# HotFuzz

## Discovering Algorithmic Denial-of-Service Vulnerabilities through Guided Micro-Fuzzing

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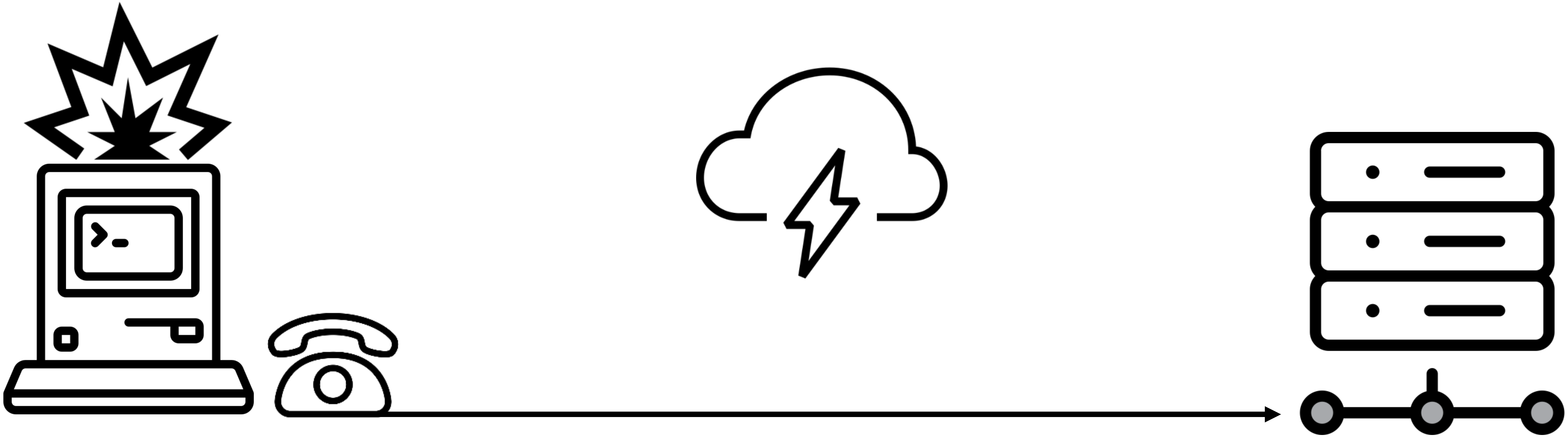
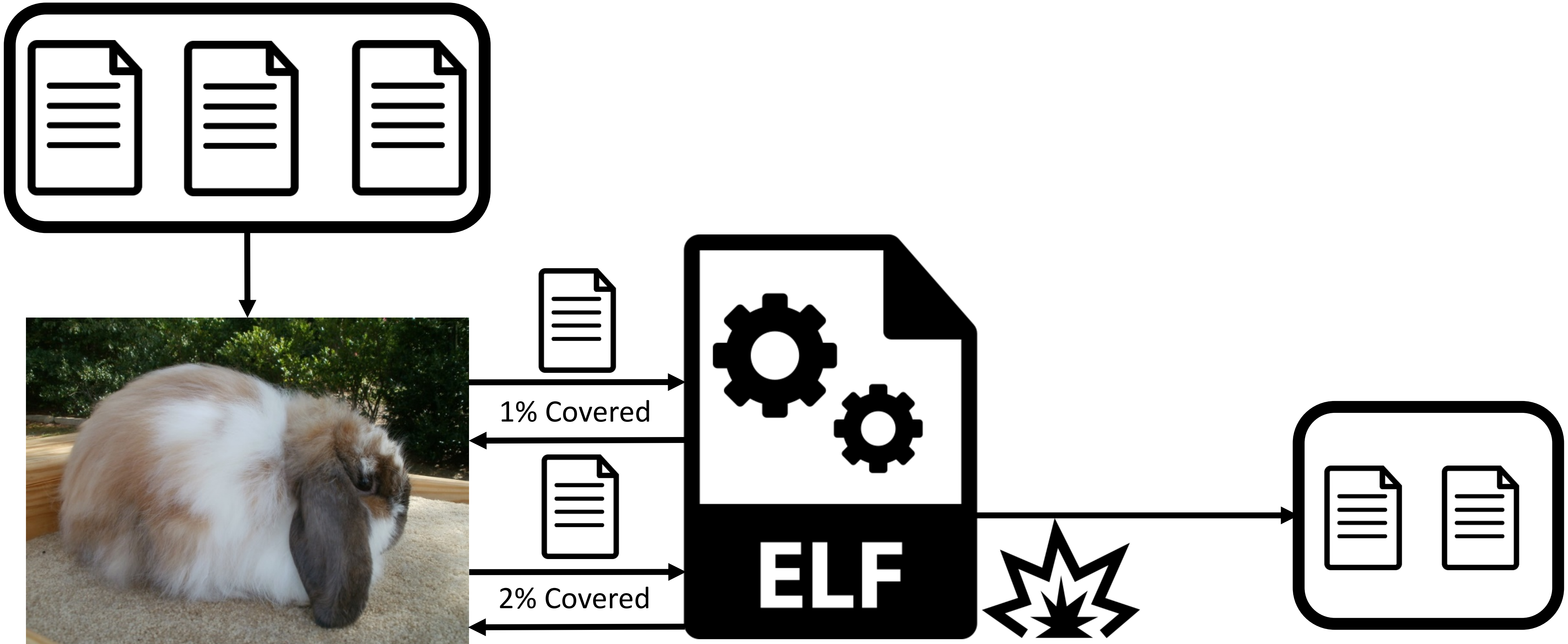
# 1988



