From Network Verification to Synthesis

Breaking new ground in network automation

Laurent Vanbever

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2015–	Assistant professor	ETH Zurich
2012–2014	Postdoctoral researcher	Princeton University
2008–2012	PhD in Computer Science	University of Louvain
2008–2010	MSc in Management	Solvay Brussels School of Economics
2003–2008	MSc in Computer Science	University of Louvain

a *couple* of hours

Google accidentally broke the internet throughout Japan

A mistake led to internet outages for about half of the country.

Mallory Locklear, @mallorylocklear
08.28.17 in Internet

Forbes / Personal Finance

The Little Black Book of Billionaire Secrets

JUL 8, 2015 @ 03:36 PM 11,261 VIEWS

United Airlines Blames Router for Grounded Flights

'Configuration Error' Blamed for AWS Outage

By David Ramel ■ 08/12/2015

The summer of network misconfigurations

Amazon's massive AWS outage was caused by human error

One incorrect command and the whole internet suffers.

By Jason Del Rey | @DelRey | Mar 2, 2017, 2:20pm EST

CenturyLink: 750 calls to 911 missed during Aug. 1 outage caused by human error in Minnesota, North Dakota

By Barry Amundson on Aug 15, 2018 at 4:43 p.m.

Data Centre ▸ Networks

Level3 switch config blunder for US-wide VoIP blackout

affected Comcast, Spectrum, Verizon and AT&T customers

BY: CNN

Data Centre ▸ Networks

CloudFlare apologizes for Telia screwing you over

Unhappy abou

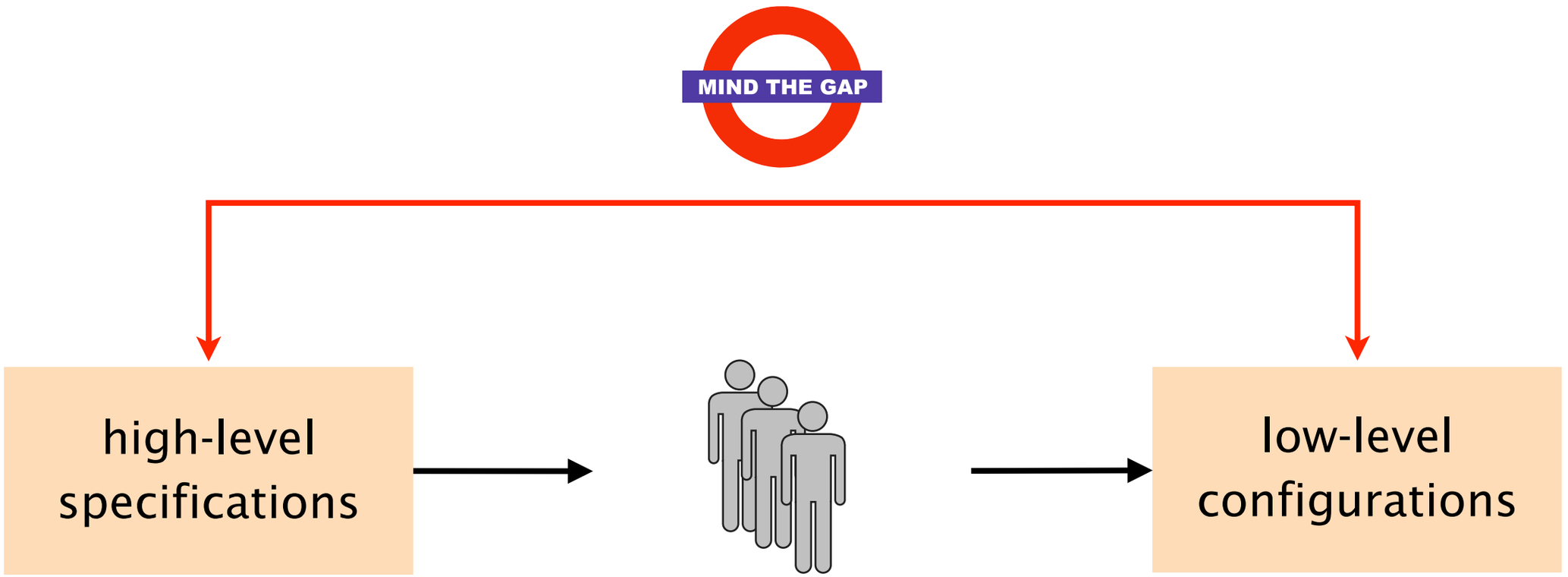
By Kieren McCarthy in

Facebook struggles to deal with epic outage

By Donie O'Sullivan and Heather Kelly, CNN Business

Updated 0654 GMT (1454 HKT) March 14, 2019

Managing distributed networks is hard
because of a fundamental semantic gap



network operators

manually configuring each device

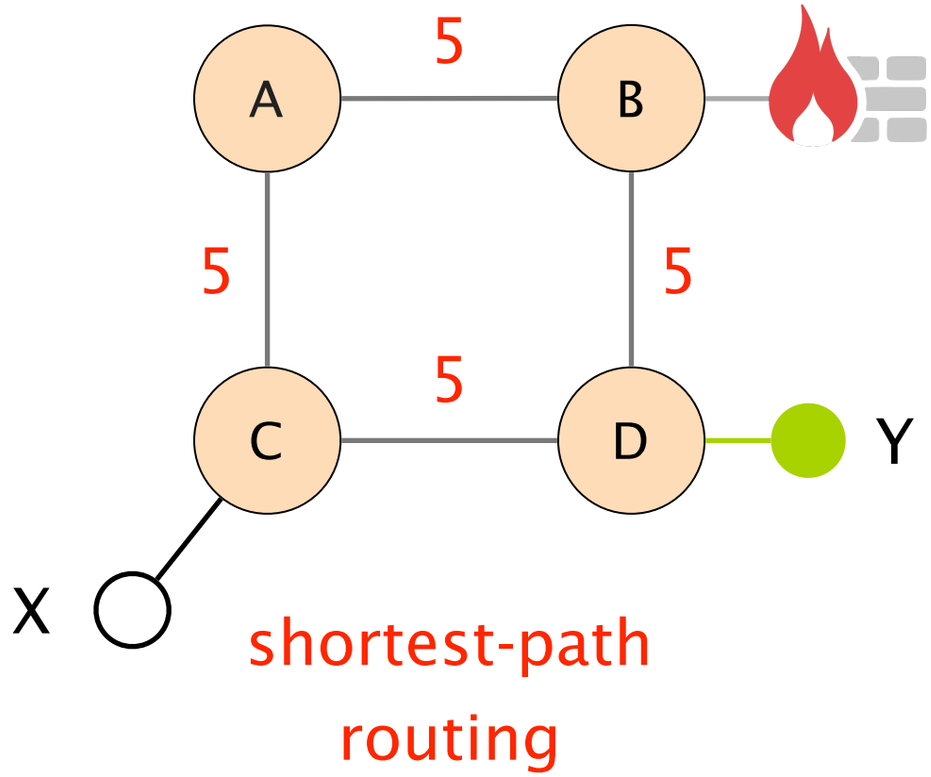
Specification

Traffic from X to Y

follow [C,A,B,D], if available

else drop

Configuration



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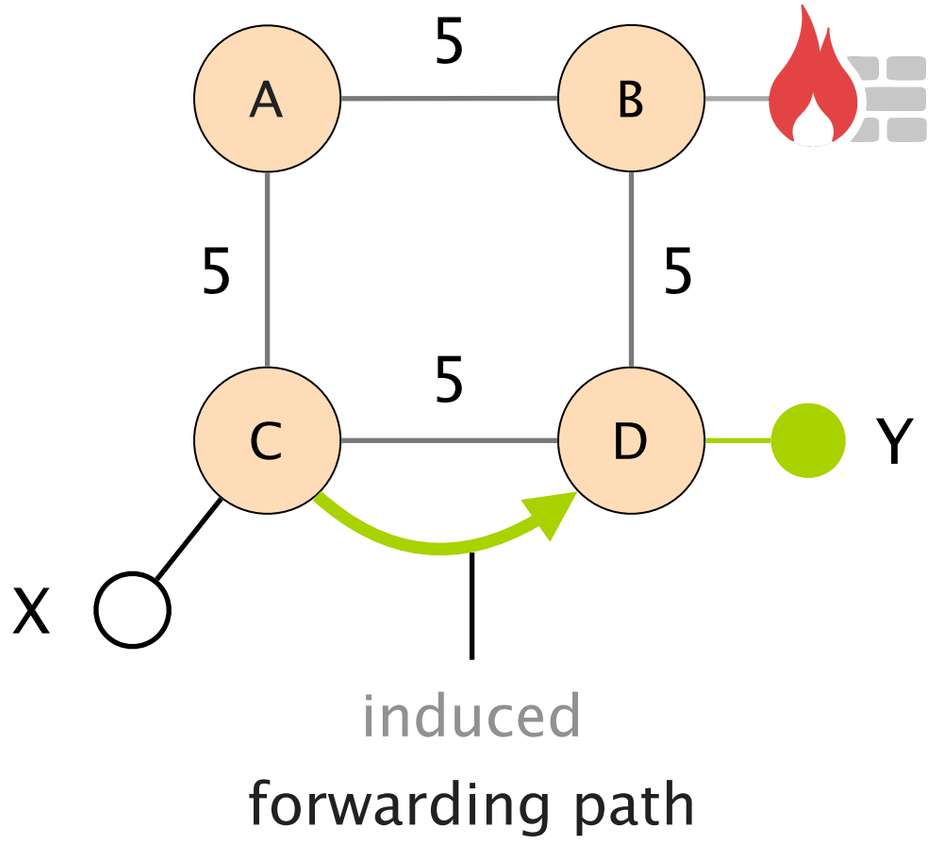
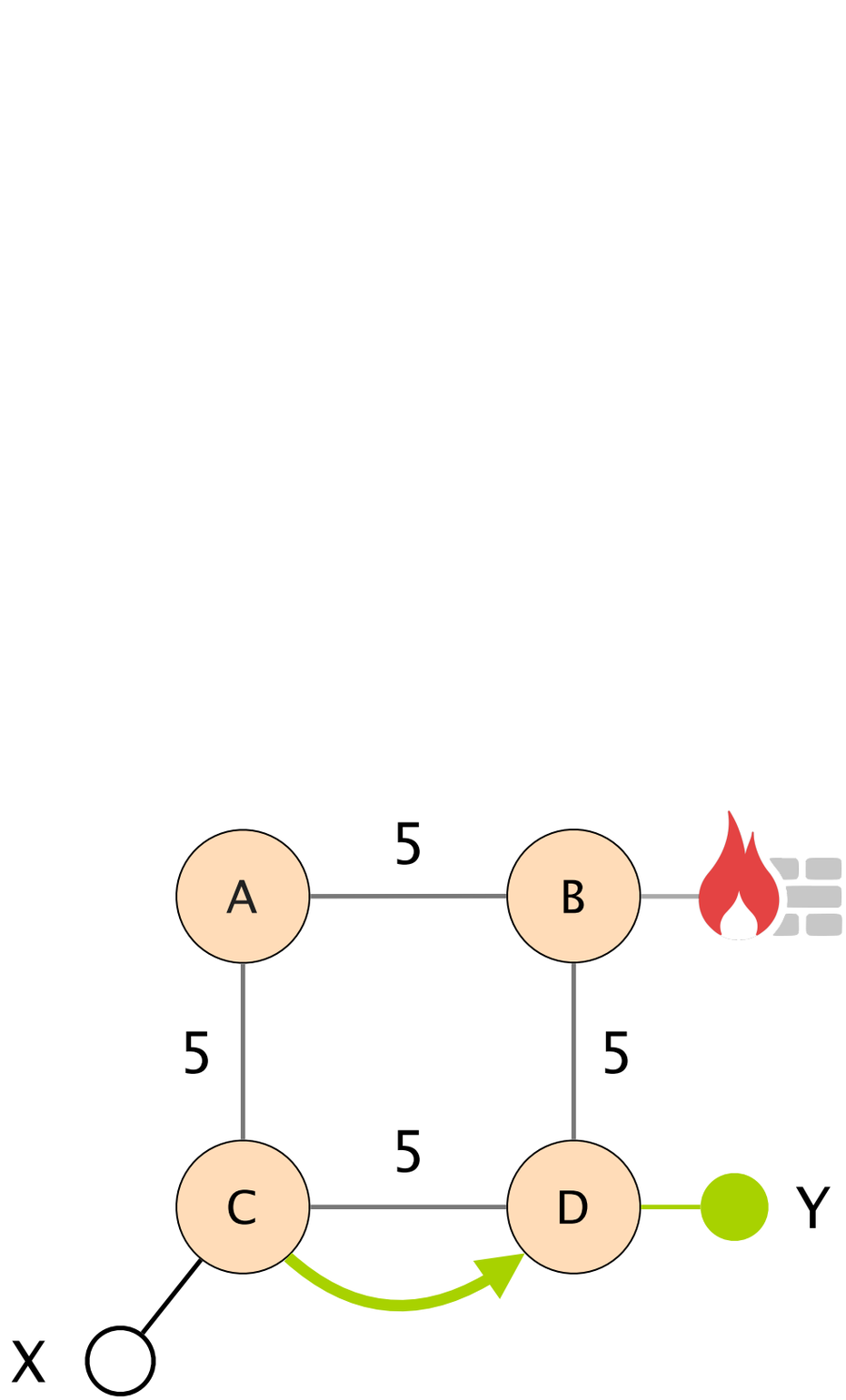


