Metha:
Network Verifiers Need To Be Correct Too!

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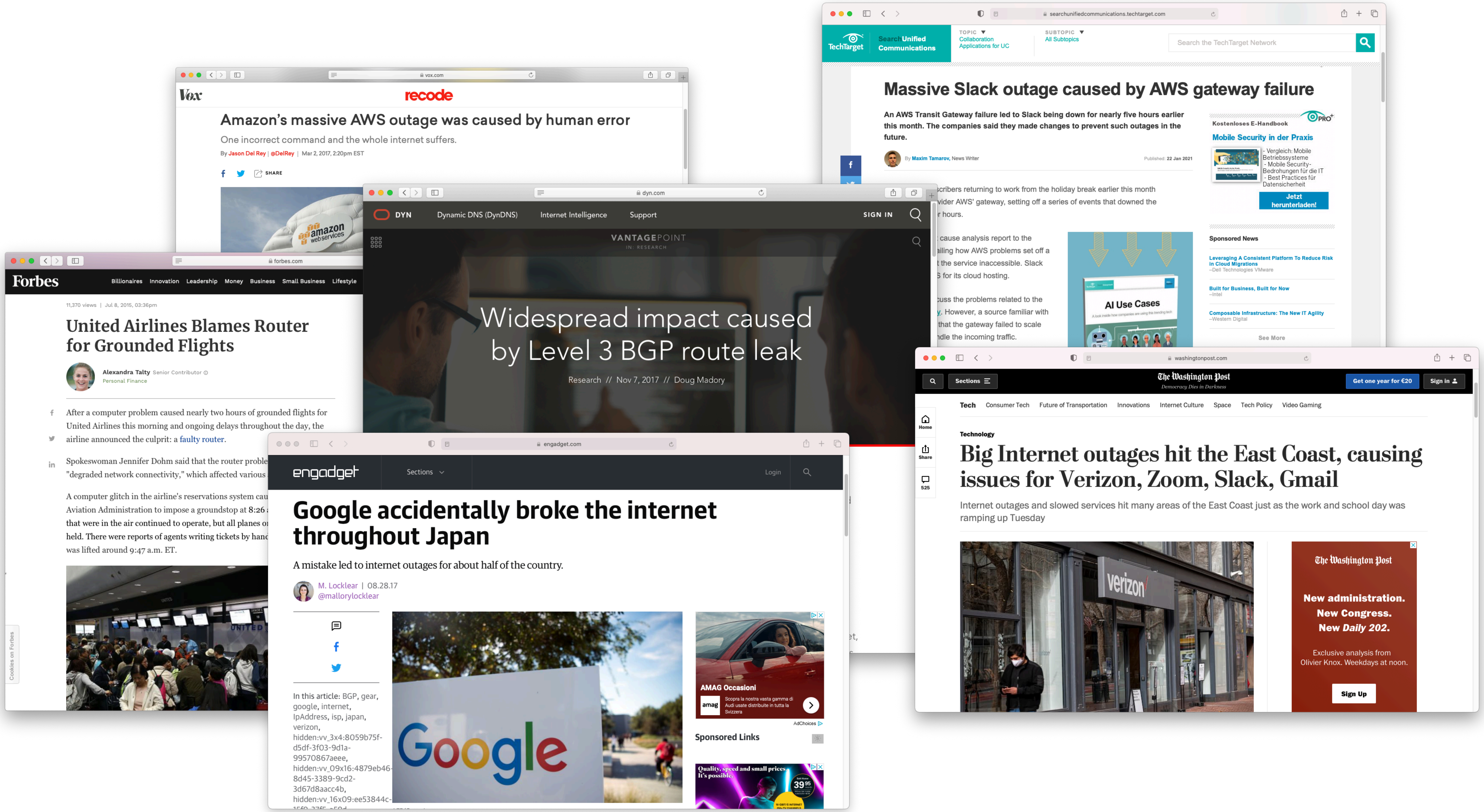
With the rise of network analysis and verification tools, network outages should soon be a relic of the past...



