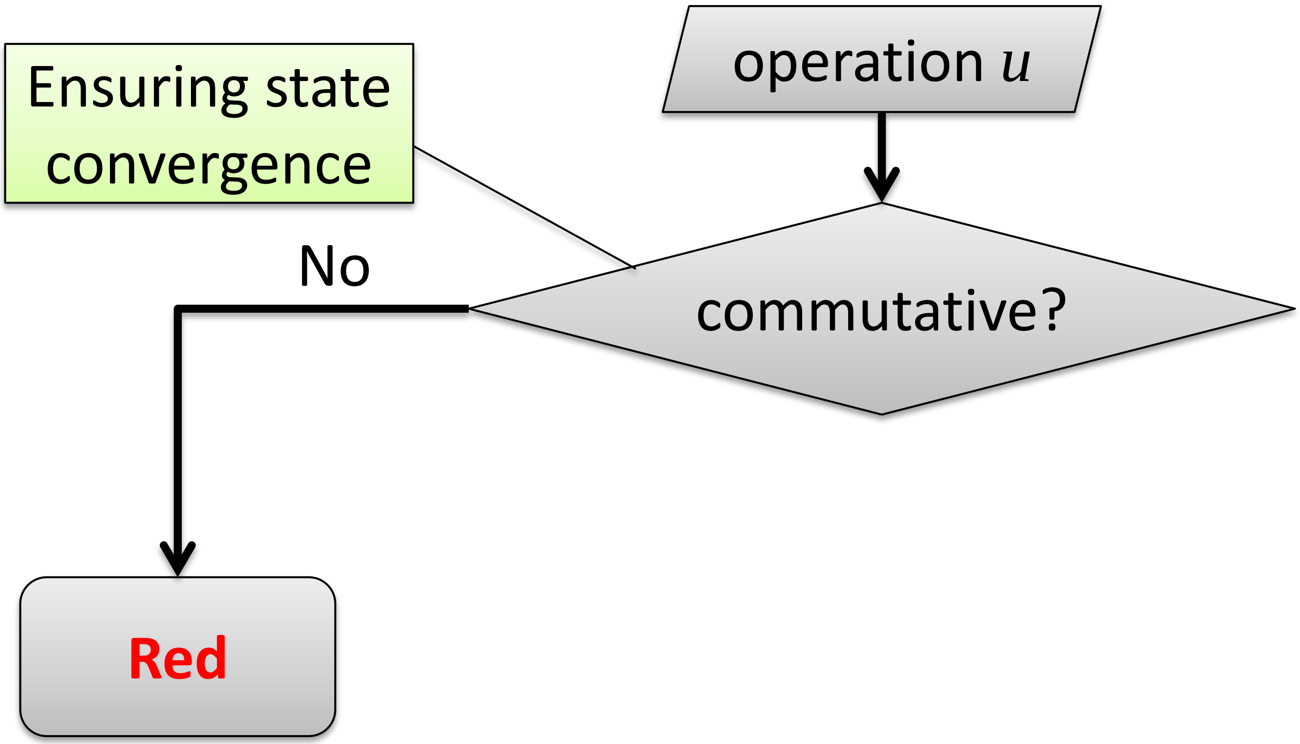
- State convergence
- Invariant preservation

Blue ops: local, fast, weakly consistent

Red ops: global, slow, strongly consistent



Choosing between Blue or Red



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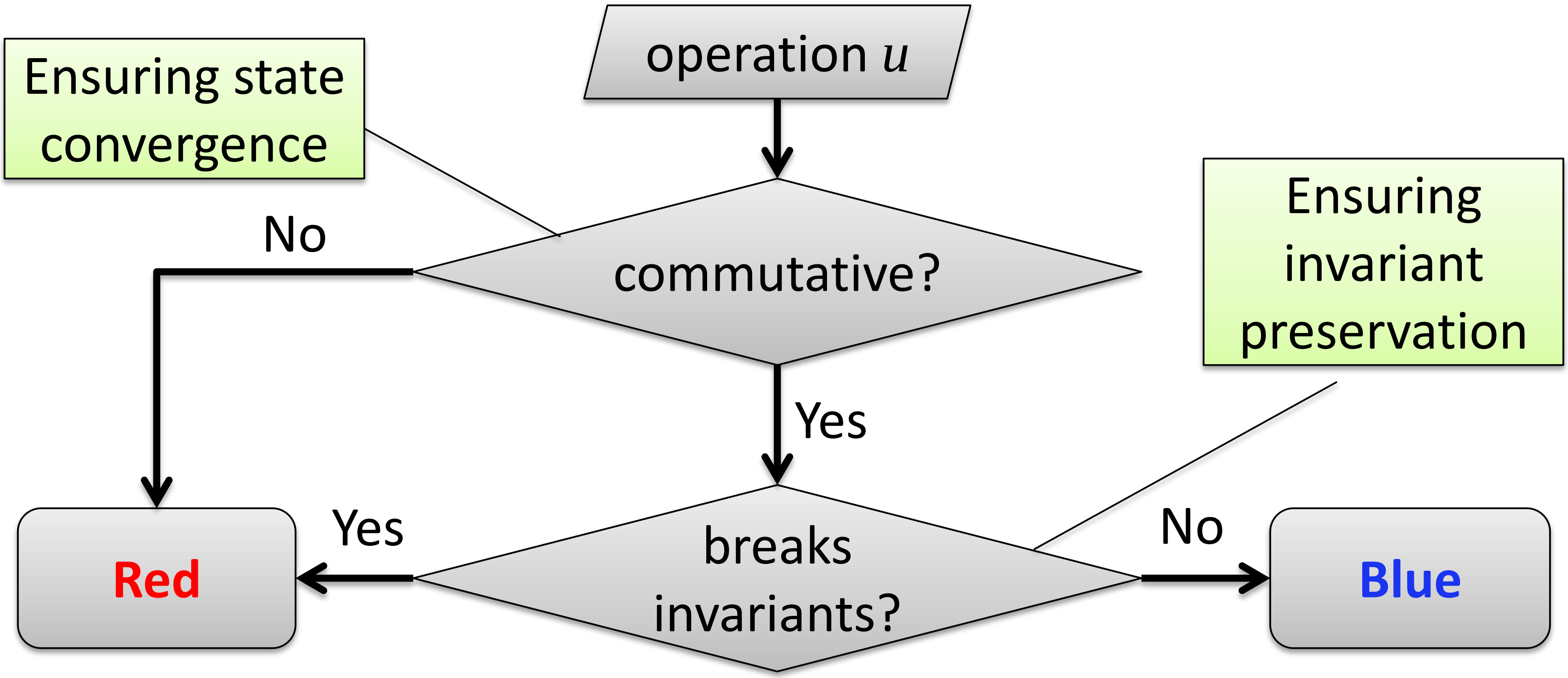
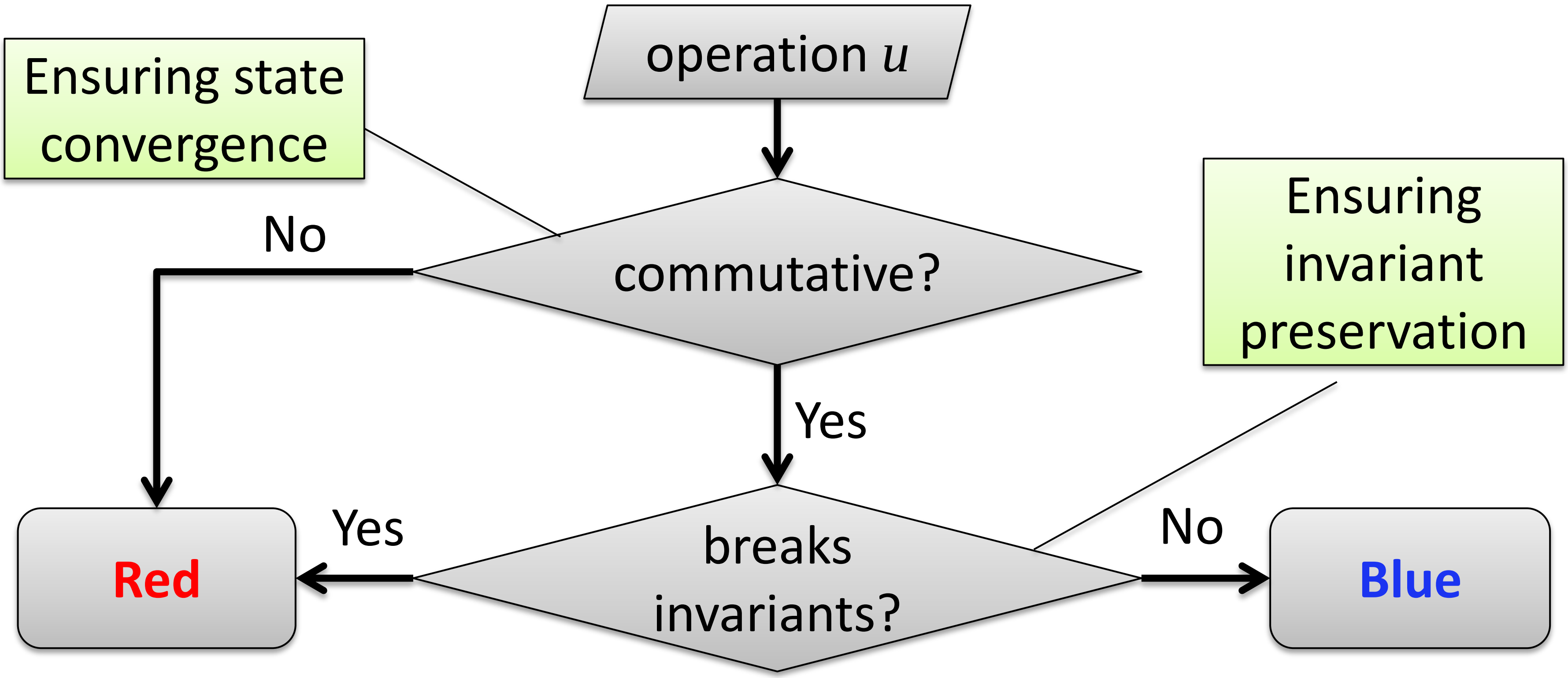
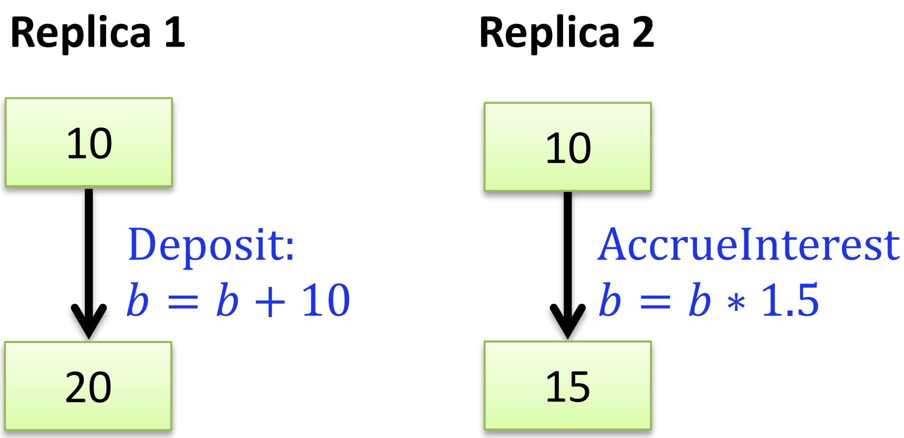


