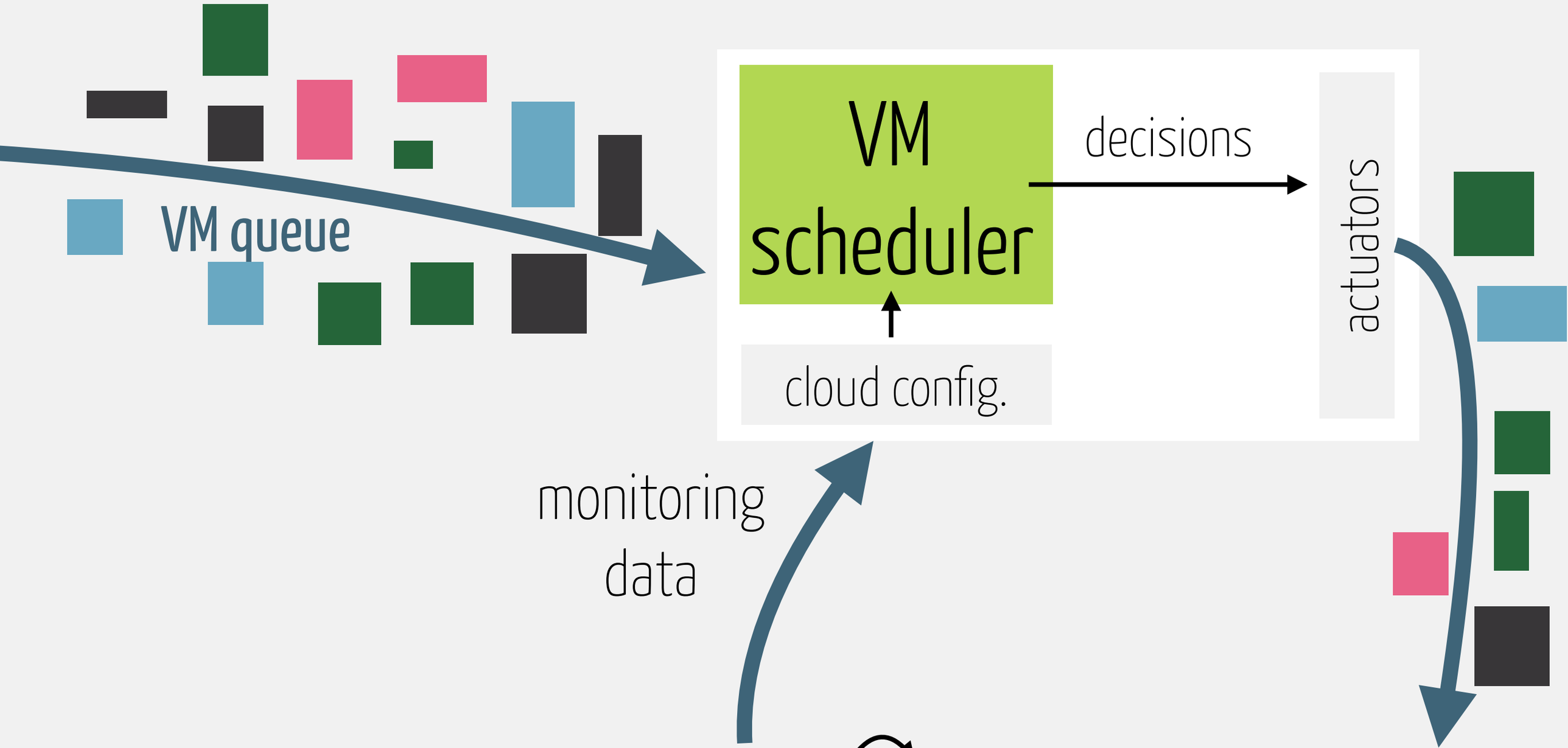
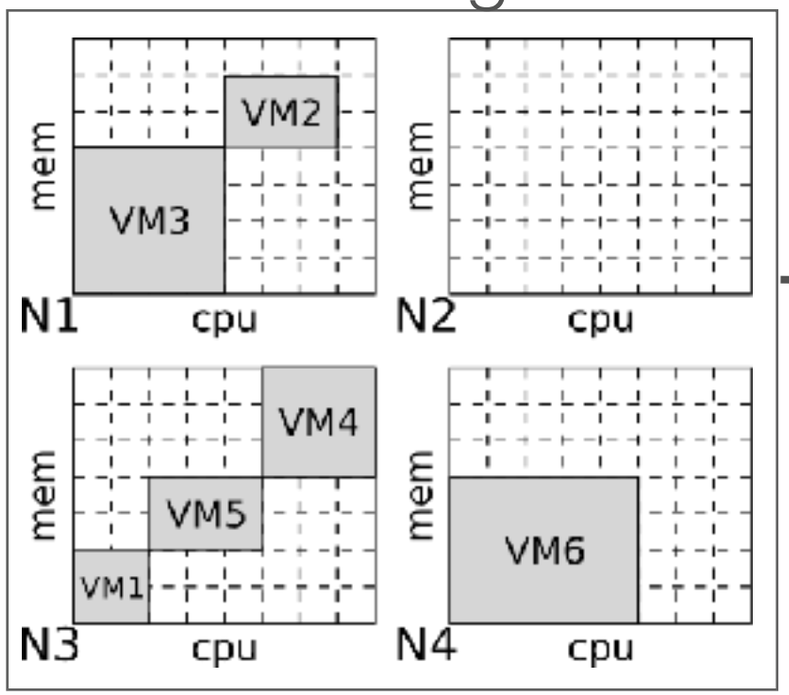
Trustable VM Scheduling in a Cloud

Fabien Hermenier, Ludovic Henrio


VM queue
VM scheduler
decisions
actuators
cloud config.
monitoring data

current configuration



constraints

```
anti-affinity(VM[2..3]);
allocate({VM1},'ucpu', 3);
offline(@N4);
```

openstack.