With the rise of network analysis and verification tools, network outages should soon be a relic of the past…

…provided these tools make no mistakes

Building an accurate network analysis tool is extremely difficult (…if not impossible)

one has to accurately capture

all protocols and their features

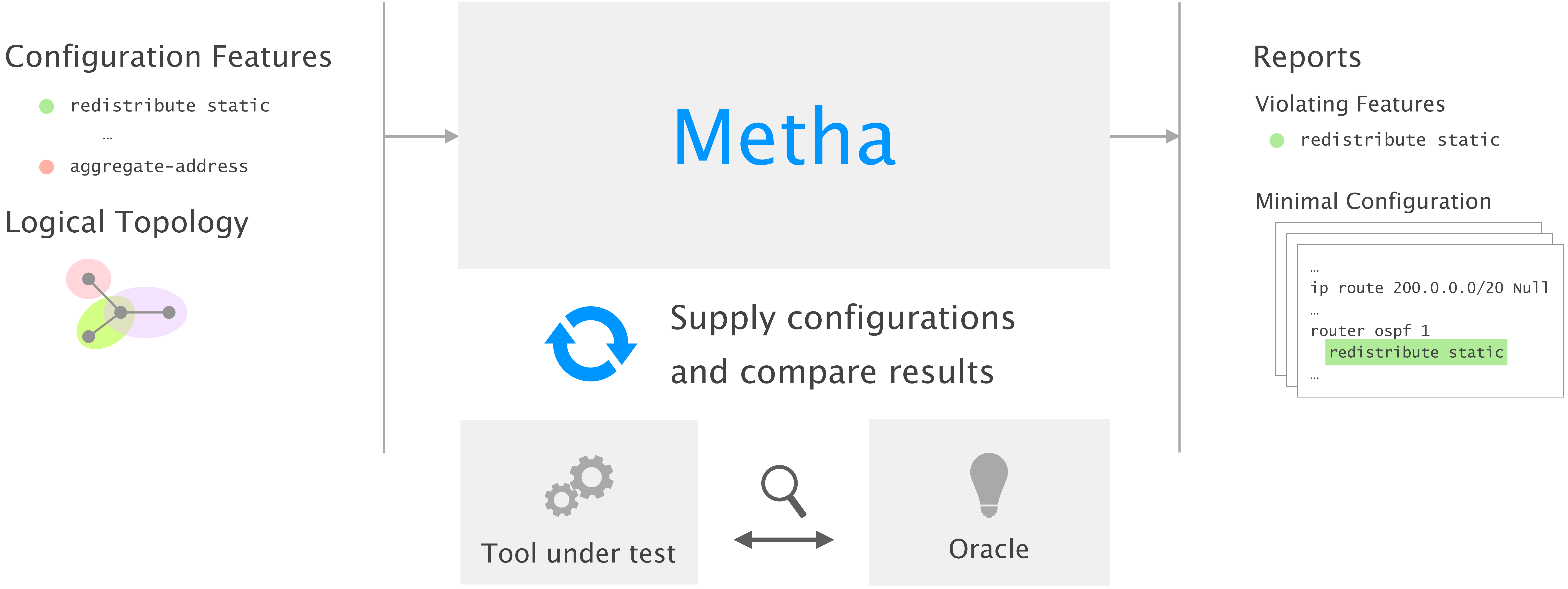
BGP, OSPF, IS-IS, EIGRP, …

for all vendors, devices and OSes

Cisco, Juniper, Arista, …

How can we help building accurate tools?

Metha systematically tests network analysis tools through automated configuration generation



Metha: Automated Testing of Network Analyzers

1. **Sensible configurations**
   satisfying configuration dependencies

2. **Systematic exploration**
   covering the search space thoroughly

3. **Evaluation**
   finding bugs in the wild

Metha: Automated Testing of Network Analyzers

1 **Sensible configurations**

satisfying configuration dependencies

Systematic exploration

covering the search space thoroughly

Evaluation

finding bugs in the wild

For effective testing, configurations must be syntactically and semantically valid

configs need to	adhere to a configuration syntax such that the devices/tools can parse them
	be consistent and coherent such that used resources are also defined
	allow for control-plane computations such that routes are exchanged

Metha takes a two-stage approach to generate semantically valid configurations

```
interface FastEthernet0/0
  ip address 1.1.1.1/24
!
router bgp 100
  distance bgp 100 100 100
  redistribute static
  neighbor 1.1.1.2 remote-as 50
  neighbor 1.1.1.2 route-map XYZ out
  neighbor 1.1.1.2 next-hop-self
!
route-map XYZ permit 10
  match ip address prefixList
!
```

define a base configuration

set up basic infrastructure

provision resources

randomly add config features

activate features

choose parameters

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The search space of all configurations is prohibitively large

```
interface FastEthernet0/0
  ip address 1.1.1.1/24
!
router bgp 100
  distance bgp 100 100 100
  redistribute static
  neighbor 1.1.1.2 remote-as 50
  neighbor 1.1.1.2 route-map XYZ out
  neighbor 1.1.1.2 next-hop-self
!
route-map XYZ permit 10
  match ip address prefixList
!
```