Traffic from X to Y

follow [C,A,B,D], if available

else drop

specification is not satisfied



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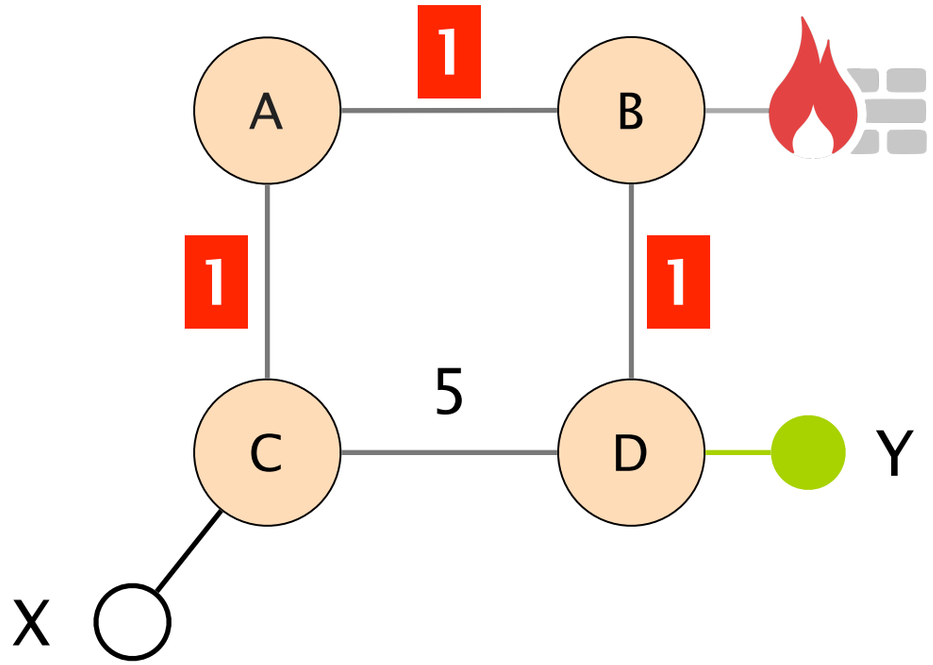

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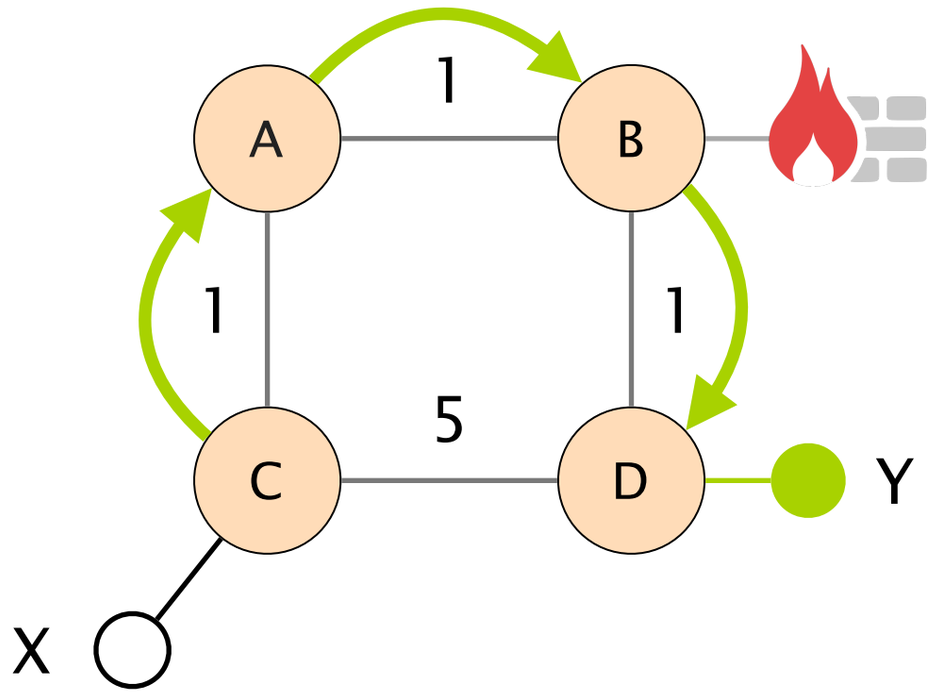

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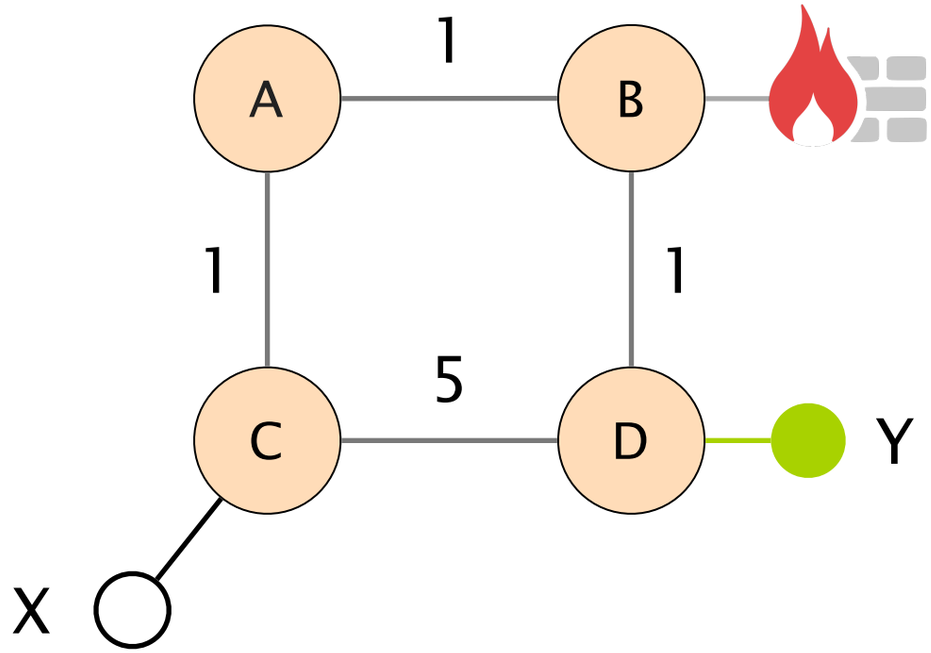
follow [C,A,B,D], *if available*