# 2020 Fuzz Testing



Seed Inputs

1% Covered

2% Covered

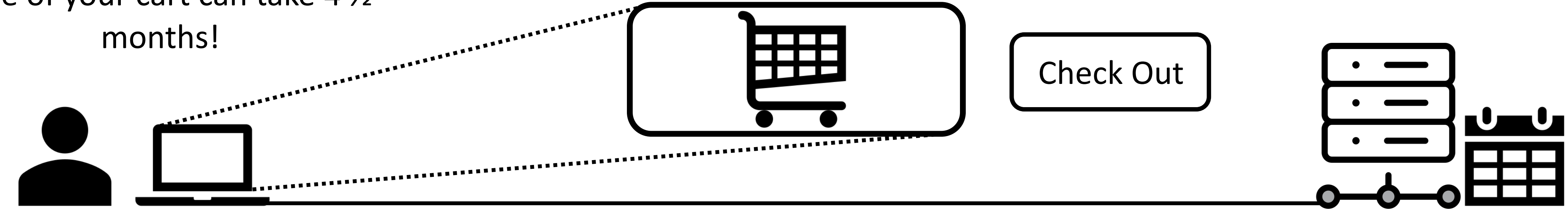
Fuzzer (AFL, LibFuzzer)

Program Under Test

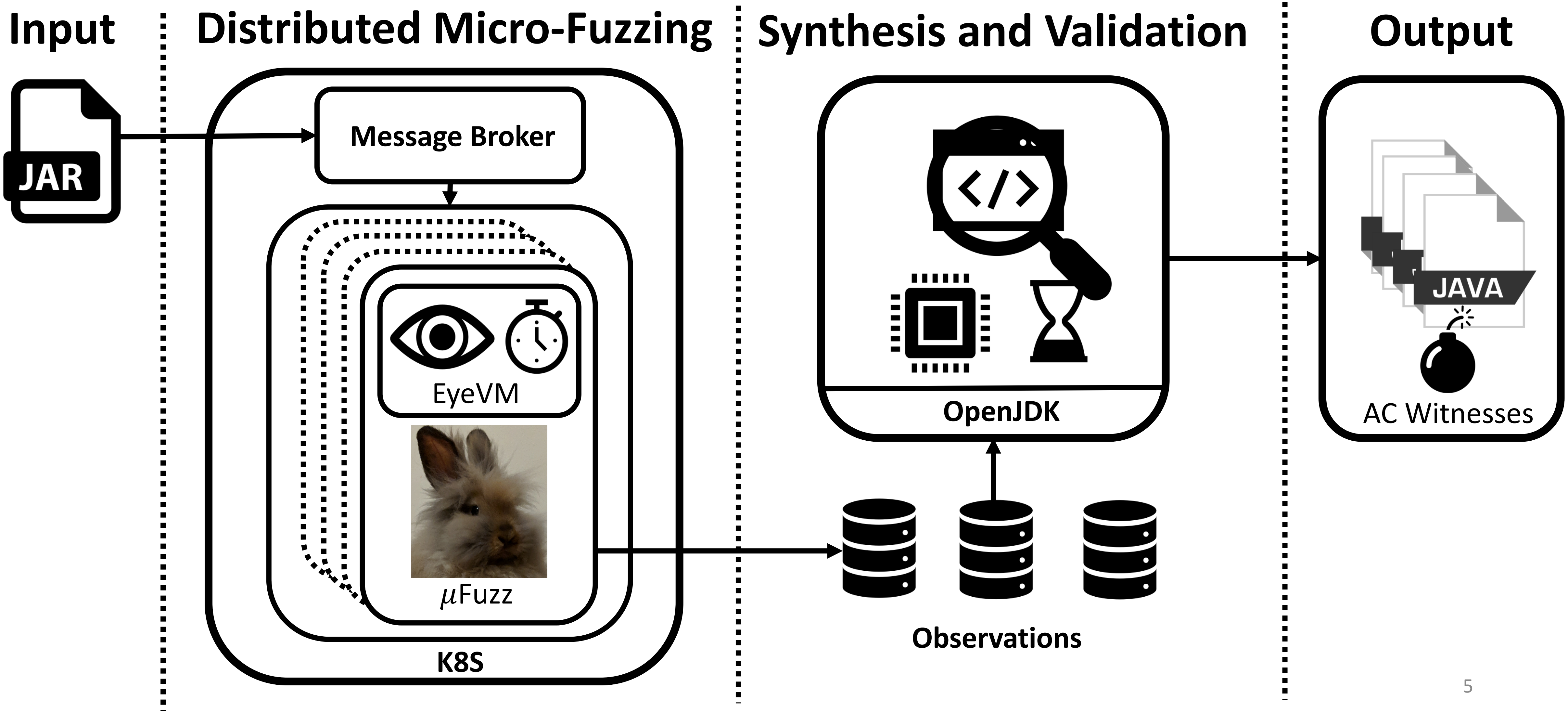
Crashing Inputs

# Algorithmic Complexity (AC) Bugs

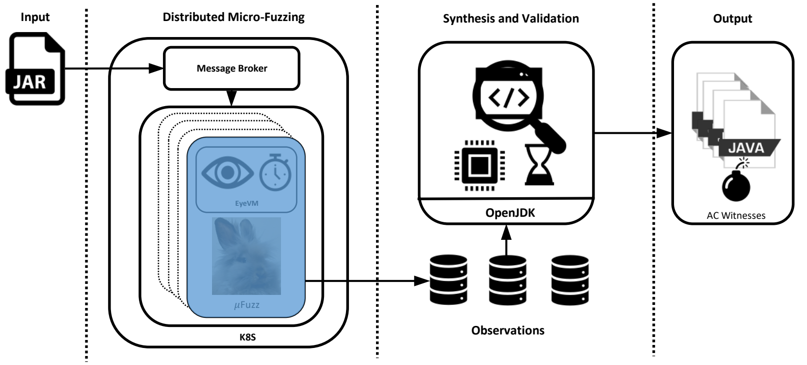
We observed computing the total price of your cart can take 4 ½ months!