Choosing between Blue or Red

Good performance obtained if blue ops dominate op space



RedBlue Consistent Bank



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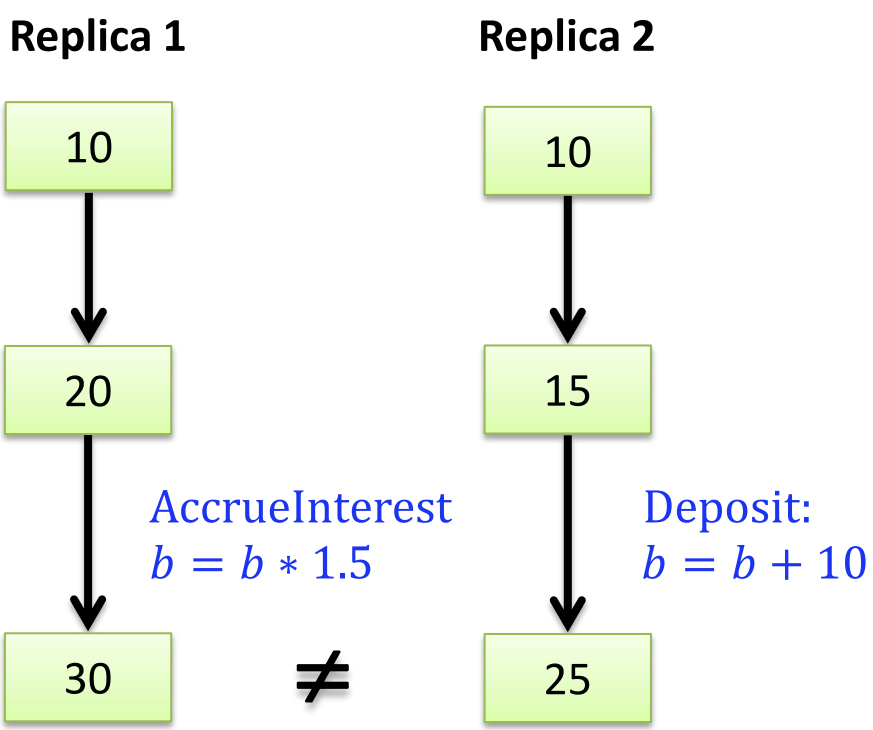

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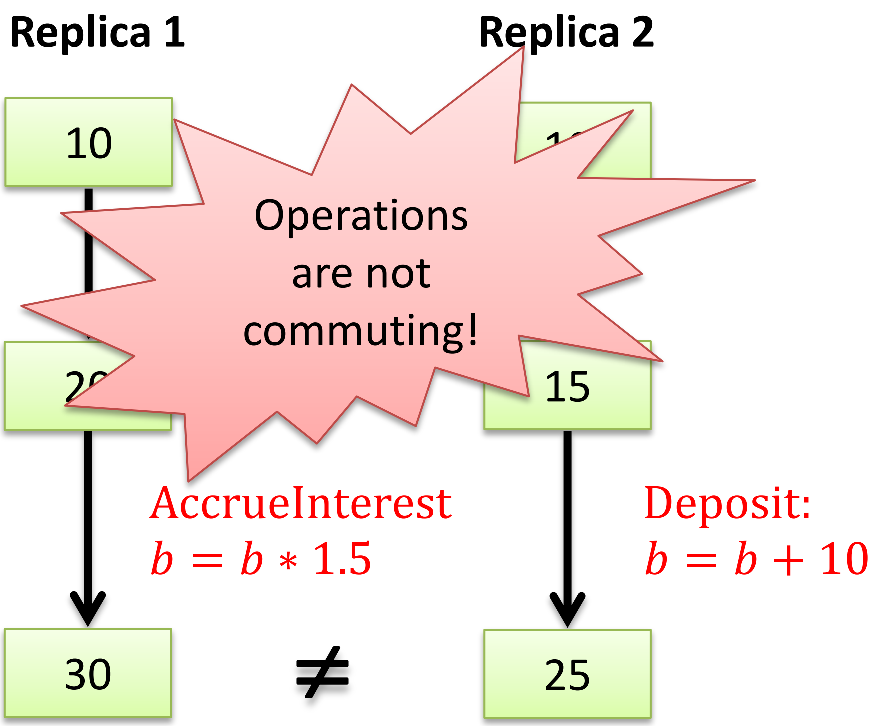

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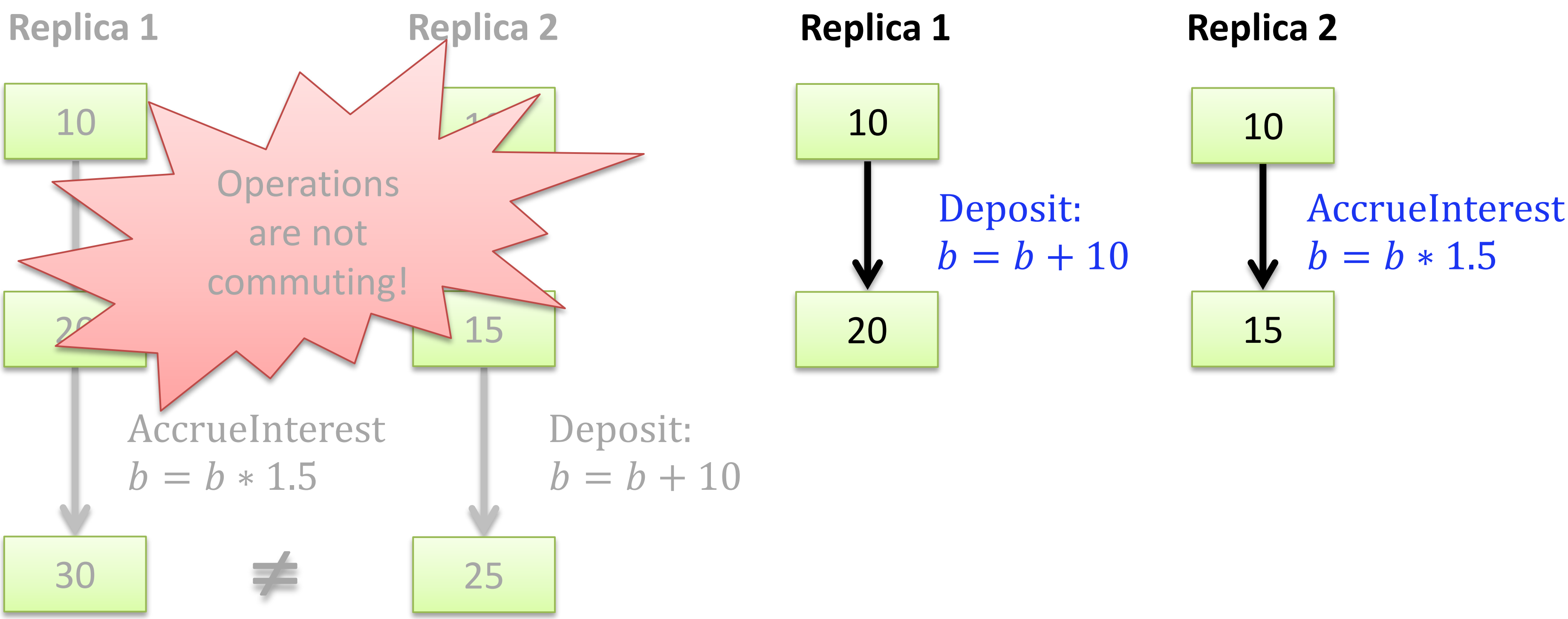

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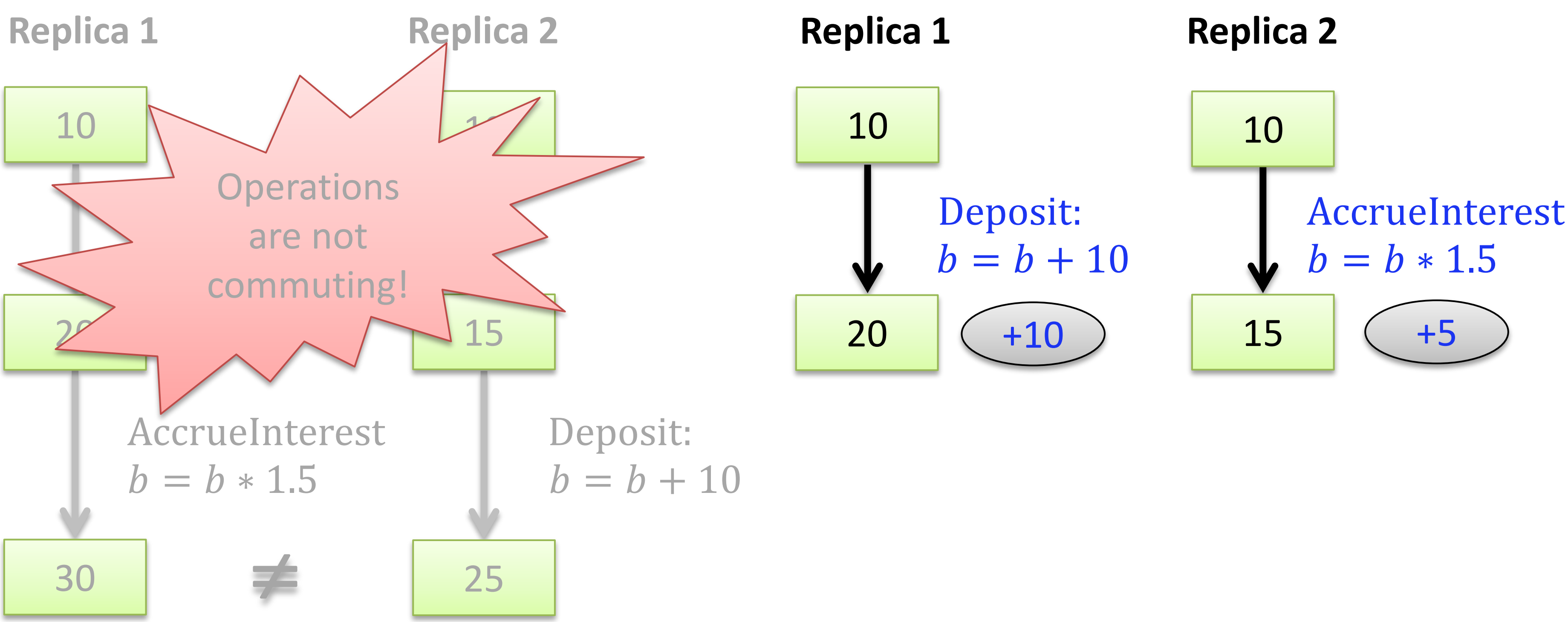