cloudstack

BtrPlace

NUTANIX

vmware®

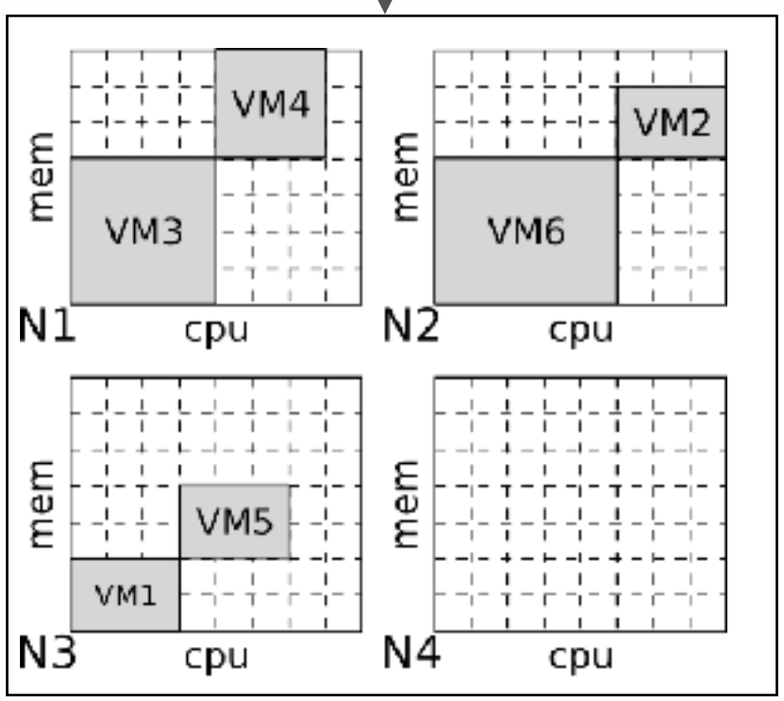
Microsoft Hyper-V

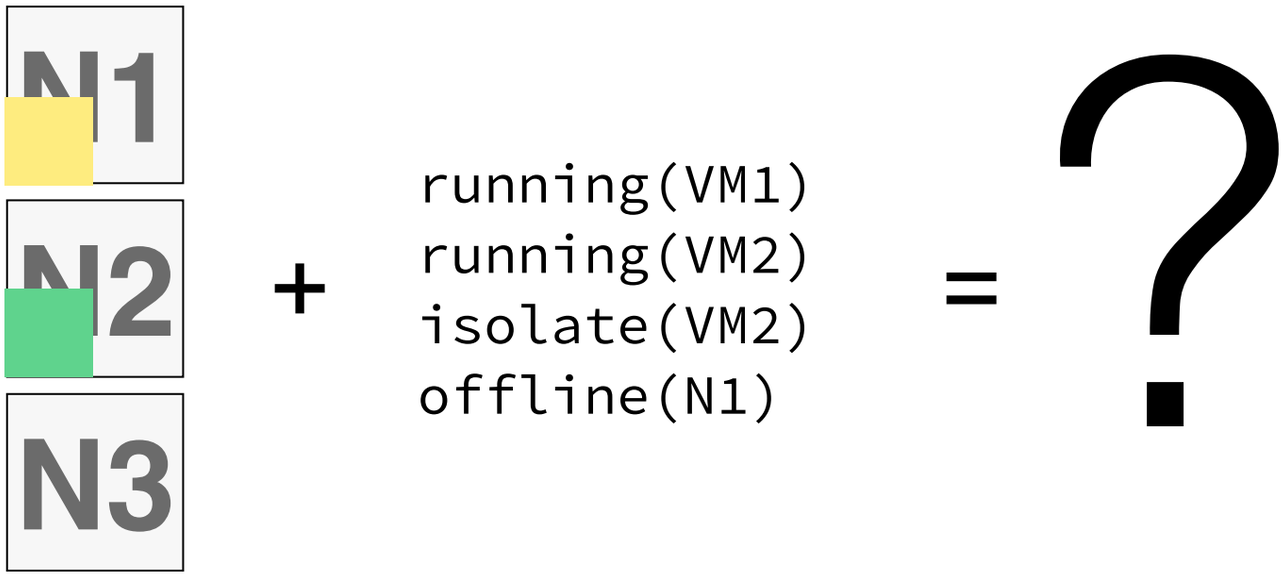
.

.