# HotFuzz


Input
Distributed Micro-Fuzzing
Synthesis and Validation
Output
JAR
Message Broker
EyeVM
$\mu$Fuzz
K8S
Observations
OpenJDK
JAVA
AC Witnesses

# HotFuzz Micro-Fuzzing



```
class A {
  public method(B b, C c);
}
```

## Micro-Fuzzing

`a, b, c = TestHarness(method)`

$$a \xleftarrow{R} A$$

$$b \xleftarrow{R} B$$

$$c \xleftarrow{R} C$$

`a.method(b, c)`

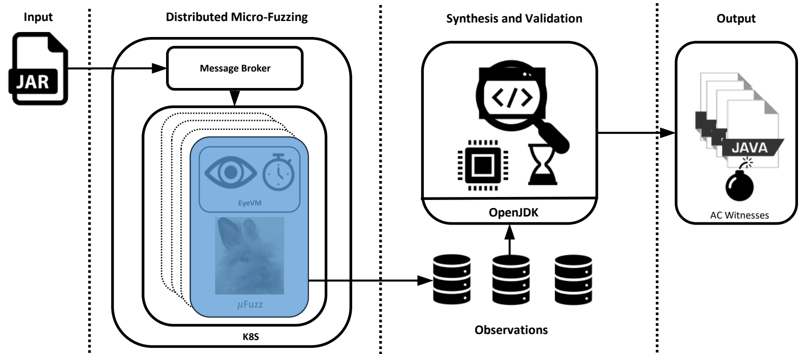
## AC Sanitization

Threshold $T$

`Runtime(a.method(b, c))` $\leq T$

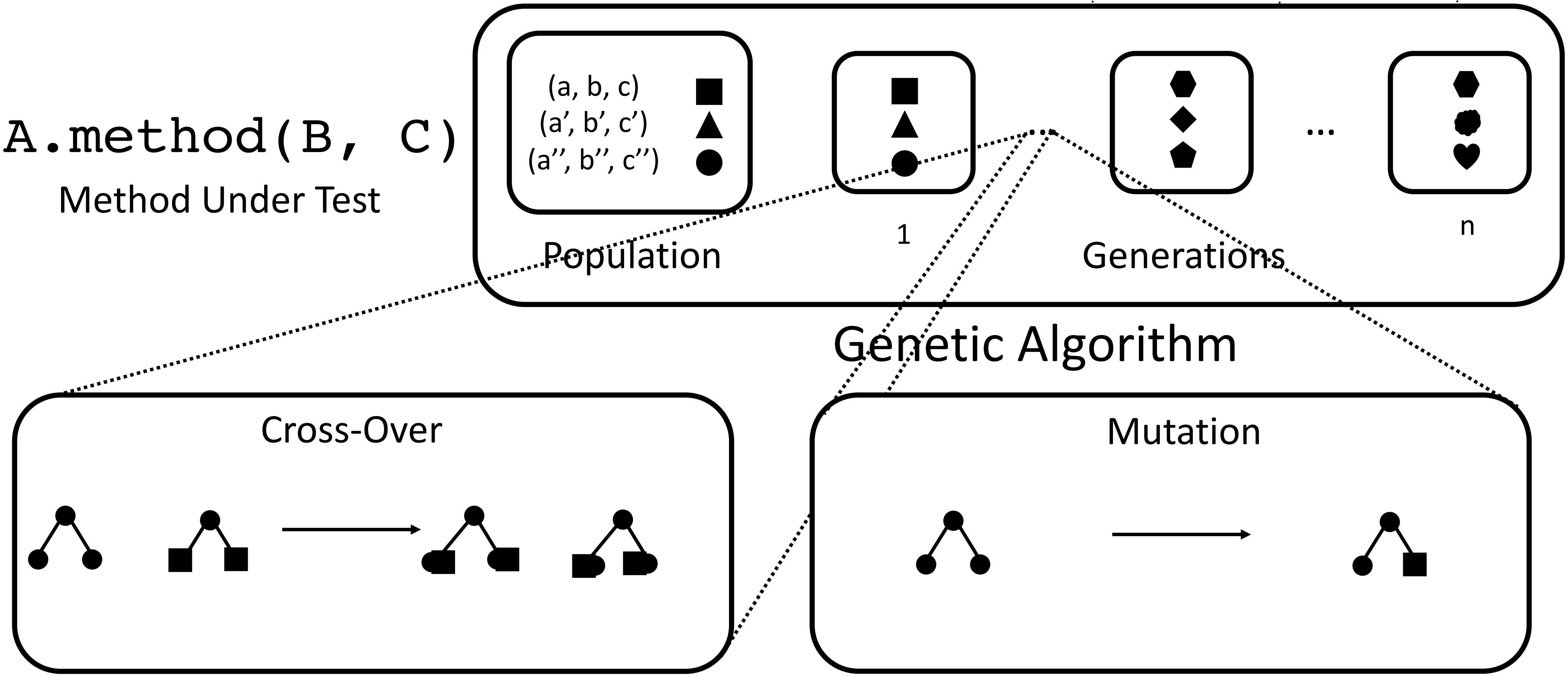
`untime(x.method(y, z))` $> T$

# Micro-Fuzzing



`A.method(B, C)`

Method Under Test



(a, b, c)
(a’, b’, c’)
(a’’, b’’, c’’)