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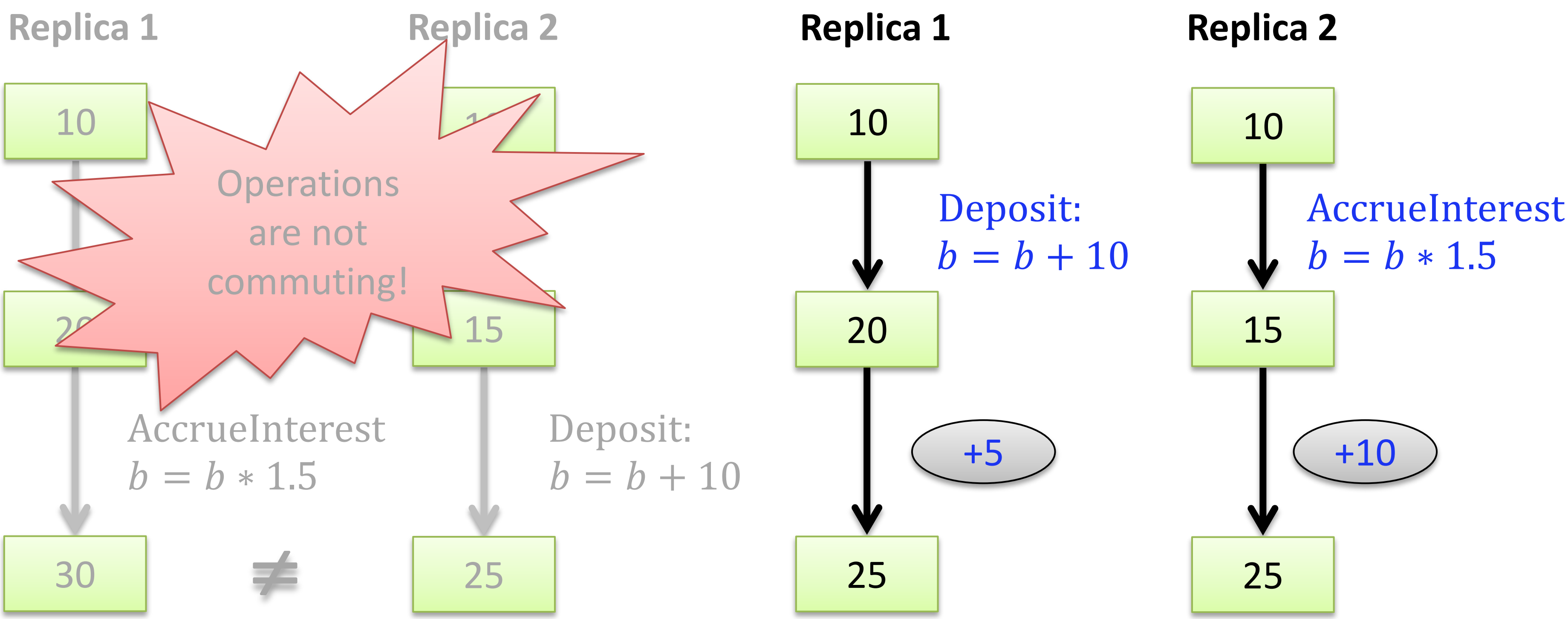
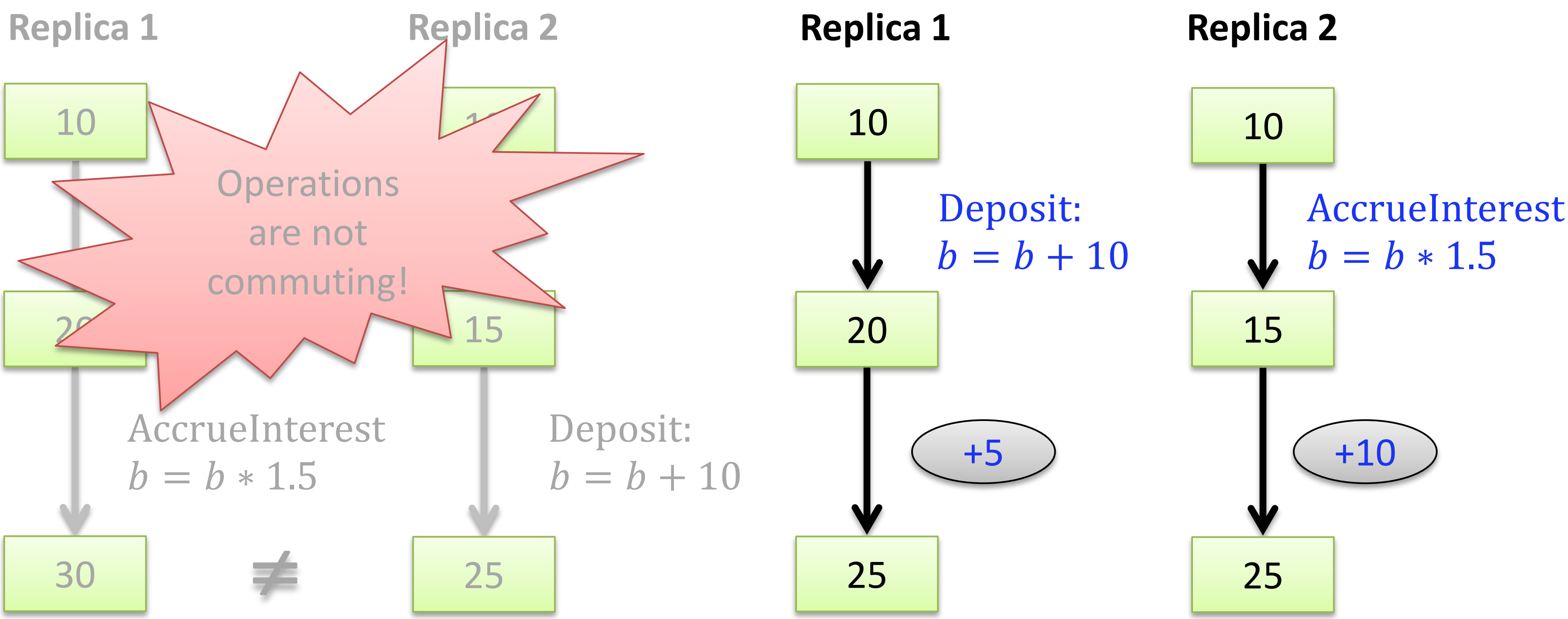
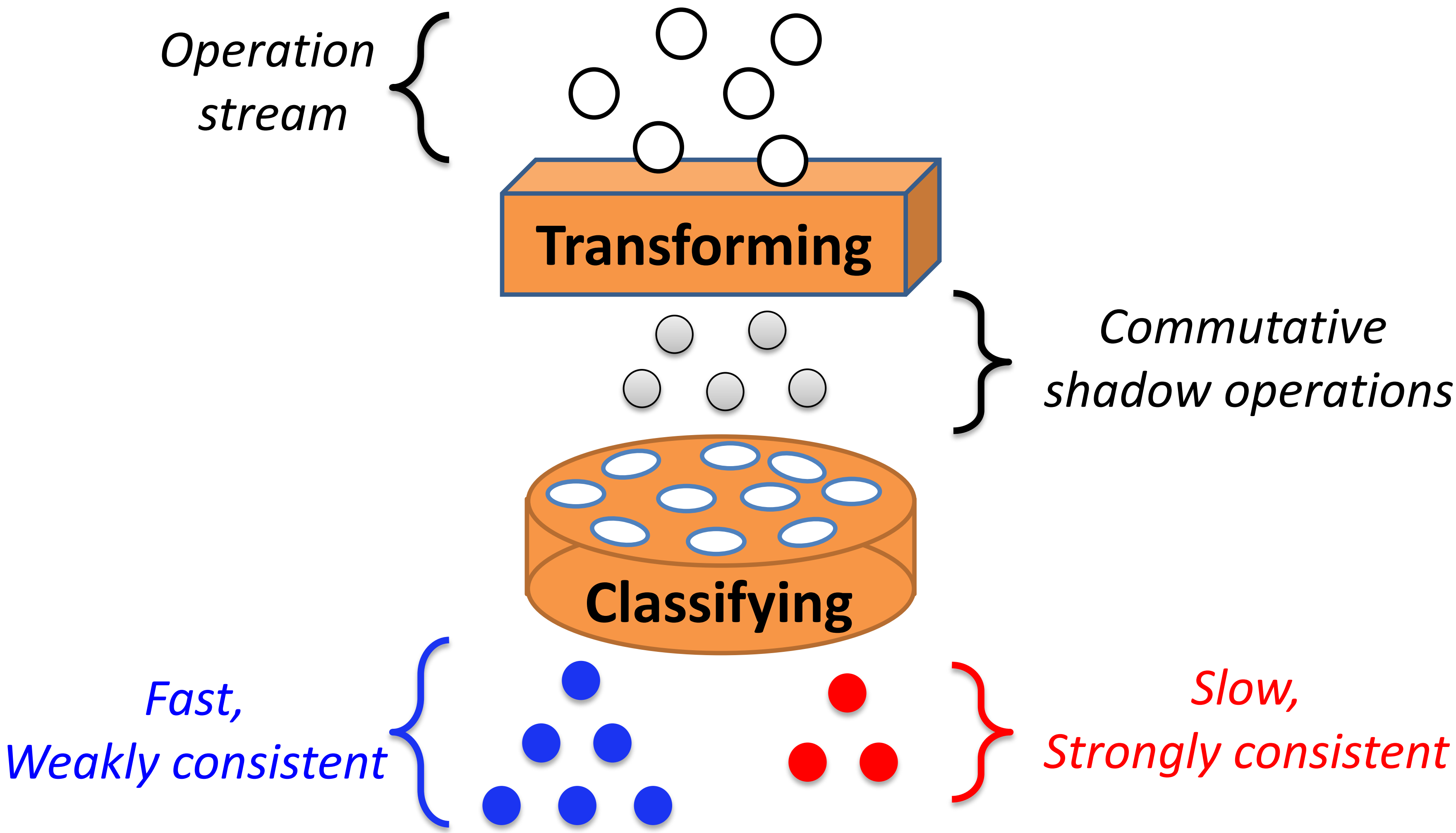


RedBlue Consistent Bank

Maximize the blue op space by encoding side effects into commutative **shadow operations**



SIEVE


Operation stream
Transforming
Commutative shadow operations
Classifying
Fast, Weakly consistent
Slow, Strongly consistent

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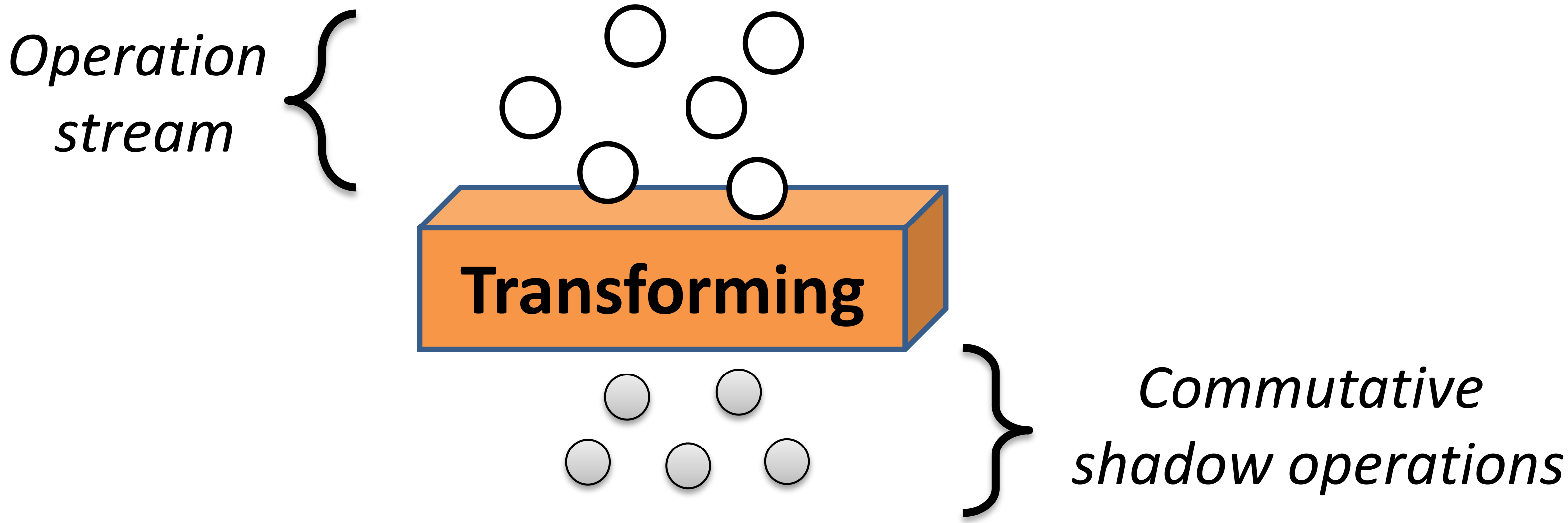

