ReproLite : A Lightweight Tool to Quickly Reproduce Hard System Bugs

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Outline

Reproduce what bugs? Why IReproLite?

Motivation

- programmable scheduler
  - e.g. PLDI 2013 "Concurrit"
- static-analysis
  - e.g. ASPLOS 2010 "Sherlog"

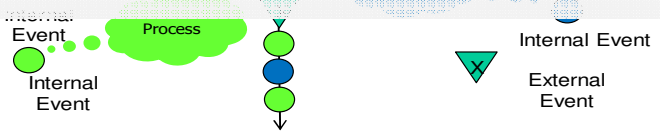
- Provides **assistance** to understand the cause of a bug from **logs**
- Focus on **system-level concurrency** issues

RE: Reproduction Engine

External events: cause them to happen

Internal events: wait for them

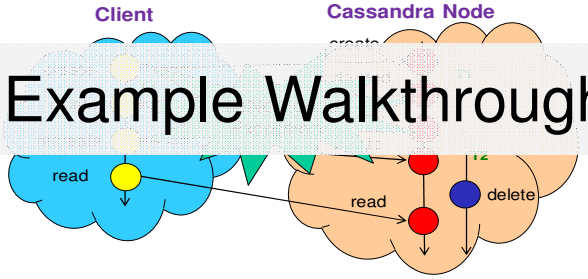
Structure



9

Cassandra bug 1477

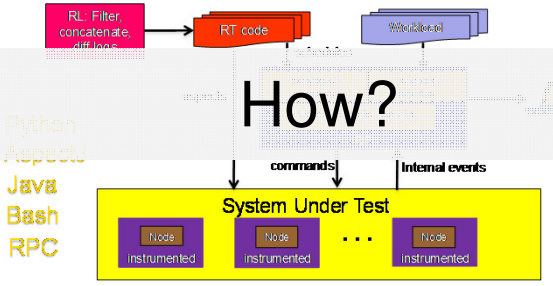
Example Walkthrough



9

Implementation

How?



18

Experiments

We experimented with using ReproLite to debug 11 bugs from

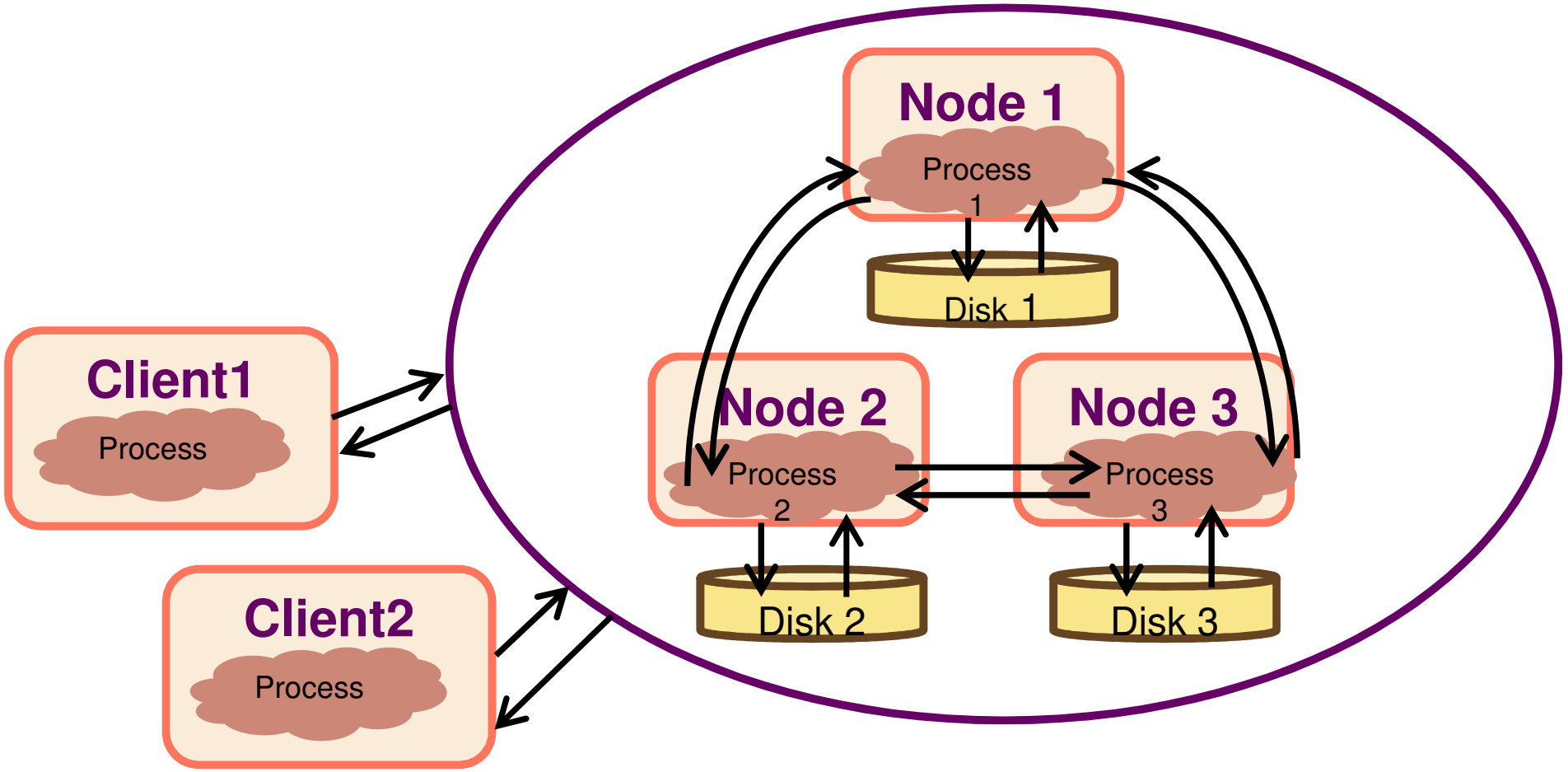
So what?

