Property-Based Testing

Beijing 2023
Autumn School

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CHALMERS QuviQ

Why is testing hard?

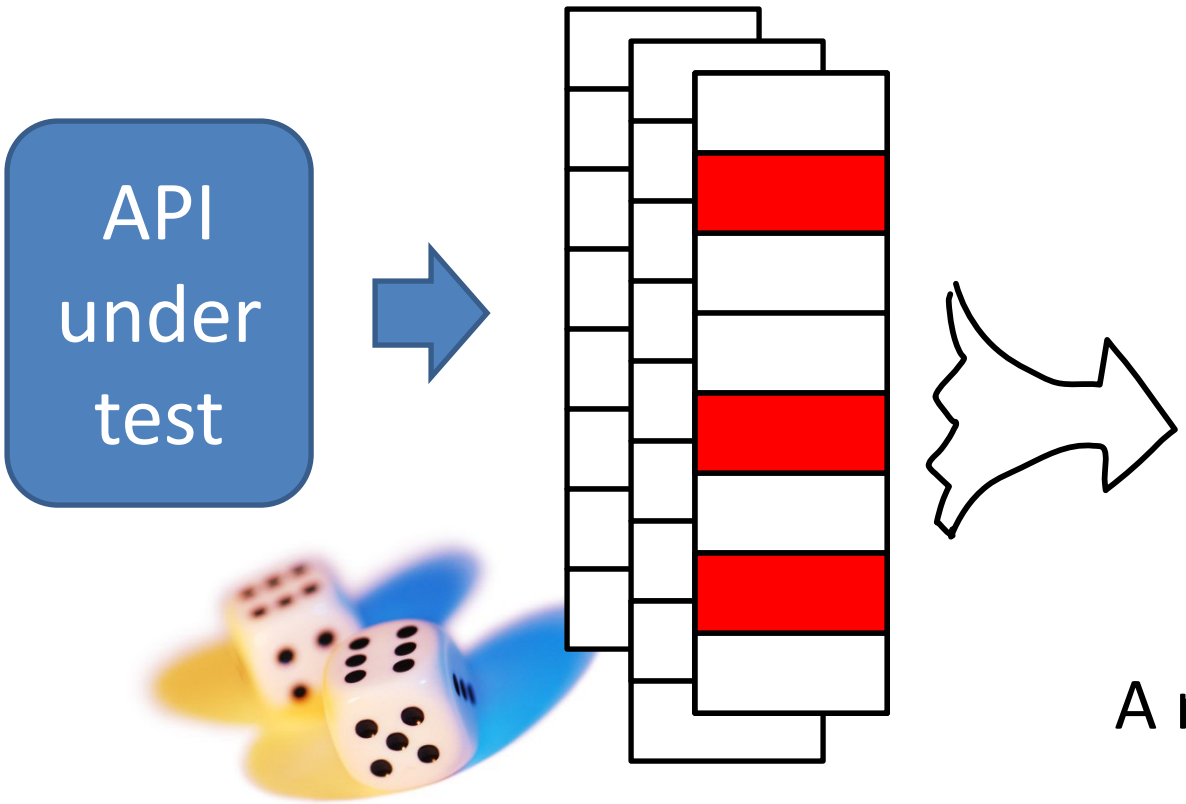
$O(n^3)$ test cases

3—4 tests per pairs of features

Don’t write tests!

