

Experiences with Pip: Finding Unexpected Behavior in Distributed Systems

Patrick Reynolds
Duke University

Janet Wiener
Jeff Mogul
Mehul Shah
HP Labs

Amin Vahdat
Charles Killian
UCSD

Overview

- Many bugs reflect discrepancies between actual and expected system behavior
 - Structural – incorrect order or placement of processing and/or communication
 - Performance – resource consumption or delays higher or lower than expected
- Pip reports behavior that violates expectations – potential bugs
- To use Pip, the programmer writes:
 - *Expectations*– external, declarative description of expected system behavior
 - *Annotations*– additions to system source code to trace relevant activity

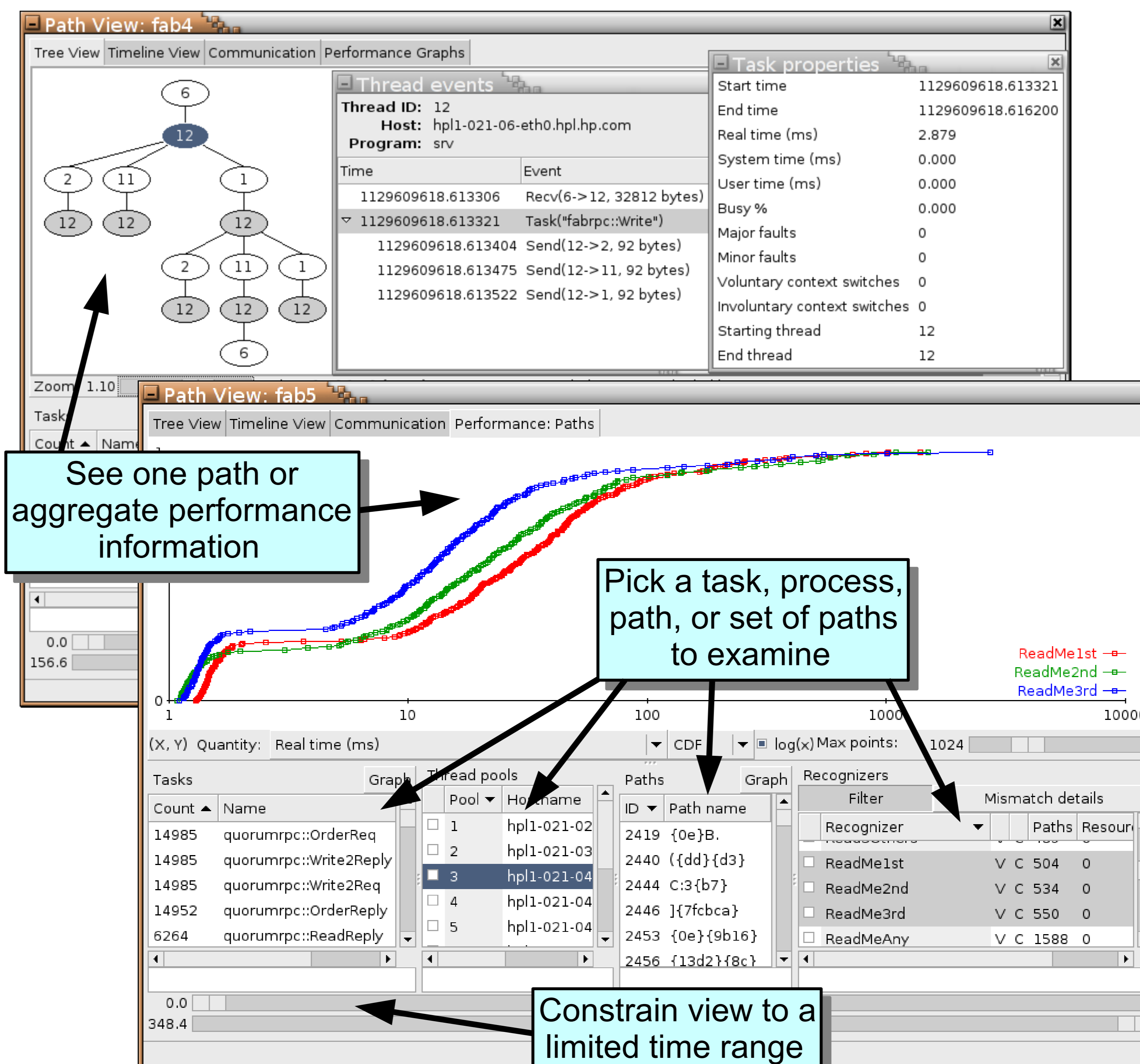
Bugs found

- **SplitStream**
 - 13 structural bugs found
 - 11 found using expectations
 - 2 found in the GUI
 - 7 were many months old
- **FAB**
 - 4 protocol implementations checked
 - 1 performance bug found
- **RanSub**
 - 2 bugs found
 - One performance, one structural
 - One found using expectations, one in the GUI

