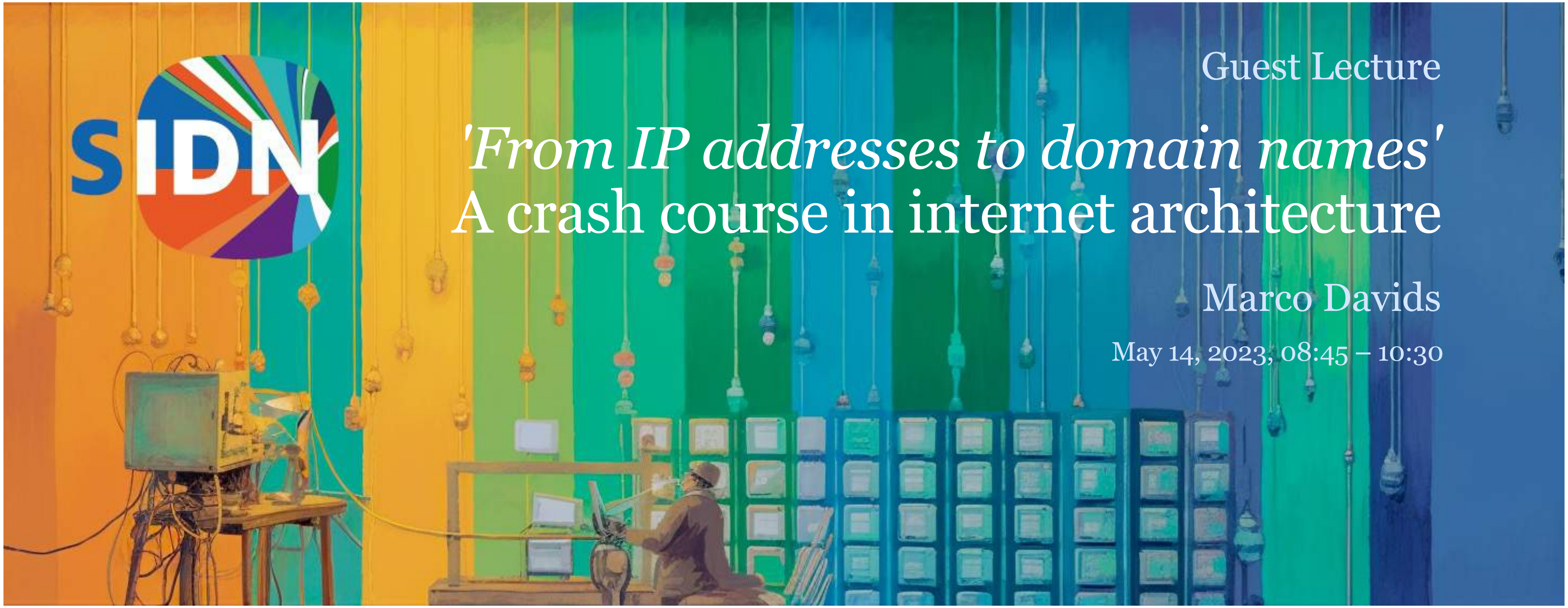
Zorgeloos online

(For confidence online)



