Lightweight and Modular Resource Leak Verification

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What's a Resource Leak?

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try {
    Socket s = new Socket(address, port);
    ...
    s.close();
} catch (IOException e) {

}
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Missing call to close()

Problems Caused by Resource Leaks

- Resource starvation
- Slowdowns
- System crashes
- Denial-of-service attack
  - E.g. CVE-1999-1127, CVE-2001-0830, CVE-2002-1372

Key Challenge: Pointer Aliasing

- Resource can be closed through *any* alias

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Heuristic bug-finding tools

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Heuristic bug-finding tools	**Ownership type systems**
Ignore aliasing	Enforce uniqueness

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Heuristic bug-finding tools	Ownership type systems	**Whole-program static analysis**
Ignore aliasing	Enforce uniqueness	Track all aliases

Key Insight

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  - FSM contains no loops

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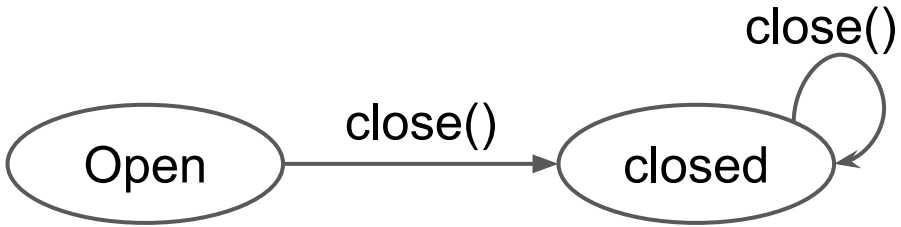
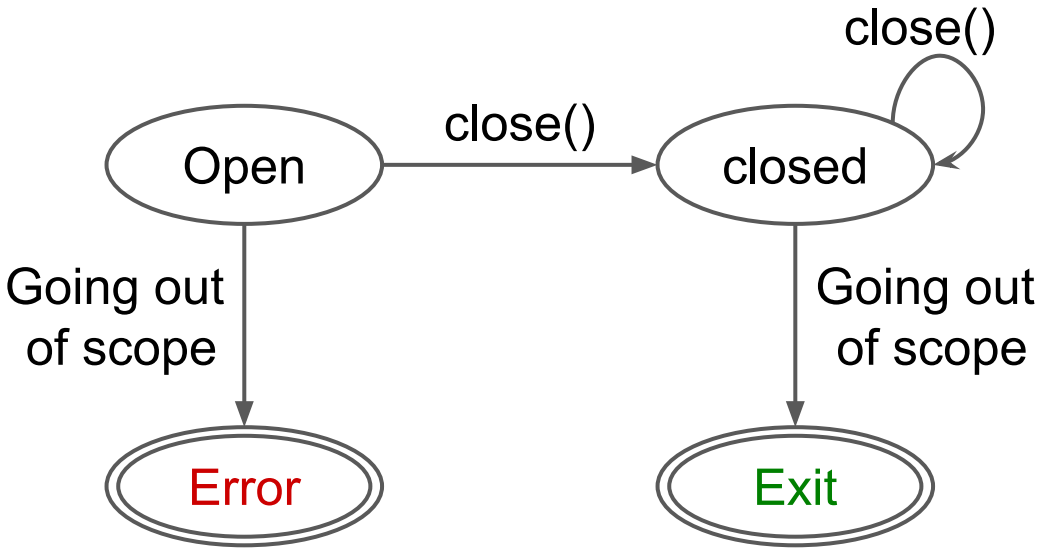
  - FSM contains no loops
  - **Sound with no alias analysis**