Instrumentation Overhead	Almost nil for half of the bugs
Usefulness of Logs	70% percent of bug causes hidden in logs.

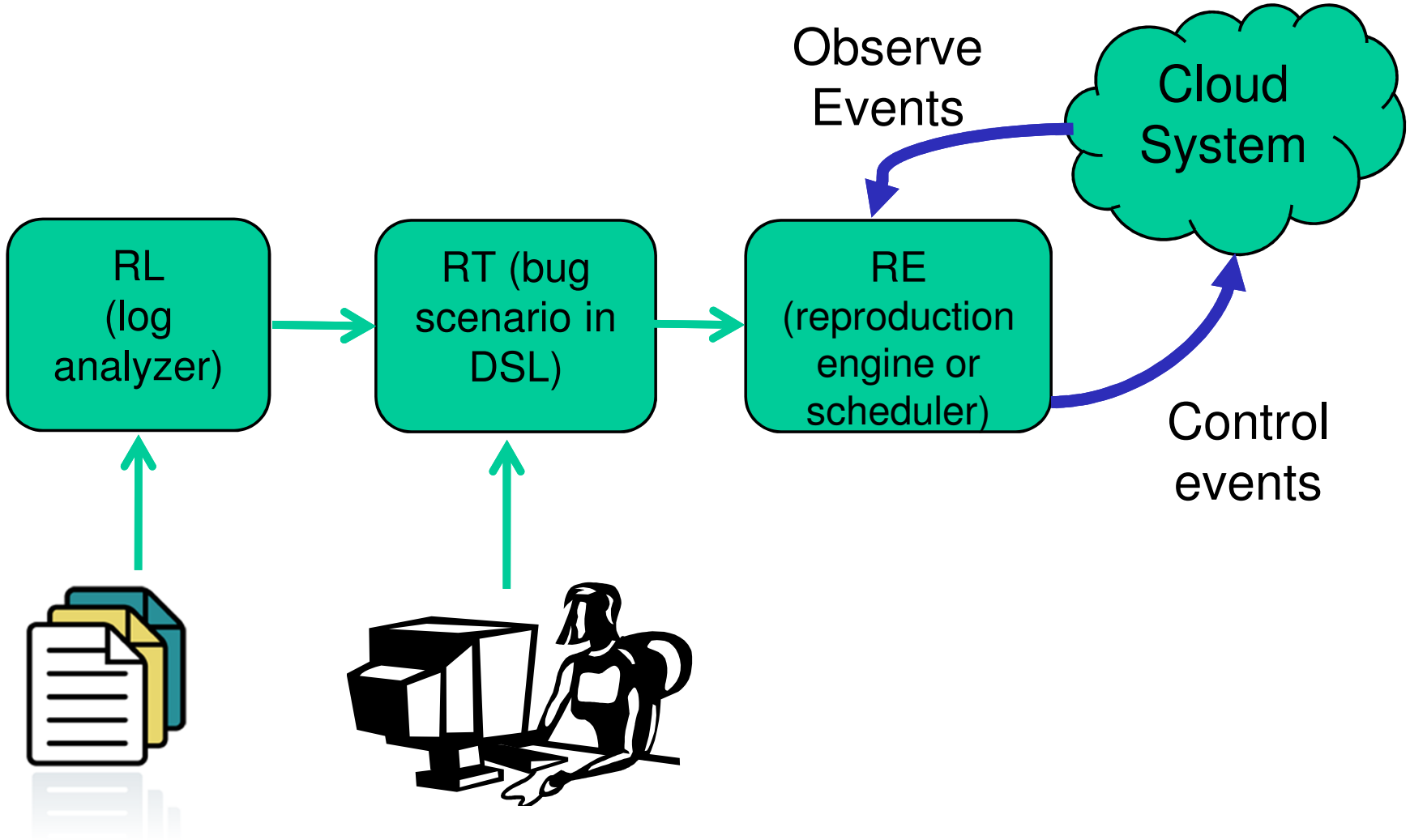
19

Motivation

Cloud Systems



ReproLite's Approach:
3 Main Elements (RL, RT, RE)



Reproduce what bugs? Why ReproLite?

- System-level bugs involving
  - Concurrency
  - System component interaction
  - Environment

Main new element:
DSL for scenarios + scheduler

- Benefits
  - RT (DSL)
    - Expressive for specifying bug scenarios in a deterministic manner
  - RL (log analyzer)
    - Provides assistance to understand the cause of a bug from logs
  - RE (scheduler)
    - Repeatedly reproduce
    - lightweight

Structure

RL: Parse, extract and diff buggy and non-buggy logs

Log level

Date & Time

Thread name

DEBUG [GC inspection] 2014-10-22 16:23:29,160 GCInspector.java (line 131) GC for ParNew: 5 ms, 266519024 reclaimed leaving 28339384 used; max is 1263271936