Background image: Thijs van den Hout & Midjourney

Guest Lecture

'From IP addresses to domain names'
A crash course in internet architecture

Marco Davids

May 14, 2023, 08:45 – 10:30

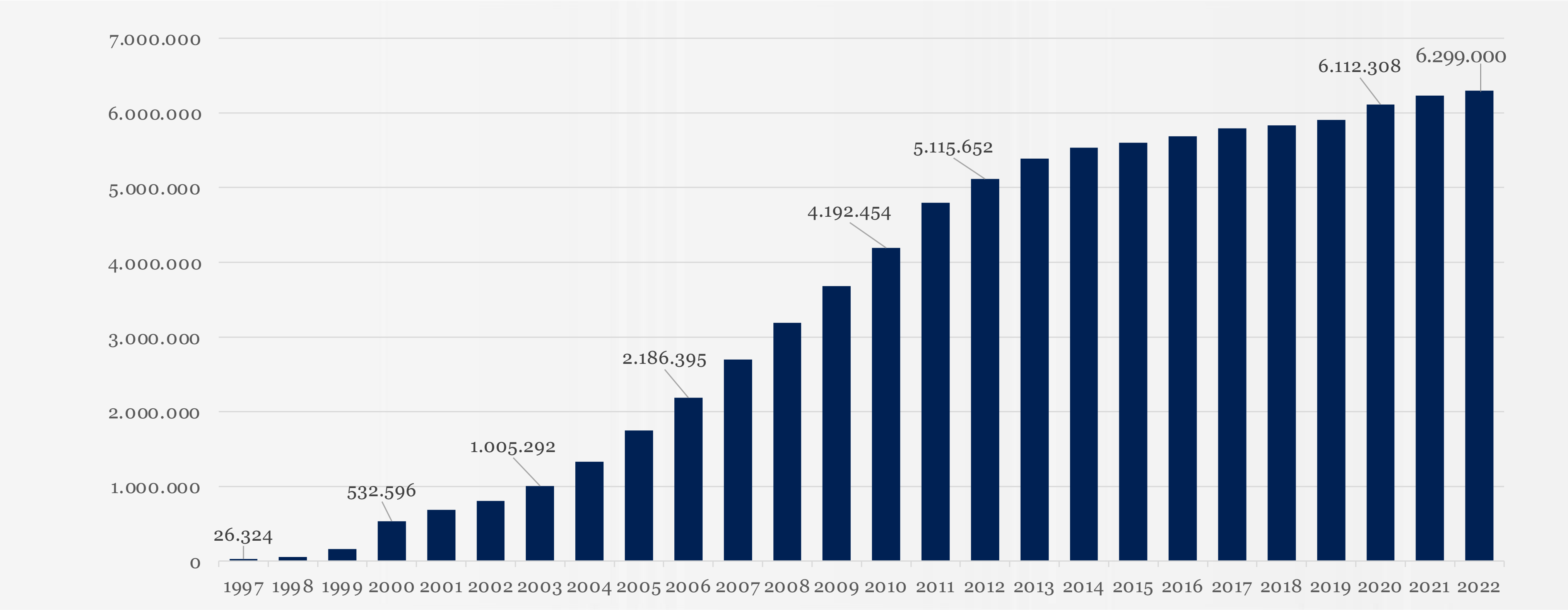
@marcodavids

About SIDN

- *Registry* for the .nl *country code top-level* domain
  - Nowadays also .amsterdam, .politie and .aw (technical management)
  - 6,3 million .nl domain names - 61% DNSSEC
  - Brand monitoring, .nl-Control, portfolio checker, abuse204.nl, etc.
- SIDN Fonds
- SIDN Labs

https://www.sidn.nl/en/about-sidn/what-we-do

Number of .nl domain names: 4th largest ccTLD



About SIDN Labs

Applied technical research

to the security of internet infrastructure

- Three themes:
  - Domain name security
  - Infrastructure security
  - Emerging internet technologies

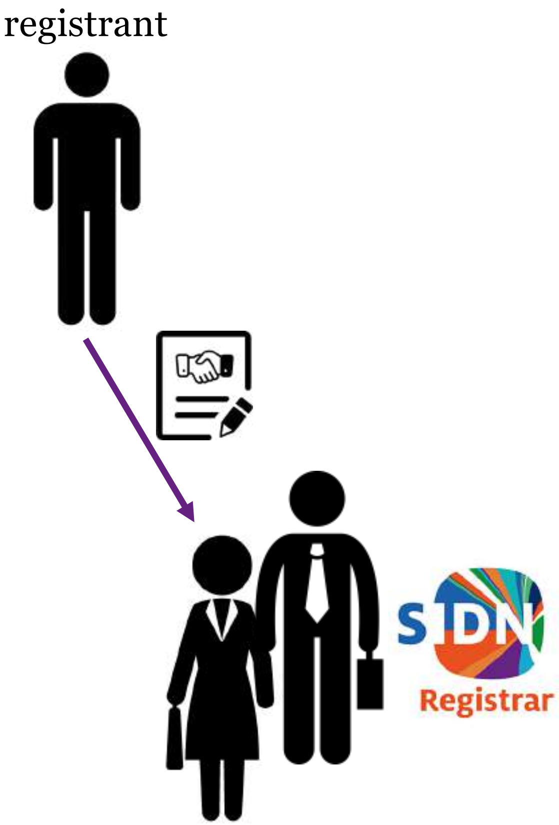
https://www.sidnlabs.nl/en/about-sidnlabs

Terminology

- Registrant wants domain name

Terminology

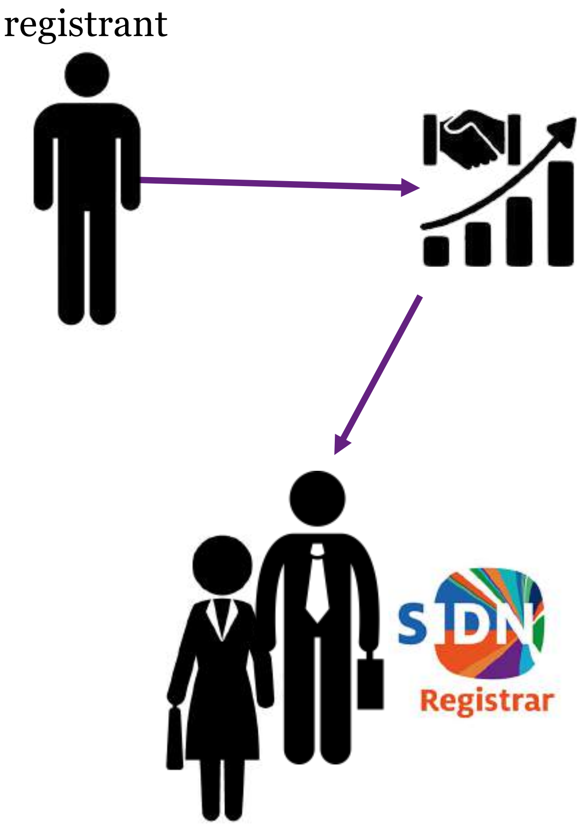
- Registrant wants domain name
- Goes to Registrar