reconfiguration plan

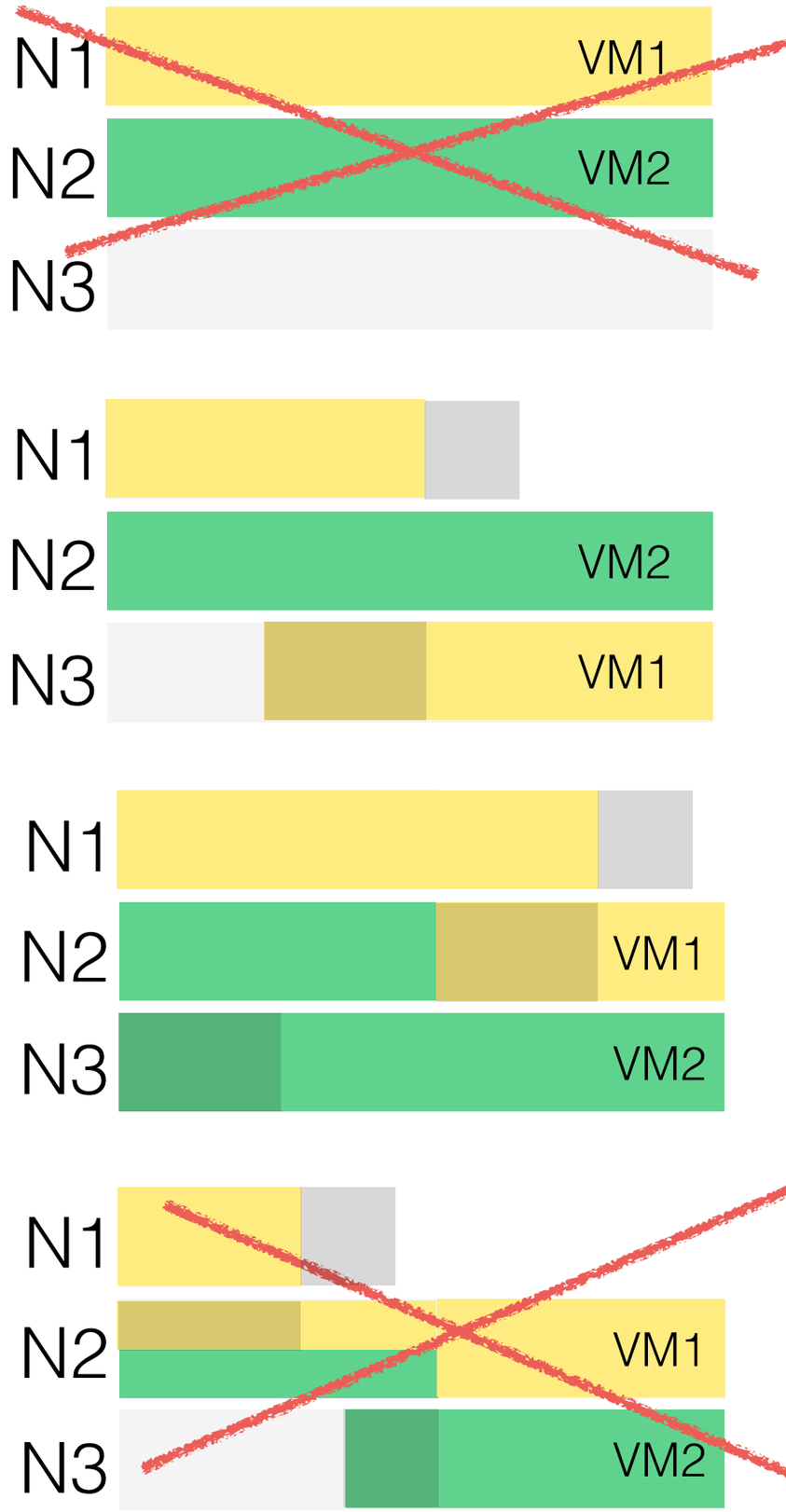
```
0'00 to 0'02: relocate(VM2,N2)
0'00 to 0'04: relocate(VM6,N2)
0'02 to 0'05: relocate(VM4,N1)
0'04 to 0'08: shutdown(N4)
0'05 to 0'06: allocate(VM1,'cpu',3)
```



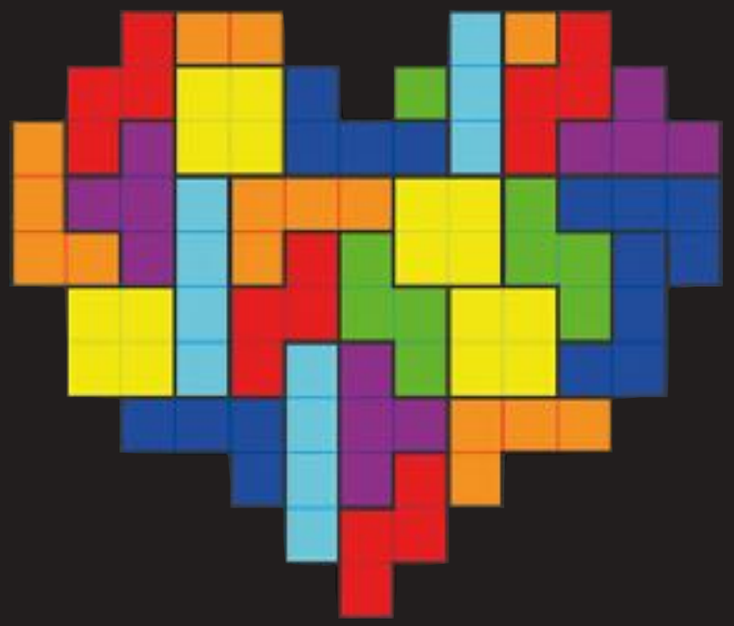


Computing solutions is filtering out non-viable decisions

Explicit in OpenStack, CloudStack
Implicit in BtrPlace



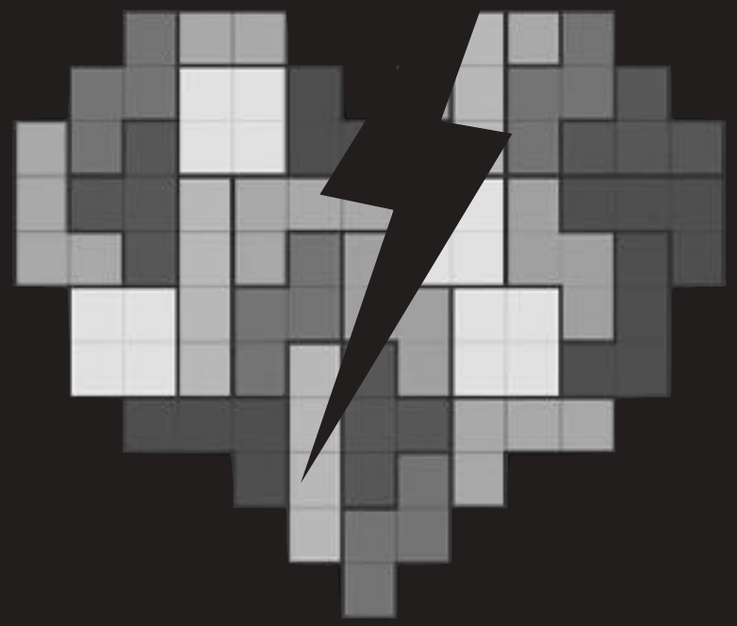
VM scheduler brings



high consolidation, performance,
trustworthy placements, valid schedules

openstack. BtrPlace cloudstack NUTANIX + BtrPlace

Behind the scene



over-filtering — Filter-out viable decisions
Reduce the hosting capabilities

under-filtering — Let non-viable decisions
Break SLA & user confidence

crash — *...*

```
/* CAmongTest.java */
@Test public void testContinuousWithNotAlreadySatisfied() {…}
@Test public void testWithOnGroup() { …}
@Test public void testWithGroupChange() {…}
@Test public void testWithNoSolution() {…}
@Test public void testContinuousWithAlreadySatisfied() {…}
```

A limited vision of the significant use cases (specific state/transitions)

Continuous among is too restrictive bug

#44 opened on 29 Aug 2014 by fhermeni

fhermeni commented 6 minutes ago — Owner

In theory, there is a solution to this problem: https://gist.github.com/fhermeni/76358167e5371ce6c128
Only VM1 is running so it's ok to migrate it to the second partition, then to boot the other vms.