Generate them

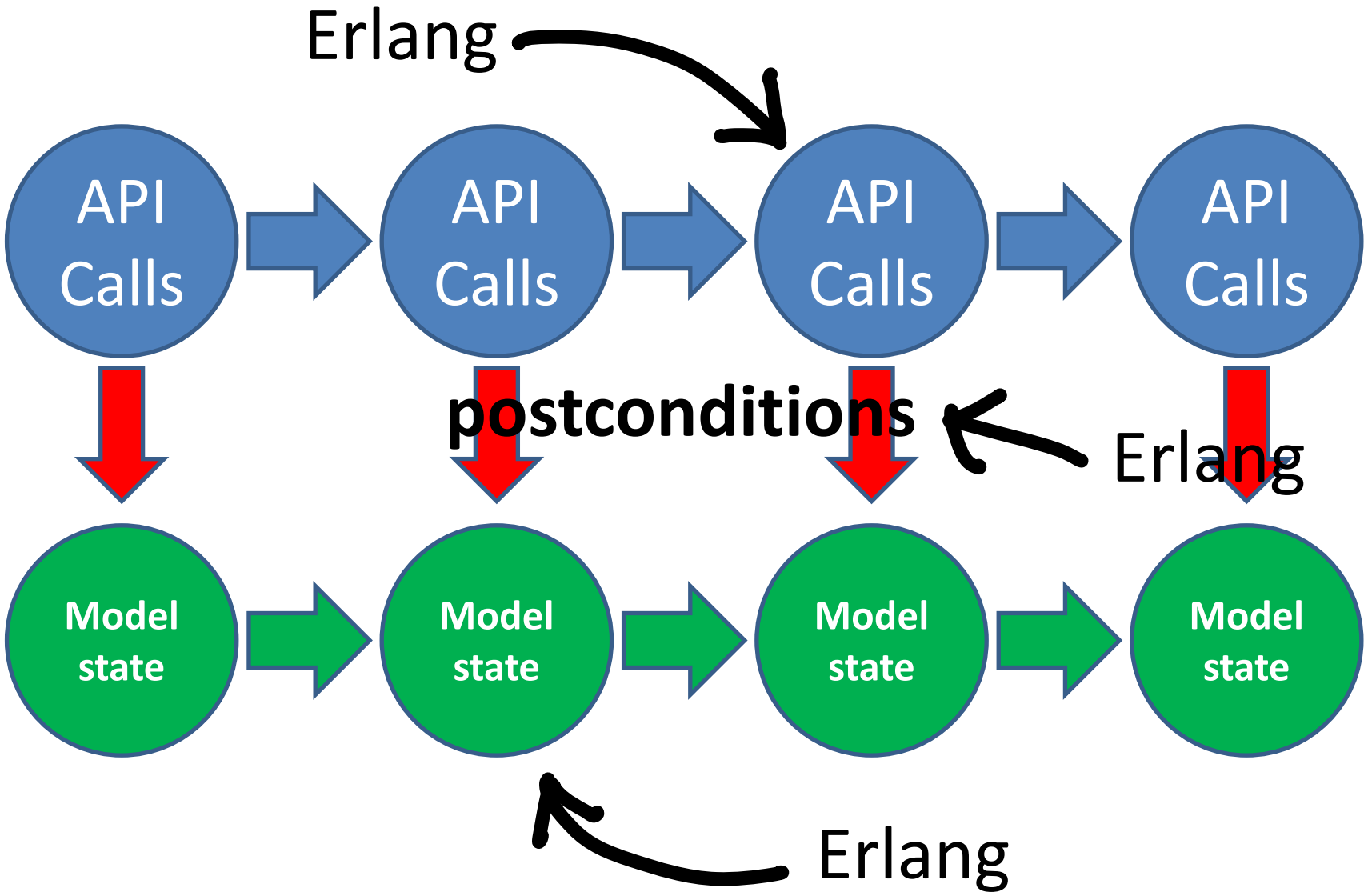
QuickCheck



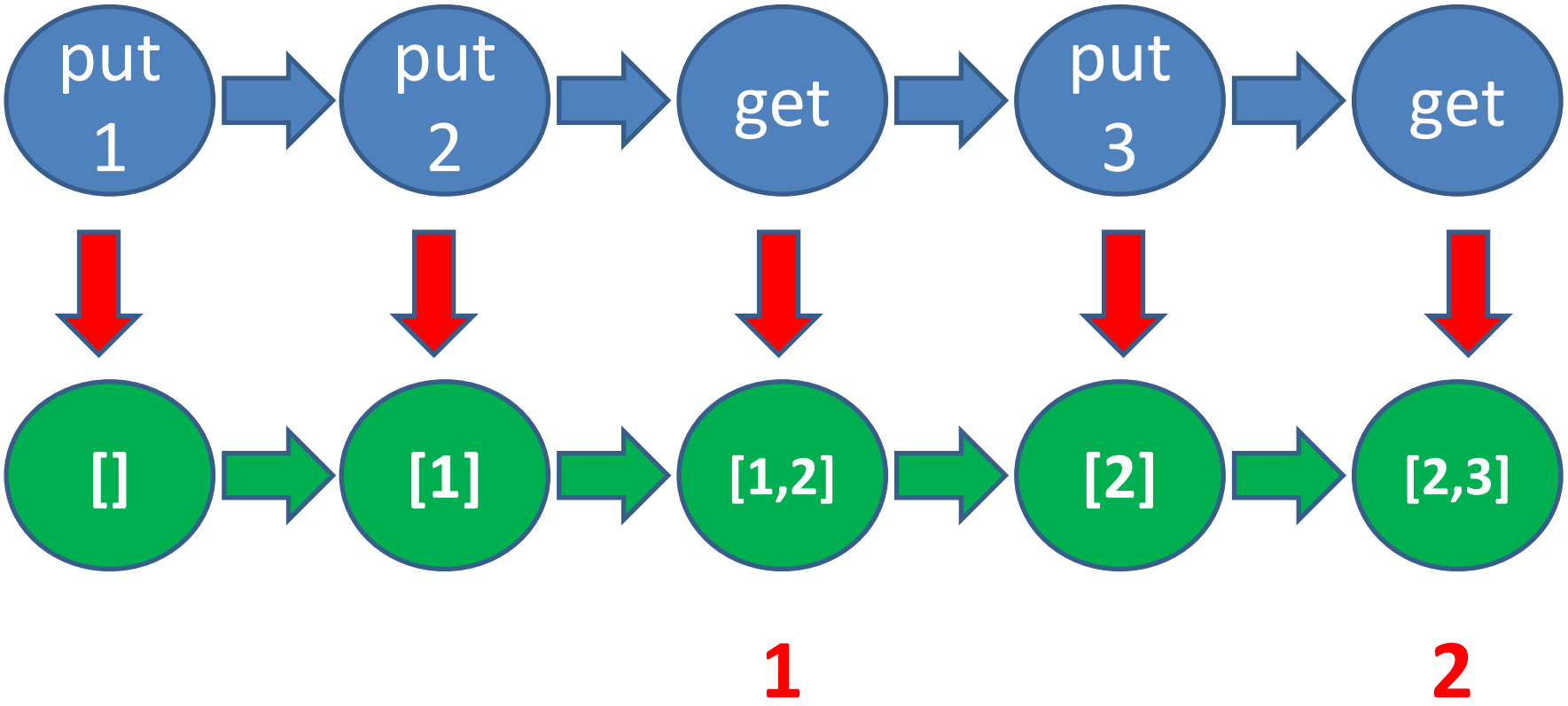
A minimal failing example

Example: a Circular Buffer

State Machine Models



Example



Code Fragments: specifying get

```
get_pre(S) ->
    S#state.ptr /= undefined andalso
        S#state.contents /= [].
```

Precondition

```
get_next(S,_Value,_Args) ->
    S#state{contents=tl(S#state.contents)}.
```

State transition

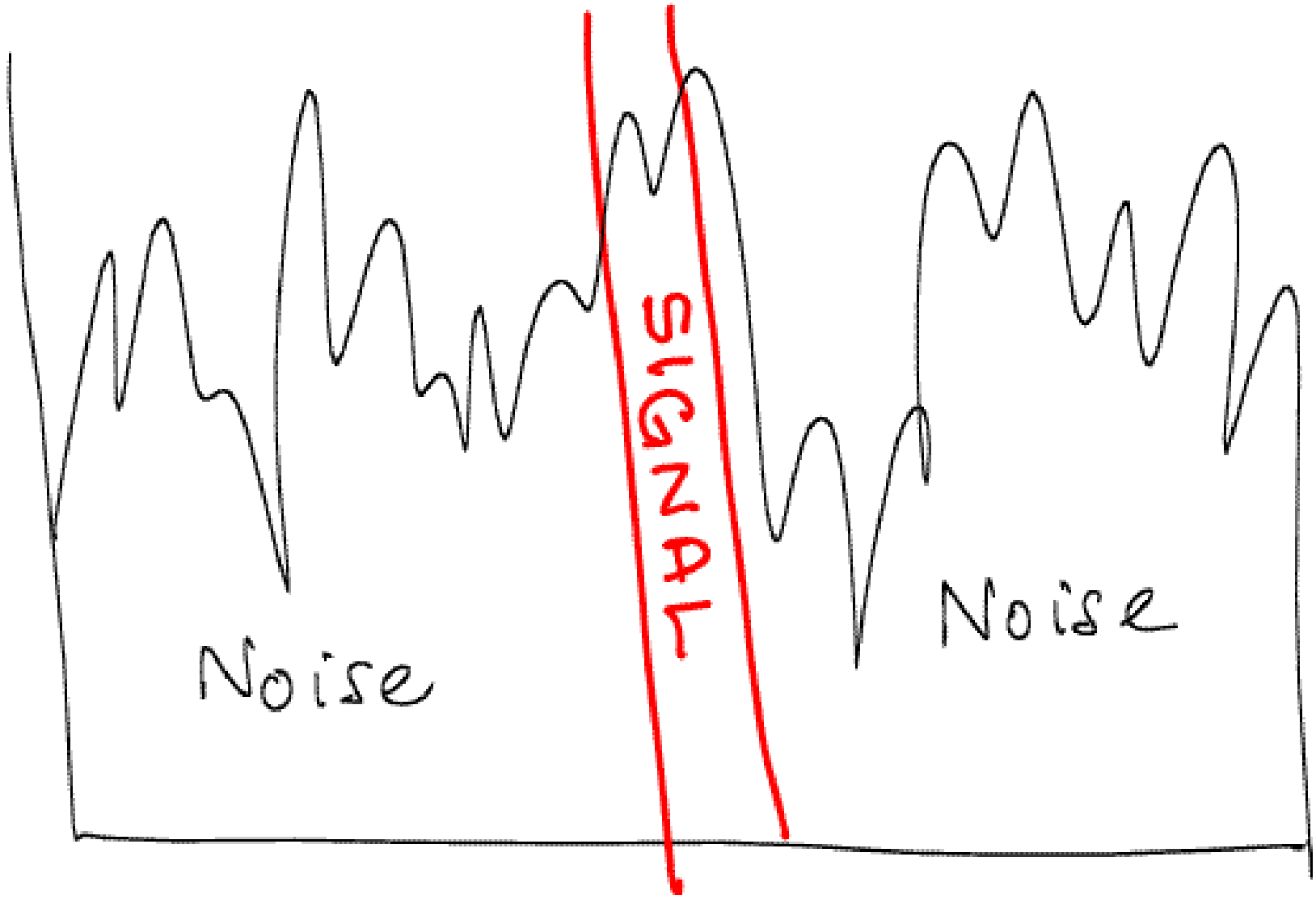
```
get_post(S,_Args,Res) ->
    eq(Res,hd(S#state.contents)).
```