else drop



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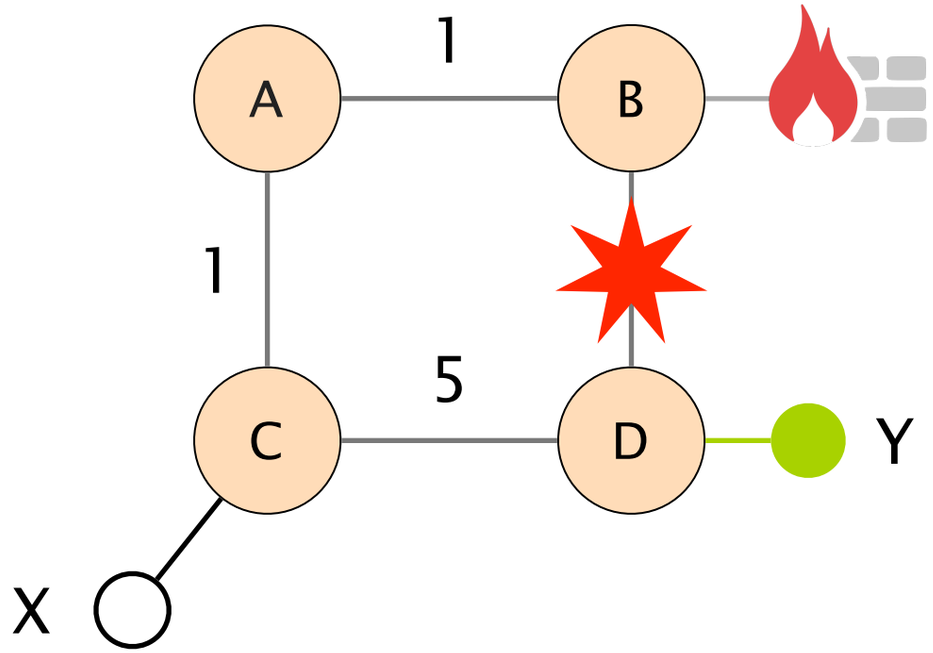

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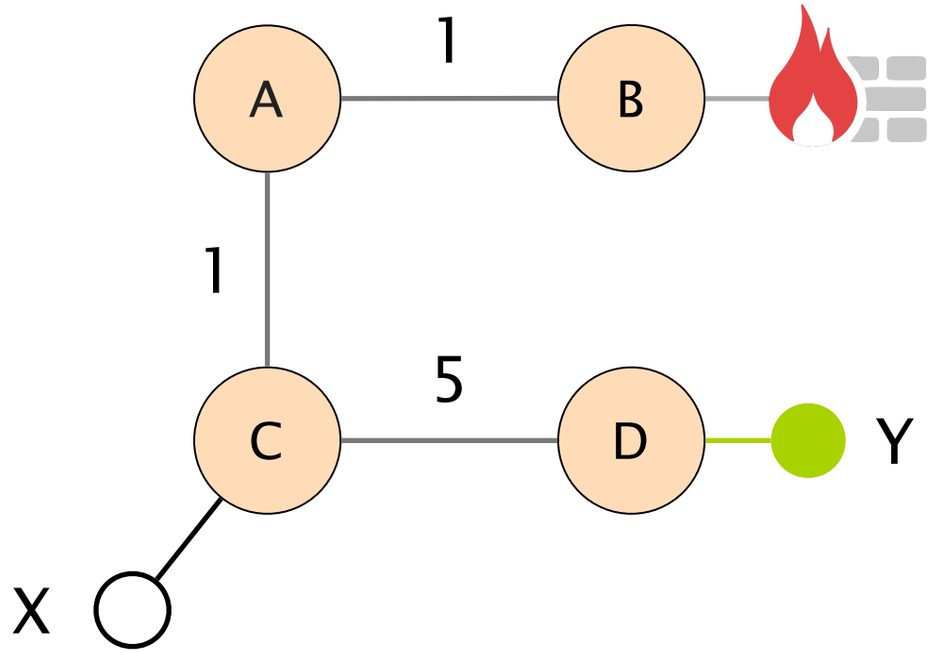

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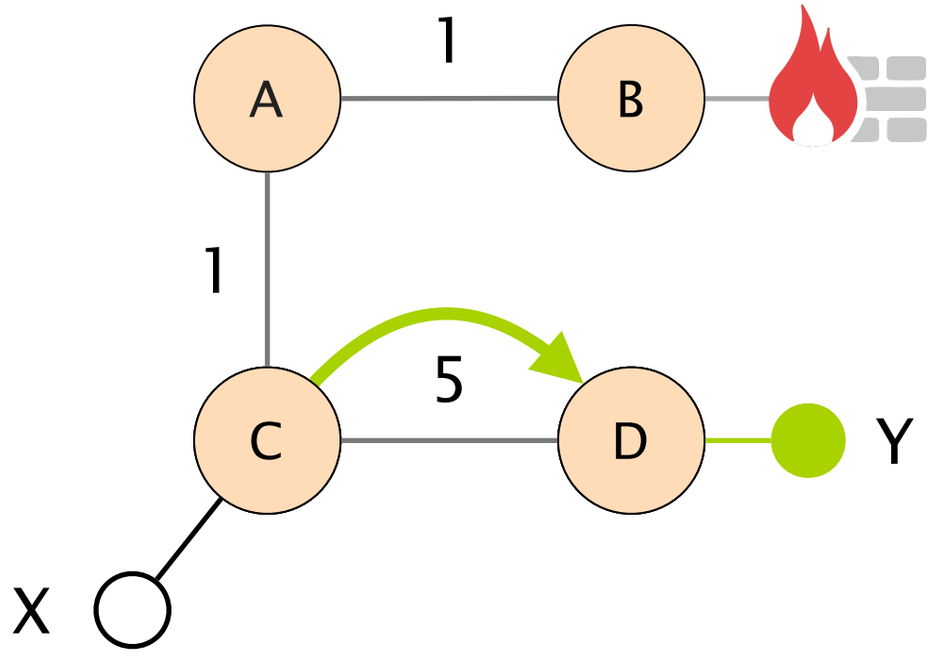
else drop