CloudStack / CLOUDSTACK-8896

Allocated percentage of storage can go beyond 100%

MEDIUM FIX RELEASED #1379451 anti-affinity policy only honored on boot
OpenStack Compute (nova) 26

MEDIUM CONFIRMED #1012822 broken instances are considered to be consuming resources
OpenStack Compute (nova) 34

A limited expertise in the theoretical foundations

discrete maxOnline(N[1..10], 7)::=

$$\sum_{i=1}^{10} n_i^q \leq 7$$

ZERØ

to HERO

continuous maxOnline(N[1..10], 7)::=

$$\forall i \in [1,10], \quad n_i^{on} = \begin{cases} 0 & \text{if } n_i^q = 1 \\ a_i^{start} & \text{otherwise} \end{cases}$$

$$n_i^{off} = \begin{cases} max(T) & \text{if } n_i^q = 0 \\ a_i^{end} & \text{otherwise} \end{cases}$$

$$\forall t \in T, card(\{i | n_i^{on} \geq t \wedge n_i^{off}\}) \leq 7$$

continuous constraints [hotdep'13]

unit tests,
smoke testing,
peer review
cannot address
reasoning issues

SafePlace

a specification langage

to state the awaited VM scheduler behaviour

fuzz testing + simulator

to exhibit reasoning issues

applied to BtrPlace

The specification language

First order logic

Business functions in native code (Java)
Added dynamically through reflections
Provide extensibility

Core constraints reflect element lifecycle
Must always be satisfied

temporal call,
Refers to the initial state

```
toRunning ::= !(v : vms)
  vmState(v) = running –> ^vmState(v) : {ready, running, sleeping}

noVMsOnOfflineNodes ::=
  !(n : nodes) nodeState(n) /= online –> card(hosted(n)) = 0
```

Side constraints are enabled on demand

```
MaxOnline(ns <: nodes, nb : int)::=
  card({i. i:ns , nodeState(i)=online}) <= nb // set builder notation
```