~16.5 million different options

To cope with the huge search space
Metha restricts it to few representative configurations

#1 **boundary value reduction**

restrict parameter values

#2 **combinatorial testing**

restrict feature combinations

#1 boundary value reduction

restrict parameter values

#2 combinatorial testing

restrict feature combinations

For every parameter, Metha considers only few representative values

boundary value reduction

reduces all parameters to boundary values

minimum, middle and maximum

restricts the space by orders of magnitude

8bit int needs 3 values instead of 256

helps to actively test all features

unlike randomly choosing the values

#1 boundary value reduction

restrict parameter values

#2 combinatorial testing

restrict feature combinations

Metha creates a test suite that covers all pairwise feature interactions

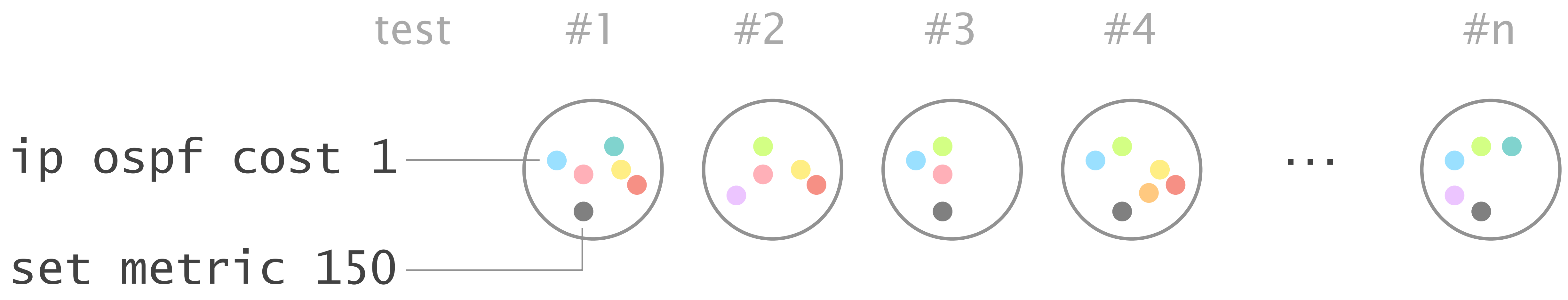
combinatorial testing

defines a testing strategy,

which is the input for config generation

tests pairwise feature interactions,

but considers all of these interactions



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Question #1

Does Metha manage to find real bugs?

Question #2

How do the components contribute to Metha’s effectiveness?

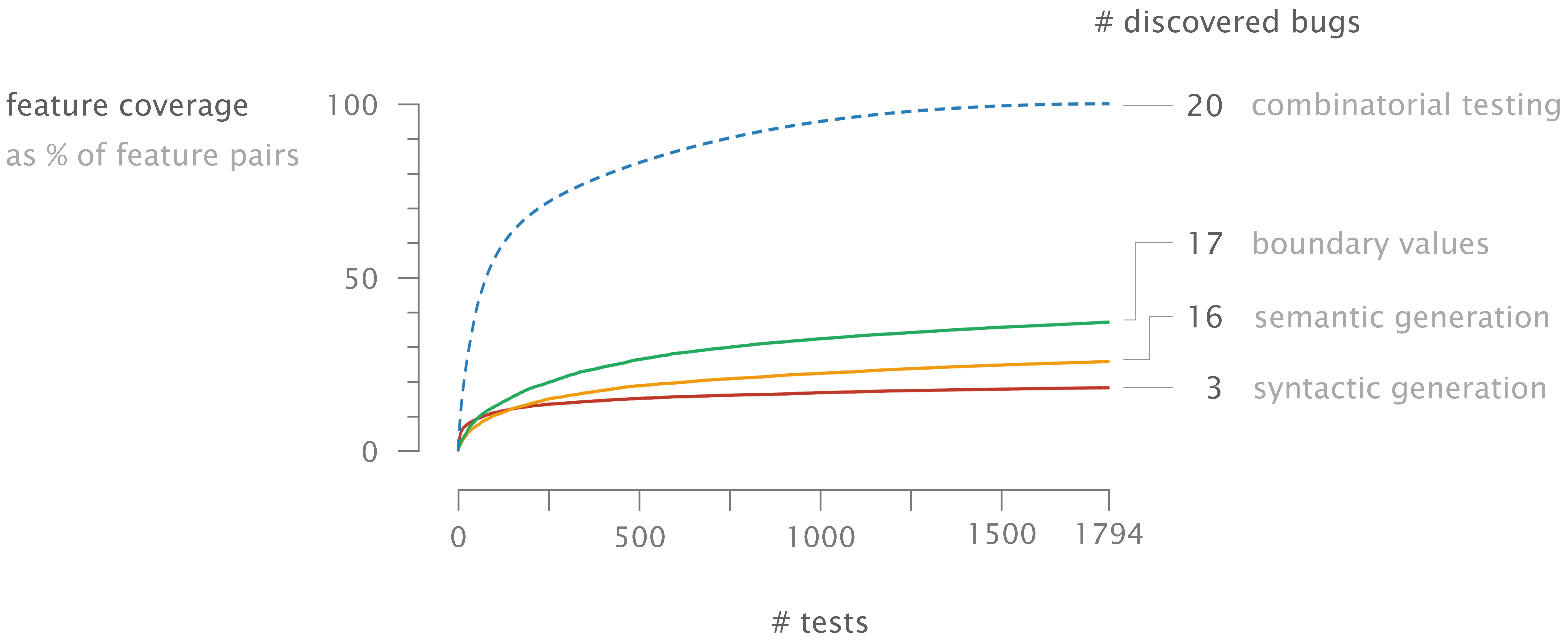
Implementation	7k lines of Python github.com/nsg-ethz/Metha
Features	static routes, OSPF, BGP, route-maps covering most common features
Oracle	virtualised GNS3 network with 4 routers using Cisco 7200 and Juniper vMX images