Line number

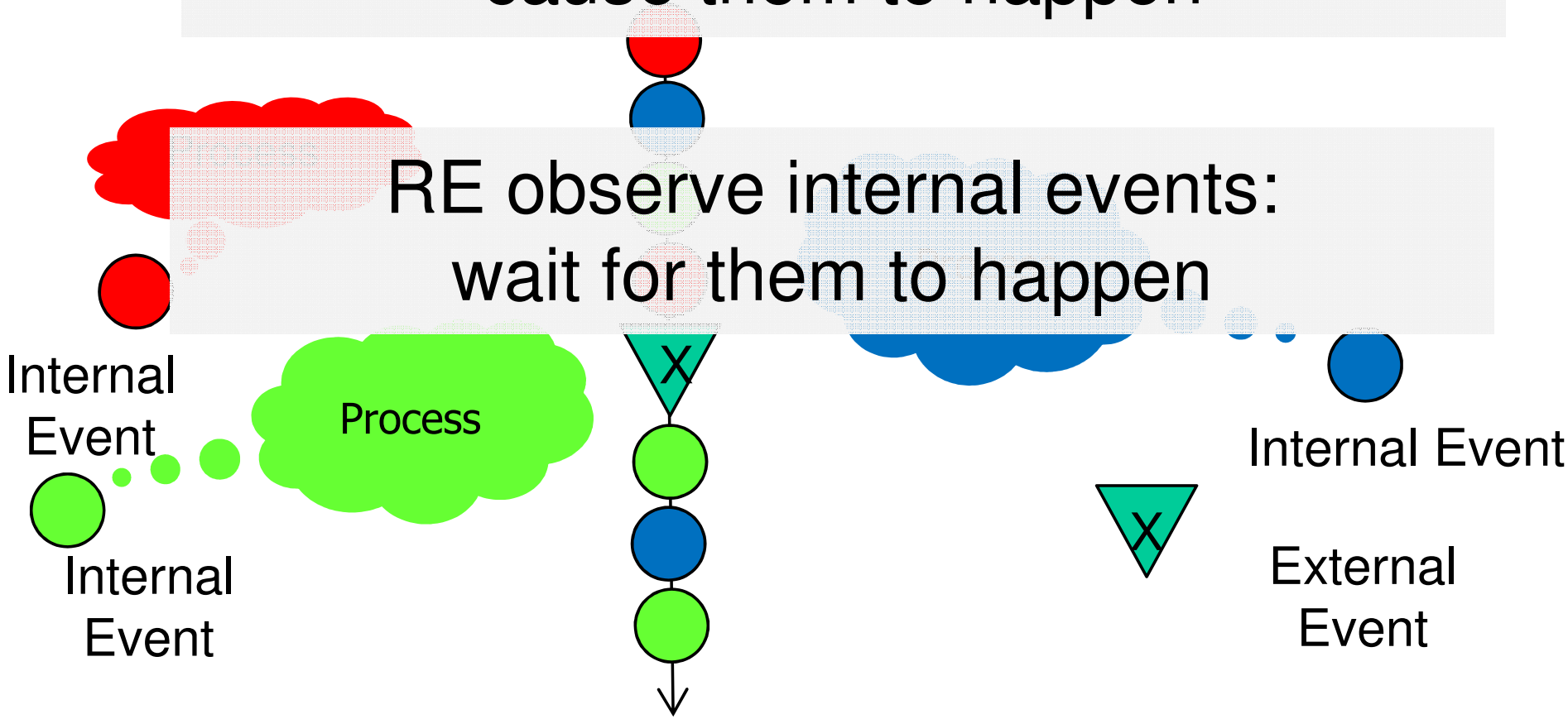
File name

Log message

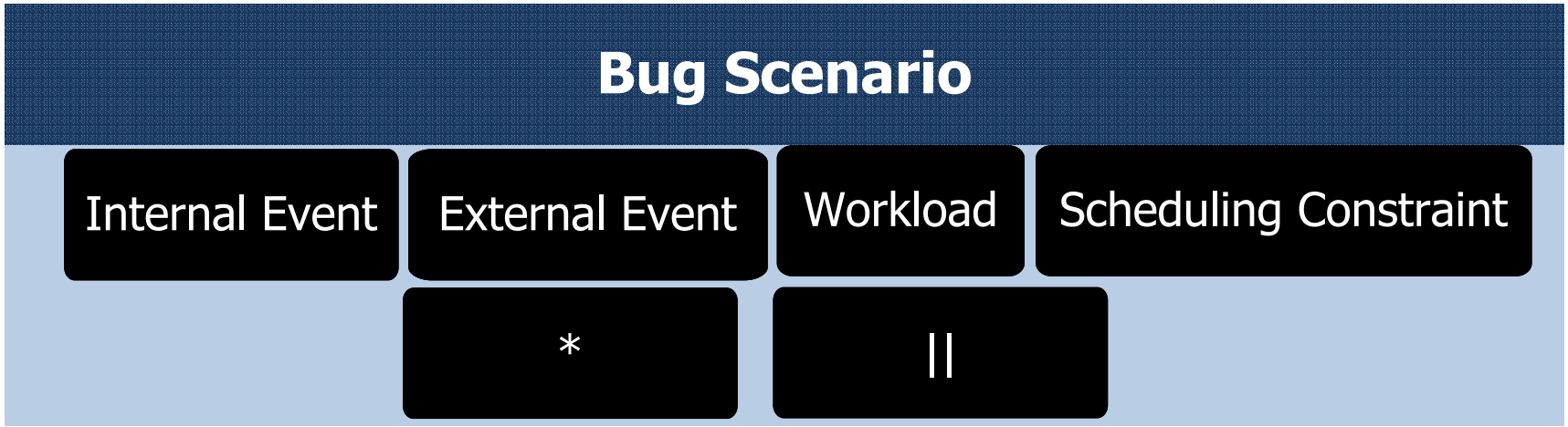
RE: Reproduction Engine

RE control external events:
cause them to happen

RE observe internal events:
wait for them to happen



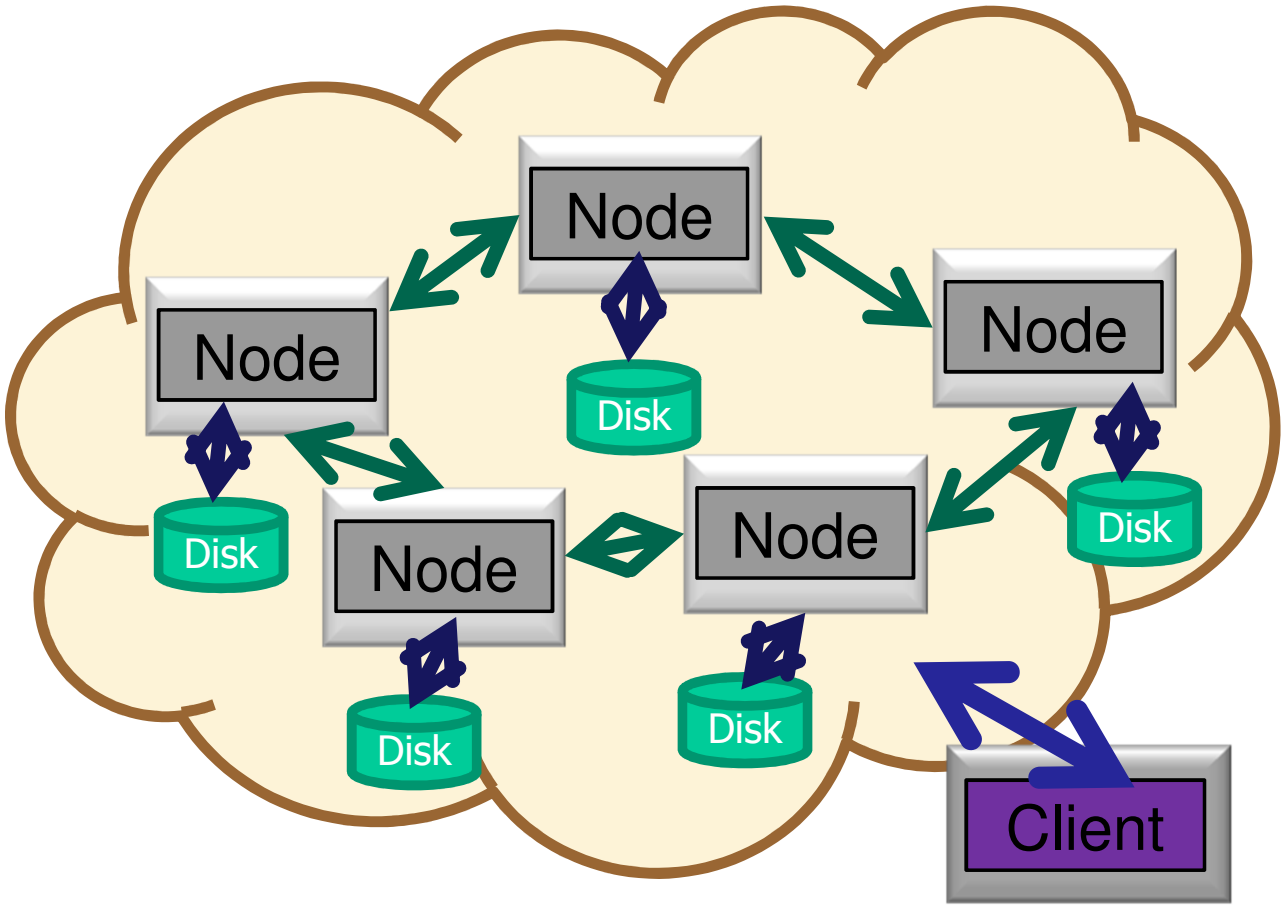