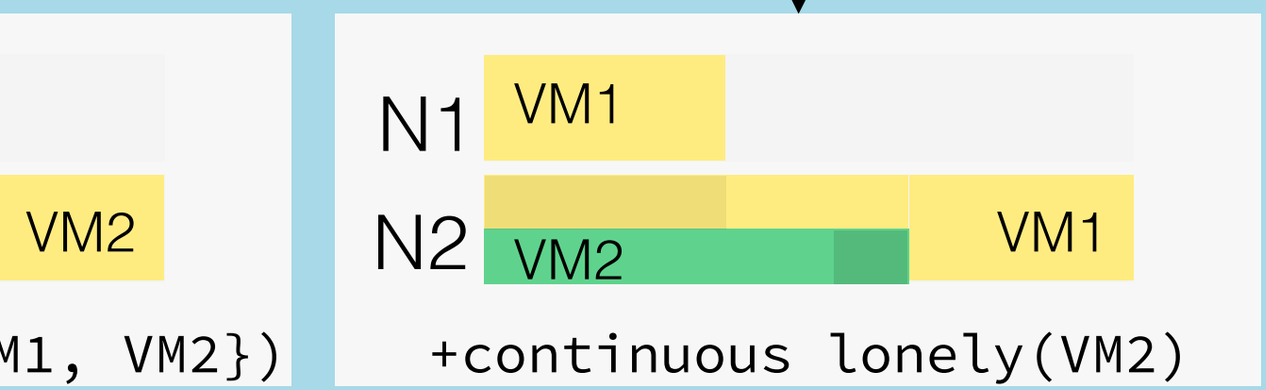
The testing framework

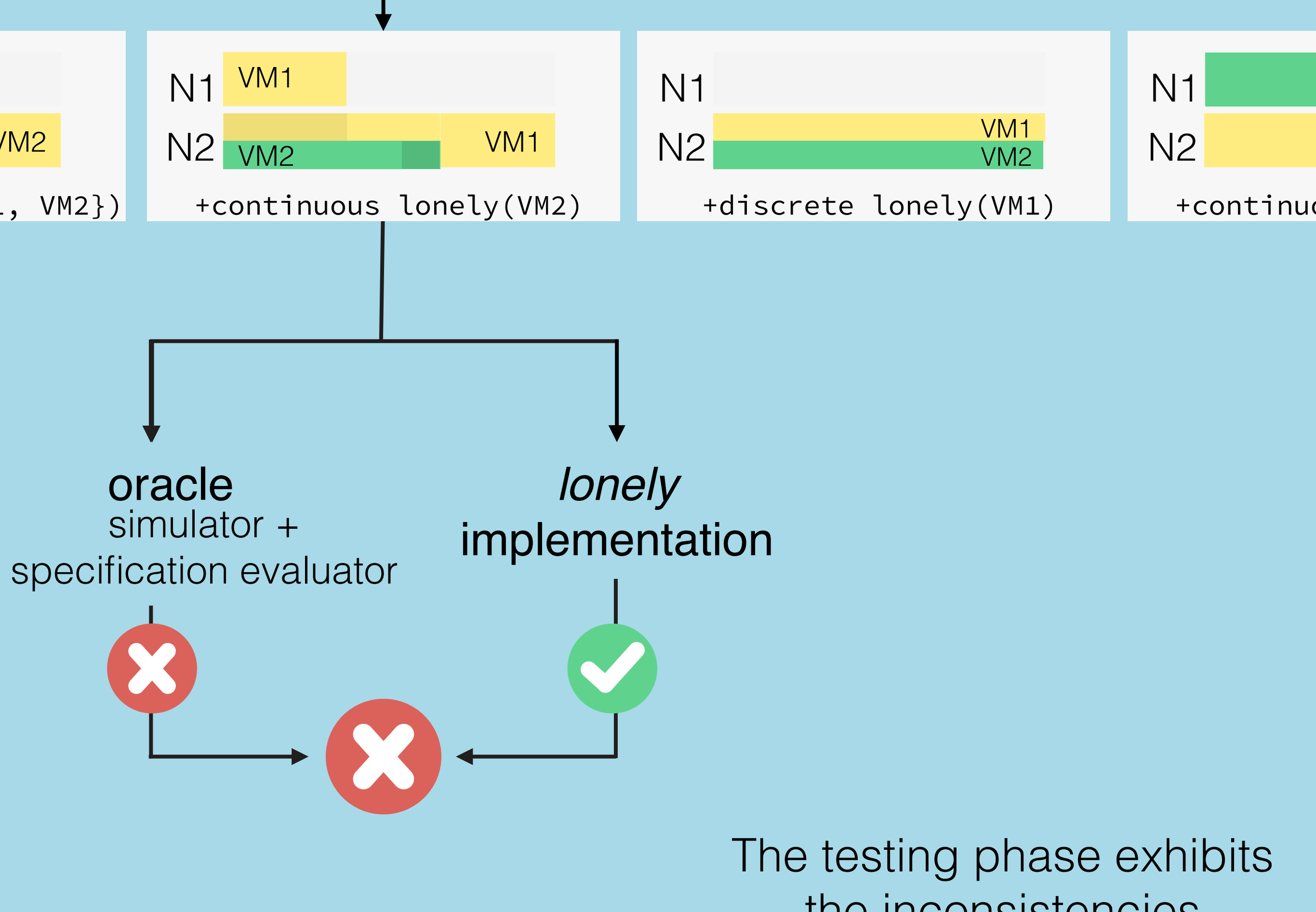
Test campaign

```
@CstrTest(groups = {"lonely", "affinity"})
public void testLonely(TestCampaign c) {
  c.fuzz().constraint(“lonely”)
   .vms(2).nodes(2).srcVMs(1, 9, 0);
  c.limits().tests(100).failures(1);
}
```

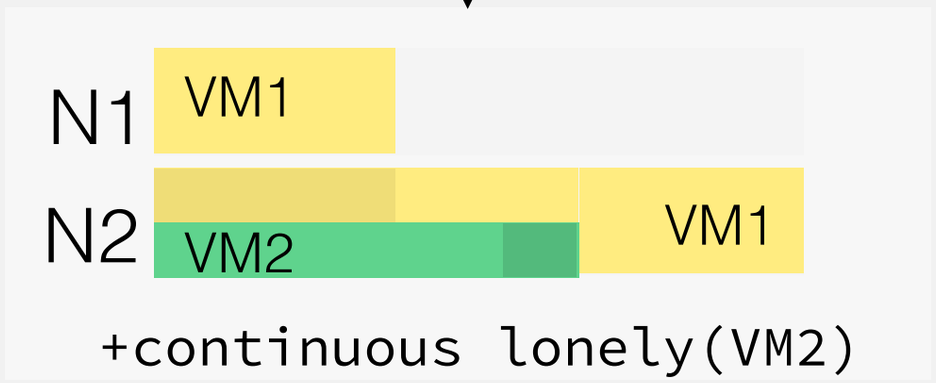
test case fuzzer

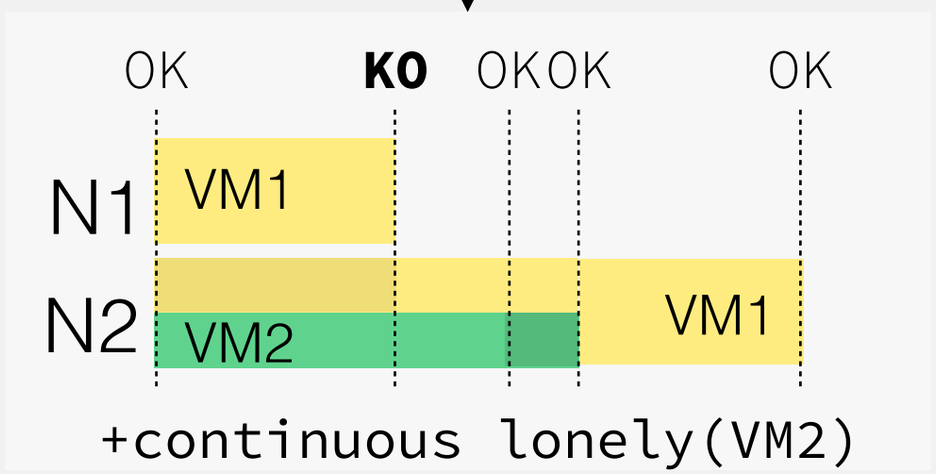
TestCase
valid plan + sample constraint





The testing phase exhibits the inconsistencies



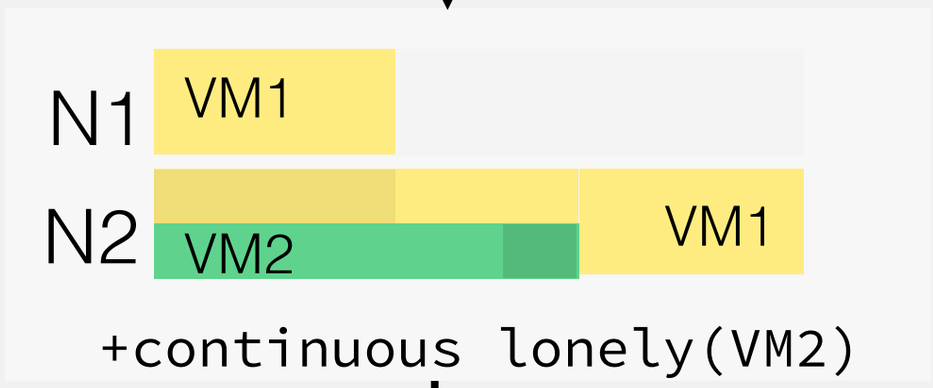


Testing with an oracle

a simulator executes the plan

the invariant is checked at every timestamp of interest

```
lonely(vs <: vms) ::=
  !(i : vs) vmState(i) =
    running --> (colocated(i) - {i}) <: vs
```