Metha found bugs in all of the three tested tools

	# bugs
Batfish	29
C-BGP	3
NV	30

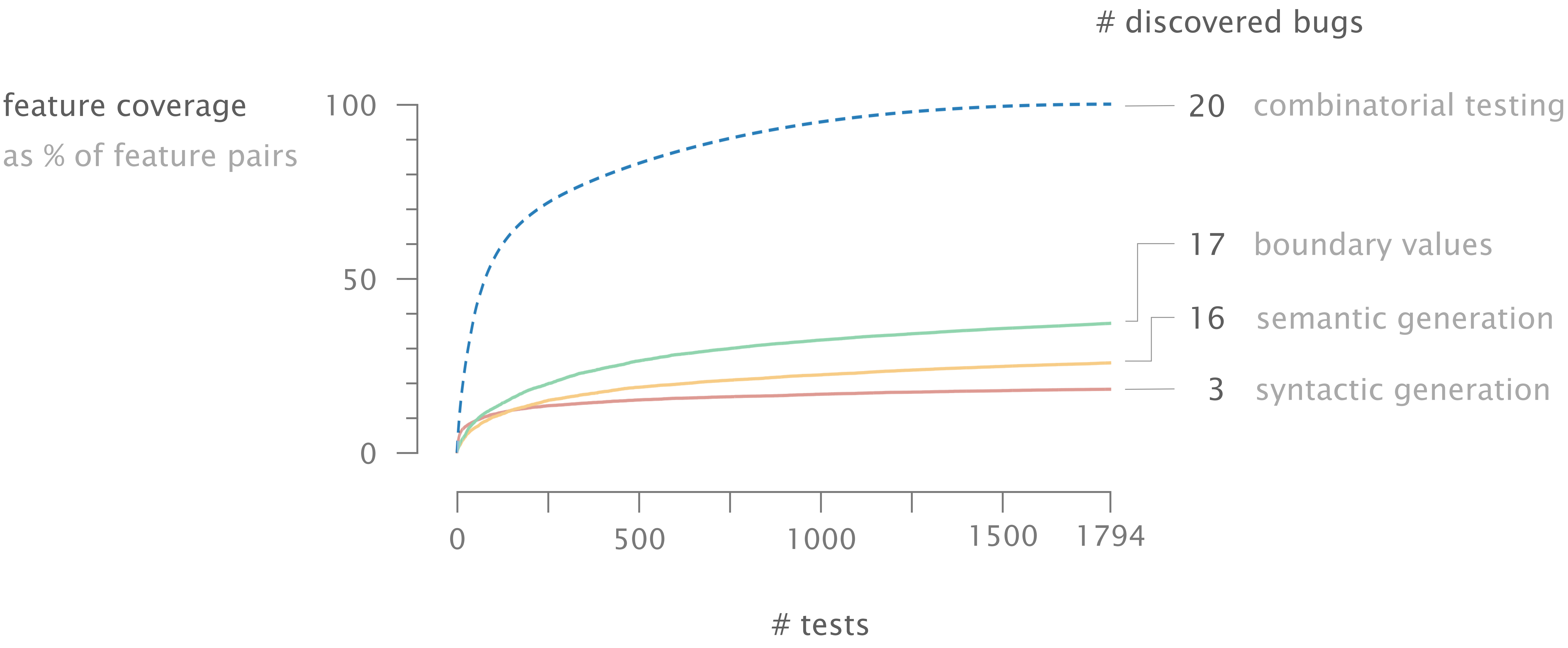
Only few bugs lead to crashes, while the majority leads to false analyses