Resource Leaks as Accumulation



Resource Leaks as Accumulation



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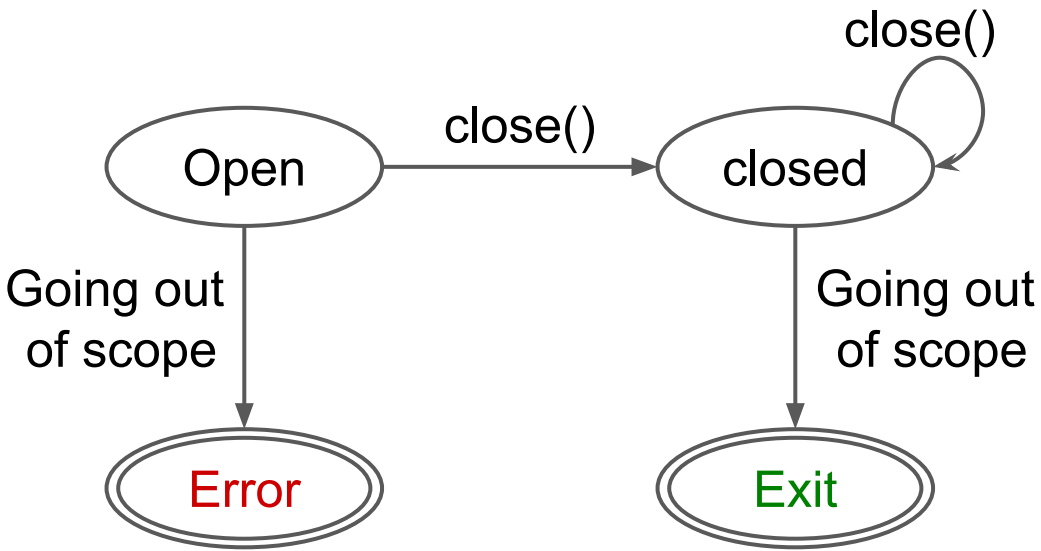
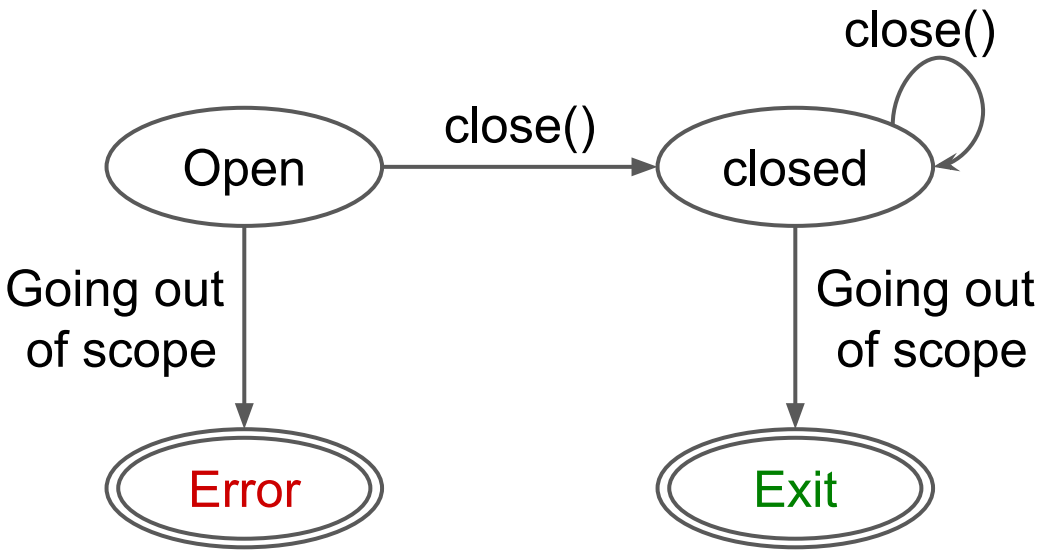


FSM contains no loops

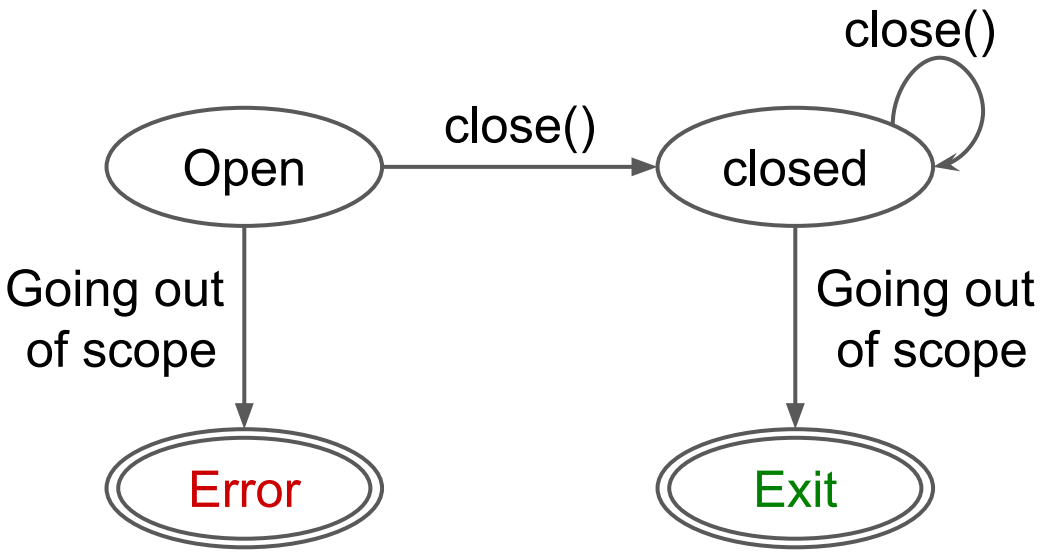
Resource Leaks as Accumulation



FSM contains no loops

Alias analysis not required for soundness

Resource Leaks as Accumulation



FSM contains no loops

Alias analysis not required for soundness

can be implemented modularly

Leak Detection Approach:

1. Compute what methods must be called
2. Compute what methods are called
3. Issue error if mismatch when going out of scope

Example

```
{
  s = new Socket(address, port);
  ...
  if (...) {
    s = ...;
  }
  s.close();
}
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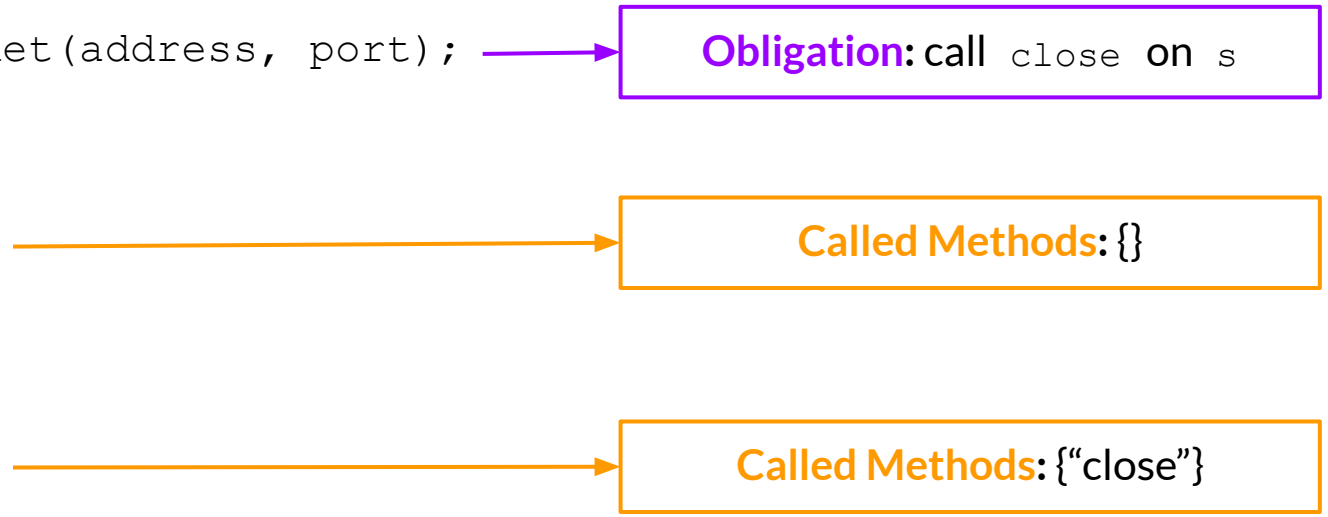

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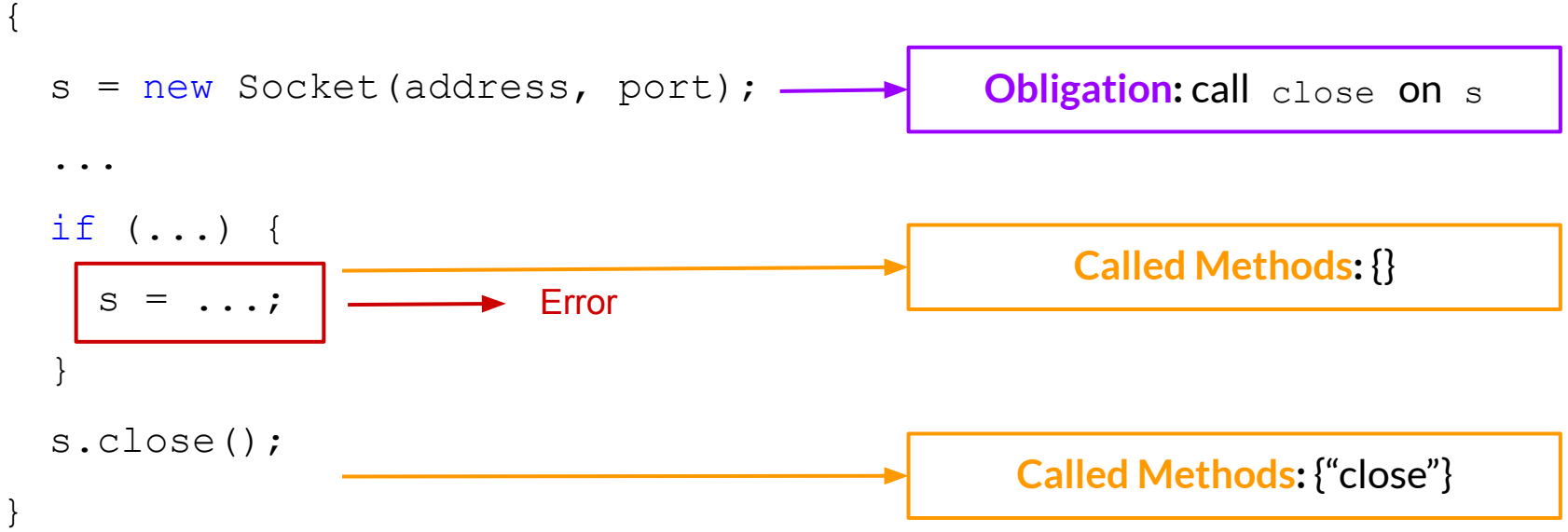
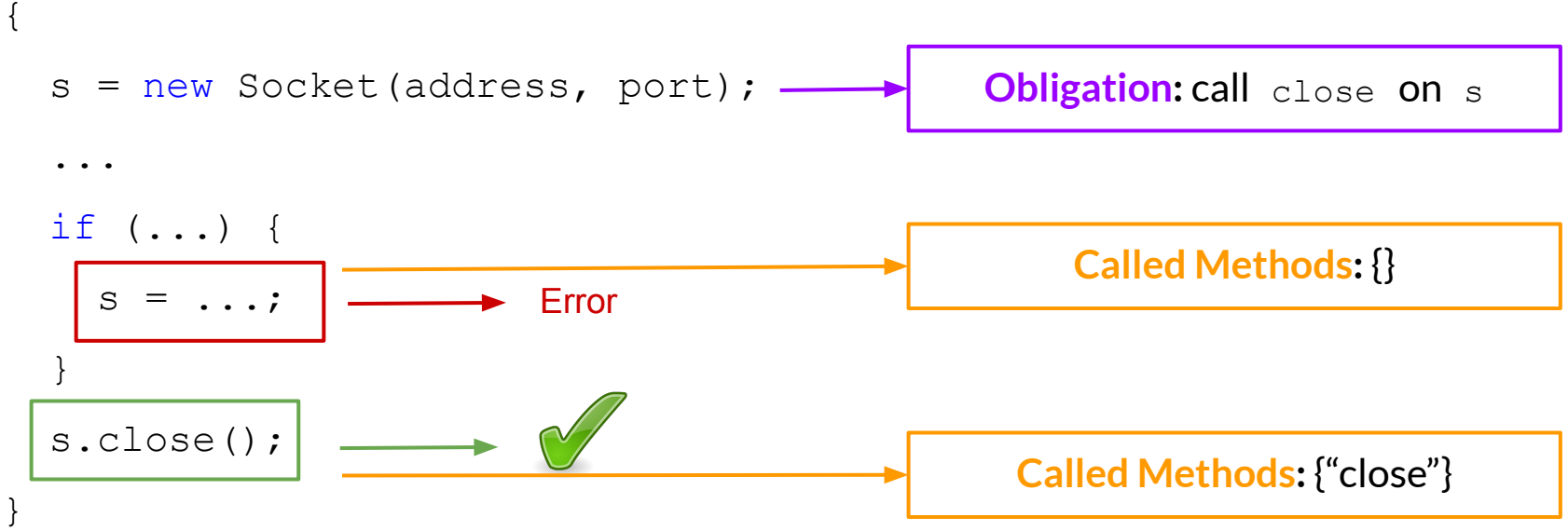

