Using Time Travel to Avoid Bugs and Failures in SDN Applications

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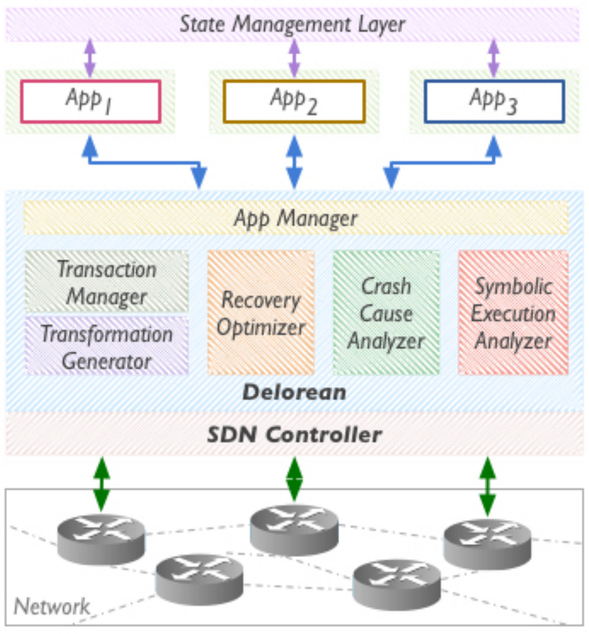
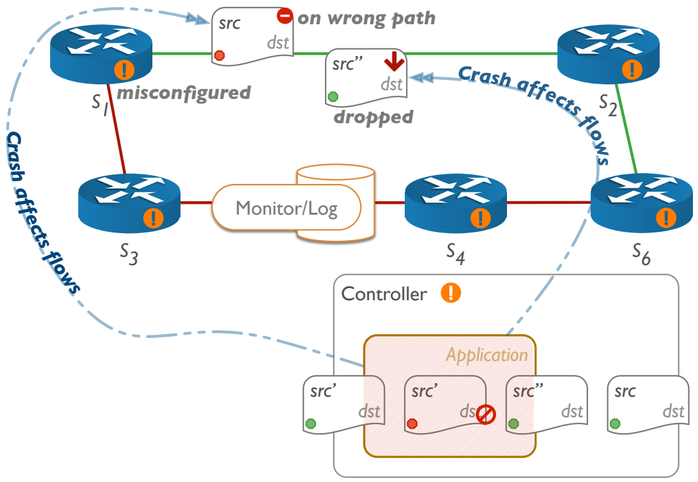
Problem

How to devise an online technique to safely and systematically circumvent a bug that manifests even in a well- designed and well-tested real applications running in a production environment?

- Bugs are *endemic* in real applications.
- Network outages cost *$1000s* per minute.
- SDN controllers *do not tolerate* application failures.
- Simple failover strategies suffer from **deterministic** faults.





Design

Delorean provides a *quick, safe, online* recovery of the real applications, even in case of **deterministic** faults.

Key insight: Discover a set of possible code paths (i.e., path through the source code indicating the control flow) and drive the execution away from the crash path.

- **App Manager**: *Record messages* sent from/to the applications.
- **Transaction Manager**: *Enable rollback* of both control and data plane.
- **Transformation Generator**: *Generate transformations* for a given event.
- **Recovery Optimizer**: *Rank the transformations* for efficient tests.
- **Crash Cause Analyzer**: *Find the crash cause* that changes the code path to the crash path, ie. It changes the state and its previous events do not fall into the crash path.
- **Symbolic Execution Analyzer**: *Build the execution tree*, which comprises all code paths, to help circumvent the crash path.

Workflow

When a crash happens:

1. Determine the *crash path* and the *crash cause*.
2. Produce *transformations* of the crash cause and rank them.
3. *Restart* the application and restore its states.
4. *Inject* a set of transformed events.
5. If current transformation fails, resume from (3) with the next one. If all transformations are exhausted, revert to (1) to find another crash cause from an earlier instance of time.

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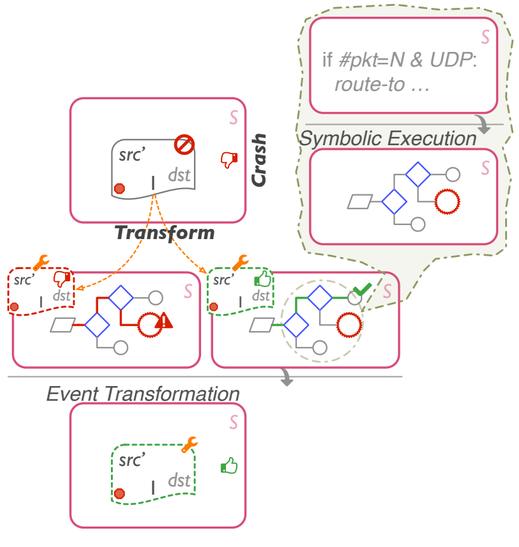


Challenges

Delorean addresses two fundamental challenges in crash recovery:

- Determine the precise input event to rollback.
- Determine the transformations to apply while minimizing recovery time and the likelihood of another crash.

Takeaway: Delorean aims to recover from both deterministic and non-deterministic bugs of real applications based on the insights provided by symbolic execution.

Evaluation

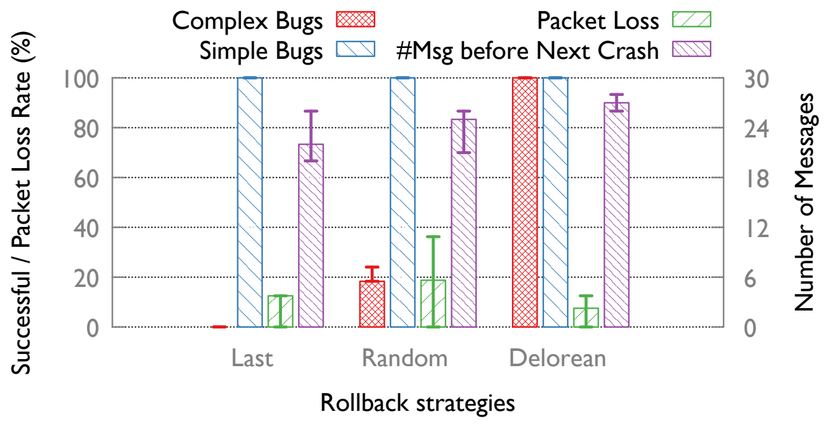
Experiment Setup:

Data plane: Mininet and simple traffic generators.

Control plane: Realistic Floodlight applications.

Key takeaways:

- Naive rollback strategies do not suffice for complex failures; *a more principled approach* is required.
- Delorean performs *better and faster* than naive strategies such as controller reboot or application reboot (both of which are similar to “last” in the figure).
- The time for symbolic execution does increase with more code paths, while *not significantly*: 2.33s, 2.61s and 2.78s for Hub (1 path), Learning Switch (9 paths) and Hedera (13 paths), respectively.



*Simple bugs refer to the bugs triggered only by the code while the complex ones also depend on the input.