	# bugs	crash	silent
Batfish	29	5	24
C-BGP	3	0	3
NV	30	5	25

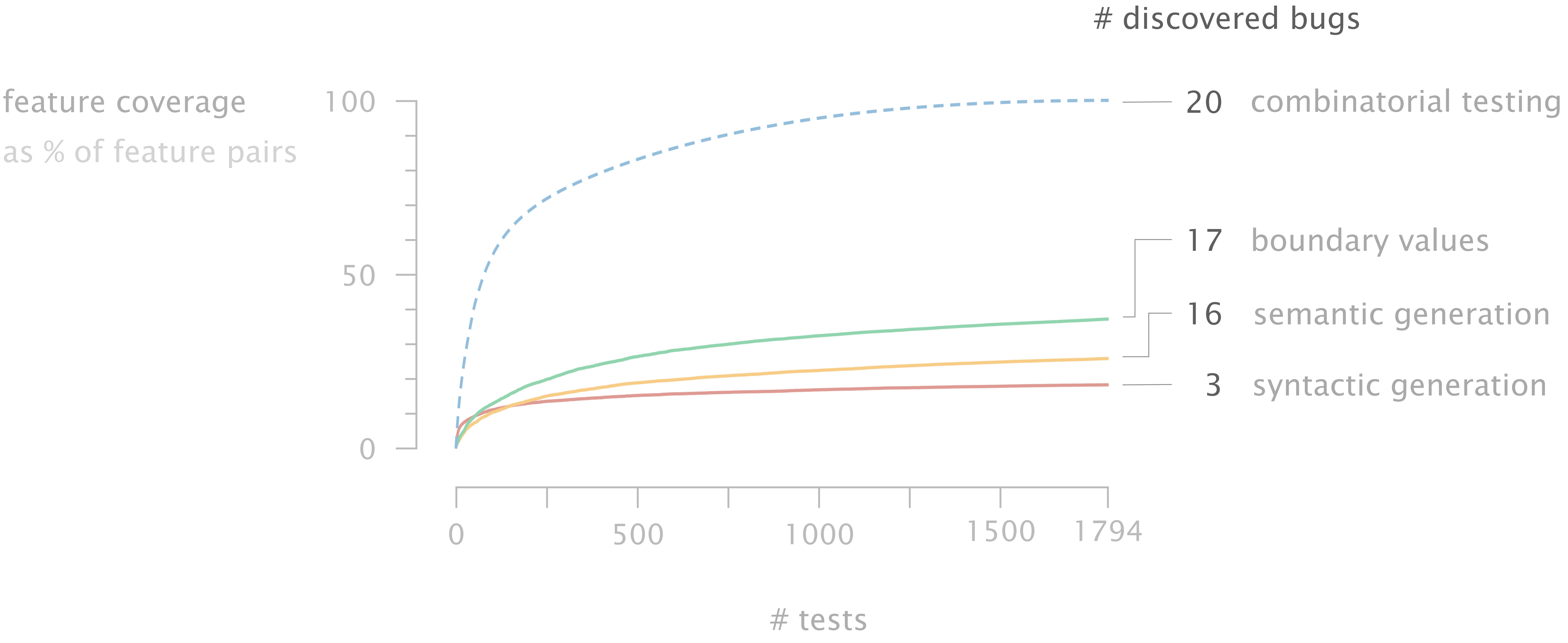


discovered bugs
feature coverage
as % of feature pairs
100
50
0
0
500
1000
1500
1794
tests
20 combinatorial testing
17 boundary values
16 semantic generation
3 syntactic generation

By definition, combinatorial testing achieves complete feature coverage



Semantic configuration generation is critical for Metha's effectiveness



Metha: Automated Testing of Network Analyzers

Metha

generates semantically valid configs

using a two-stage approach

systematically covers the search space

through restricting the search space

provides actionable bug reports

including a minimal config example

Metha

Automated Testing of Network Validation Tools

github.com/nsg-ethz/Metha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