Postcondition

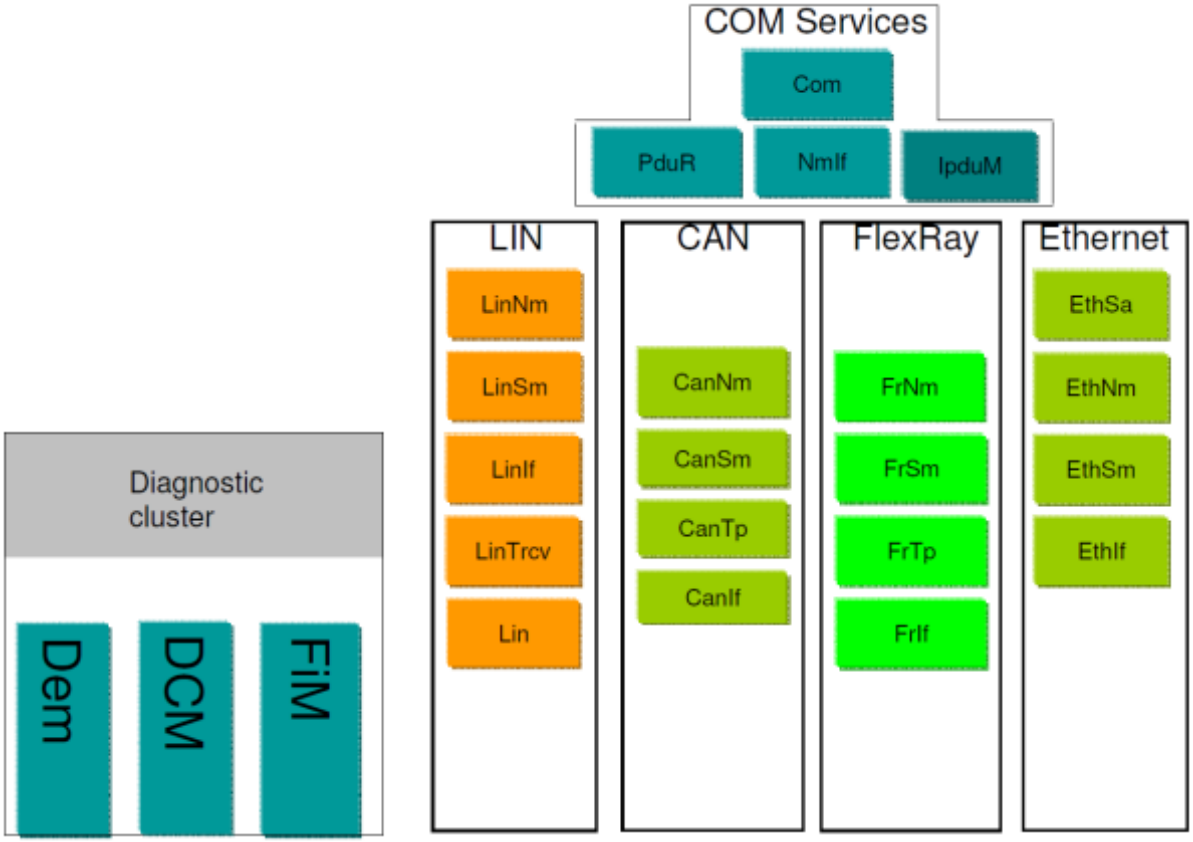
Time for some tests!

Lessons

- The *same* property can find *many* different bugs
- Minimal failing tests make diagnosis easy


SIGNAL
Noise
Noise

Doing it for real…



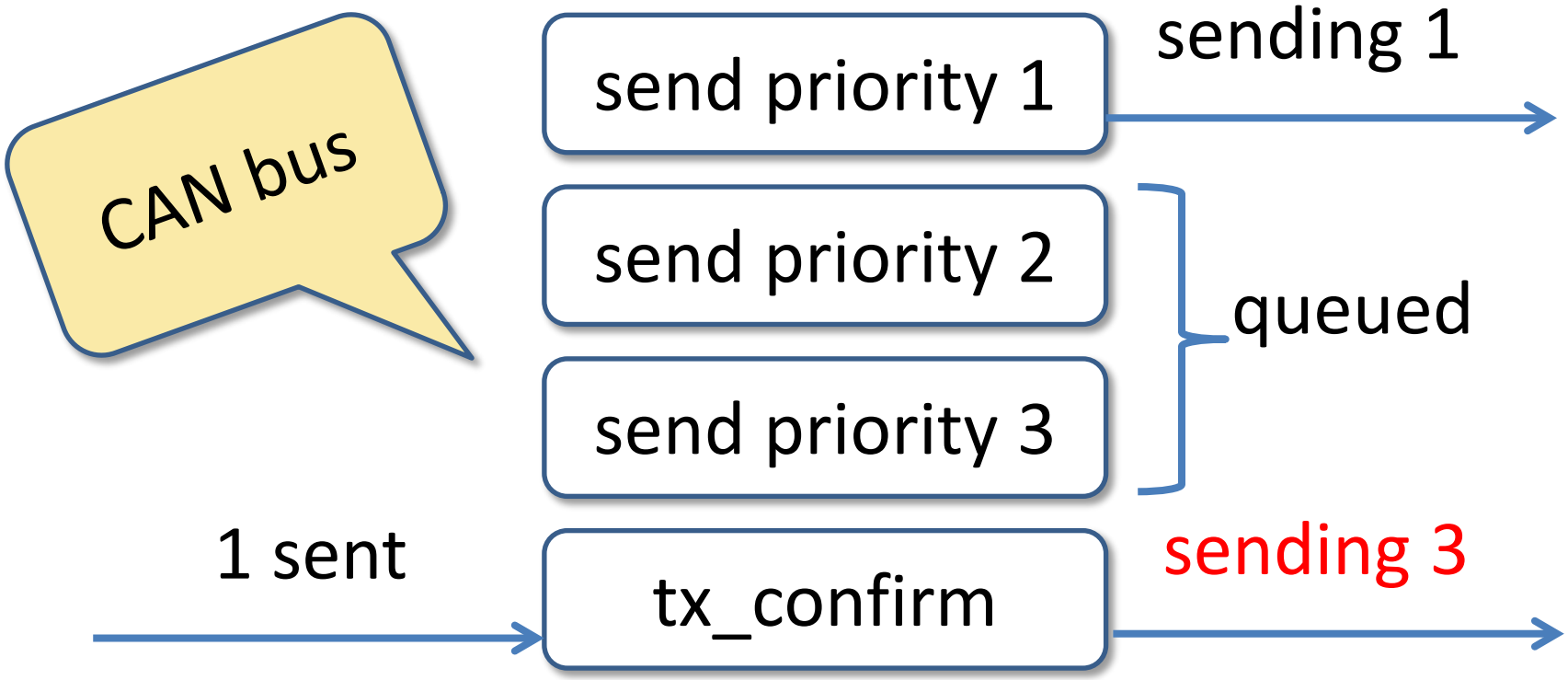
Theory

Car manufacturers should be able to buy code from different providers and have them work seamlessly together

Practice

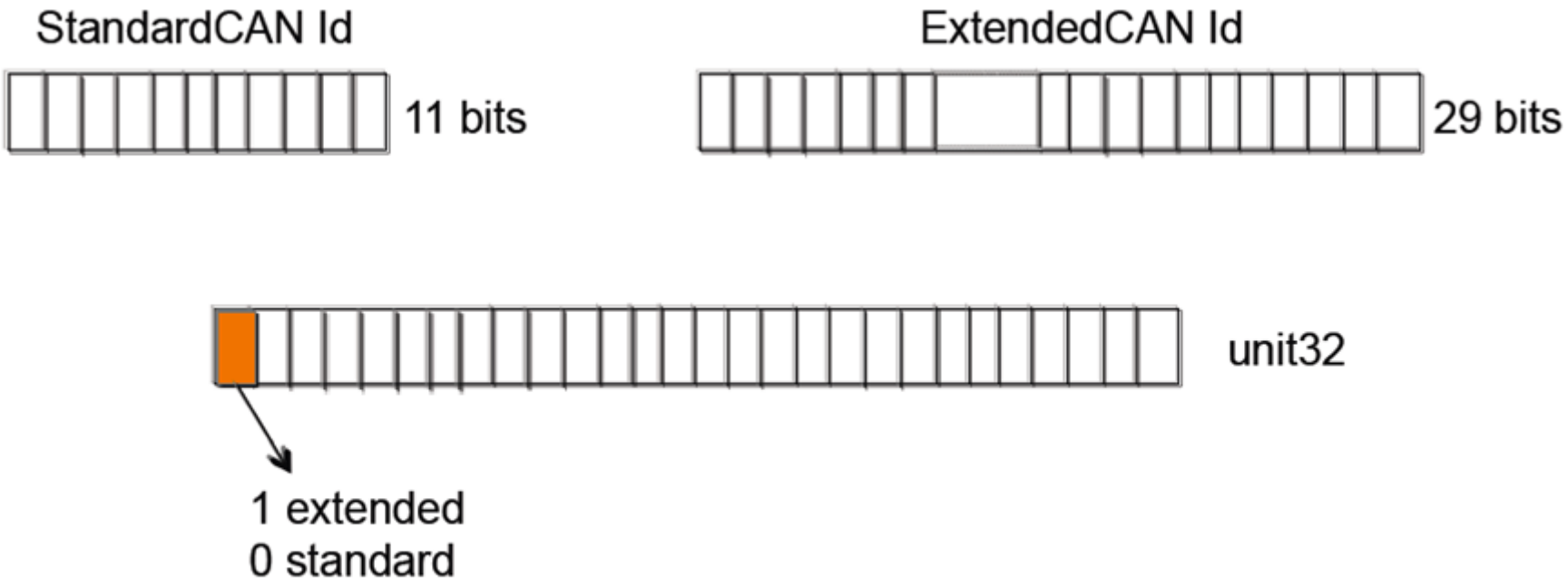
VOLVO's experience has been that this is often not the case

