Towards fast and deterministic system tests

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Overview

- Explain the problem with current approaches to system tests;
- Give a high-level overview of test library we've started to develop that addresses said problems;
- Demo;
- More detailed explaination of how the test library works, in particular:
  - Lineage-driven fault injection;
  - Elle checker.
- Next steps and future work;
- Summary.

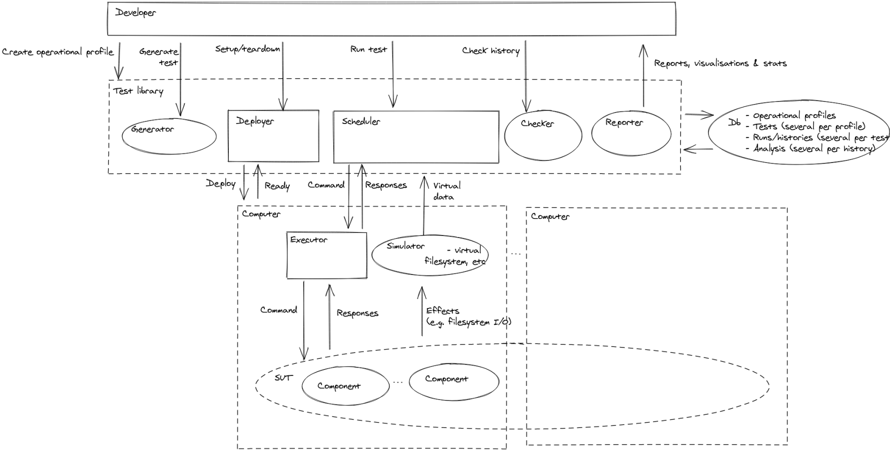
The problem

System tests, in general, are:

- Non-deterministic
  - Running the same test twice can yield different outcomes, esp. around fault-injection;
- Ill-specified or provide weak guarantees
  - What exactly have we shown if the tests pass?
- Ephemeral
  - Hard to test performance over time;
  - Hard to test upgrades, or backup and restore;
- Language specific
  - Test libraries/frameworks/tools are programming language specific, while the components of systems under test are written in different languages.

Parts of the solution

- Generator: generates random test cases;
- Scheduler: determinstically controls the network traffic during the test;
- Executor: receives messages from the scheduler and executes them against the system under test (SUT);
- Ldfi: figures out which faults to inject;
- Checker: analyses the output of a test case execution and determines if it was a success or not.


Developer
Create operational profile
Generate test
Setup/teardown
Run test
Check history
Reports, visualisations & stats
Test library
Generator
Deployer
Scheduler
Checker
Reporter
Db
- Operational profiles
- Tests (several per profile)
- Runs/histories (several per test
- Analysis (several per history)
Deploy
Ready
Command
Responses
Virtual data
Computer
Executor
Simulator
- virtual filesystem, etc
Computer
Command
Responses
Effects (e.g. filesystem I/O)
SUT
Component
Component

Solution for non-determinism

- SUT is assumed to be written on reactor form, i.e. given an incoming message and some internal state, update the state and produce a set of outgoing messages;
- All messages get set via the Scheduler which randomly, but deterministically using a seed, determines the arrival order of the messages;
- Timeouts and retires are handled by explicit tick messages, that are also deterministically sent by the Scheduler.

Language agnostic solution

- In between the SUT and the Scheduler sits the Executor, whose job is to receive messages from the Scheduler via an http interface and pass them on to the SUT;
- The Executor is written in the same language as the SUT, so once it got the message via http it decodes the message from JSON into a datastructure in the native language and does a simple function call to the the SUT;
- Porting an Executor to a new programming language is simple, which means it's easy to test systems written using many languages.

Solution to ill-specified guarantees

- The Checker component uses Jepsen's state-of-the-art Elle checker, which provides precise models and guarantees;
- Lineage-driven fault injection is used to give guarantees in the presence faults;
- Operational profiles/usage models will later be used to drive test case generation, and guarantee system test coverage.