{
s = new Socket(address, port);
...
if (...) {
s = ...;
}
s.close();
}
Obligation: call close on s
Called Methods: {}
Error
Called Methods: {“close”}

Example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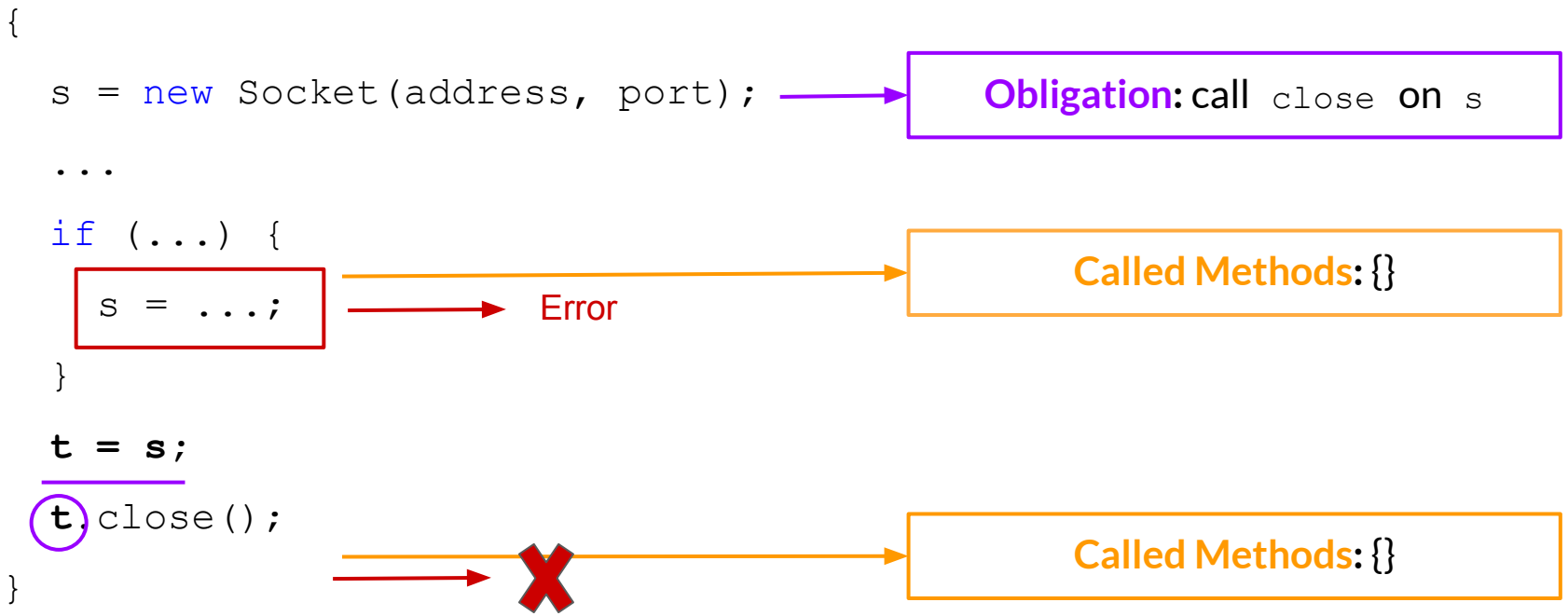
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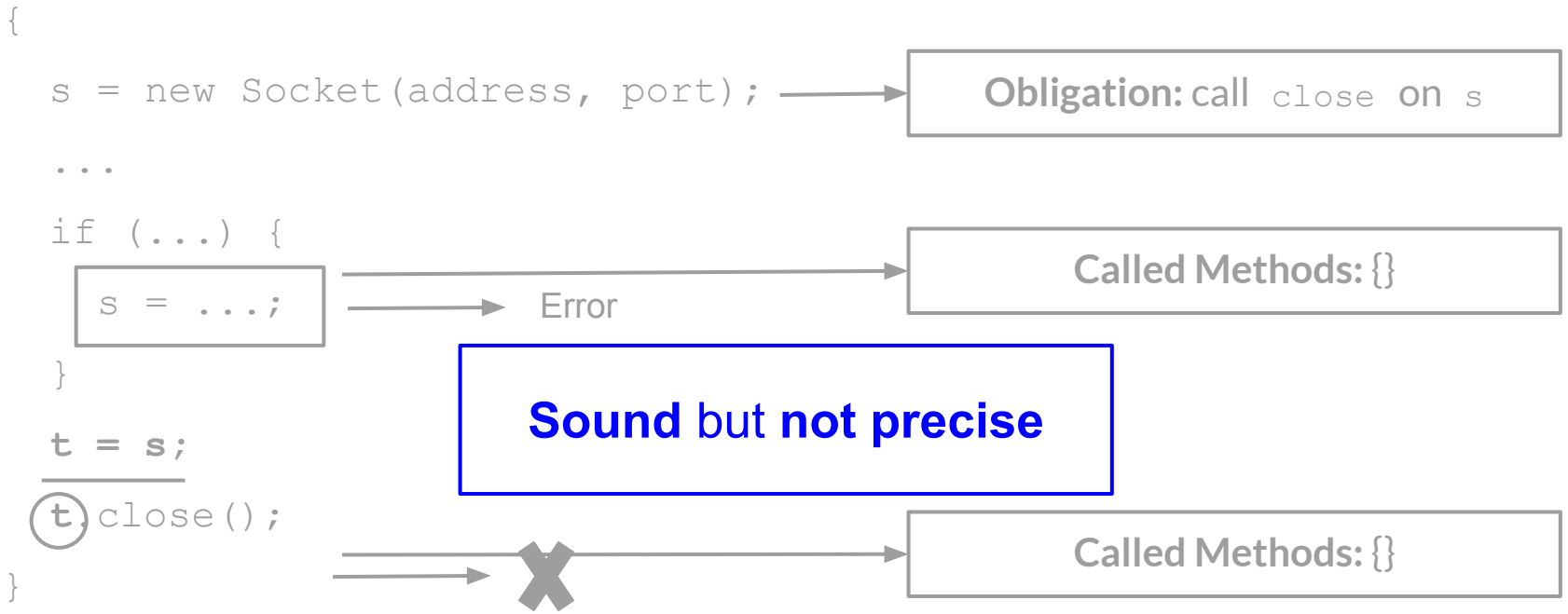
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if (...) {
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Obligation: call close on s
Called Methods: {}
Error
Sound but not precise
Called Methods: {}

Precision via Local Alias Reasoning

- Local must-aliases
- Lightweight ownership
- Resource aliasing
- Obligation creation

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- **Lightweight ownership**
- Resource aliasing
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Lightweight Ownership