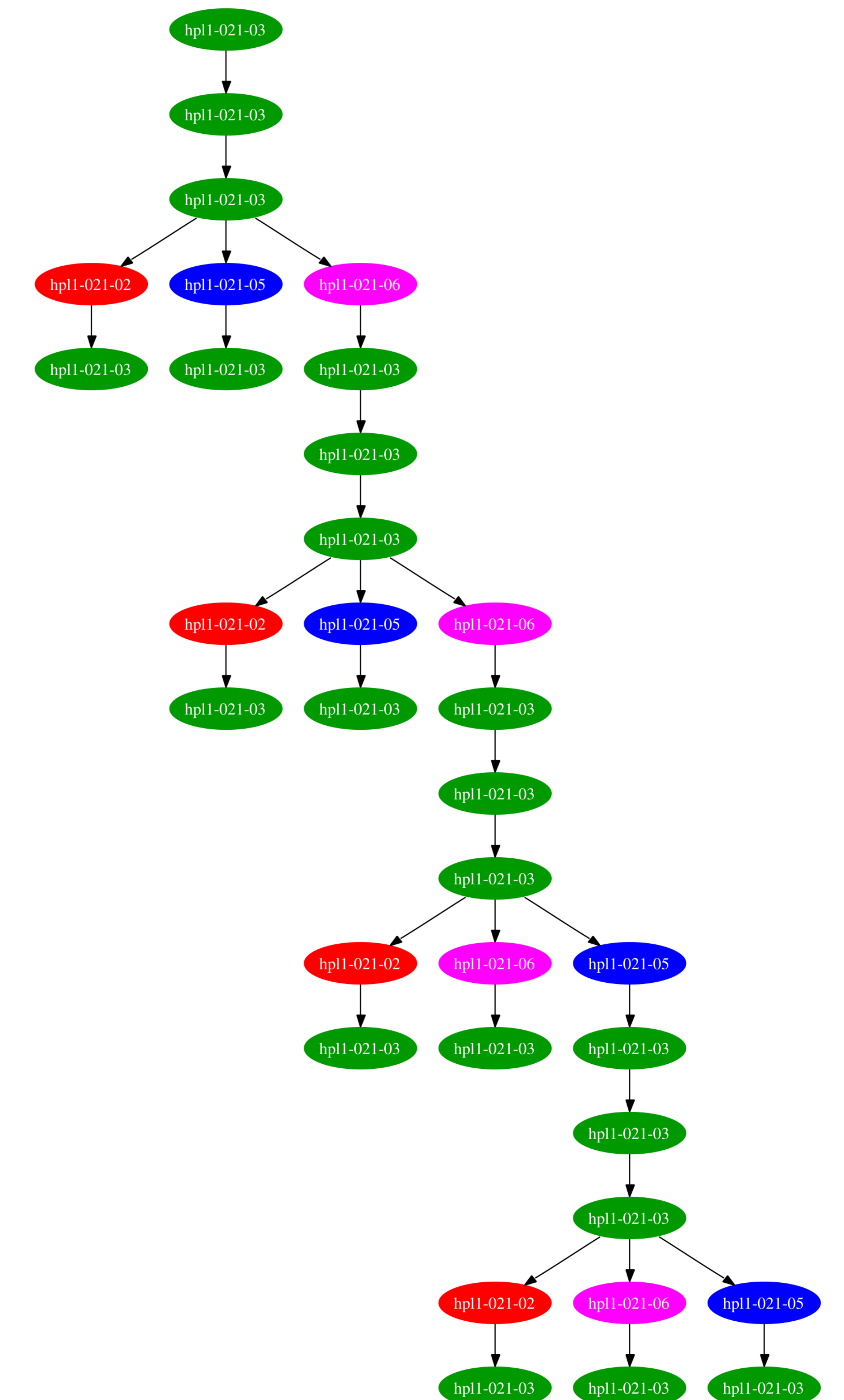
```

validator Read3Others
limit (VOL_CS, 0);
threadClient(*, 1)
    send (Coordinator) limit (SIZE, {=44b});
    recv (Coordinator);
threadCoordinator(*, 1)
    recv (Client) limit (SIZE, {=44b});
    task ("fabrpc::Read")
        repeat 3 send (Peer);
        repeat 2
            recv (Peer);
            task ("quorumrpc::ReadReply");
        future // happens now or later
            recv (Peer);
            task ("quorumrpc::ReadReply");
        send (Client);
threadPeer(*, 3)
    recv (Coordinator);
    task ("quorumrpc::ReadReq")
        send (Coordinator)
    
```

Expectation for the FAB read protocol



Exploring FAB Read and Write paths



Structural visualization: FAB Paxos protocol

Expectations

- Expectations describe how to recognize and classify paths
- Separate from application source code
- Expectations can be generated automatically
- Concise description of system behavior
- Reading it helps you understand the system, find bugs

Language design

- Goals
 - Match every valid path
 - Reject (almost) every invalid path
 - Keep life simple for the programmer