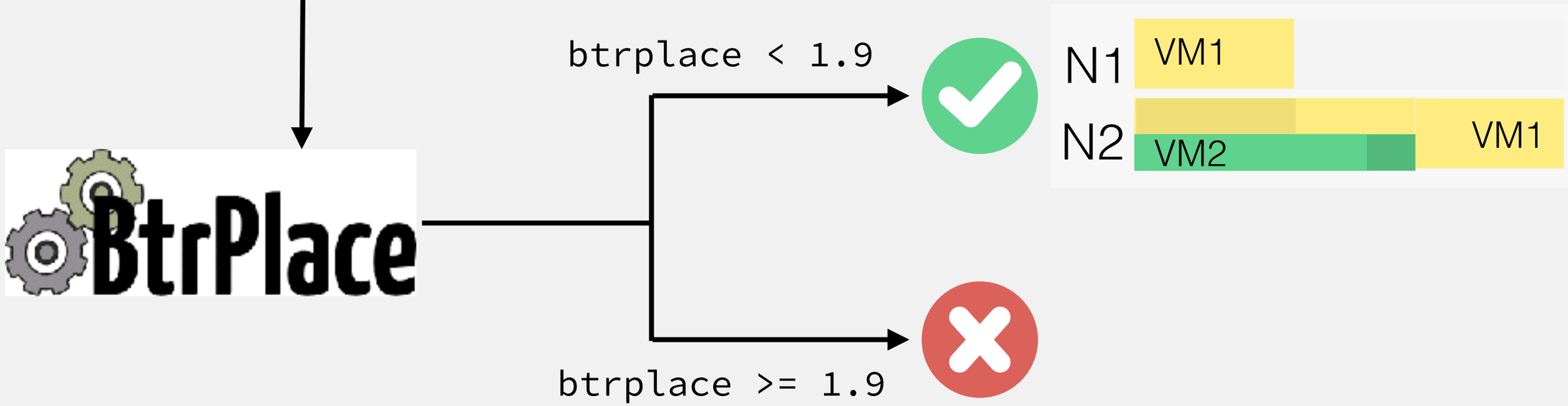


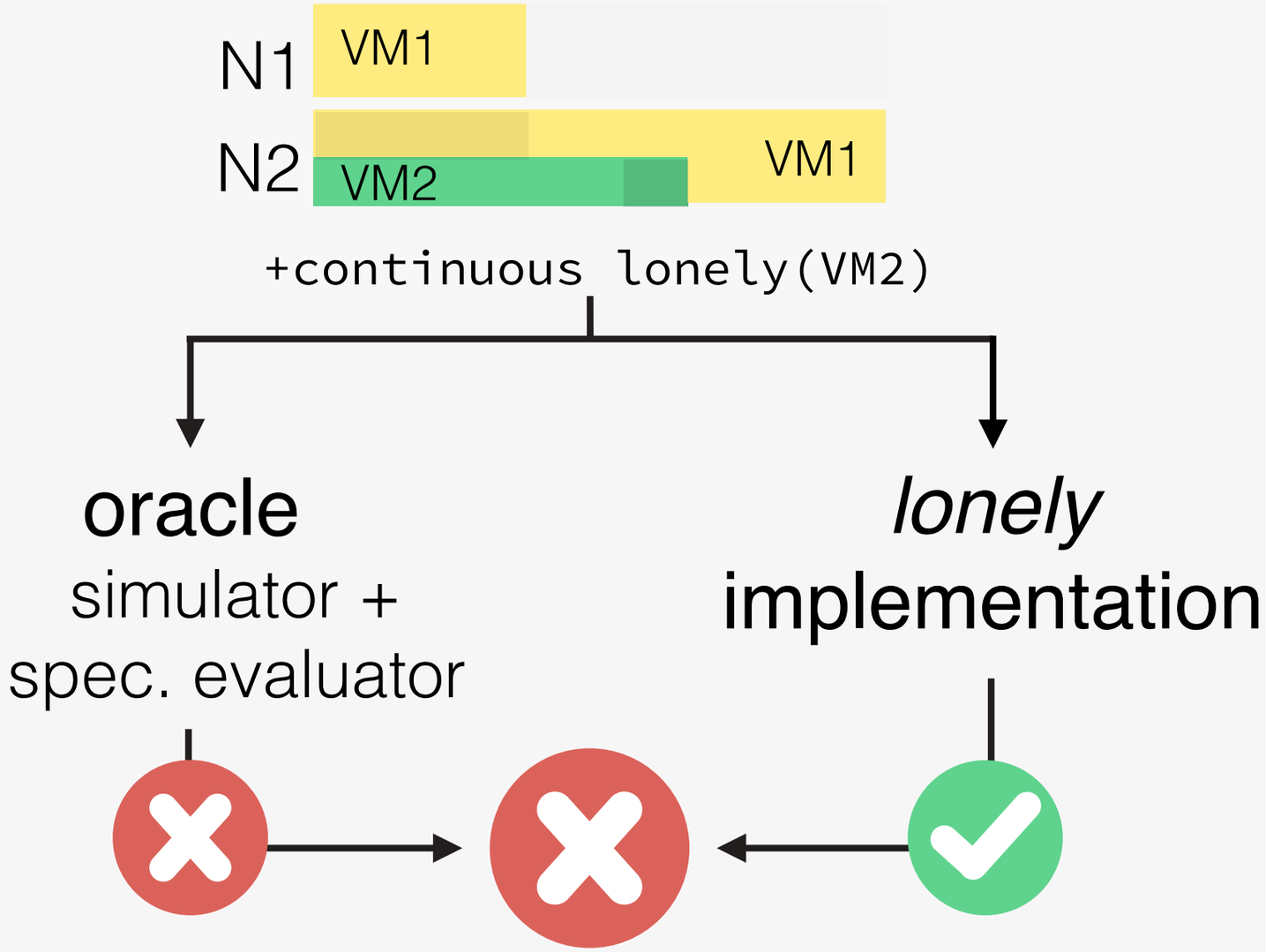
N1
N2

```
online(N[1..2])
running(VM1)
shutdown(VM2)
fence(VM1, N2)
schedule(VM1, 0, 11)
schedule(VM2, 20, 26)
continuous lonely(VM2)
```