A Bug in a vendor's CAN stack

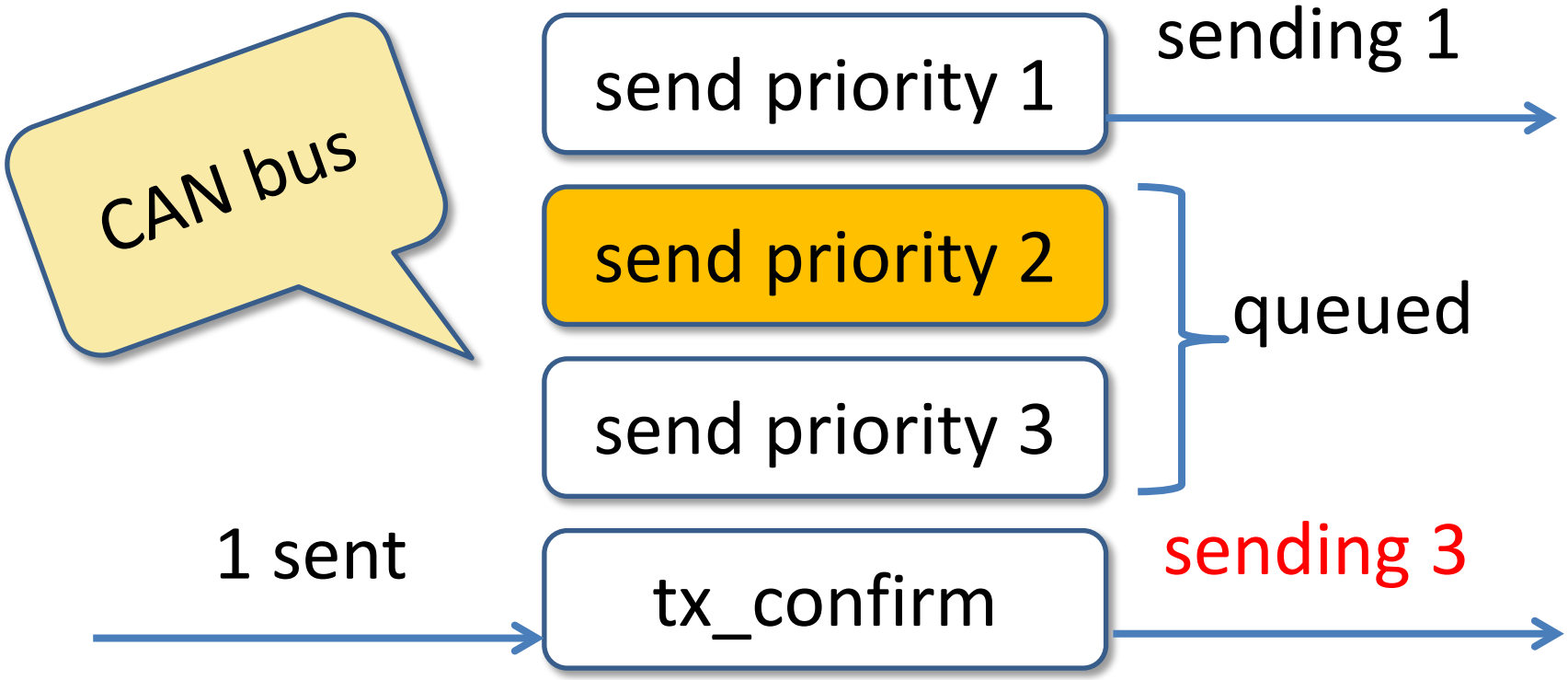


The Problem

CAN bus identifiers determine bus priority



A Bug in a vendor's CAN stack



Failed to mask off the top bit before comparing priorities

3,000 pages of specifications

20,000 lines of QuickCheck

1,000,000 LOC, 6 suppliers

200 problems

100 problems in the standard

10x shorter test code

"We know there is a lurking bug somewhere in the dets code. We have got 'bad object' and 'premature eof' every other month the last year. We have not been able to track the bug down since the dets files is repaired automatically next time it is opened.“

Tobbe Törnqvist, Klarna, 2007

What is it?

klarna

Invoicing services for web shops

Distributed database: transactions, distribution, replication

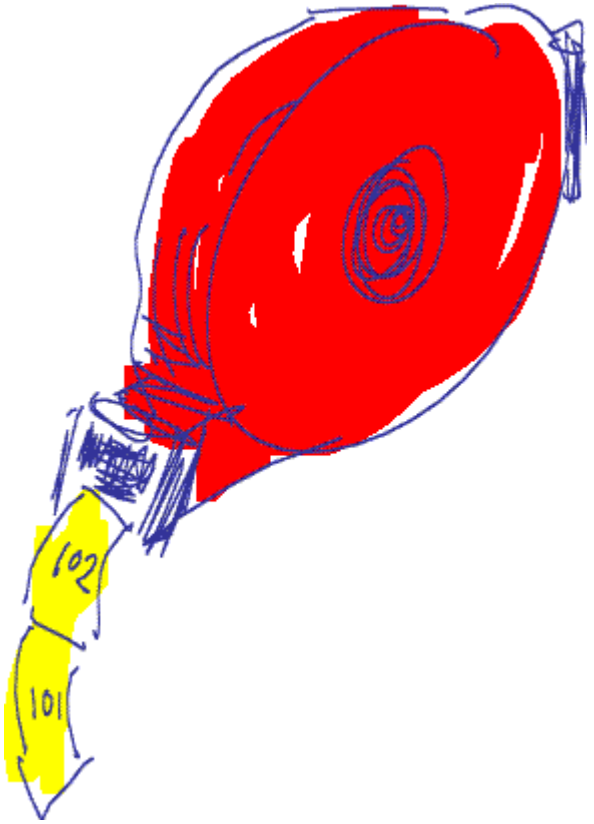
Tuple storage

Race conditions?