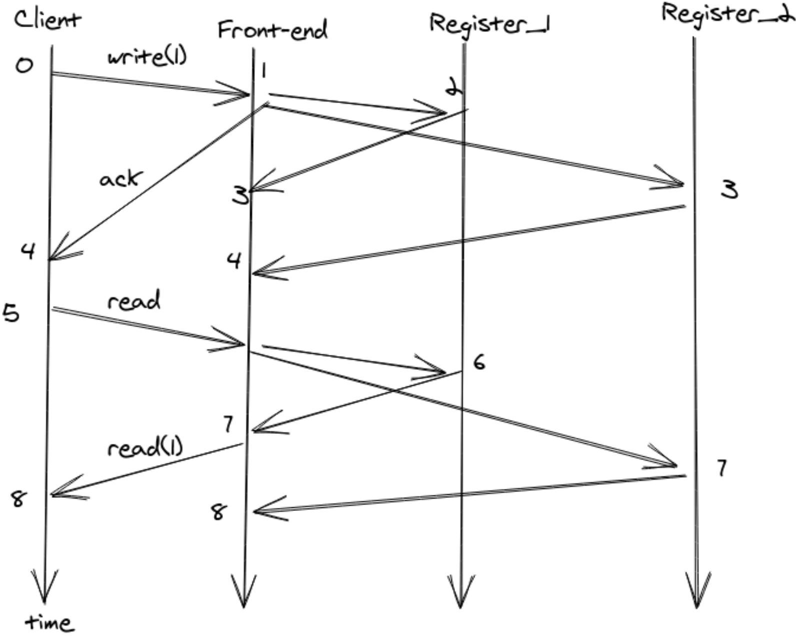
Solution to long-lived testing

- Every interaction that the developer can do, e.g. generation, execution, checking, can be done in isolation because the input and output comes and goes via a database;
- The above in combination with determinism means that we can replay an old test and bring the system to the state it was in at the end of a test, we can then extend the test can carry on from there.

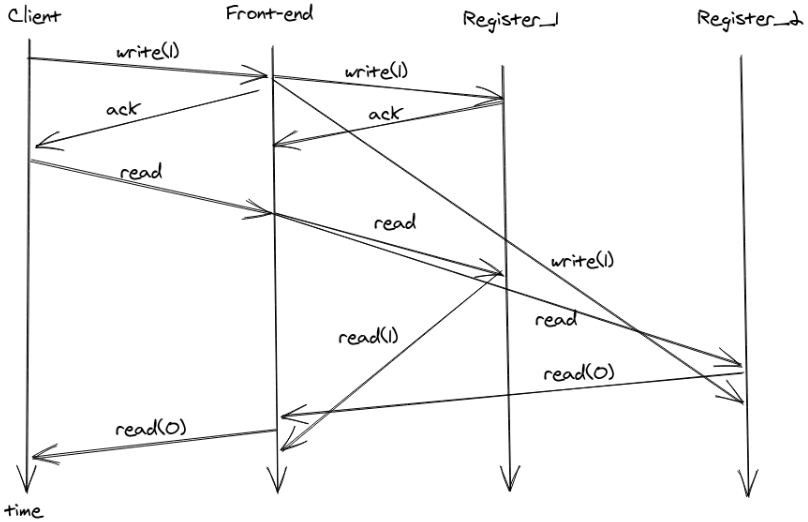
Demo: the SUT

- The example SUT is a integer-valued shared/distributed register;
- Any number of clients can write or read an integer from the register;
- The register is replicated to try to achieve fault tolerance.

Demo: shared register v1, success



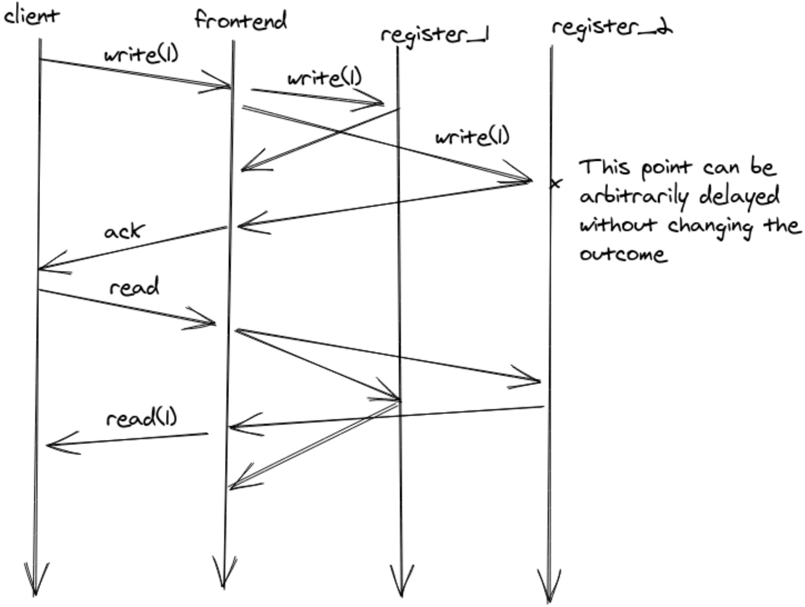
Demo: shared register v1, counterexample