Population

1

…

n

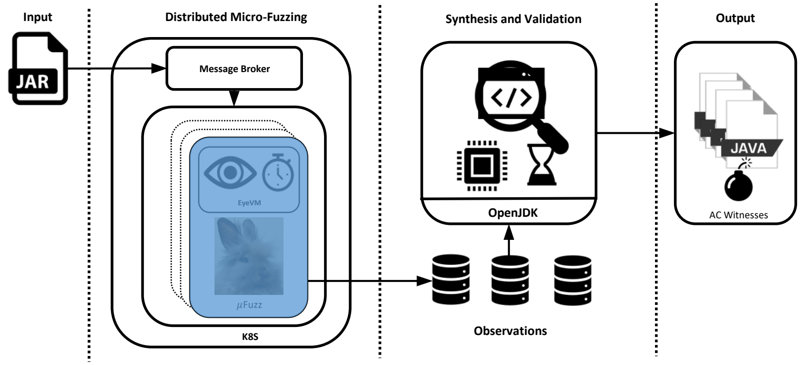
Generations

Genetic Algorithm

Cross-Over

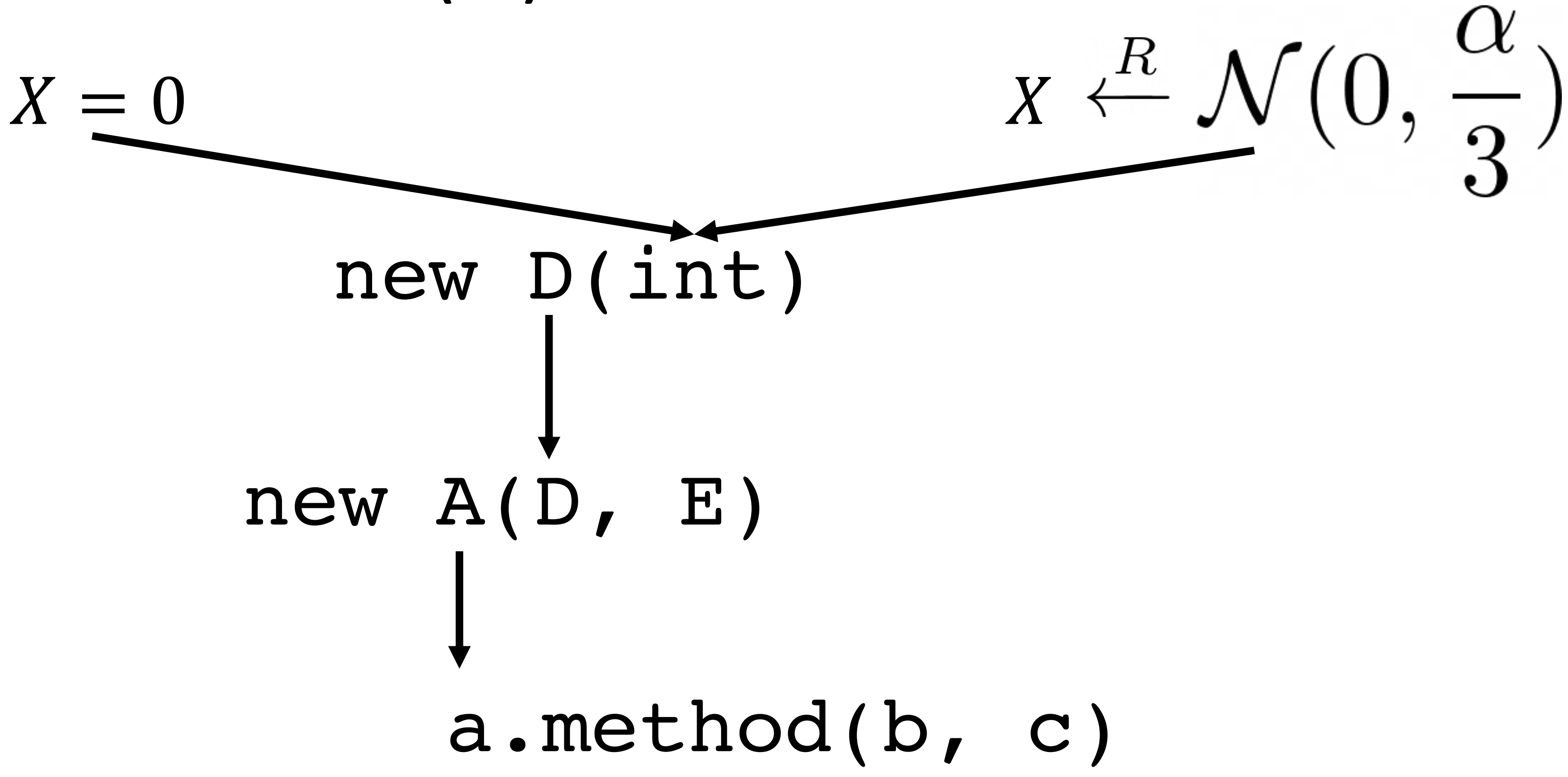
Mutation

# Instantiating Seed Inputs



**Identity Value Instantiation (IVI)**

**Small Recursive Instantiation (SRI)**

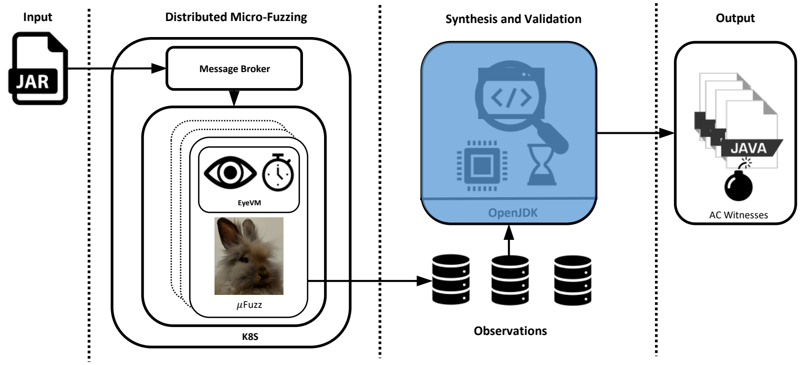


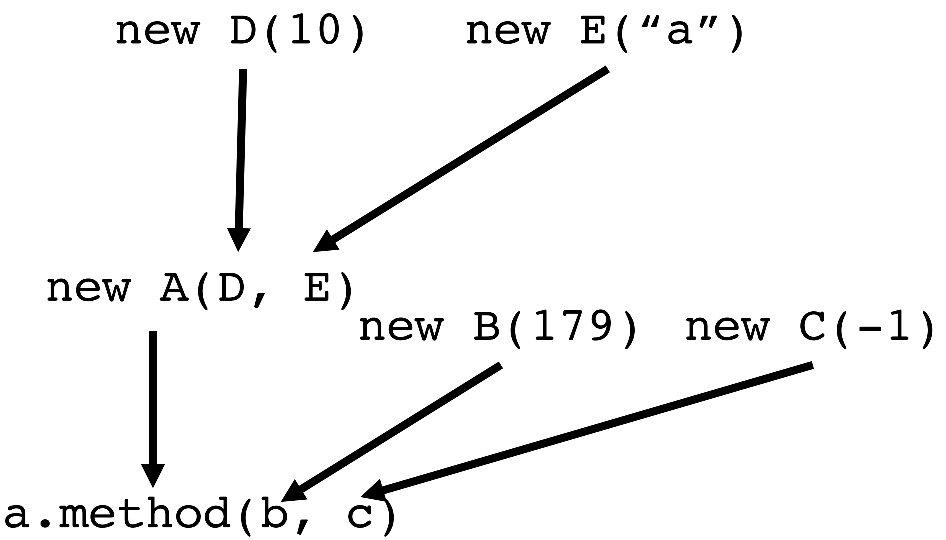
$X = 0$

$X \xleftarrow{R} \mathcal{N}(0, \frac{\alpha}{3})$

```
new D(int)
new A(D, E)
a.method(b, c)
```

# Synthesizing Test Cases





new D(10) new E(“a”)

new A(D, E)

new B(179) new C(-1)

a.method(b, c)

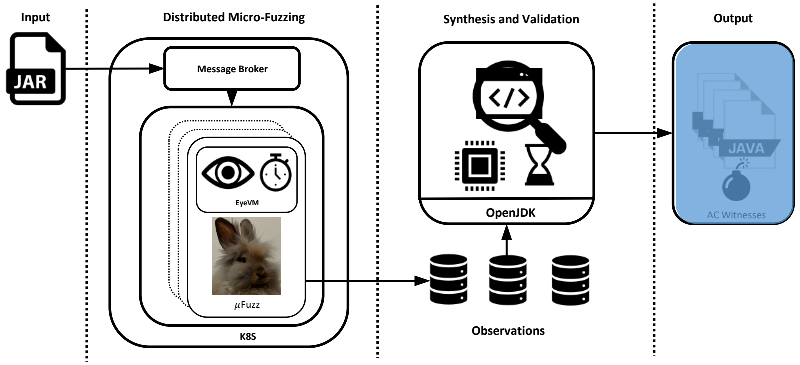
```
public static void main(String argv[]){





}
```

# Micro-Fuzzing Evaluation



| Library | No. Methods | AC Bugs Detected | | | AC Bugs Confirmed | | | Methods Covered | | | Throughput | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Both | IVI | SRI | Both | IVI | SRI | Both | IVI | SRI | IVI | SRI |