Imagine Testing This…

dispenser:take_ticket()

dispenser:reset()

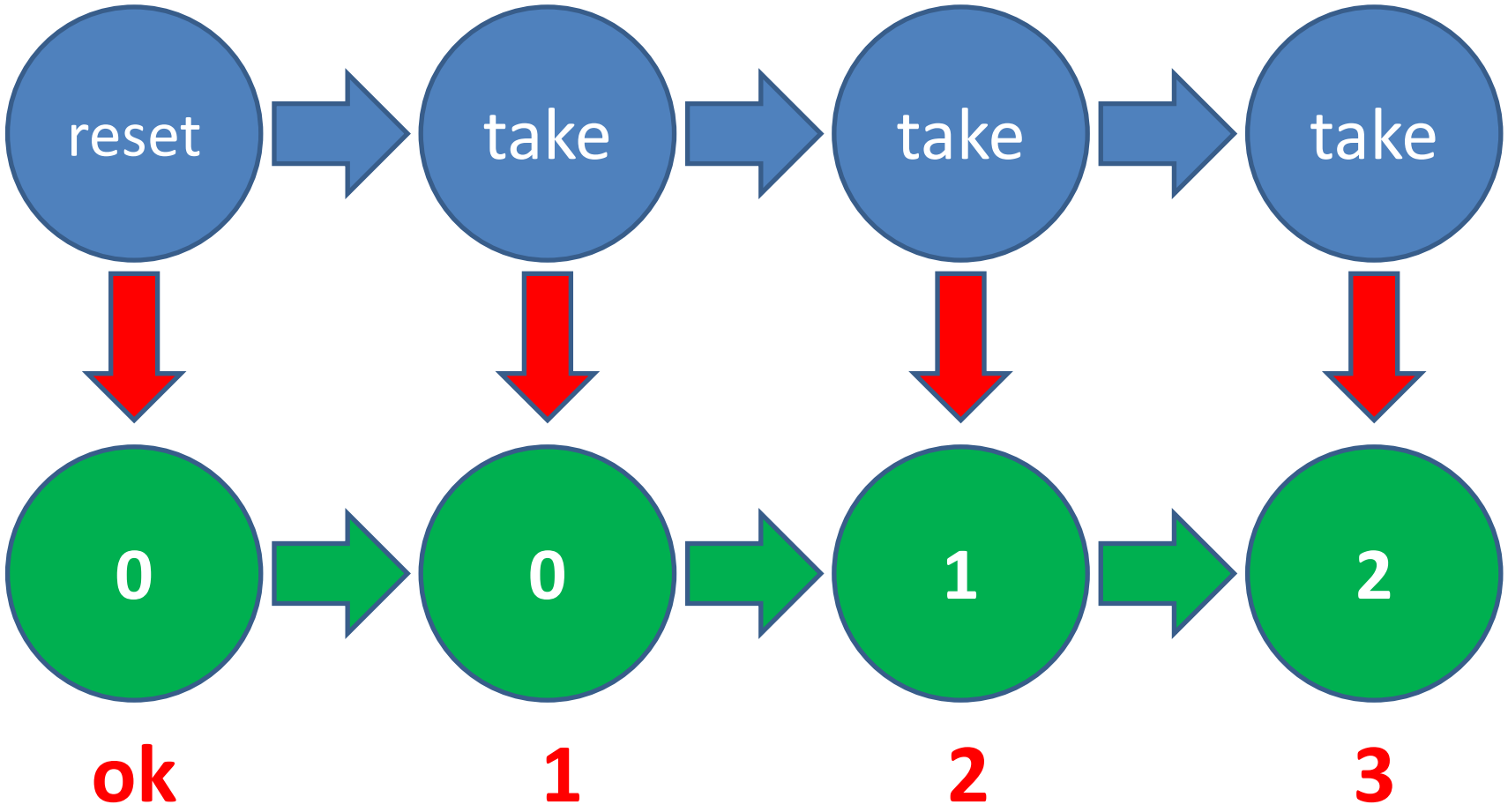


A Unit Test in Erlang

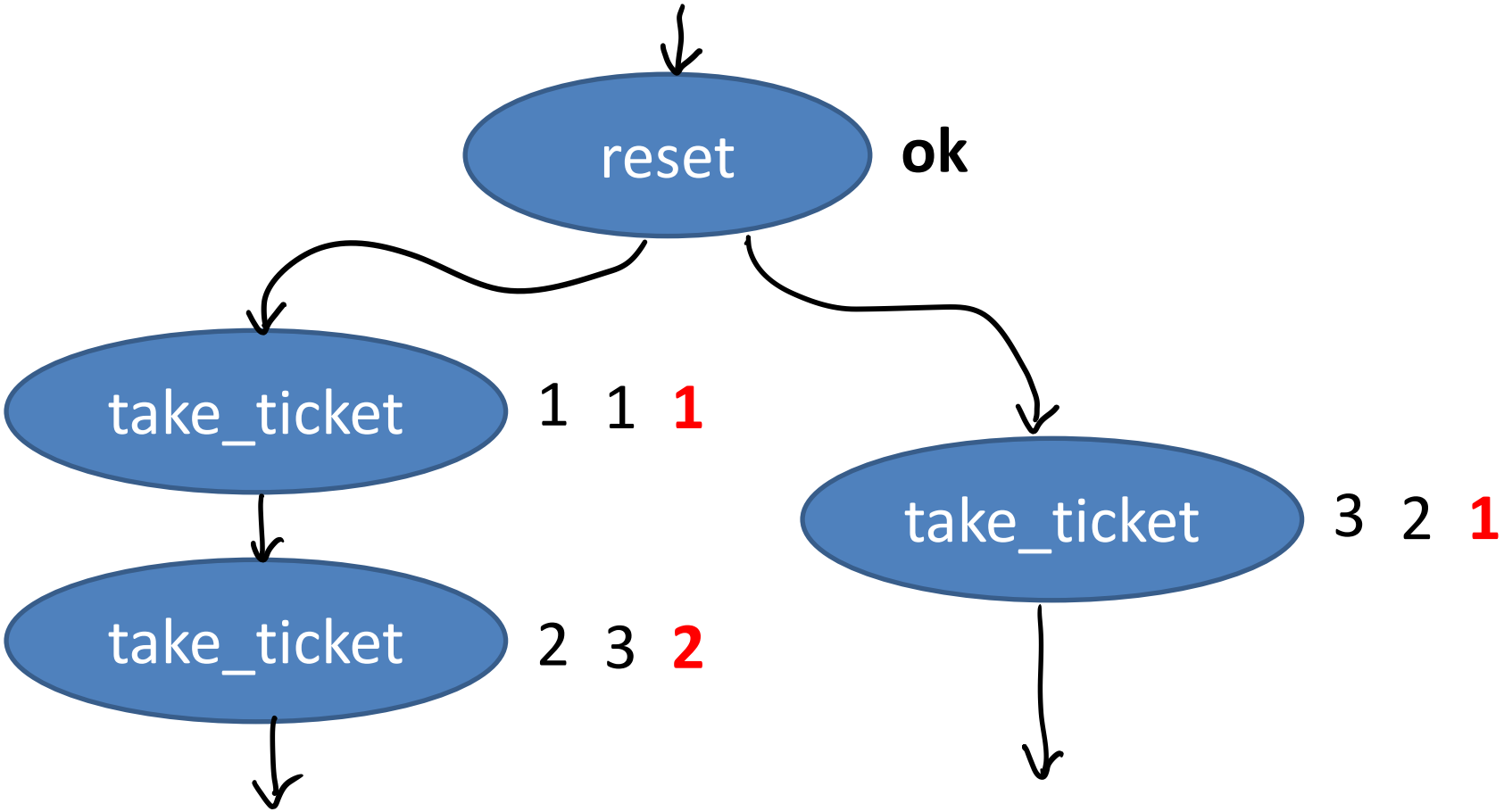
```
test_dispenser() ->
      ok =  reset(),
      1  =  take_ticket(),
      2  =  take_ticket(),
      3  =  take_ticket(),
      ok =  reset(),
      1  =  take_ticket().
```