RT: DSL for expressing bug scenario



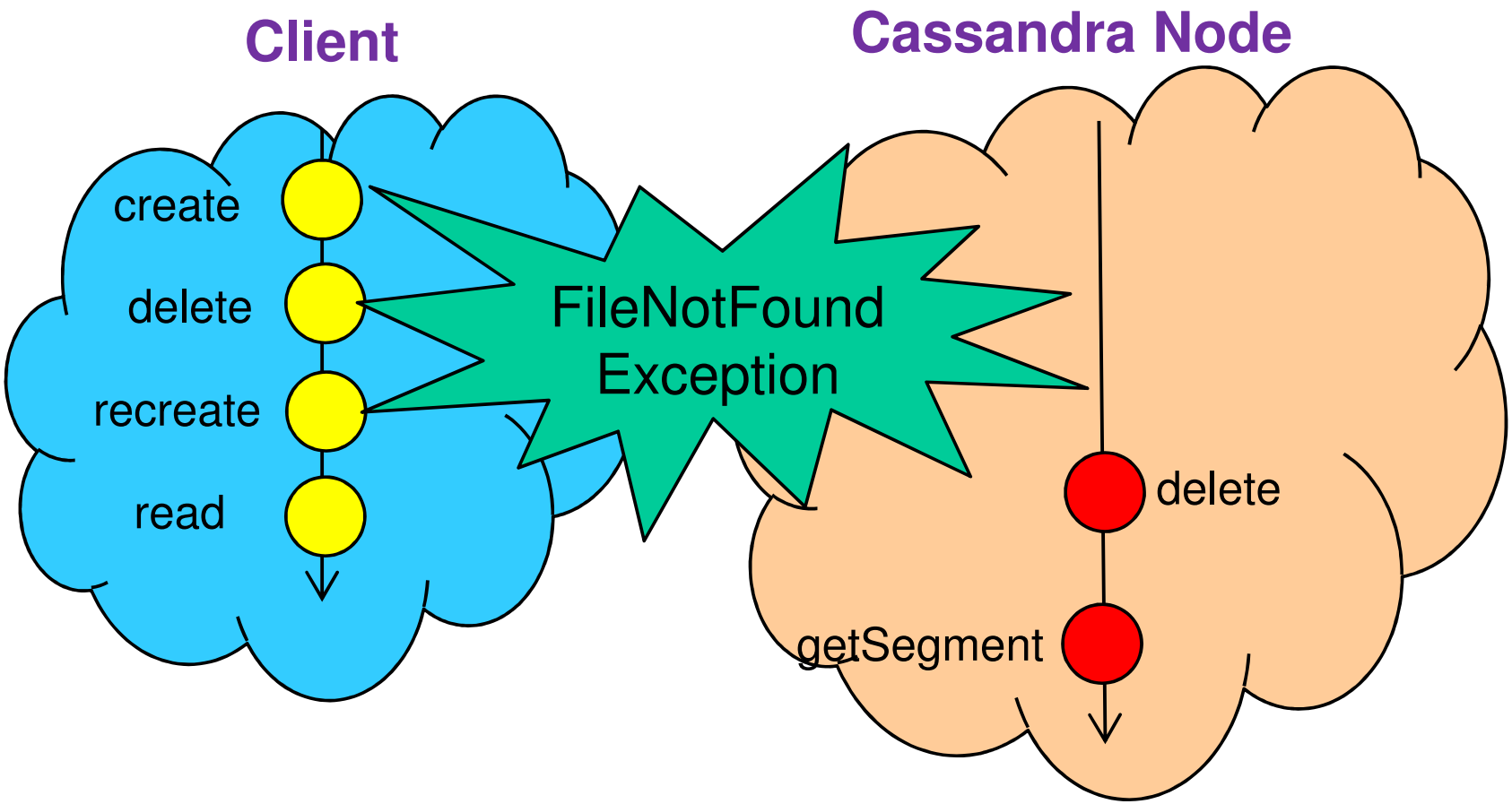
Run in sequence E1 * E2

Left and right run in parallel E1 || E2

Cassandra



Cassandra bug 1477



DSL example

```
W1 = 'create-ks.sh test'
W2 = 'add-cf.sh test cf'
W3 = 'write.sh 20 test cf'
W4 = 'flush.sh'
W5 = 'drop.sh cf'
W6 = 'add-cf.sh test cf'
W7 = 'read.sh test cf'
```

A workload given by bash script names and arguments

Stack traces to identify an internal event

```
E1 [ stack ]= 'File.delete`
E2 [ stack ]= 'BufferedSegmentedFile.getSegment'
```