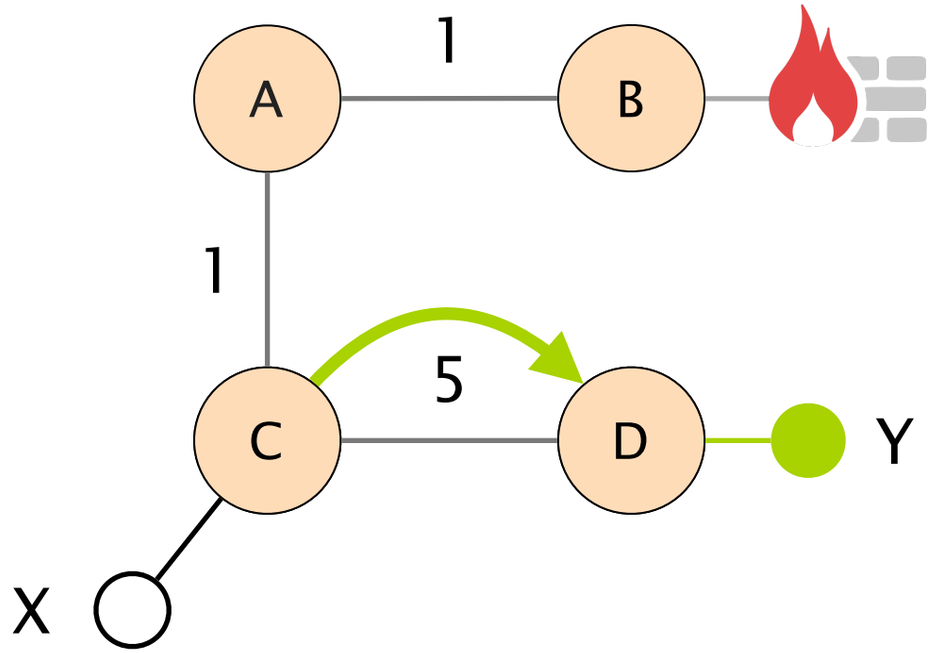


Traffic from X to Y

follow [C,A,B,D], *if available*

else ***drop***

specification is not satisfied



Traffic from X to Y

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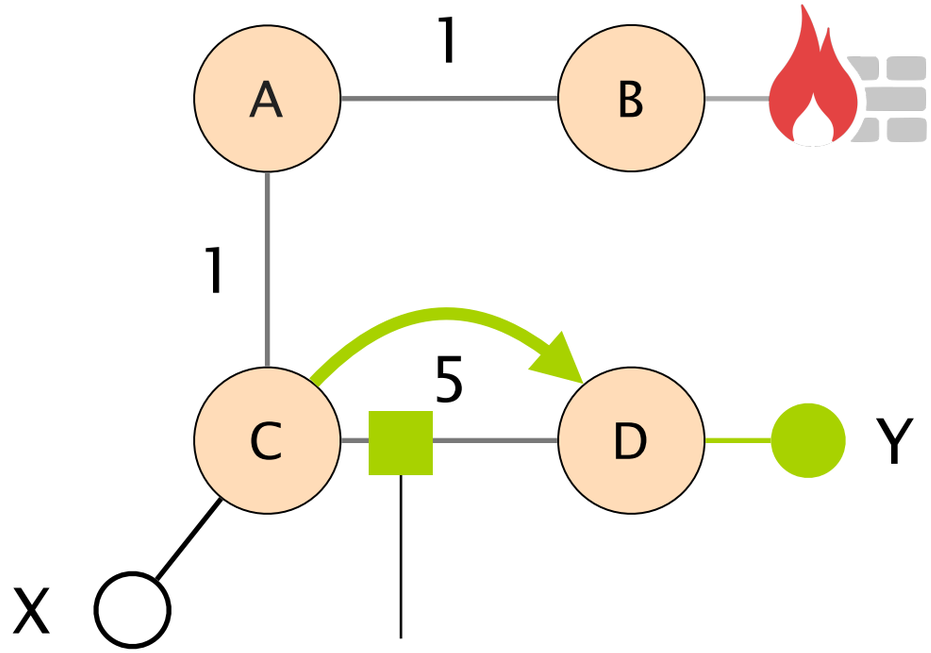
else drop



match(Y): drop

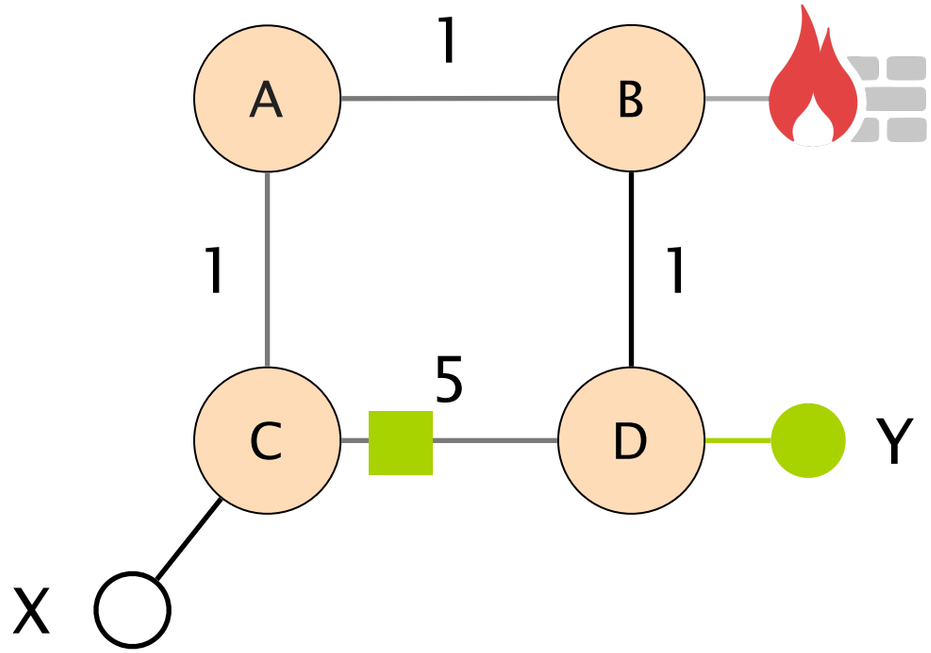
filtering rule

Traffic from X to Y

follow [C,A,B,D], if available

else drop

specification is satisfied



Traffic from X to Y

follow [C,A,B,D], if available

else drop

```
interface Loopback0
 ip address 120.1.7.7 255.255.255.255
 ip ospf 1 area 0
!
! interface towards A
interface TenGigabitEthernet1/1/1
 ip address 120.0.0.1 255.255.255.252
 ip ospf 1 area 0
 ip ospf cost 1
!
! interface towards D
interface TenGigabitEthernet1/1/2
 ip address 120.0.0.3 255.255.255.252
 ip ospf 1 area 0
 ip ospf cost 1
 access-list 101 deny ip 121.0.0.0 0.0.0.255
!
router ospf 1
 router-id 120.1.7.7
!
...
```