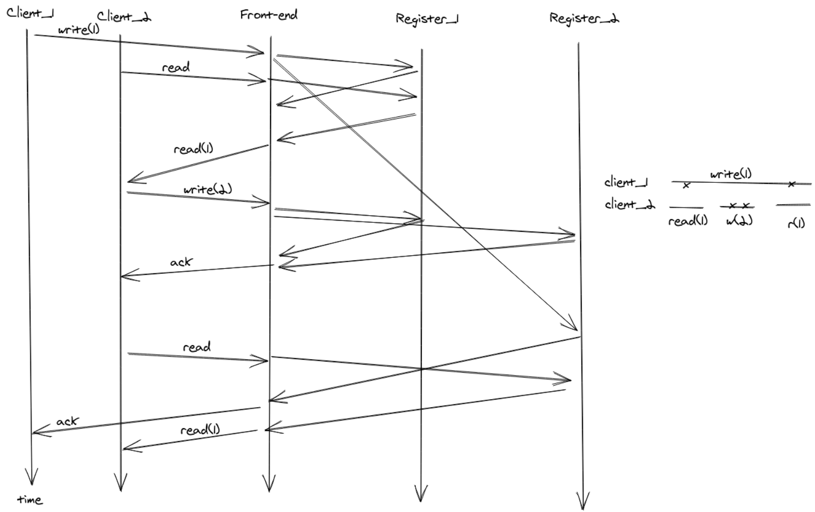
Demo: the testsuite of the SUT

- Show the code of `detsys/sut/register_test.go`;
- `go test`;
- Ensure that we find the problem.

Example: shared register v2, success



Example: shared register v2, counterexample



How does the Elle checker work?

How does lineage-driven fault injection work?

```
traces := []
faults := {}
result := ""

forever:
    inject(faults)
    success, trace := run(test)
    if !success:
        result := failure(faults)
        break
    traces.append(trace)
    faults := ldfi(traces)
    if faults is empty:
        result := "success"
        break
```

How does lineage-driven fault injection work? #2

```
fun ldfi(list of trace) -> set of fault

type trace =
  { message: Msg,
    from: Node,
    to: Node,
    at: Time }

type fault
  = omission { from: Node, to: Node, at: Time}
  | ...
```

How does lineage-driven fault injection work? #3

- `fun ldfi(traces: list of trace) -> set of fault`
- Each trace contains possible messages to drop, so create a big OR-formula like:

  ```
  omission(msg0...) OR omission(msg1...) OR ...
  ```

- For each run/trace we gather more constrints, so create a big AND-formula between traces, e.g.:

  ```
  (omission(msg0...) OR omission(msg1...) OR ...)
  AND
  (NOT(omission(msg0...)) OR omission(msg1...) OR ...)
  AND ...
  ```

- Solve this CNF-formula using SAT solver
  - Minimal solution = smallest set of faults that can potentially break the test
  - No solutions = no set of faults can break the test

Next steps and future work

- Regression tests
- Integration with Sean's work

Summary

Questions or comments?

References

Alvaro, Peter, Joshua Rosen, and Joseph M. Hellerstein. 2015. "Lineage-Driven Fault Injection." In *Proceedings of the 2015 ACM SIGMOD International Conference on Management of Data, Melbourne, Victoria, Australia, May 31 - June 4, 2015*, edited by Timos K. Sellis, Susan B. Davidson, and Zachary G. Ives, 331–46. ACM. https://doi.org/10.1145/2723372.2723711.

Kingsbury, Kyle, and Peter Alvaro. 2020. "Elle: Inferring Isolation Anomalies from Experimental Observations." *CoRR* abs/2003.10554. https://arxiv.org/abs/2003.10554.