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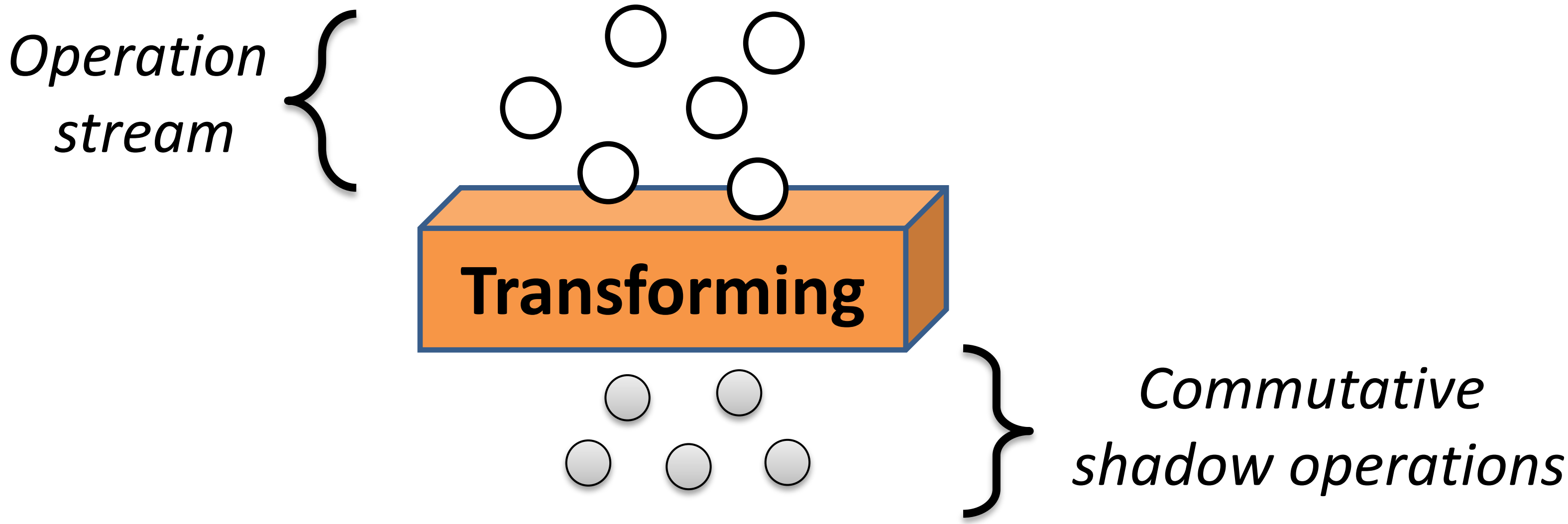
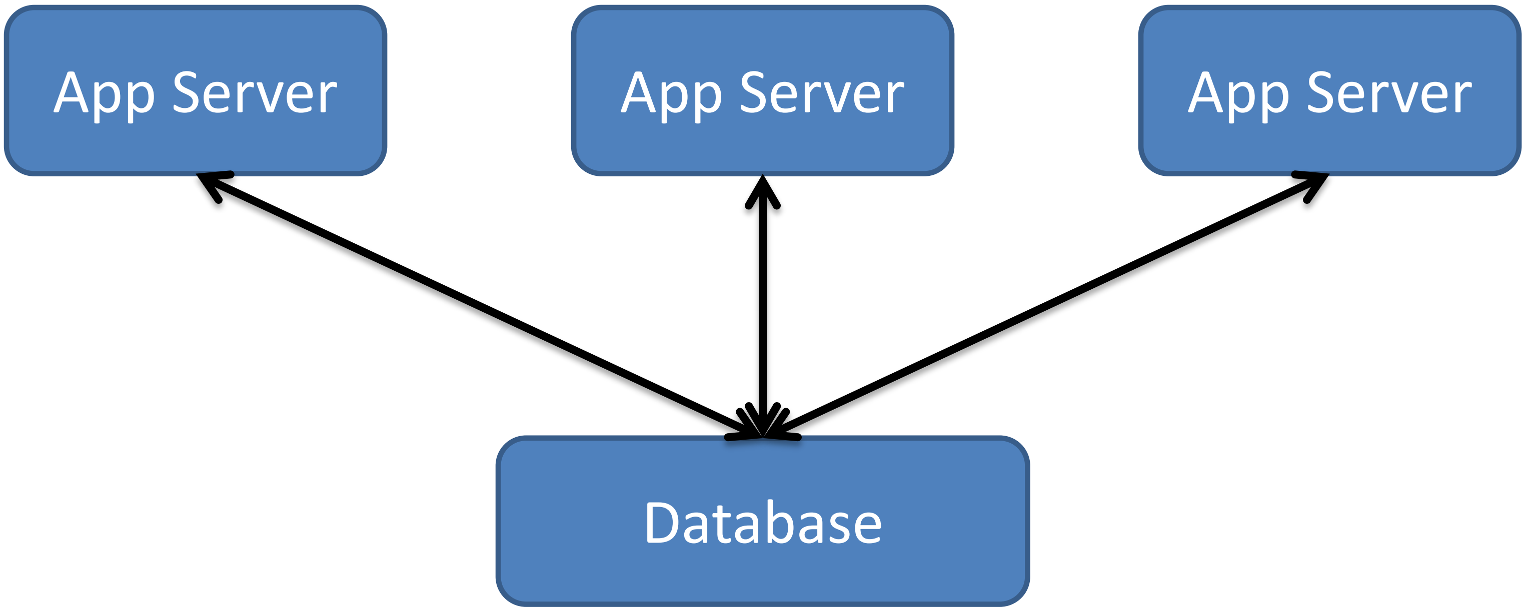


Challenges:

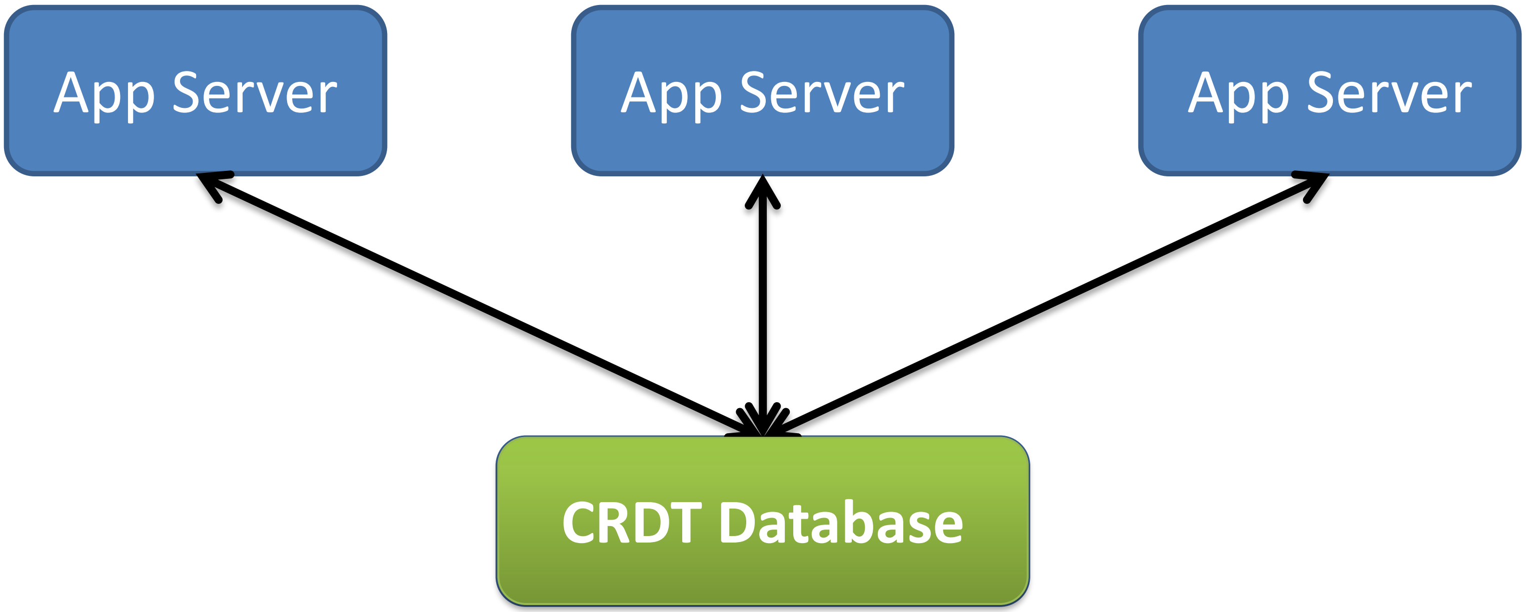
- Making arbitrary side effects commute
- Minimizing human intervention

Two-tier Application Model



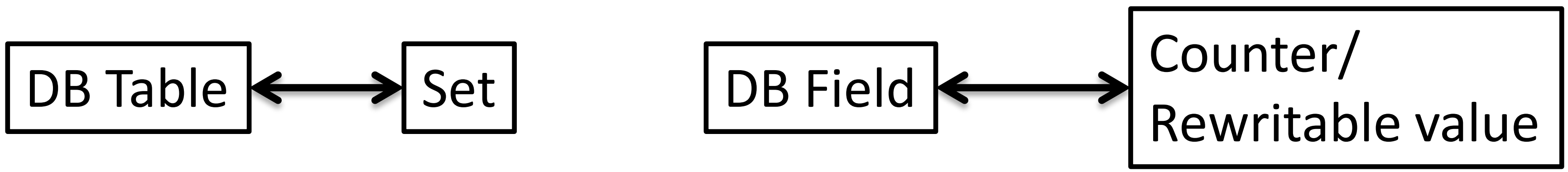
- Observation: Side effects are encapsulated into a sequence of DB statements

Two-tier Application Model

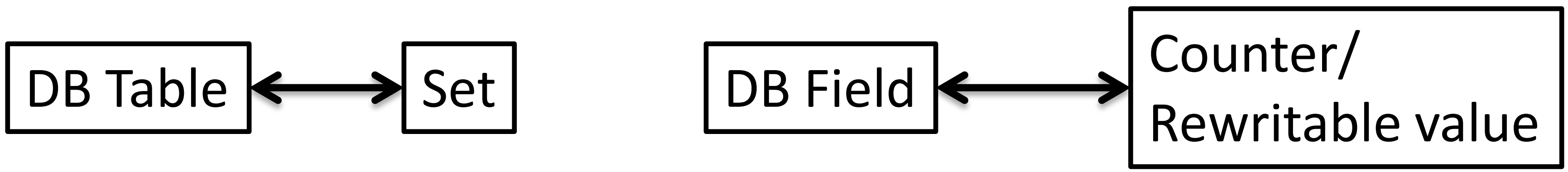


- Observation: Side effects are encapsulated into a sequence of DB statements
- Insight: We can model the database using commutative replicated data types (CRDTs)