SyNET will bridge this gap by

Building SyNET will require us solving

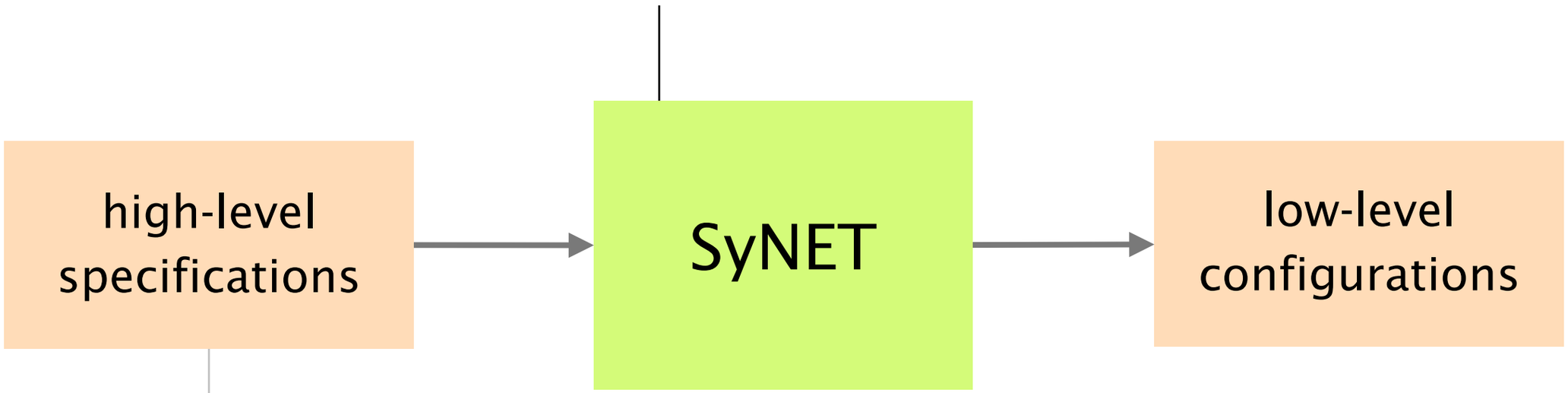
four fundamental research questions

How can we obtain the specifications?

question 1

question 2

How can we represent
the search space?



How can we obtain the specifications?

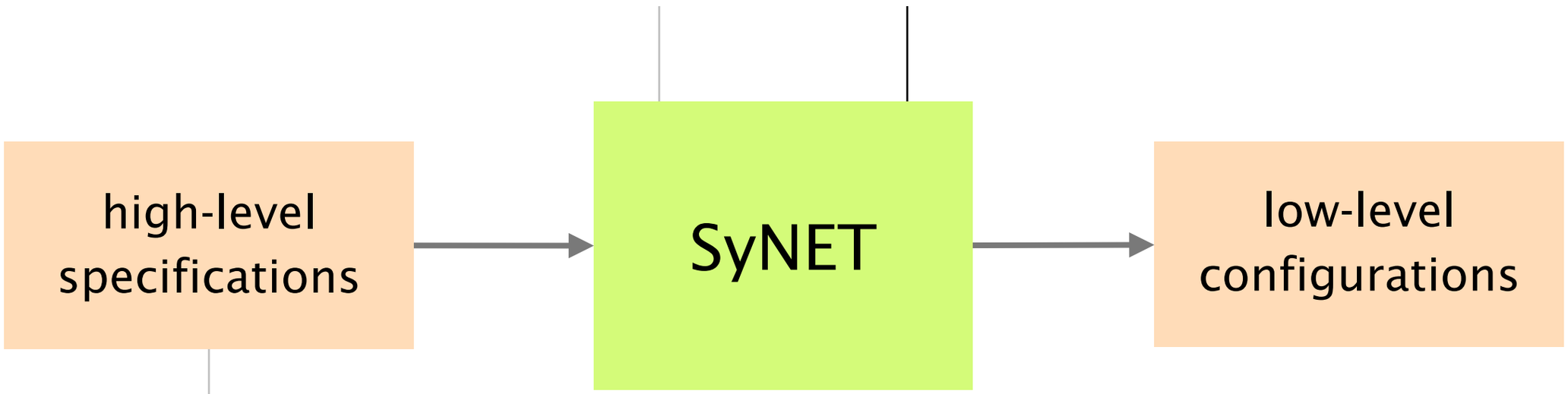
question 1

question 2

How can we represent
the search space?

question 3

How can we verify that
a configuration is compliant?



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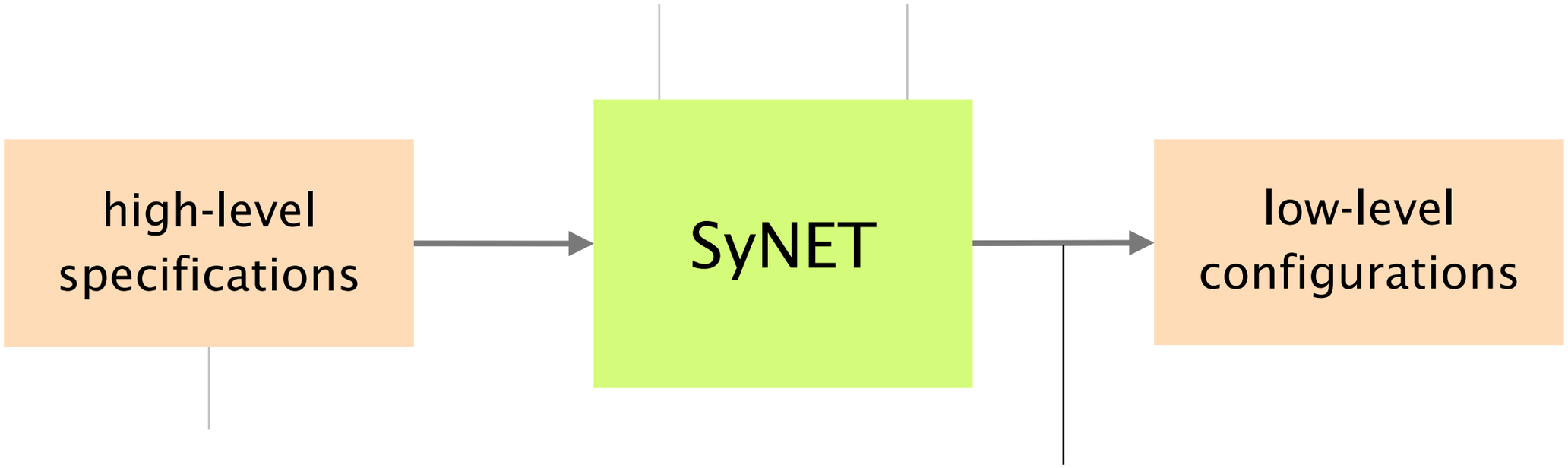


How can we obtain the specifications?

question 1

How can we synthesize
an optimal configuration?

question 4

Question 1

Obtaining the specifications φ

Writing specifications is cumbersome

Internet2 10 routers, 18 links

>3000 properties!