Expected results

Modelling the dispenser

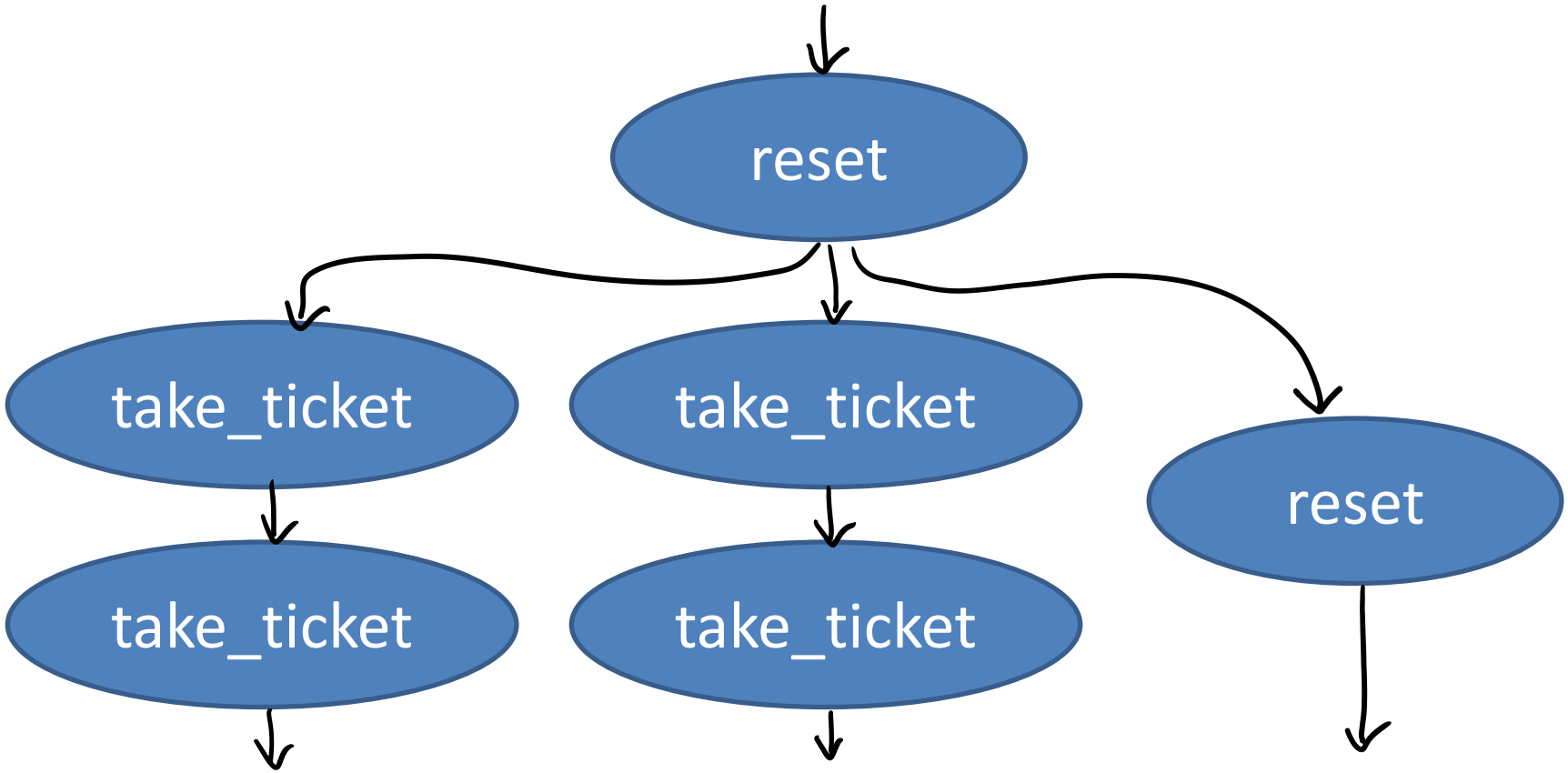


A Parallel Unit Test



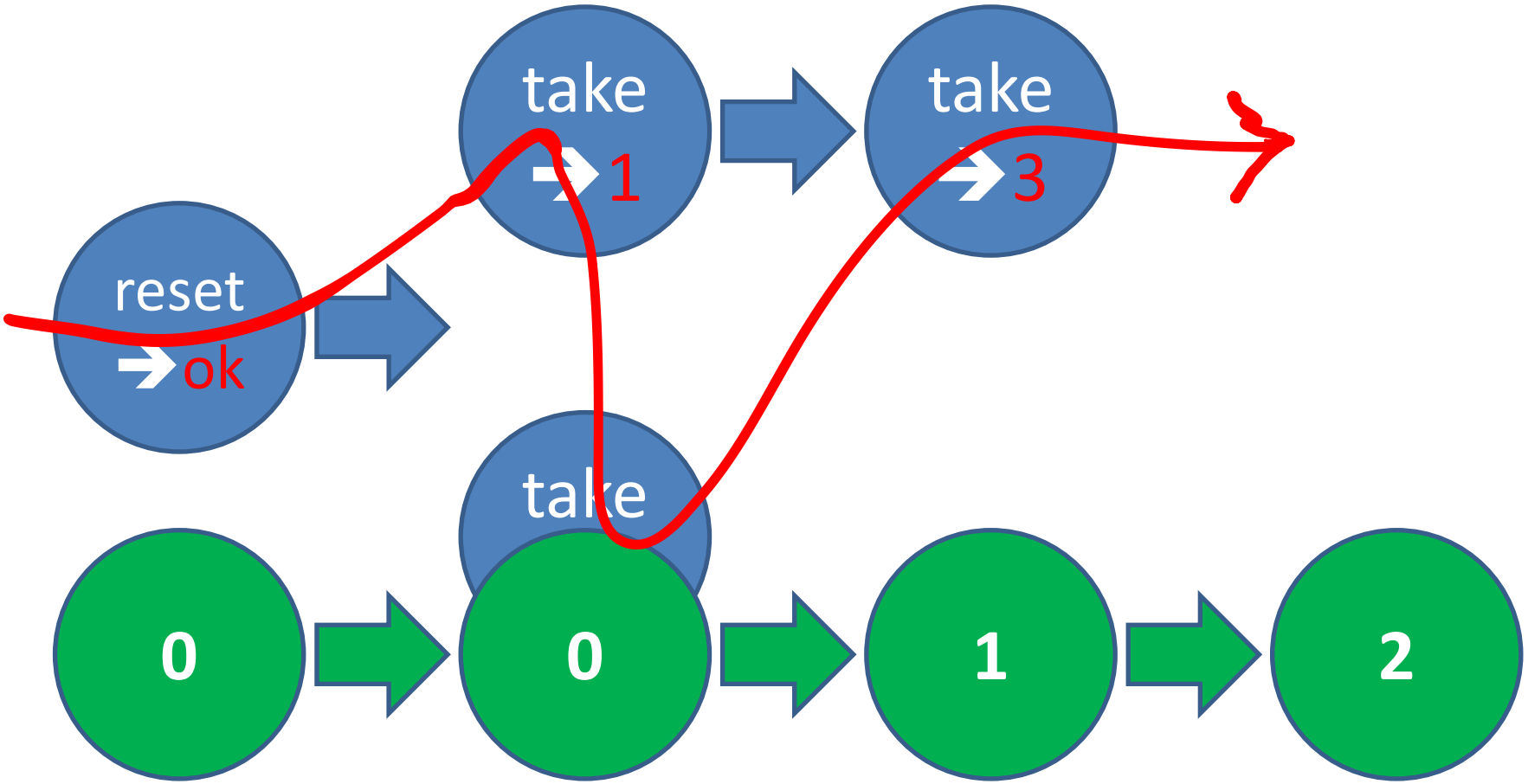
- Three possible correct outcomes!

Another Parallel Test



- 30 possible correct outcomes!