Leveraging CRDTs



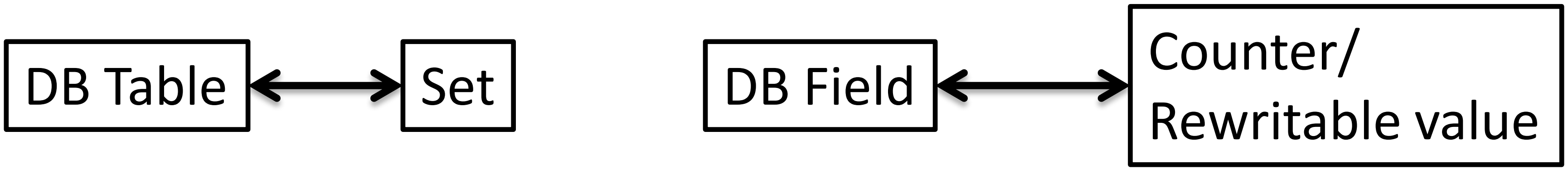
Leveraging CRDTs



- Transform each DB statement into one or more CRDT operations

Shadow operation: [CRDT_OP1; CRDT_OP2; CRDT_OP3;…]

Leveraging CRDTs



- Transform each DB statement into one or more CRDT operations

Shadow operation: [CRDT_OP1; CRDT_OP2; CRDT_OP3;…]

- Programmers ***<u>only</u>*** annotate schema with CRDTs:

@[*CRDTName*][*TableName*|*DataFieldName*]

CRDT Annotation Example

```
CREATE TABLE BankAccount(
        id INT(11) NOT NULL,
        balance INT(11) default 0,
        name char(60) default NULL,
        PRIMARY KEY (id)
) ENGINE=InnoDB
```

CRDT Annotation Example

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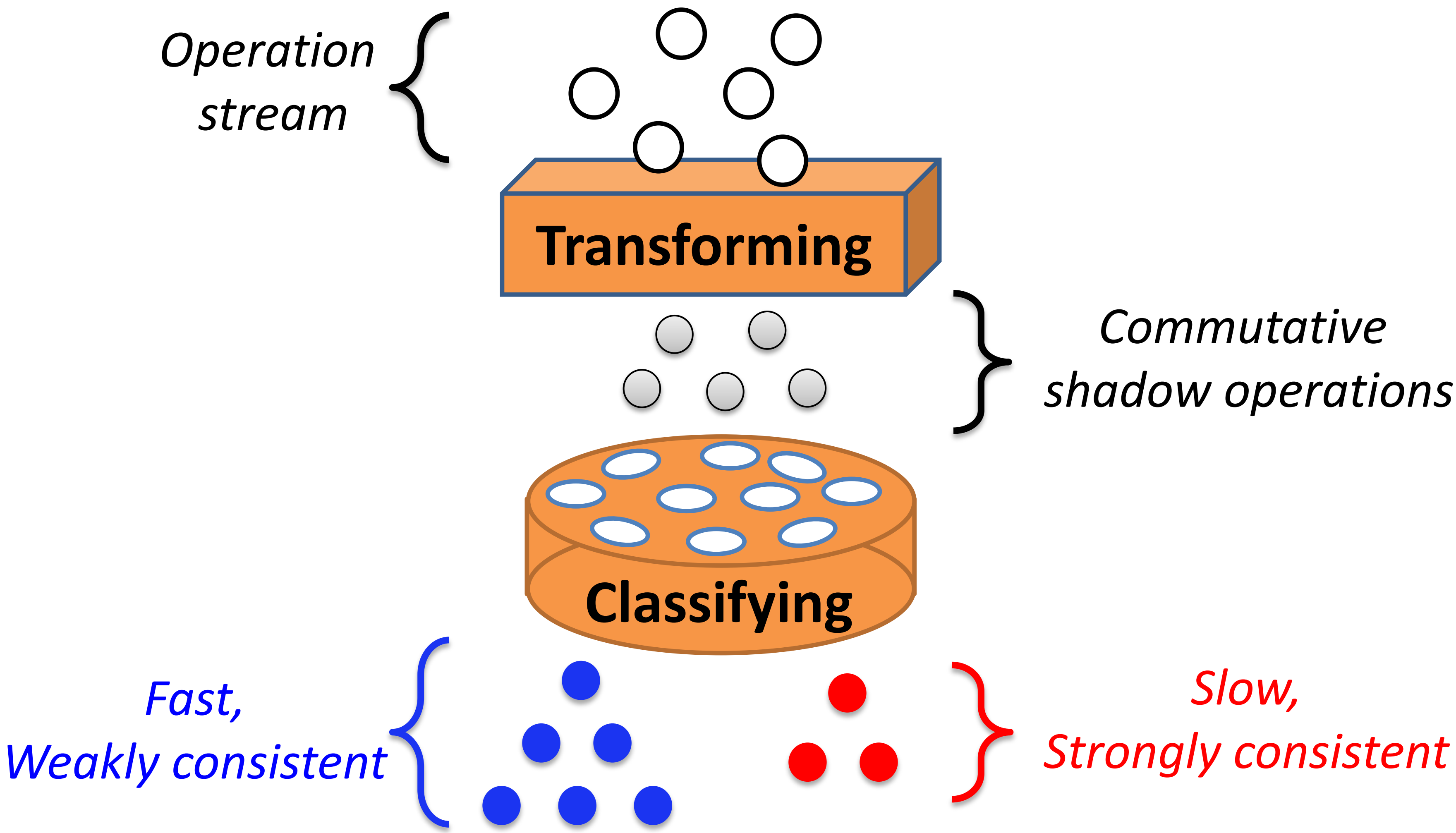
For details, refer to our paper.

SIEVE



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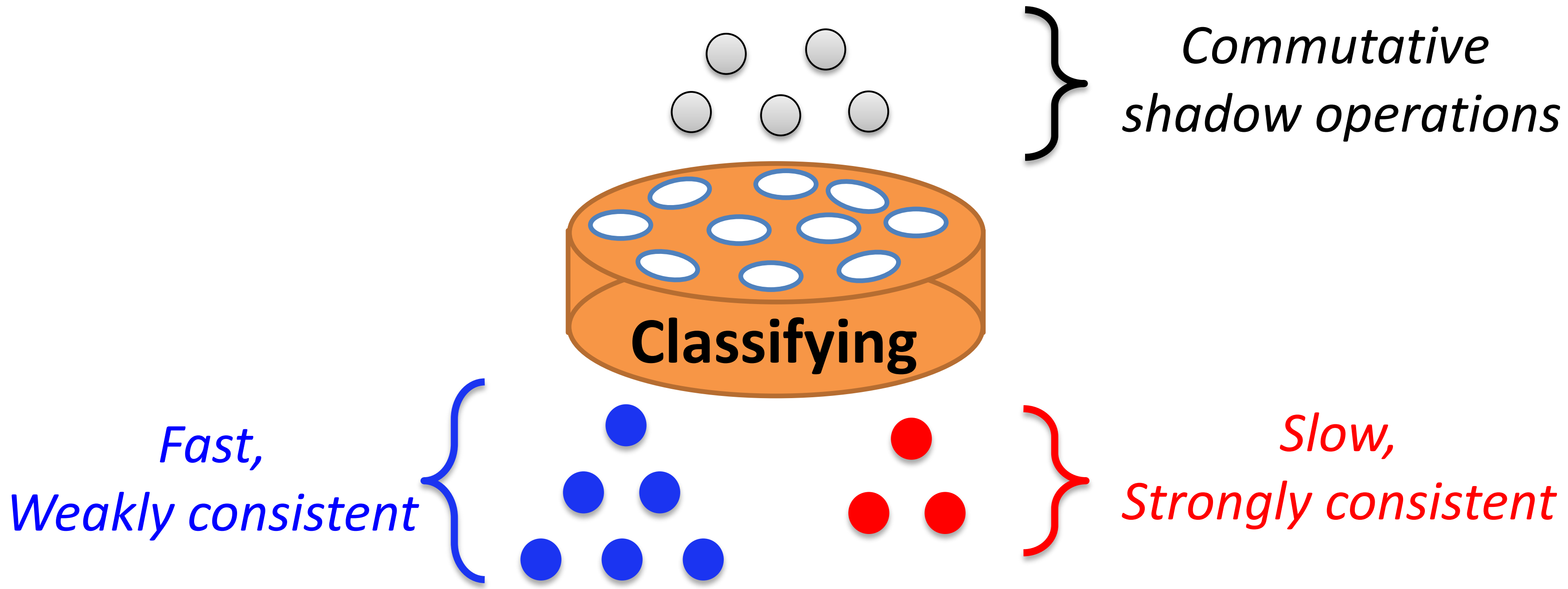
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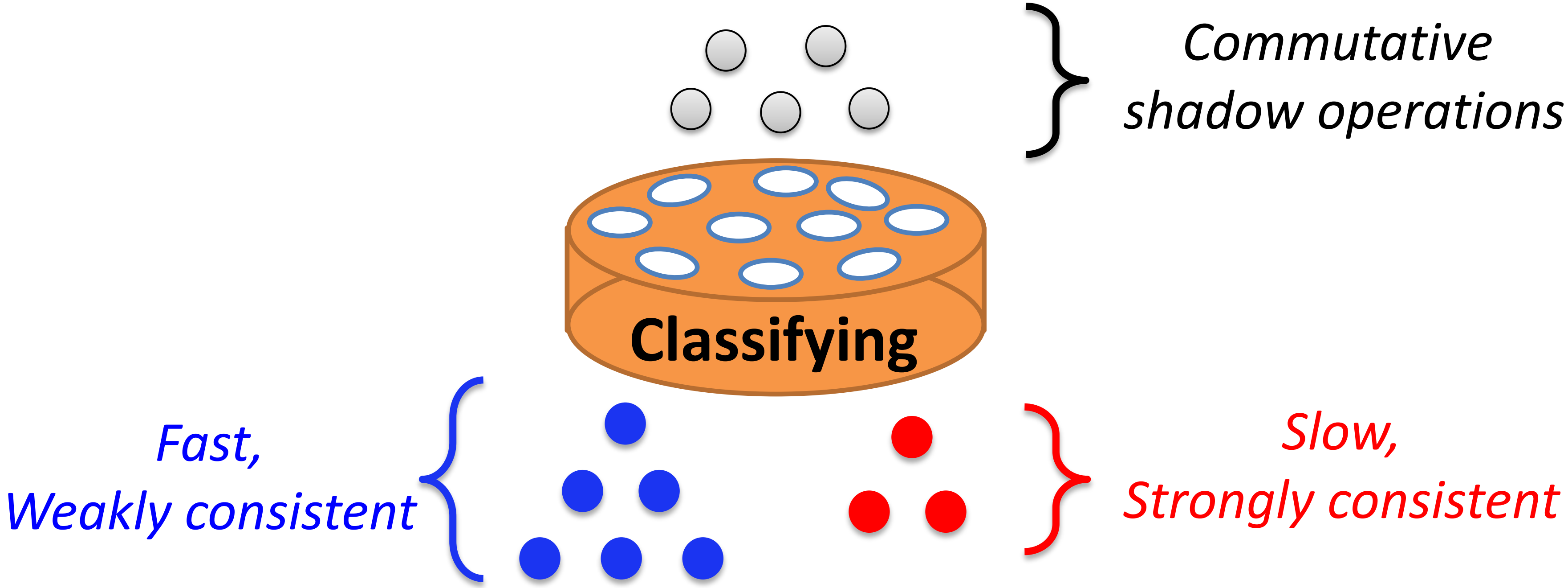
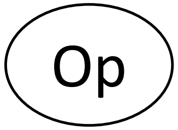
SIEVE

Challenge:

- How to classify accurately and efficiently?