Bug scenario

```
W1 * W2 * W3 * W4 * ( W5 * W6 * W7 || E1 * E2 )
```

Example Walkthrough

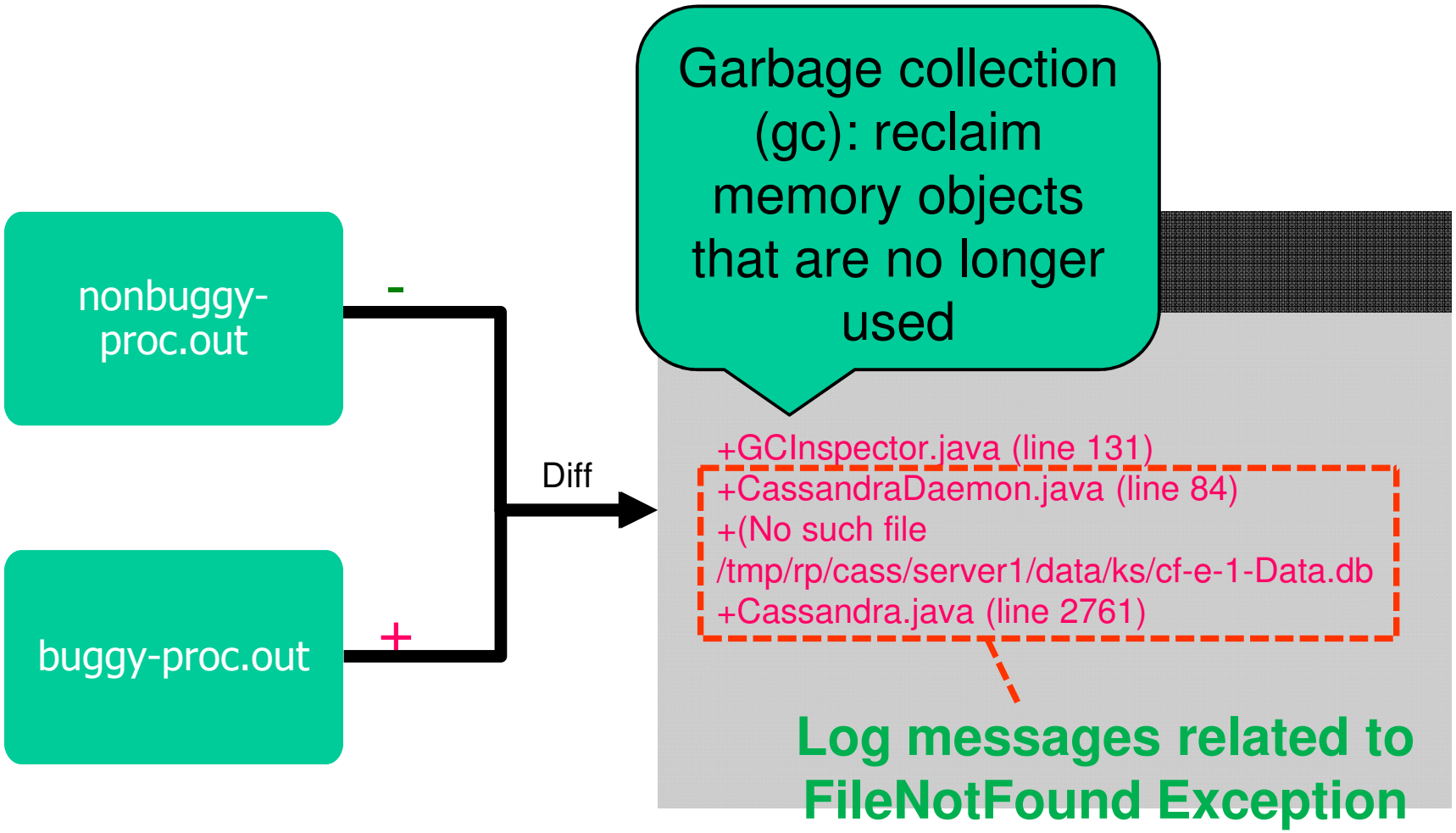
Users write code in DSL: First attempt

W1 = 'create-ks.sh test'
W2 = 'add-cf.sh test cf'
W3 = 'write.sh 20 test cf'
W4 = 'flush.sh'
W5 = 'drop.sh cf'
W6 = 'add-cf.sh test cf'
W7 = 'read.sh test cf'

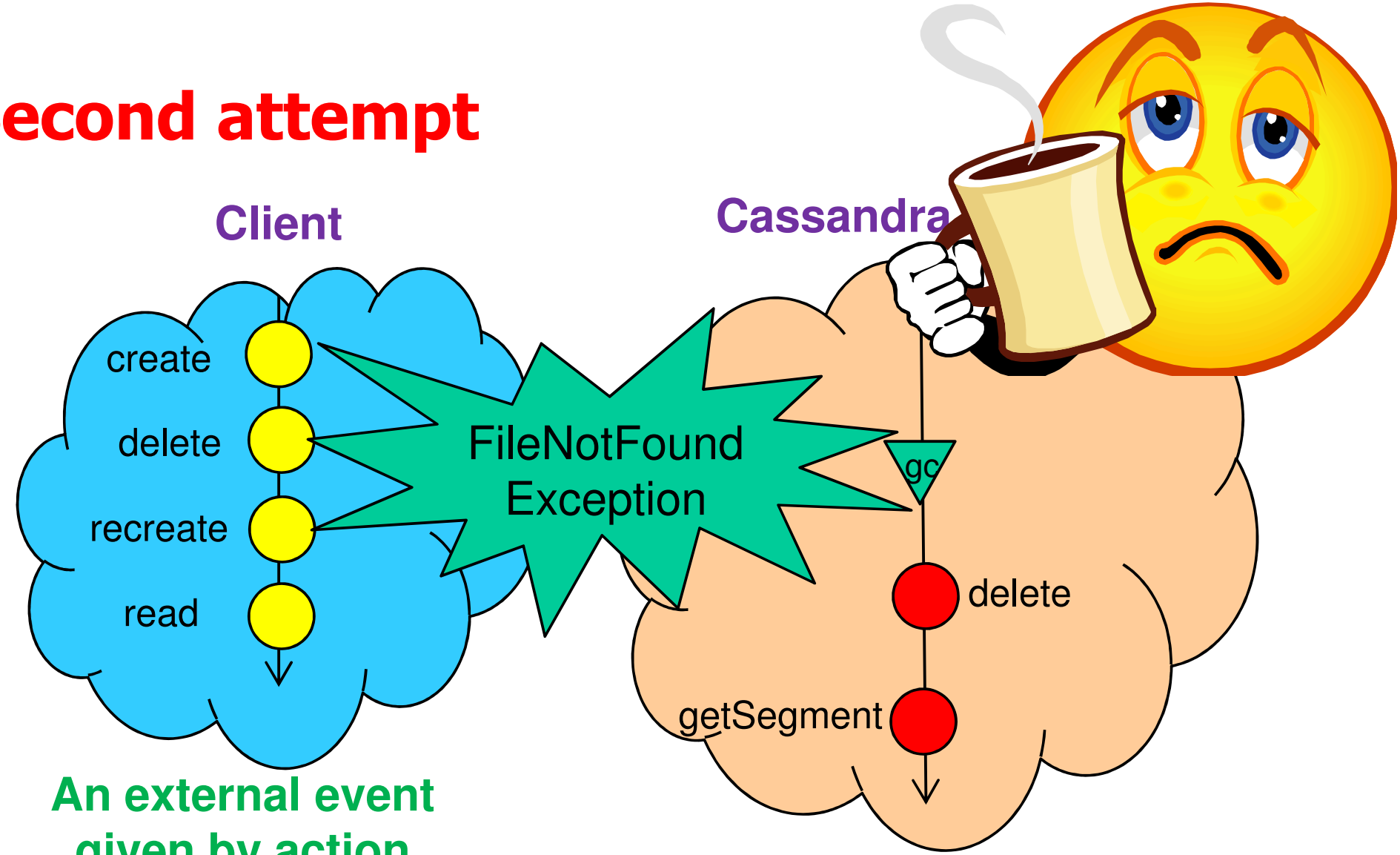
E1 [stack]= 'File.delete`
E2 [stack]= 'BufferedSegmentedFile.getSegment'