Testing BtrPlace

The test case is turned to a heavily constrained instance to solve.





comparing the results
exhibit the defects

oracle \ implementation	OK	KO	CRASH
OK		over filtering	crash
KO	under filtering		crash

Evaluation

usable
for developers

useful
to find reasoning defects

Specification capabilities

Formal documentation
Outside the business code

All the constraints (27)
state transition, action schedule,
resource sharing, affinities, counting

All the constraints

Theoretical suitability

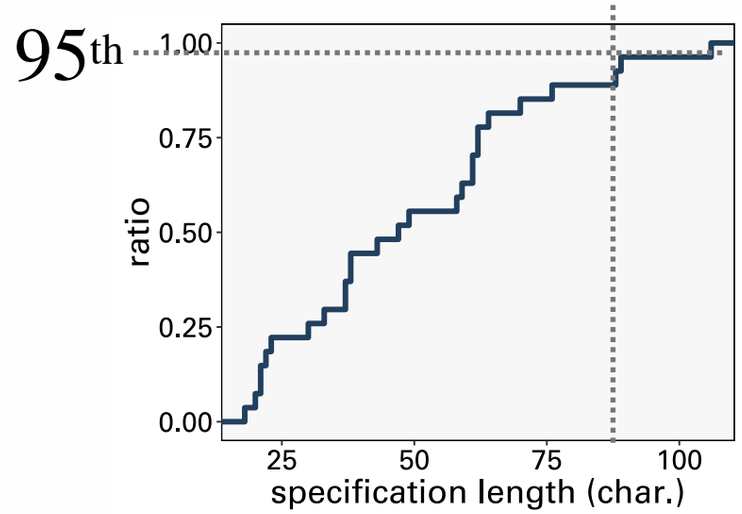
short invariants

First order logic is effective

Easy to read

89 *chars*

95th

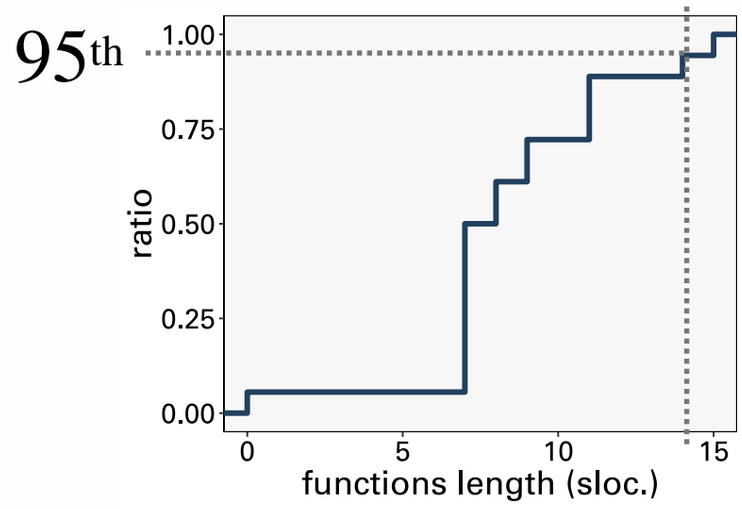


short functions

Reduce risks of bugs

14 *sloc*

95th



small test campaigns

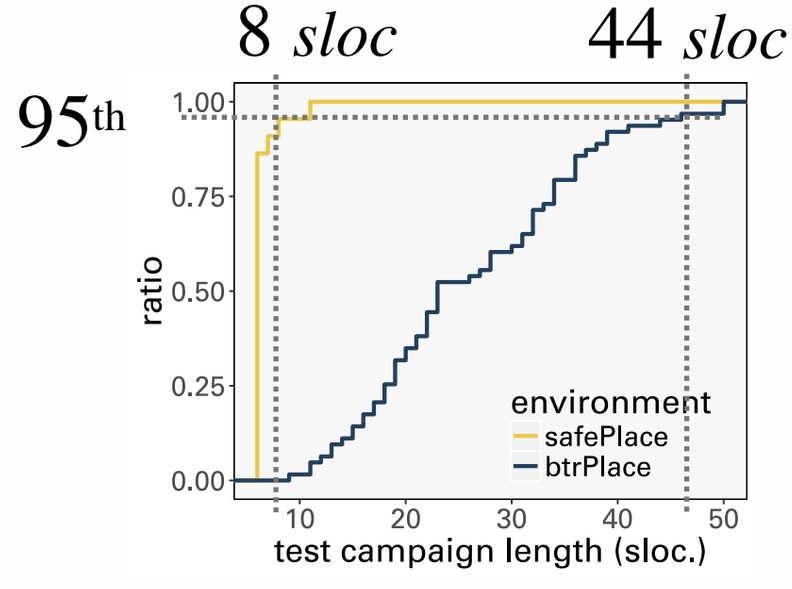
Inputs provided by the fuzzer

Expectation provided by the specification

8 *sloc*

44 *sloc*

95th



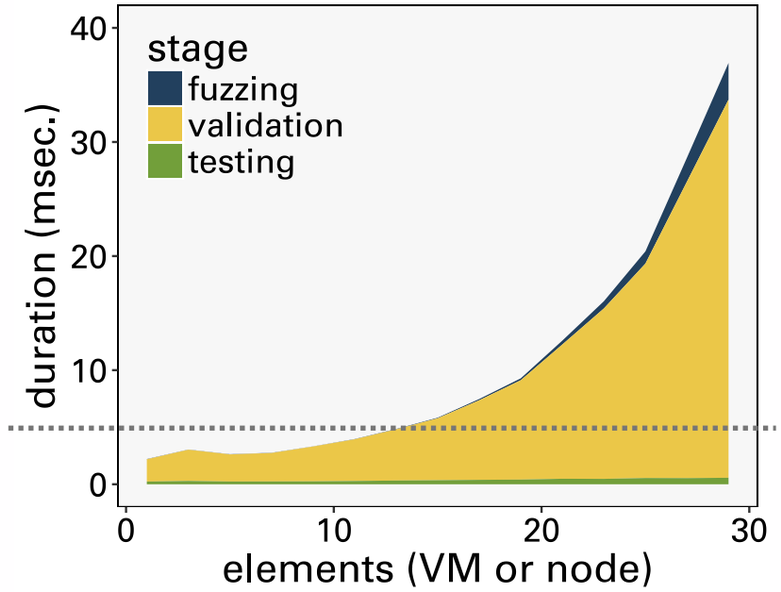
Fast enough for live testing

fuzzing: test case generation

validation: checking test case consistency wrt. core constraints

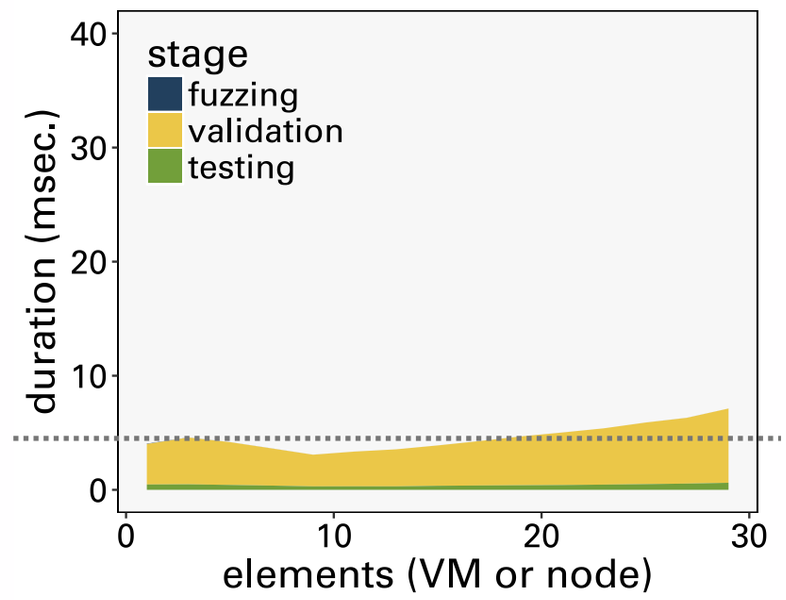