Straw man Solution



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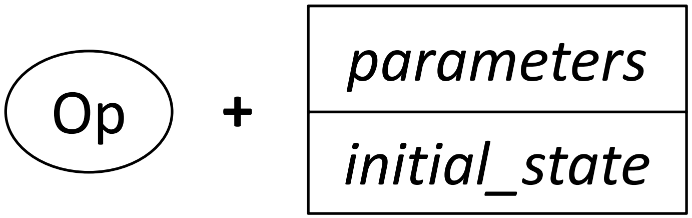

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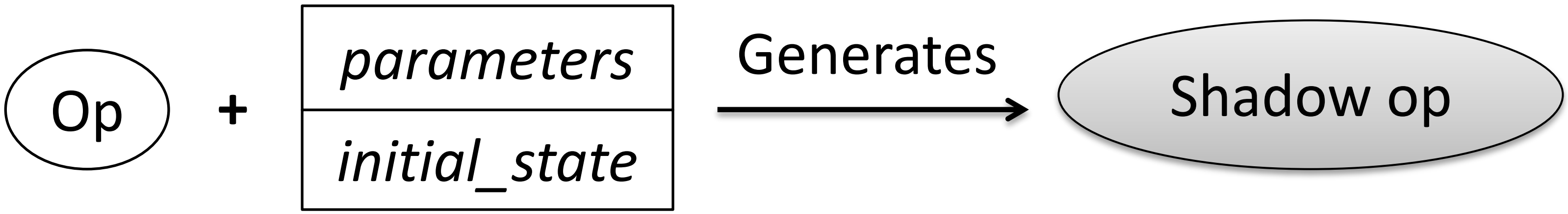

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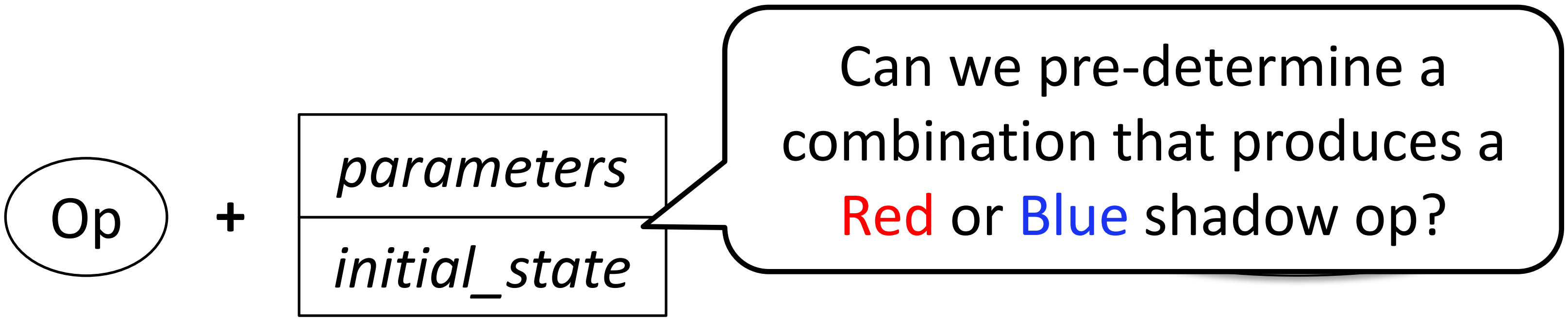

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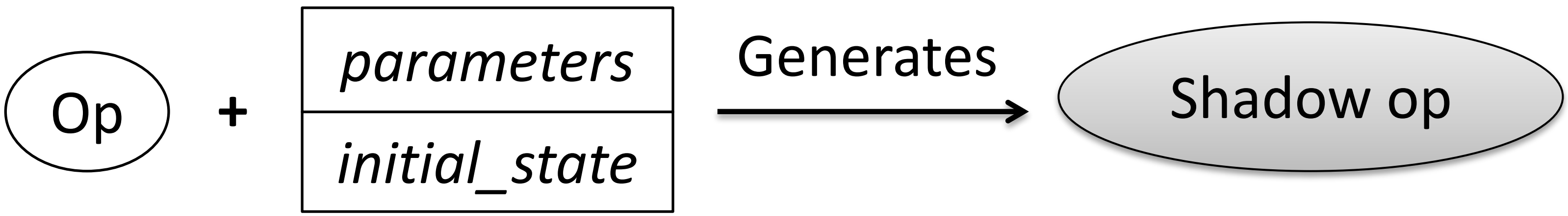

- Statically define, for each original operation, a weakest precondition (WP) for corresponding shadow op to be invariant preserving
- At runtime, we classify shadow operations by evaluating the corresponding WP