W1 * W2 * W3 * W4 * (W5 * W6 * W7 || E1 * E2)

Extract file name and line number from each log message and diff



Second attempt



An external event given by action and node ID

X1 = garbage collection 'cnode'

W1 * W2 * W3 * W4 * (W5 * W6 * W7 || **X1** * E1 * E2)

Rely on logs and source code whenever possible

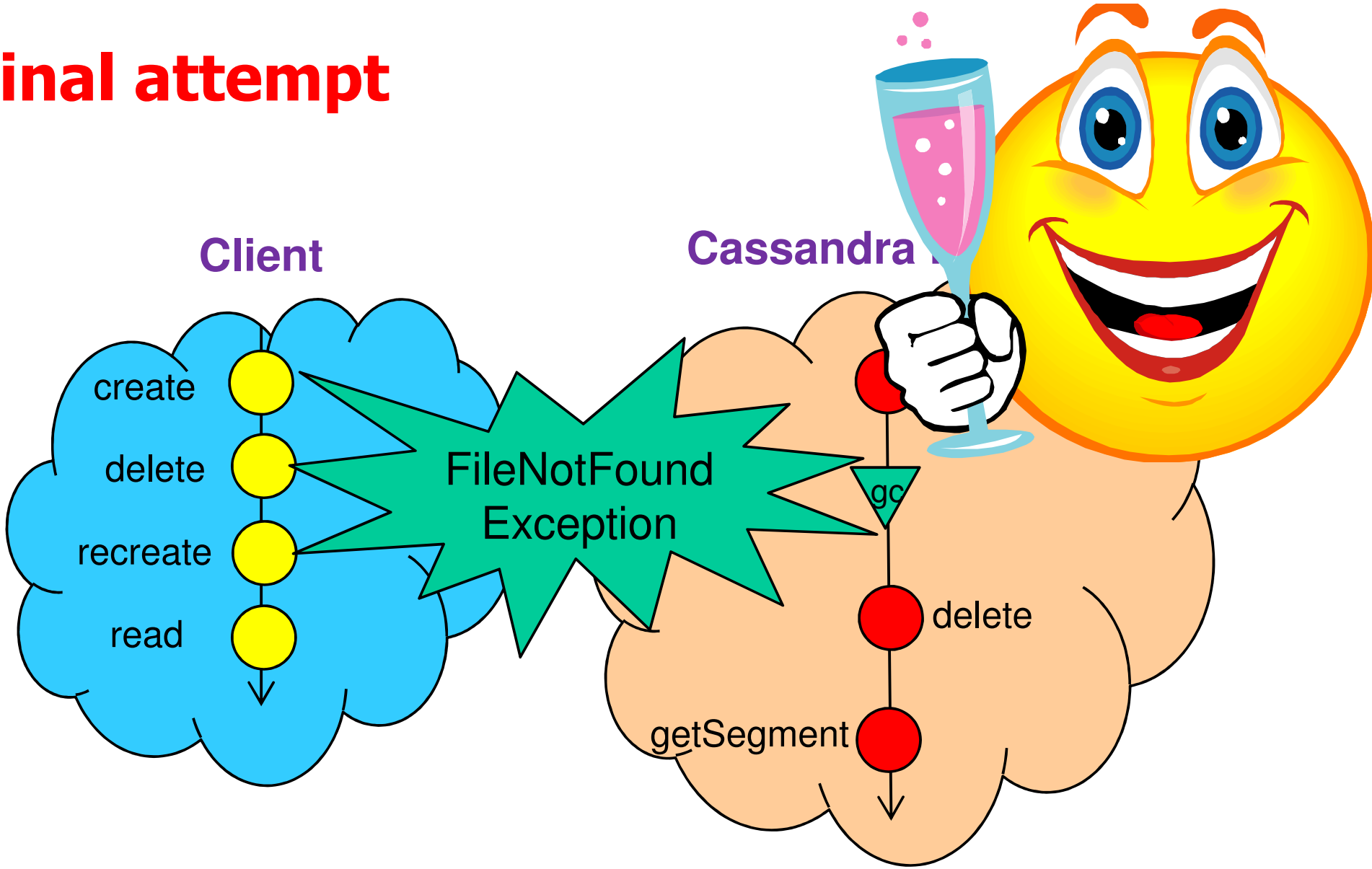
buggy-proc.out

```
SSTableReader.java (line 471)
GCInspector.java (line 131)
SSTableTracker.java (line 113)
Migration.java (line 120)
ColumnFamilyStore.java (line 418)
```

SSTableReader.java

```
471             logger.debug("Marking " + getFil
472         try
473         {
474             if (!new File(desc.filenameFor(C
475                 throw new IOException("Unabl
476         }
477         catch (IOException e)
478         {
479             throw new IOError(e);
480         }
481         phantomReference.deleteOnCleanup();
```