```
closeSocket(mySock);
```

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closeSocket(mySock);
```

Obligation: call `close` on `mySock`

```
void closeSocket(@Owning Socket s) {
```

Obligation: call `close` on `s`

```
  s.close();
}
```

Lightweight Ownership

Obligation: call `close` on `mySock`

```
closeSocket(mySock);
```

```
void closeSocket(@Owning Socket s) {
```

Obligation: call `close` on `s`

```
  s.close();
}
```

- Obligations are neither created nor destroyed
- Doesn't restrict privileges of other aliases

Precision via Local Alias Reasoning

- Local must-aliases
- Lightweight ownership
- **Resource aliasing**
- Obligation creation

Resource Aliasing

```
Socket socket = ...;
InputStreamReader stream =
    new InputStreamReader(socket.getInputStream());
...
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Which of these should be closed?

Resource Aliasing

```
Socket socket = ...;
InputStreamReader stream =
    new InputStreamReader(socket.getInputStream());
...
```

Which of these should be closed?

- Closing either `socket` or `stream` is adequate
- Extensibility

Evaluation:

Evaluation: Case Studies

Four programs: zookeeper, hadoop-hdfs, hbase, plume-util

Lines of code	Resource Leaks Found	False positive warnings	Annotations
427,858	49	121	286

Evaluation: Case Studies

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Lines of code	Resource Leaks Found	False positive warnings	Annotations
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Precision: 29%

Evaluation: Case Studies

Four programs: zookeeper, hadoop-hdfs, hbase, plume-util

Lines of code	Resource Leaks Found	False positive warnings	Annotations
427,858	49	121	286

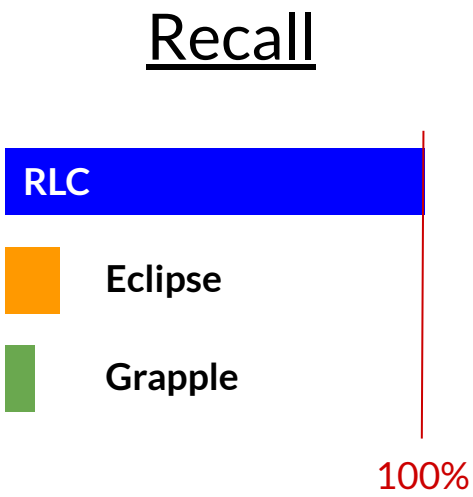
~1 per 1,500 LoC

Evaluation: Comparison