WP Computation

- Problem: WP computation is infeasible (inverting hash function)

```
Invariant: x >= 0
void foo(string s) {
  if (SHA-1(s)==SOME_CONSTANT) {
     if (x>=10)
        x -= 10;
  } else
       x +=10;
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WP Computation

- Problem: WP computation is infeasible (inverting hash function)
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Weakest precondition must be FALSE!

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Apply -10 to x

Do nothing

Apply 10 to x

Path-basis Analysis

- Creates a ***template*** per control flow path to capture all possible shadow operations following that path

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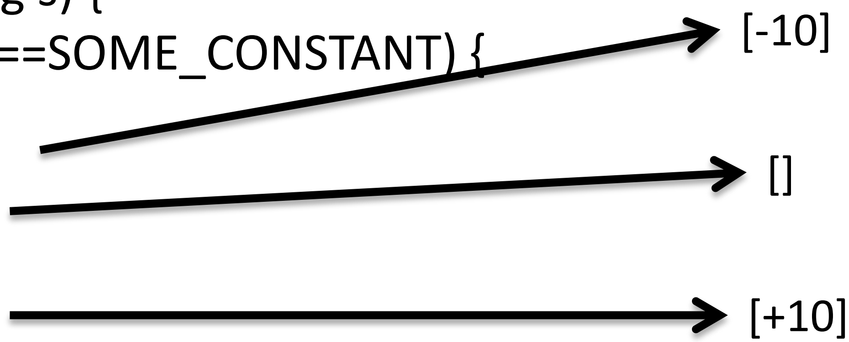

Path-basis Analysis

- Creates a ***template*** per control flow path to capture all possible shadow operations following that path
- WP computation is done over parameters of CRDT invocations in templates

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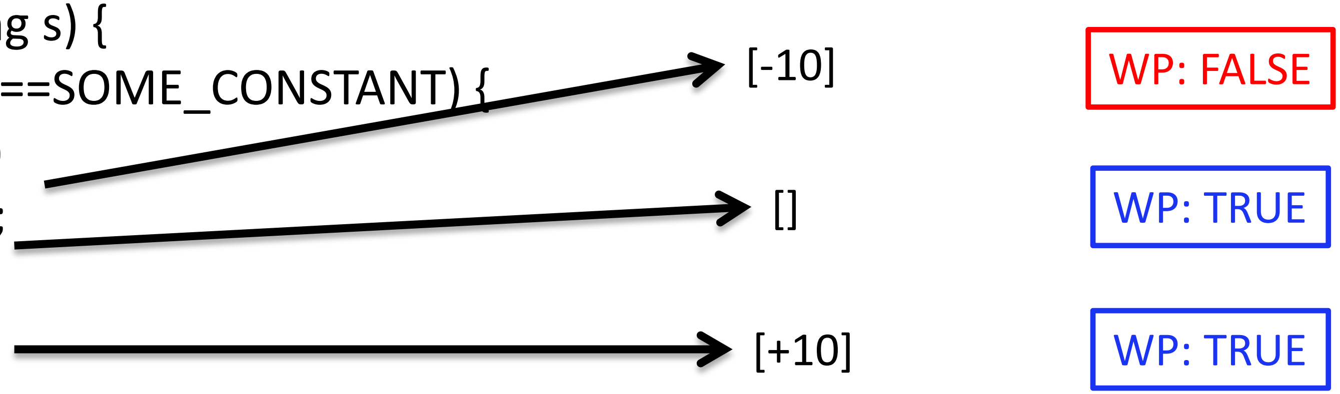

Do most (not all) work offline!

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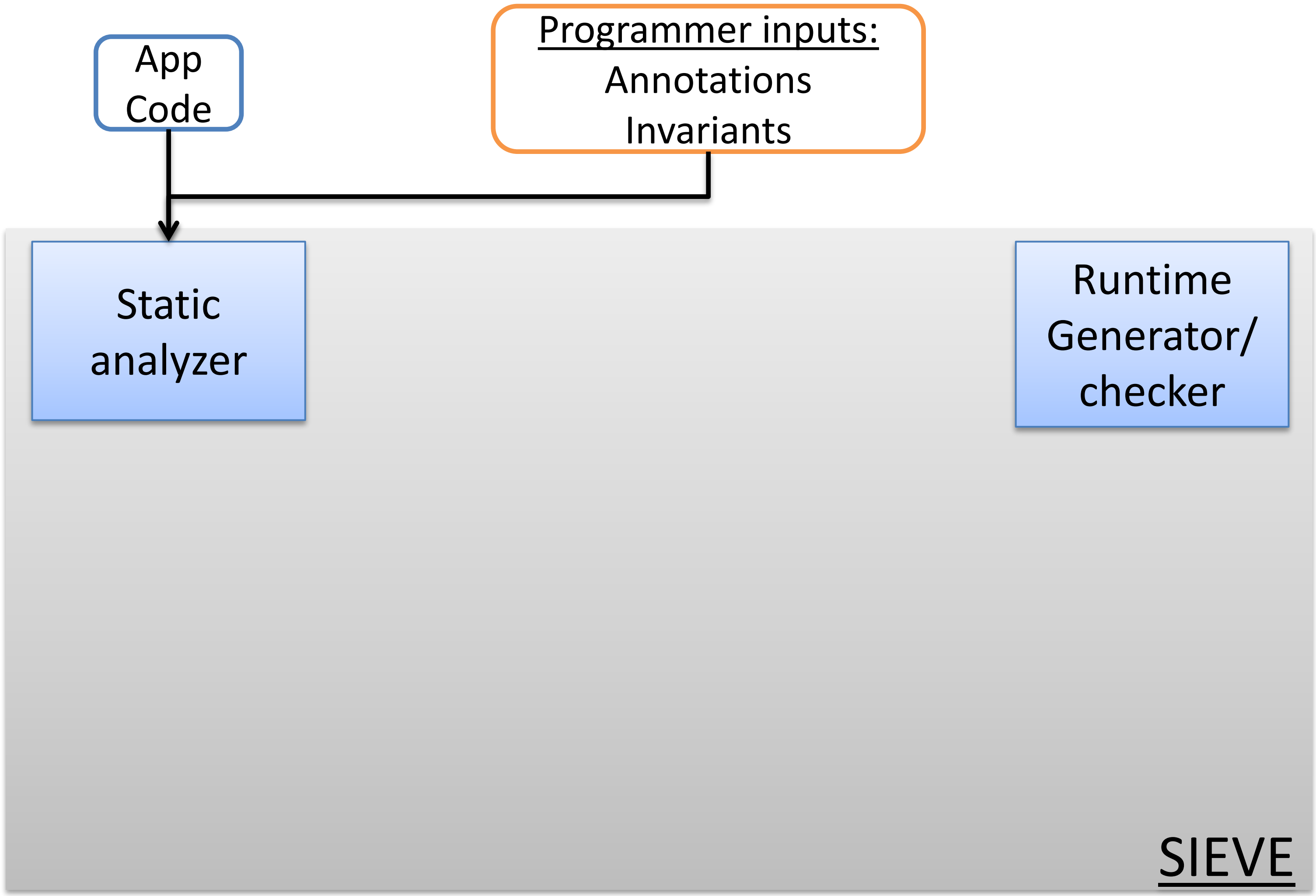

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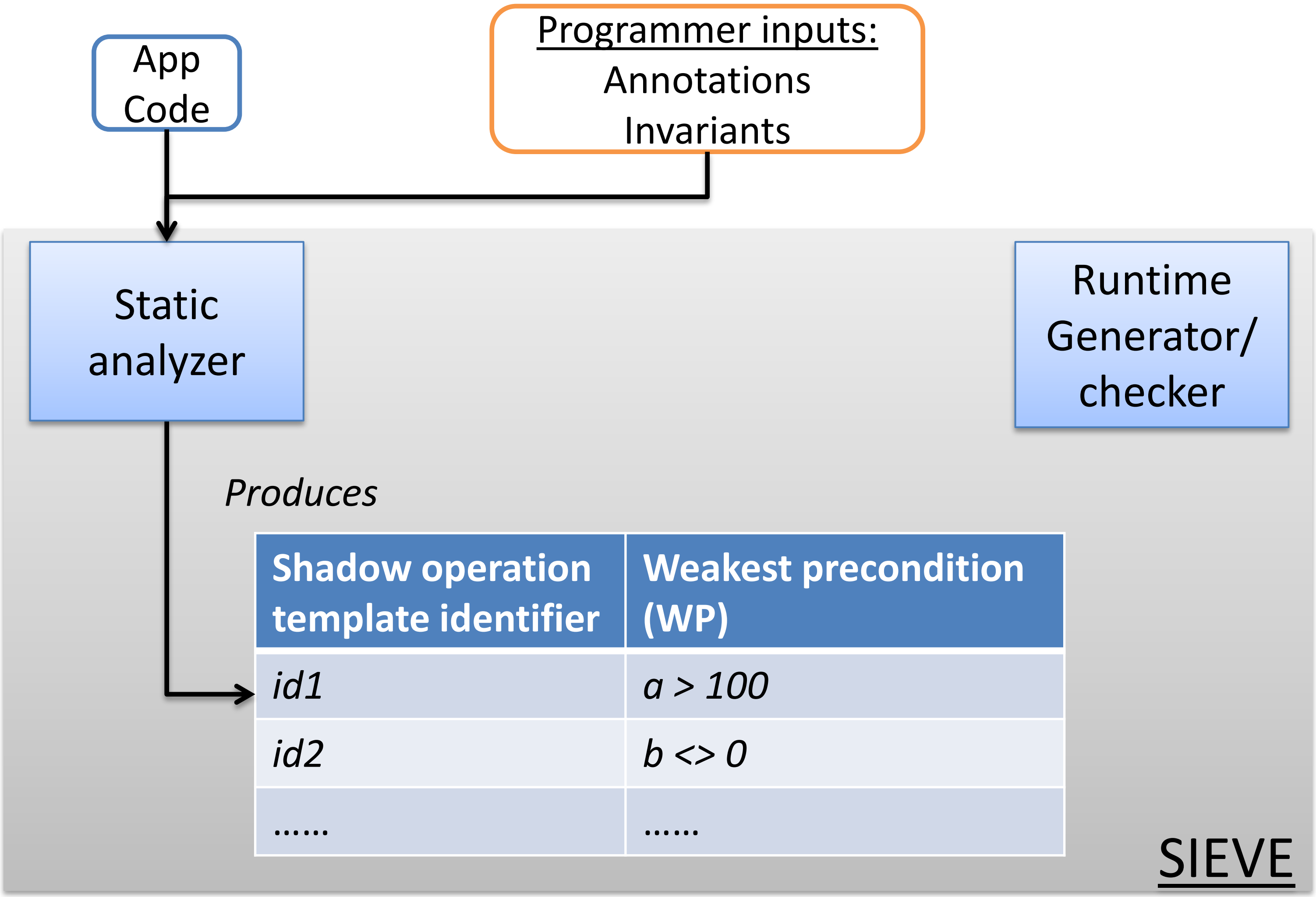

Shadow operation template identifier	Weakest precondition (WP)
id1	*a > 100*