Outcomes

Semi-automated techniques to *learn* network specifications

```
minimize(          (optimization objective)
    convergence_time ∧
    length(configurations)
)
```

such that (hard properties)

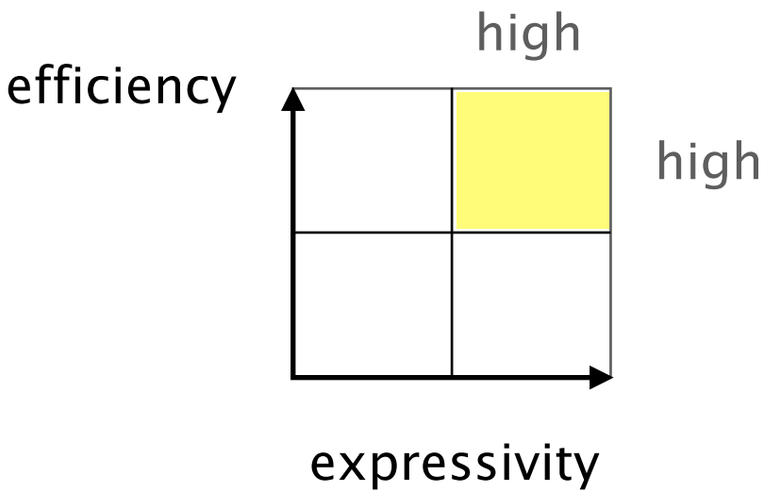
```
    reachability(A,B) ∧
    isolation(A,X)
```

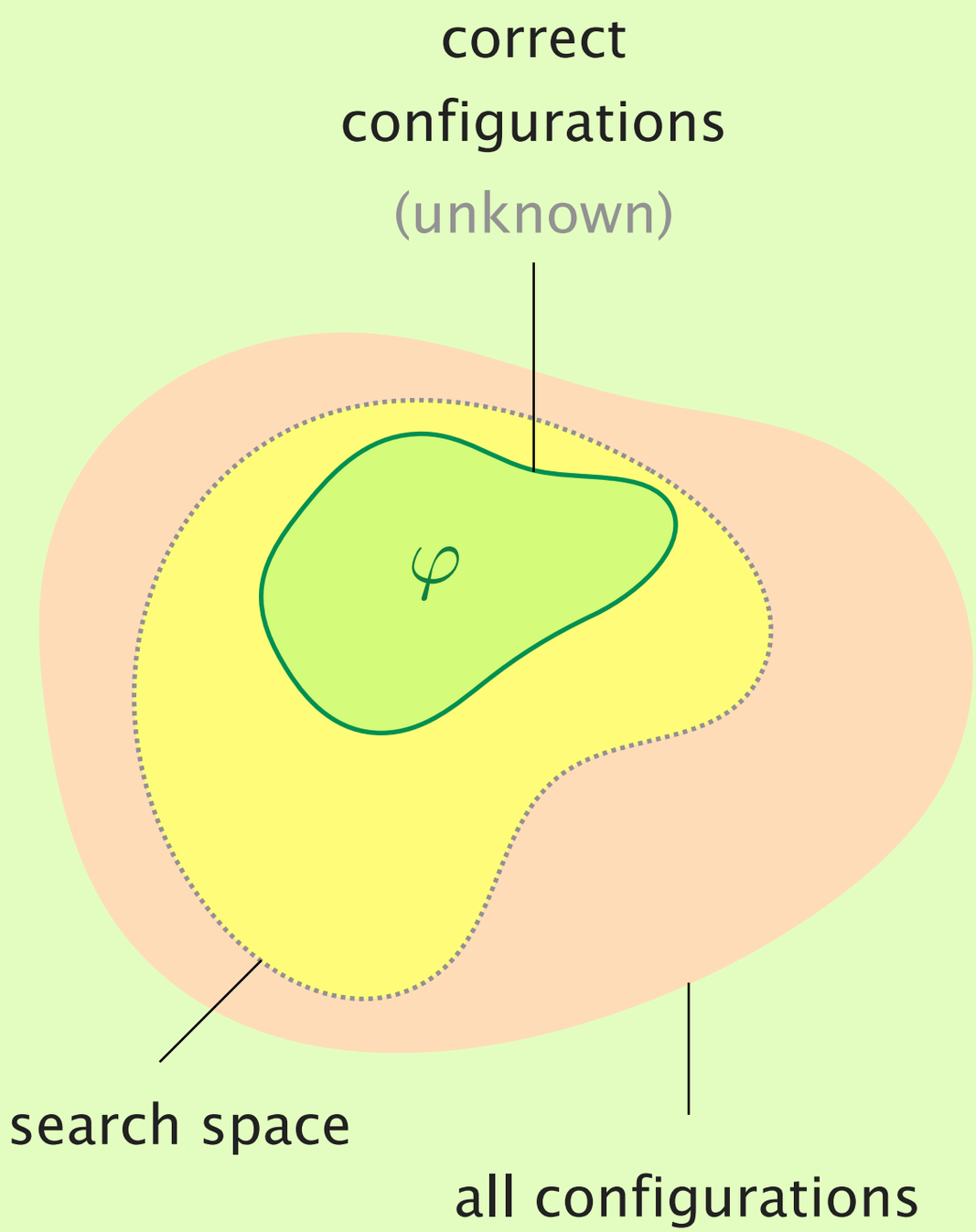
and (probabilistic properties)

```
    P(path_length(A,D)>3) < .1
```