Deciding a Parallel Test



Let’s run some tests

```
take_ticket() ->
    N = read(),
    write(N+1),
    N+1.
```

Prefix:

Parallel:

1. dispenser:take_ticket() --> 1

2. dispenser:take_ticket() --> 1

Result: no_possible_interleaving

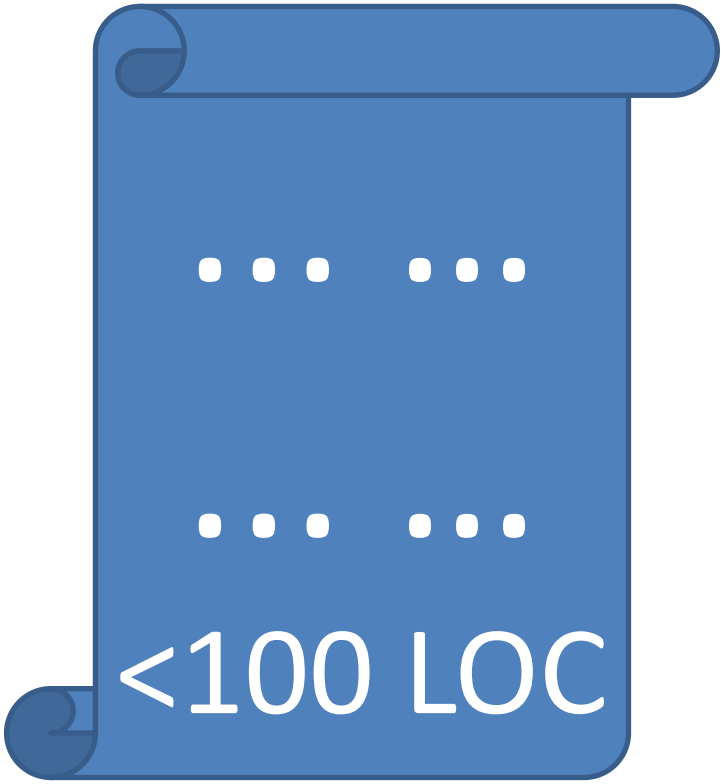
dets

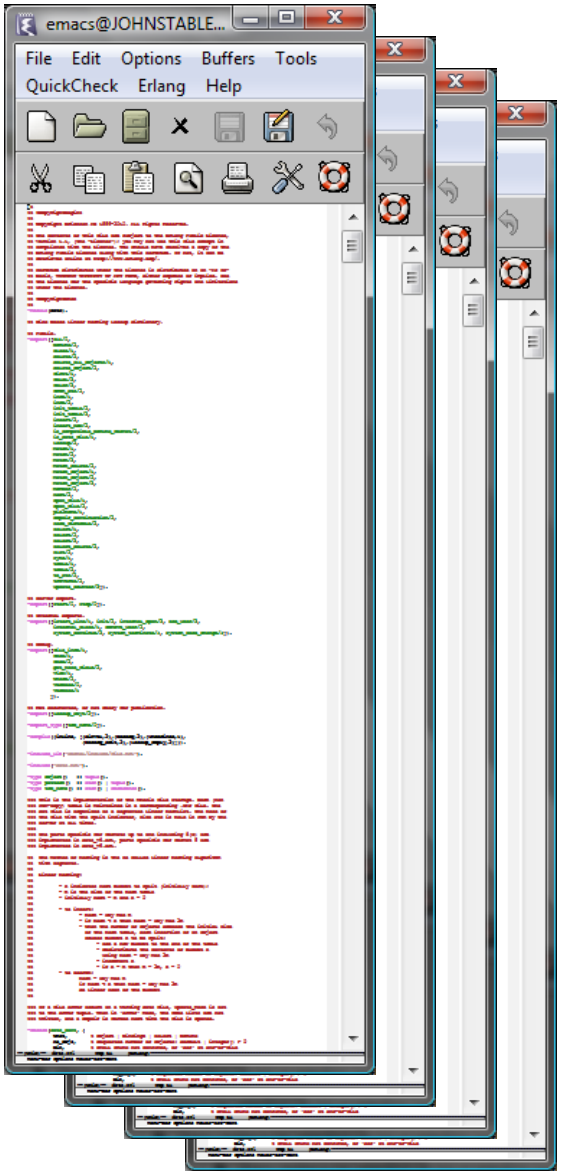
- Tuple store:

  {Key, Value1, Value2…}

- Operations:
  - insert(Table,ListOfTuples)
  - delete(Table,Key)
  - insert_new(Table,ListOfTuples)
  - …
- Model:
  - List of tuples (almost)

QuickCheck Specification





> 6,000 LOC

Bug #1

insert_new(Name, Objects) -> Bool

Types:
Name = name()
Objects = object() | [object()]
Bool = bool()

```
Prefix:
    open_file(dets

Parallel:
1. insert(dets_ta

2. insert_new(dets_table,[]) --> ok

Result: no_possible_interleaving
```

Bug #2

```
Prefix:
   open_file(dets_table,[{type,set}]) --> dets_table

Parallel:
1. insert(dets_table,{0,0}) --> ok

2. insert_new(dets_table,{0,0}) --> …time out…
```

=ERROR REPORT==== 4-Oct-2010::17:08:21 ===
** dets: Bug was found when accessing table dets_table

Bug #3

```
Prefix:
   open_file(dets_table,[{type,set}]) --> dets_table

Parallel:
1. open_file(dets_table,[{type,set}]) --> dets_table

2. insert(dets_table,{0,0}) --> ok
   get_contents(dets_table) --> []

Result: no_possible_interleaving
```

Is the file corrupt?

Bug #4

```
Prefix:
   open_file(dets_table,[{type,bag}]) --> dets_table
   close(dets_table) --> ok
   open_file(dets_table,[{type,bag}]) --> dets_table

Parallel:
1. lookup(dets_table,0) --> []

2. insert(dets_table,{0,0}) --> ok

3. insert(dets_table,{0,0}) --> ok

Result: ok
```

Bug #5

```
Prefix:
   open_file(dets_table,[{type,set}]) --> dets_table
   insert(dets_table,[{1,0}]) --> ok

Parallel:
1. lookup(dets_table,0) --> []
   delete(dets_table,1) --> ok

2. open_file(dets_table,[{type,set}]) --> dets_table

Result: ok
false
```

"We know there is a lurking bug somewhere in the dets code. We have got 'bad object' and 'premature eof' every other month the last year."

Tobbe Törnqvist, Klarna, 2007

Each bug fixed the day after reporting the failing case

Before

- Files over 1GB?
- Rehashing?
- > 6 weeks of effort!