id2	*b <> 0*
……	……

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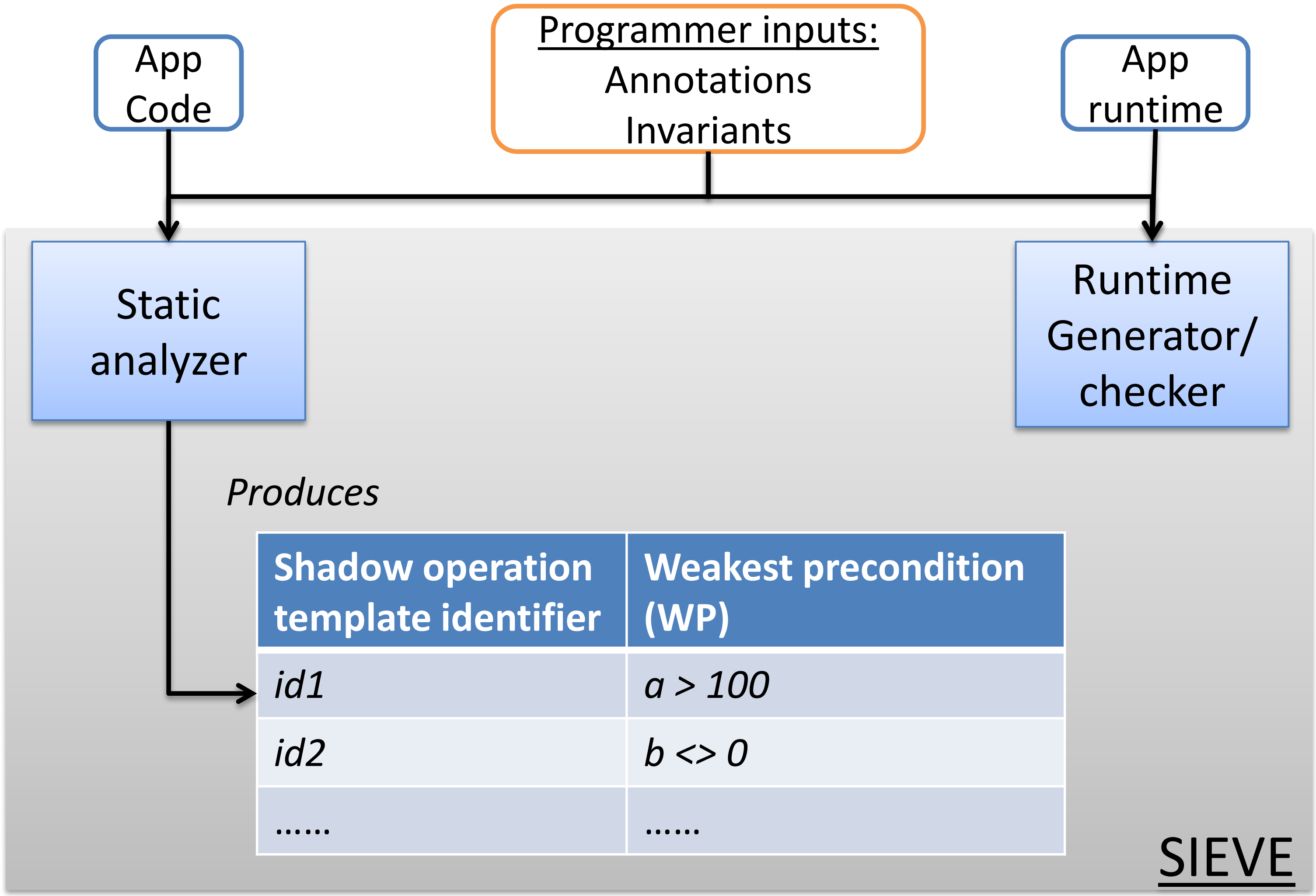

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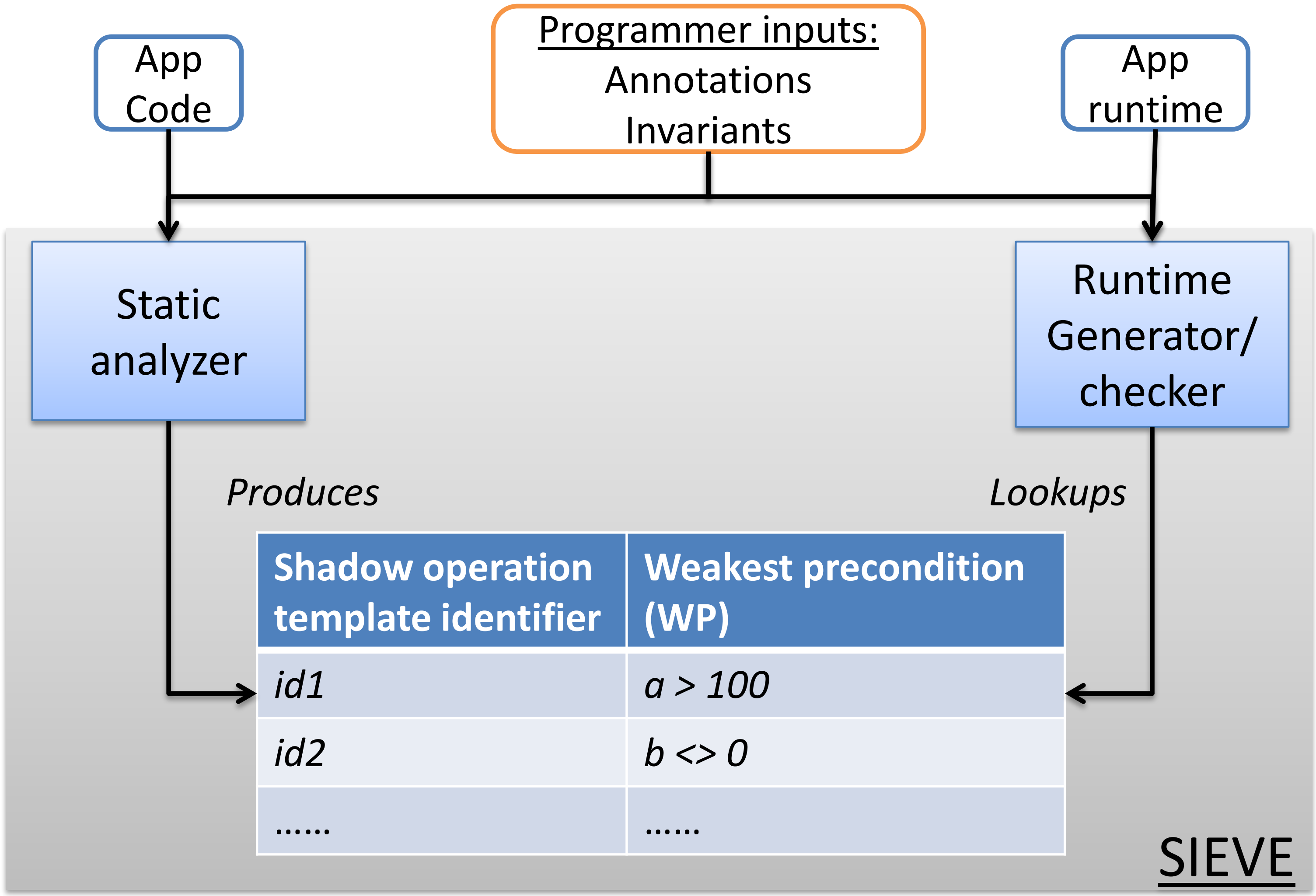

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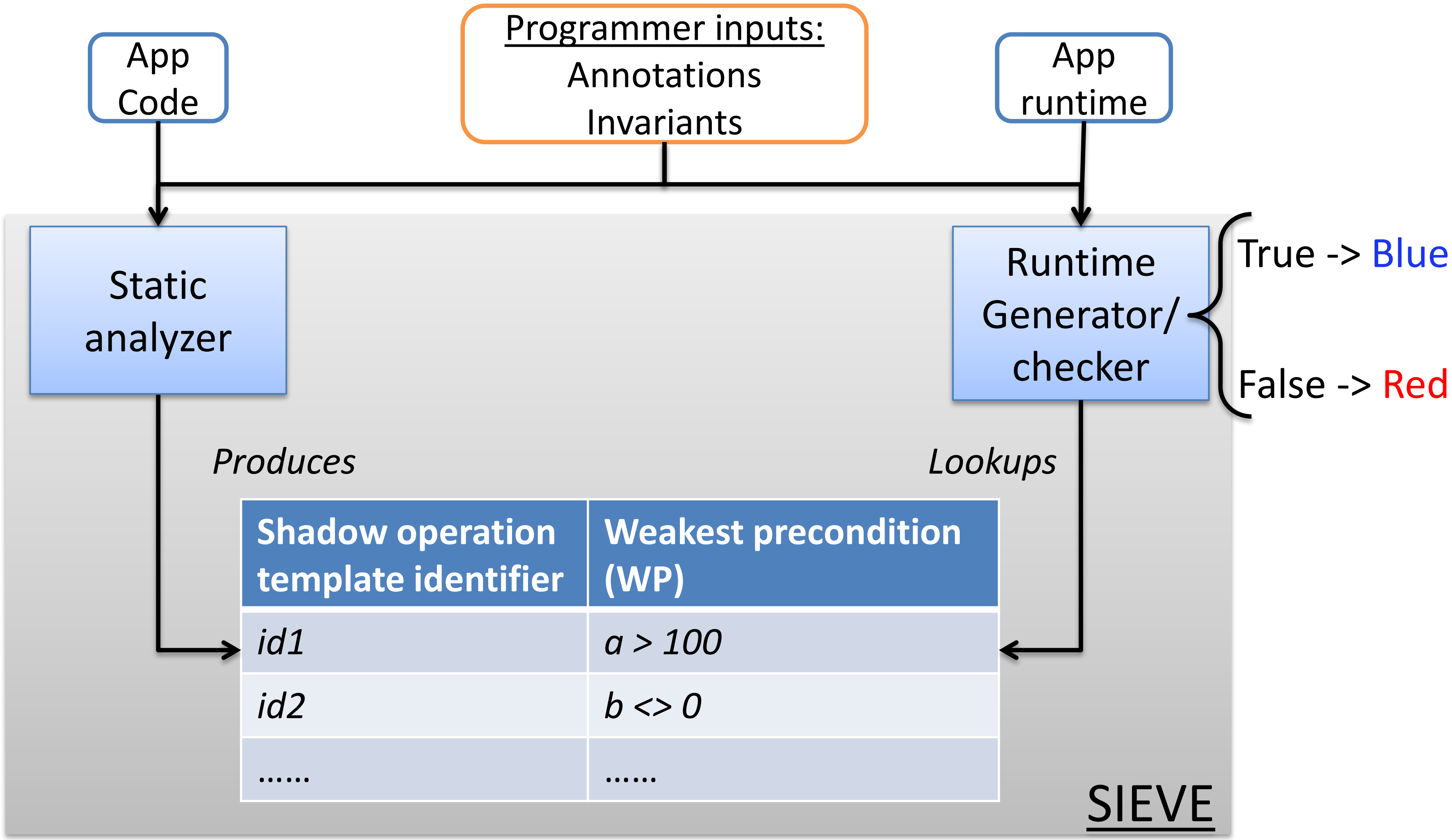

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Evaluation

Questions

- Application adaptation
  - How easy is it to adapt apps to SIEVE?
- Static analysis
  - How long does the static analysis process take?
  - How well does the static analysis scale?
- Runtime part
  - Is the runtime classification accurate?
  - What is the overhead?
  - How does the replicated application perform?

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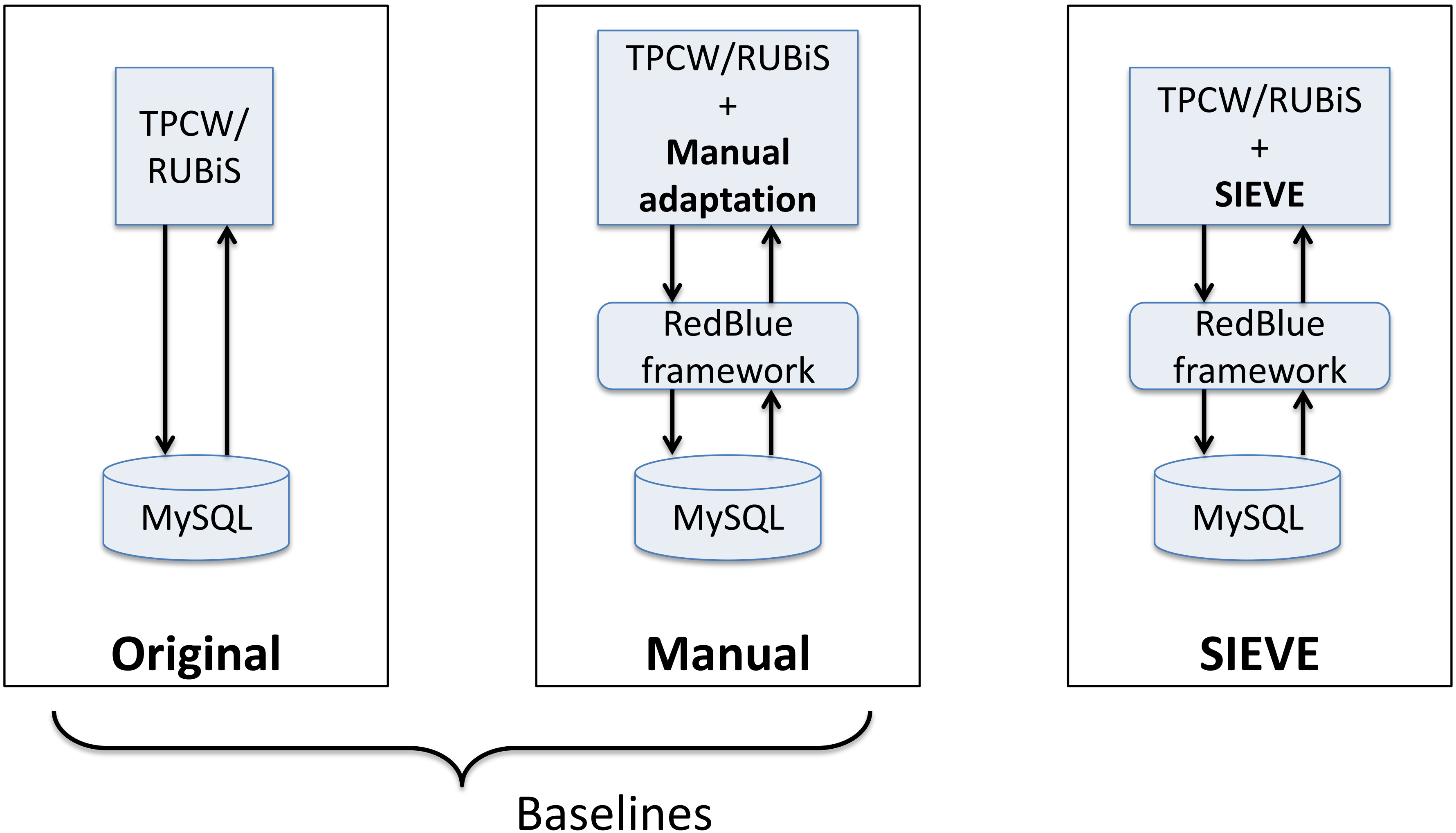
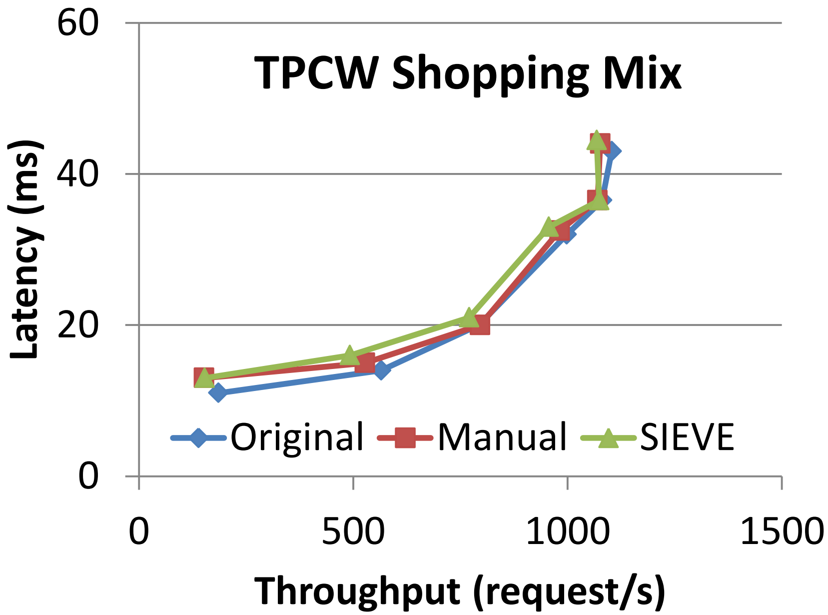
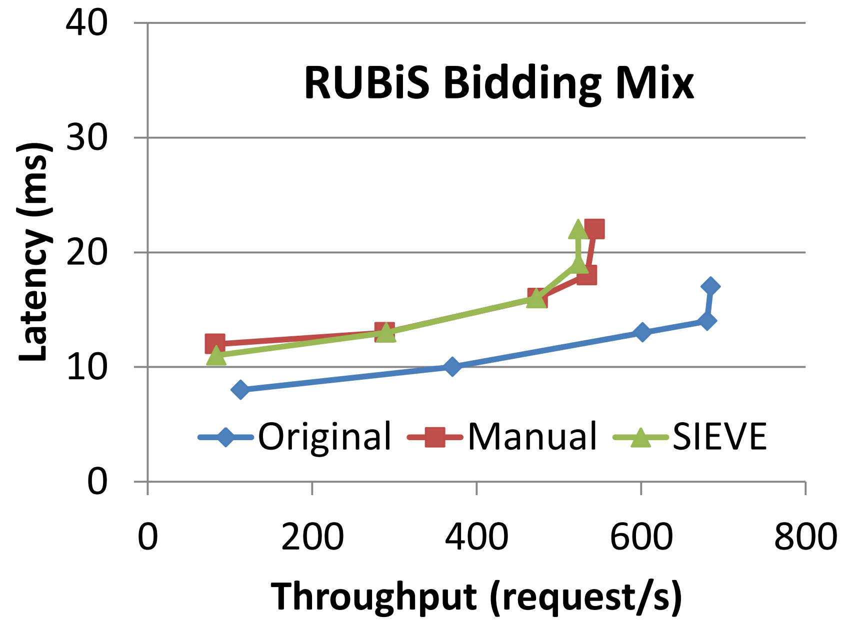
Experimental Setup



Runtime Overhead





- SIEVE performs almost as well as manual adaptation
- Runtime labeling takes negligible time
  - TPCW : 0.064 ± 0.002 ms
  - RUBiS : 0.072 ± 0.001 ms

Conclusion

SIEVE *automatically* and *efficiently* chooses weak consistency (blue) *whenever possible*, and strong consistency (red) *when needed*, only requiring little programmer input.

Automating the Choice of Consistency Levels in Replicated Systems

Thanks for your attention!

Q and A!