Question 2

Representing the search space





Outcomes

Algebraic-based semantic representation
for efficient network-wide reasoning

Question 3

Verifying that a configuration is compliant with a specification

Network configuration x Probabilistic environment

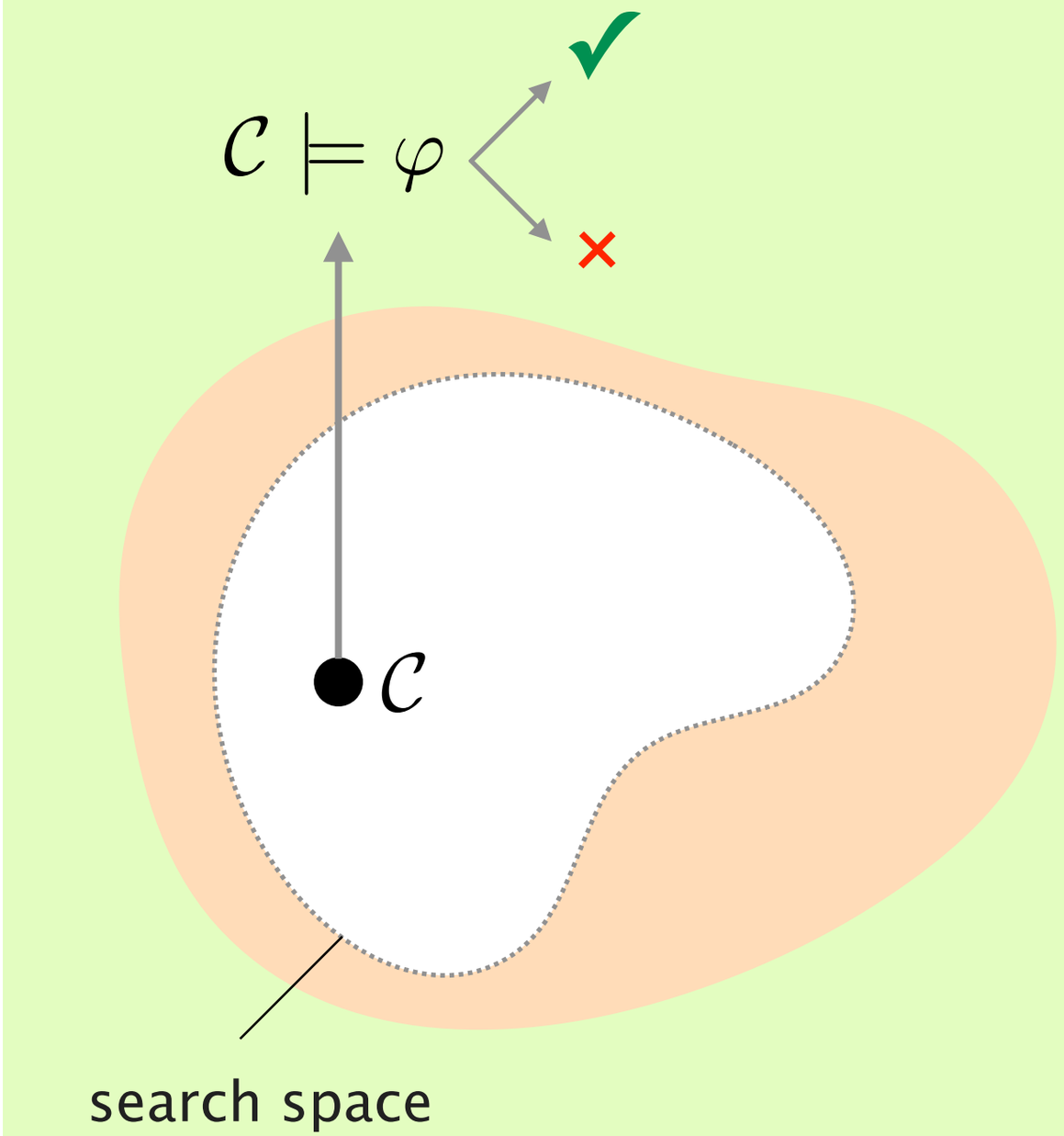
=

Probabilistic network behavior

Exact inference is #P-complete

Outcomes

Domain-specific probabilistic inference algorithms & models



Question 4

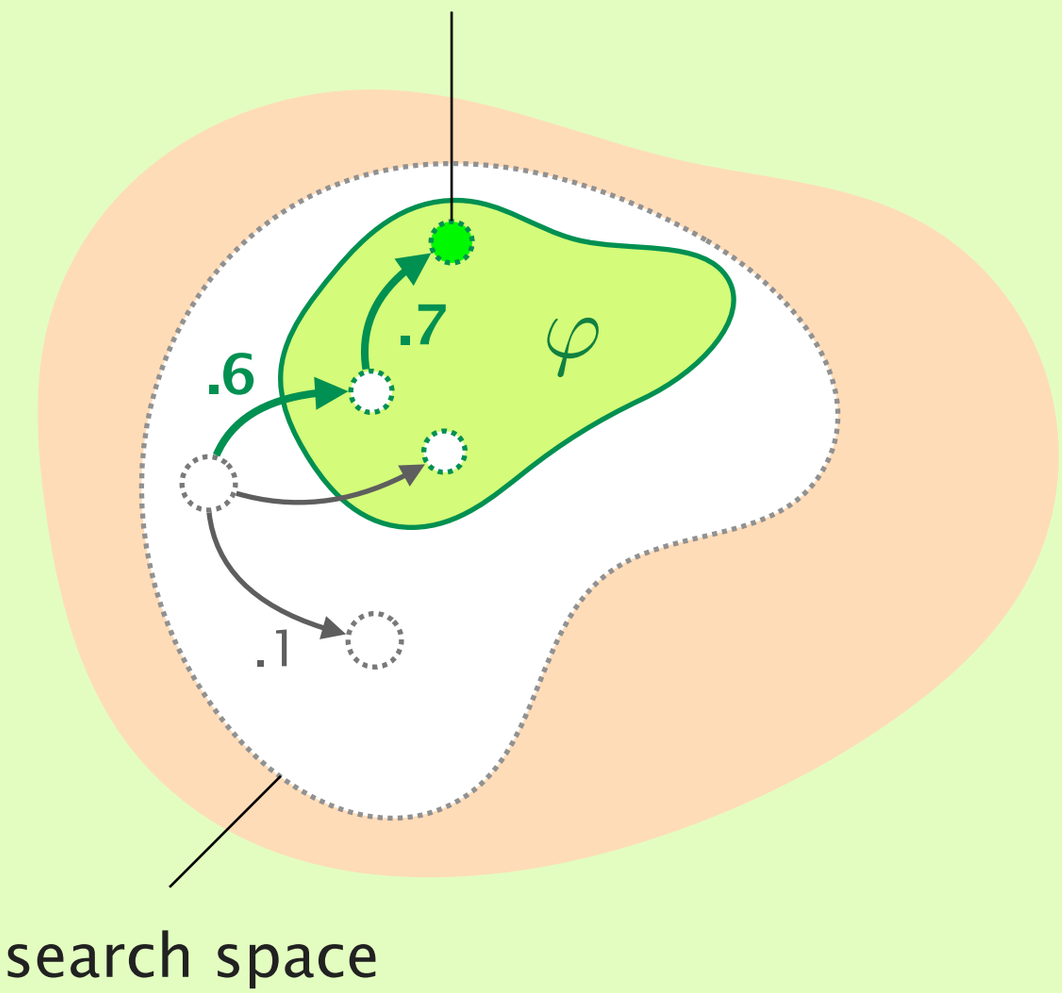
Synthesizing an optimal configuration

search space is
humongous & highly irregular

Outcomes

Novel synthesis algorithms guided by:

- probabilistic models
- counter-examples (CEGIS)
- domain-specific knowledge



Our preliminary successes indicate feasibility

while being limited

Network-Wide Configuration Synthesis [CAV'17]

Practical Network-Wide Configuration Synthesis with Autocompletion [NSDI'18]

Probabilistic Inference for Networks [PLDI'18]

Principal Investigator

Laurent Vanbever

Expertise

- management
- routing
- verification
- measurement
- security
- analysis

Scholar metrics

- citations: 2015
- h-index: 20
- i10-index: 30

Early achievements

- **3** best paper awards (ACM SIGCOMM, USENIX NSDI, IEEE ICNP)
- **4** applied networking research prizes (IETF/IRTF)
- **3** thesis awards (ACM SIGCOMM, UC Louvain, CeFIP)
- **1** teaching award (ETH Zurich)
- **51** papers (**4** SIGCOMM, **5** NSDI, **6** HotNets, **2** PLDI, …)

Community and outreach

- PC member (ACM SIGCOMM, ACM CoNEXT, USENIX NSDI, PLDI)
- Program chair (ACM CoNEXT, ACM SOSR)
- Keynote speaker, summer school organizer, …
- Frequent media appearances (podcasts, press, …)

From Network Verification to Synthesis

Breaking new ground in network automation

My vision	Provably-correct network management
5—10 years	with a focused effort of an entire research group
Impact	Next-generation configuration synthesizers
	Increased productivity for network operators
	New theory, frameworks, and tools