testing: checking the constraint under test

200 tests/sec



Fuzzer tuning to speed up the validation phase

200 tests/sec



Testing BtrPlace

22 constraints
1,000 non-unique tests per campaign

Cause	Constraints	Tests
Initial violation in continuous mode	7	704
Unexpected arguments	4	642
Discrete filtering in continuous mode	3	45
Unsupported action synchronisation	4	20
Bad action semantic comprehension	1	16
Unconsidered initial element state	1	4

Exhibit known and unknown bugs
Lead to under-filtering (57%), over-filtering(28%), crashes(15%)

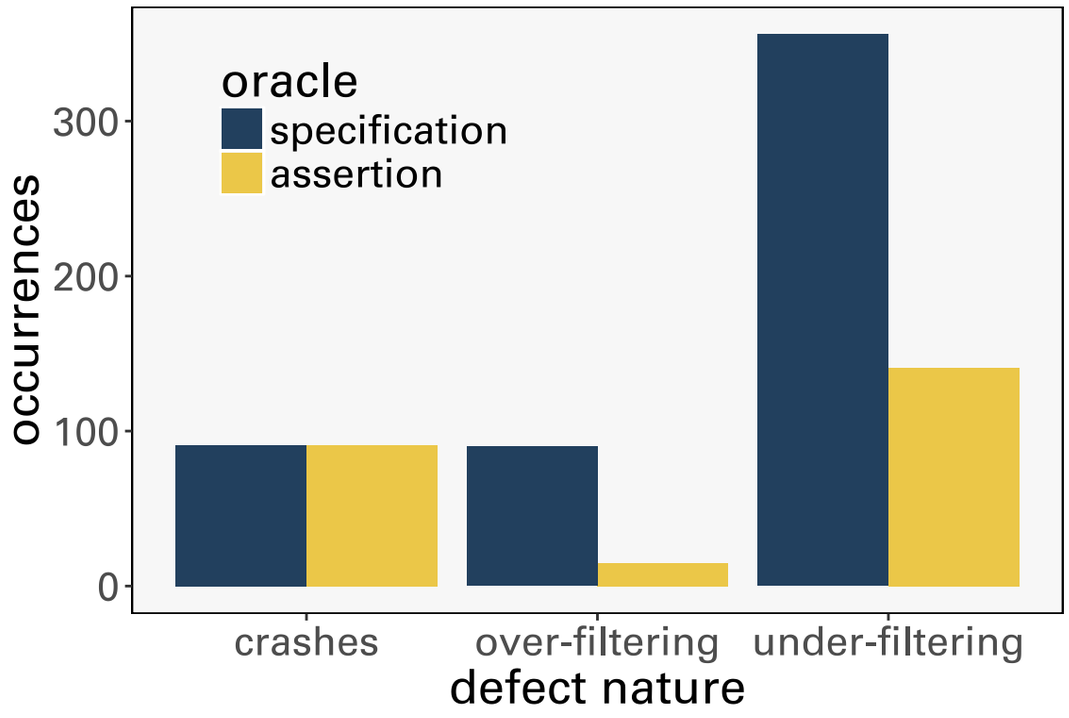
Specification vs. btrplace assertions

Assertion system

Written by the developer

Event based

Verbose



Programmatic approach is error prone

Developers forgot about action interleaving

Reasoning bugs cannot be exhibited
through regular testing methods

A concise DSL to specify the constraint invariants

Fuzz testing to detect inconsistencies

Non disruptive

Exhibit representative reasoning issues

Read the paper for more details and evaluation results

http://www.btrplace.org