3 analyses:

- **RLC**, our type-based analysis
- **Eclipse**'s high-confidence heuristic bug-finder
- **Grapple**, a whole-program graph reachability analysis

Evaluation: Comparison



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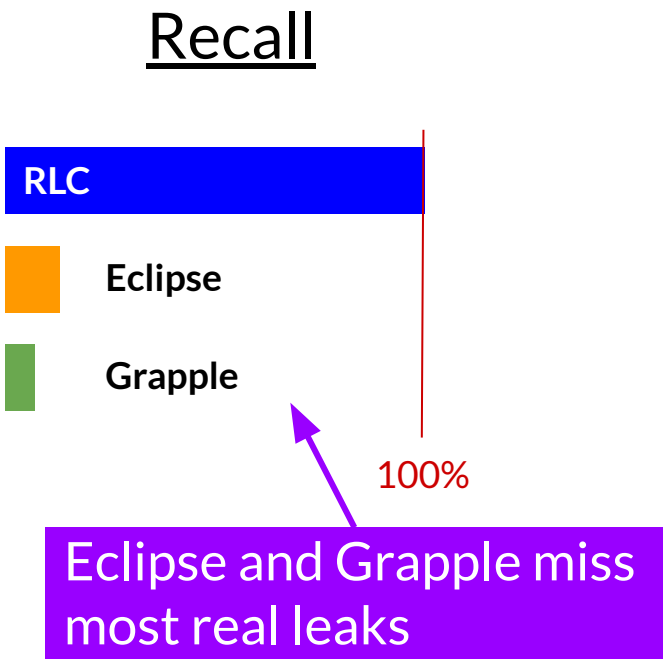

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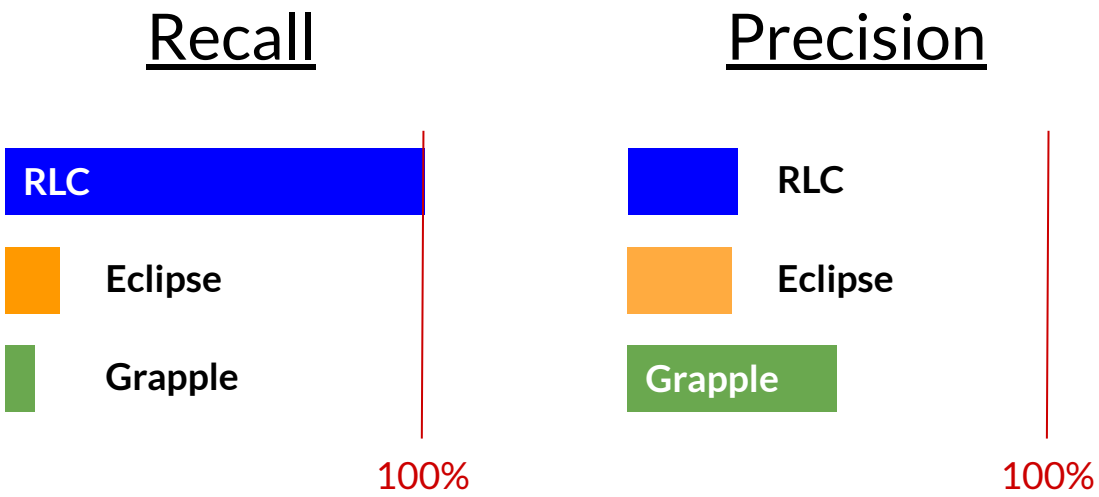

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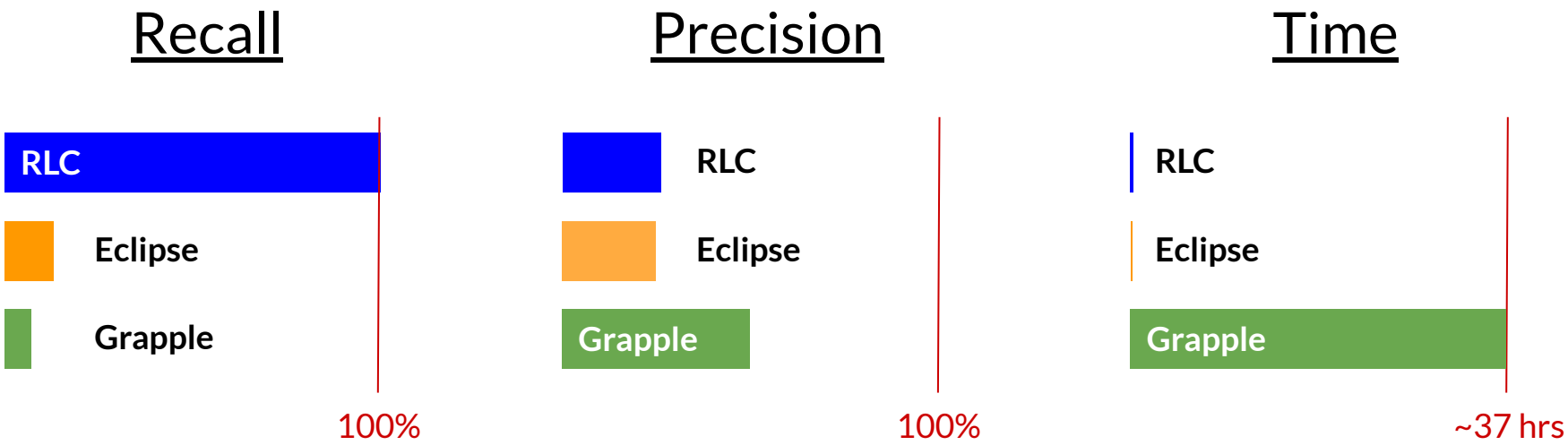

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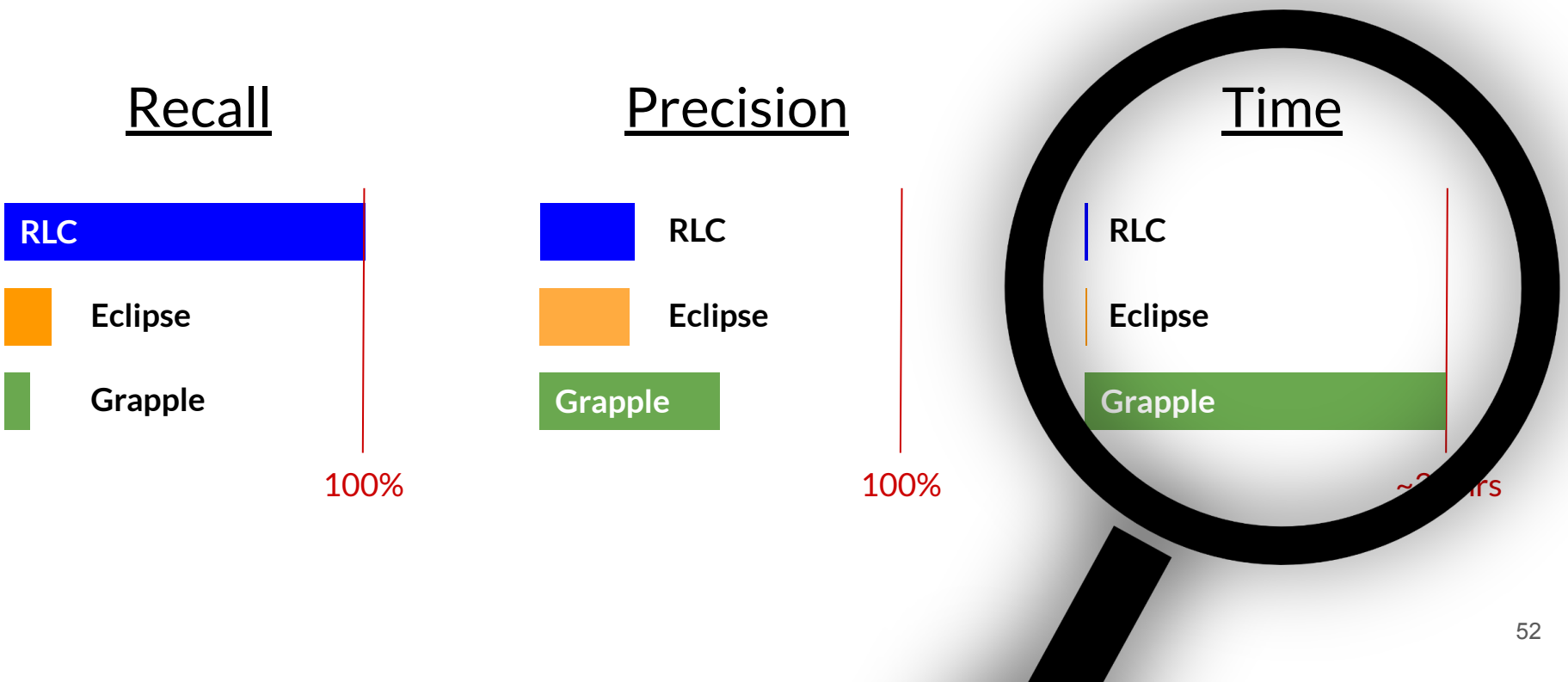

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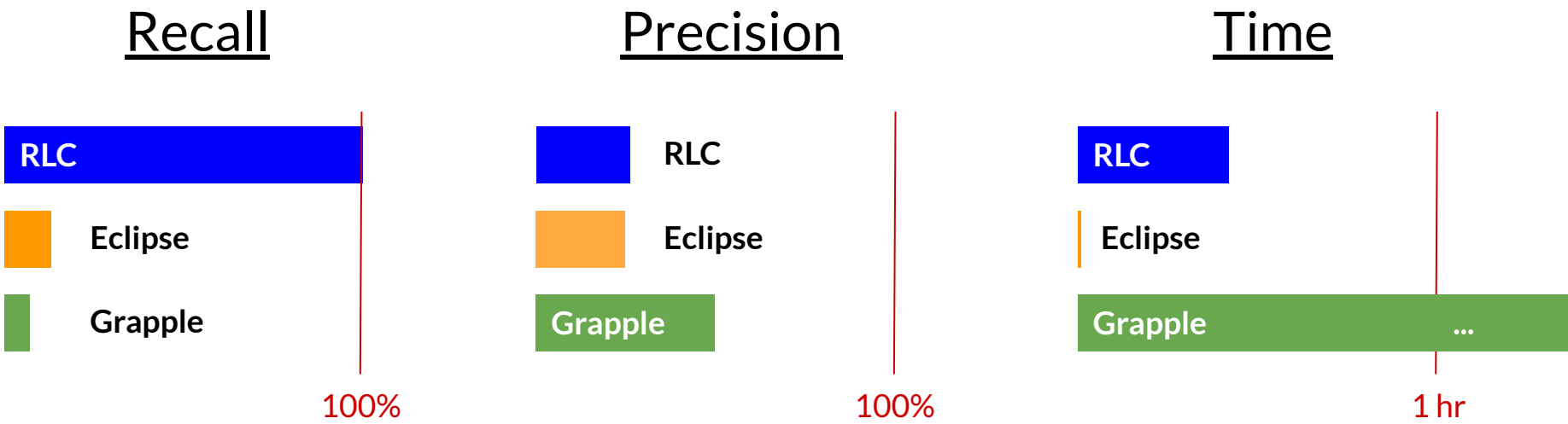

Contributions

- **Lightweight and modular resource leak verification** via *accumulation analysis*
- **Local alias reasoning** for precision
- **Extensive evaluation**
- **Open-source implementation** at checkerframework.org