After

- Database with *one* record!
- 5—6 calls to reproduce
- < 1 day to fix

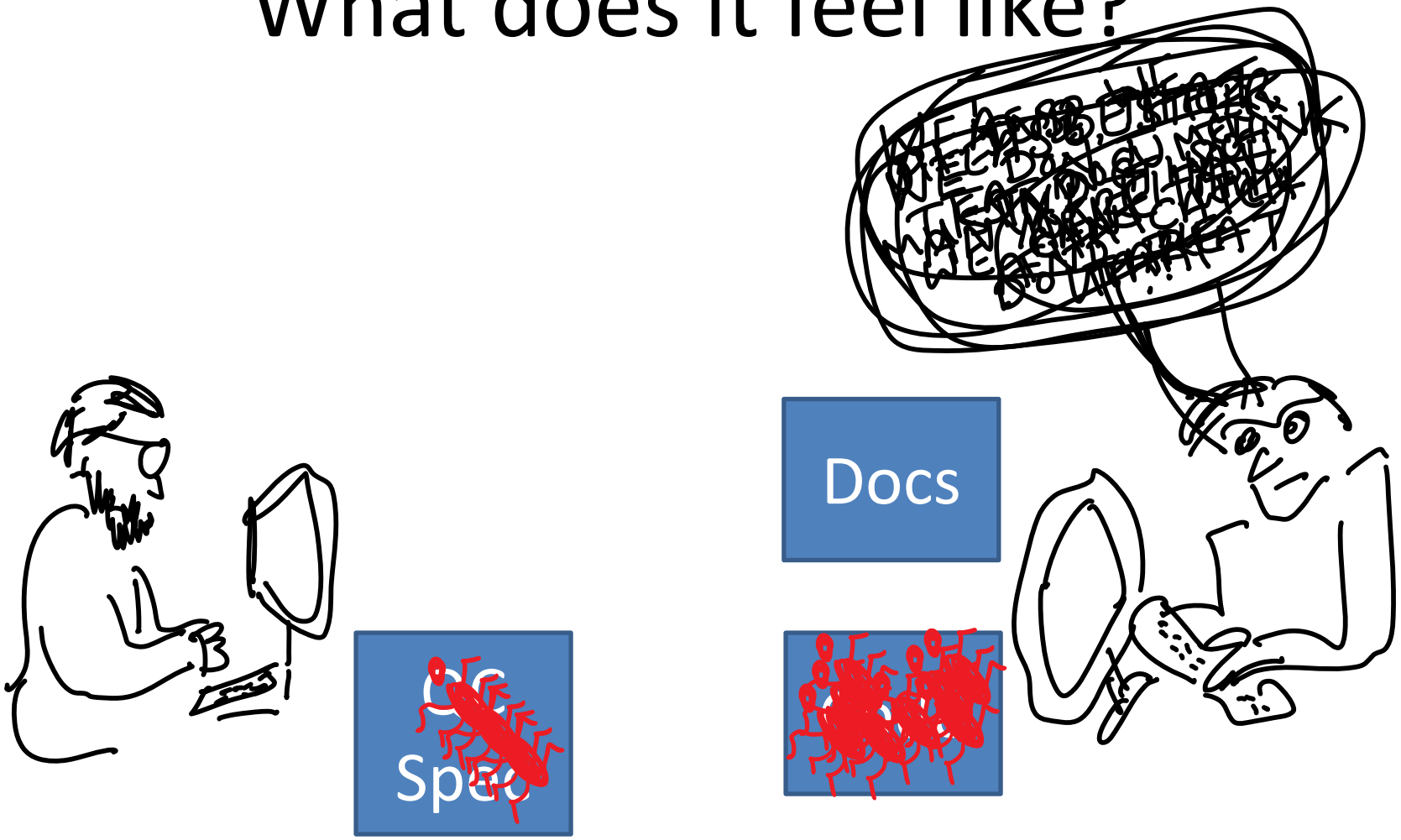
Property Based Testing

…finds more bugs with less effort!

Don’t *write* tests…

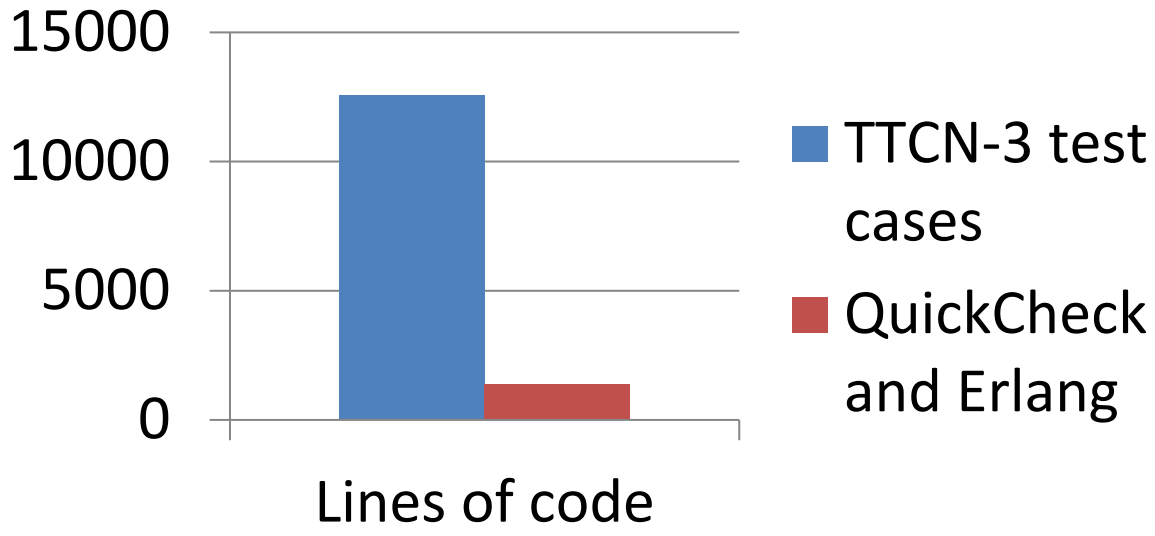
Generate them!

What does it feel like?



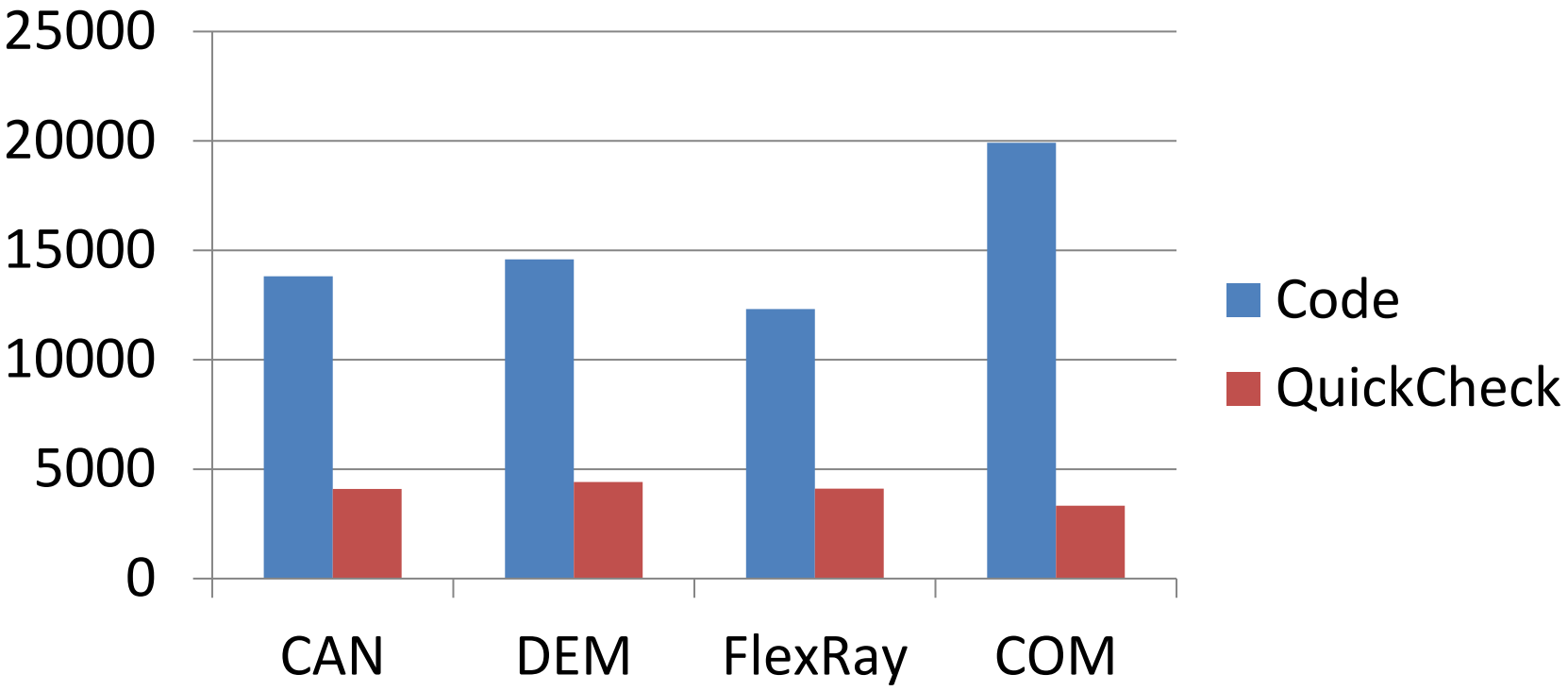
Properties vs test cases

Code sizes for the Flexray interface:



9x smaller code! …and it tests more!

Properties vs implementations



- The test code is 3—6x smaller than the implementation