Final attempt

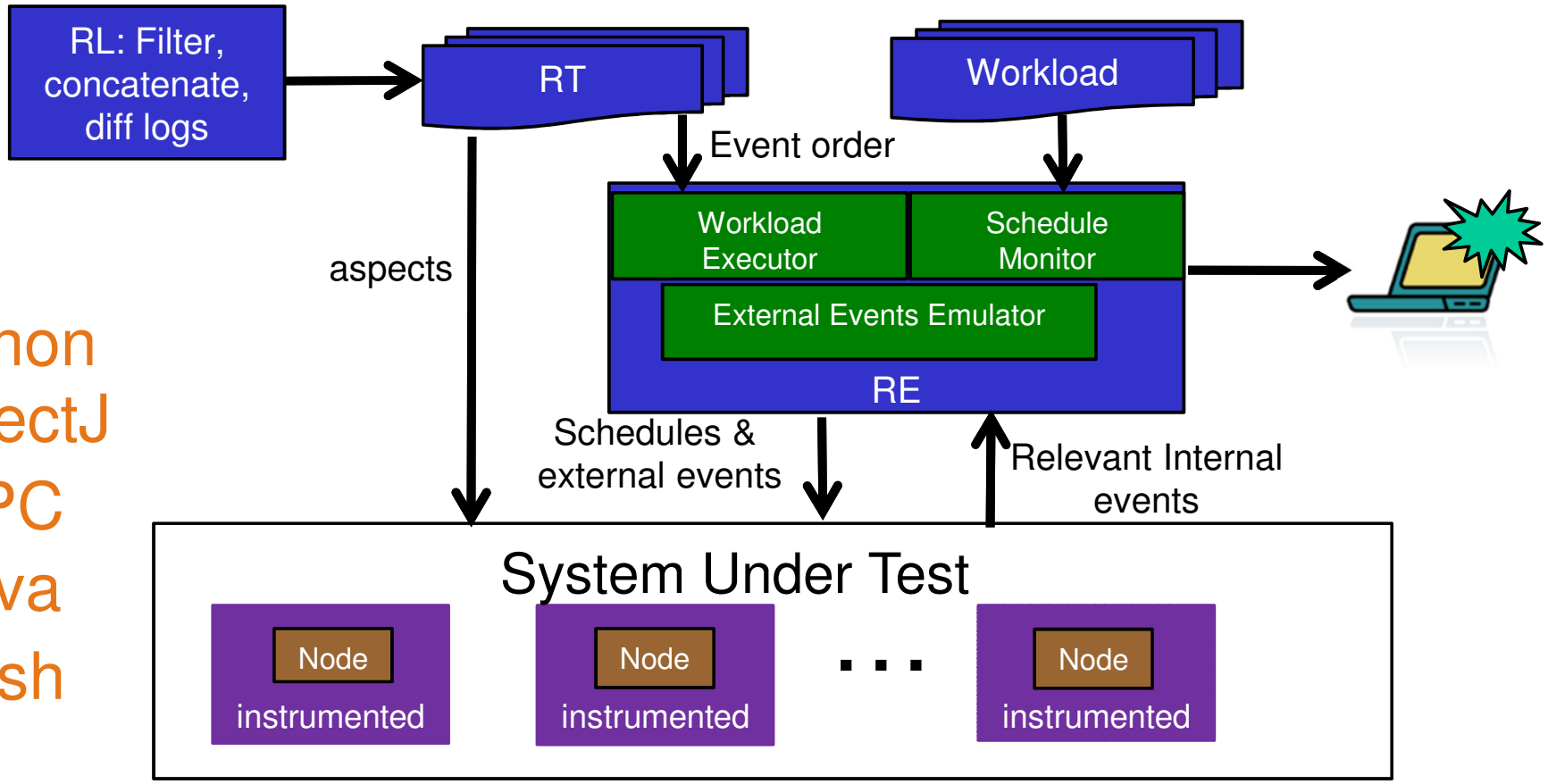


E3 [stack]= 'SSTableDeletingReference.deleteOnCleanup'

W1 * W2 * W3 * W4 * (W5 * W6 * W7 || **E3** * X1 * E1 * E2)

How? (Implementation)

Implementation



Python
AspectJ
RPC
Java
Bash

So What? (Experiments)

Experiments

We experimented with using ReproLite to debug 11 bugs from

Cassandra HBase

Complexity	<=6 events involved in each bug
Performance Overhead	0~132, close to 0 for half of the bugs
Usefulness of Logs	70% percent of bug causes hidden in logs.

Conclusion

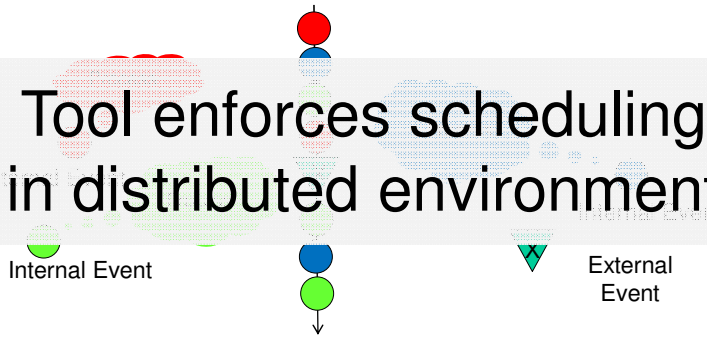
Users write code in DSL: Final attempt

```
W1 = 'create-ks.sh test'
W2 = 'add-cf.sh test cf'
W3 = 'write.sh 20 test cf'
E2 [ stack ]= 'BufferedSegmentedFile.getSegment'
E3 [ stack ]= 'SSTableDeletingReference.deleteOnCleanup'

W1 * W2 * W3 * W4 * ( W5 * W6 * W7 || E3 * X1 * E1 * E2 )
```

High-level language specifies bug scenario

RE: Reproduction Engine



Tool enforces scheduling in distributed environment

8

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Illustrated benefits with 11 hard system bugs

Usefulness of Logs — 70% percent of bug causes hidden in logs.

18

Thanks