| JRE | 91,632 | 6 | 8 | 13 | 5 | 8 | 13 | 23,818 | 2,780 | 1,439 | 4,389,675 | 3,092,866 |
| STAC | 67,494 | 34 | 6 | 15 | 5 | 0 | 0 | 8,064 | 847 | 1,162 | 3,608,741 | 3,172,502 |
| Maven | 239,777 | 46 | 38 | 56 | 46 | 38 | 56 | 66,987 | 2,622 | 1,770 | 5,906,687 | 5,591,106 |

# AC Vulnerability in the JRE

```
import java.math.BigDecimal;

BigDecimal x = new BigDecimal(s);
BigDecimal y = new BigDecimal(t);

x.add(y);
```

If an adversary can influence the value of s or t, they can trigger DoS.

Computing

new BigDecimal(“1E2147483647”)).add(“1E0”);

Takes at least an hour to complete on every major implementation of the JVM!

# Impact of BigDecimal Findings

- Affects all widely used JVM implementations
- Disclosed our findings to 3 vendors
- IBM J9
  - Proof of Concept (PoC) terminates after running for 4 ½ months
  - Issued us a CVE for our findings
- Oracle OpenJDK
  - PoC runs in an hour
  - Credited us in a Security-in-Depth Issue
- Google Android
  - PoC takes over 24 hours to run
  - Stated the issue falls outside their definition of DoS vulnerabilities

# Summary

- Introduced Micro-Fuzzing
- Presented HotFuzz
  - Prototype implementation of micro-fuzzing for Java libraries
  - Automatically detects AC bugs
- Introduced strategies for generating seed inputs for micro-fuzzing
  - IVI … Identity Value Instantiation
  - SRI … Small Recursive Instantiation
- Micro-fuzzing detected 158 AC bugs in our evaluation artifacts
- Showed how an AC bug in production code can trigger DoS

# Thank you!