https://www.sidn.nl/nl-domeinnaam/registrar-zoeken

Terminology

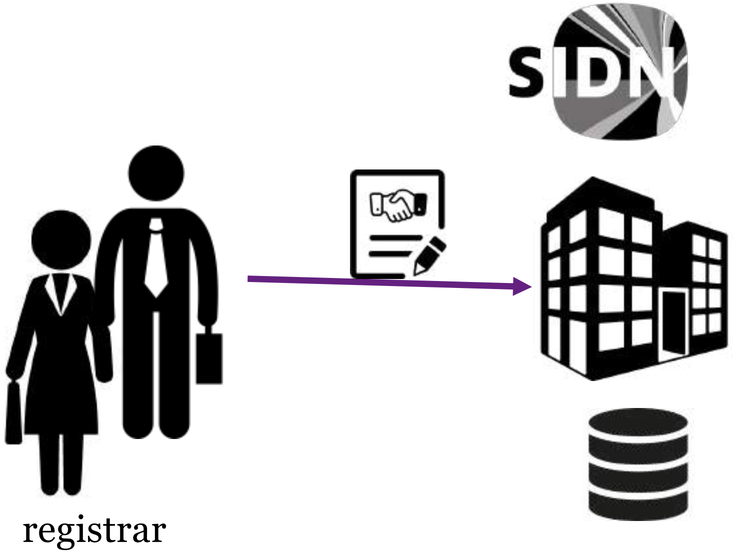
- Registrant wants domain name
- Goes to Registrar
- (possibly via Reseller)



https://www.verenigingvanregistrars.nl/

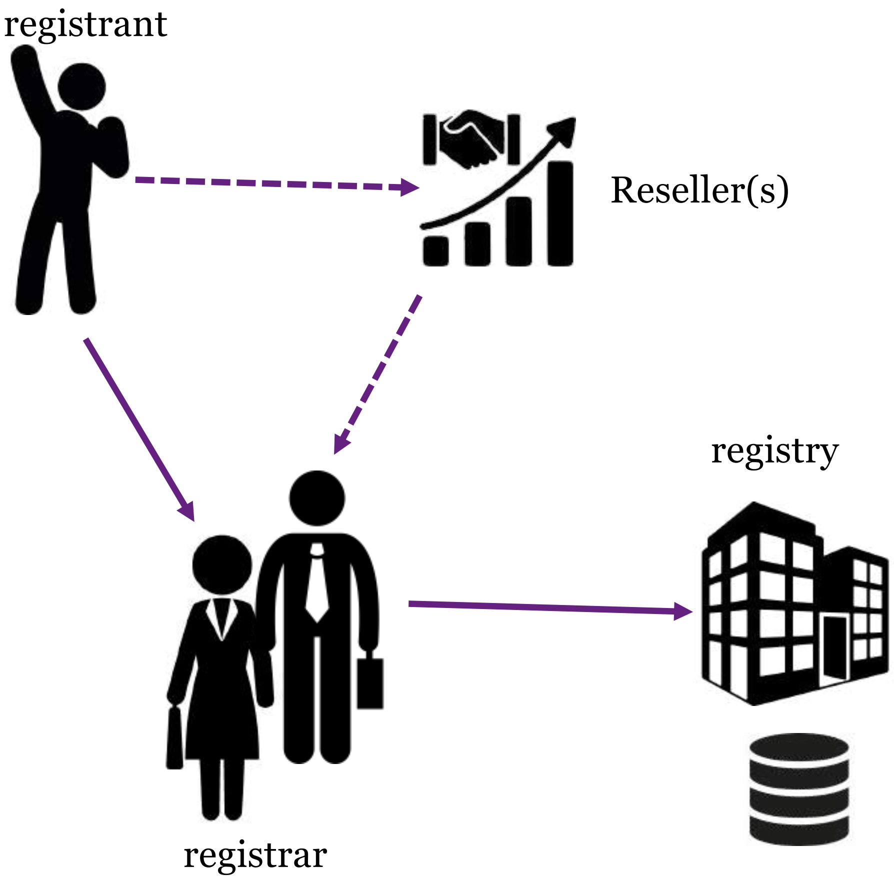
Terminology

- Registrar is affiliated with Registry
- That's us ☺



Terminology

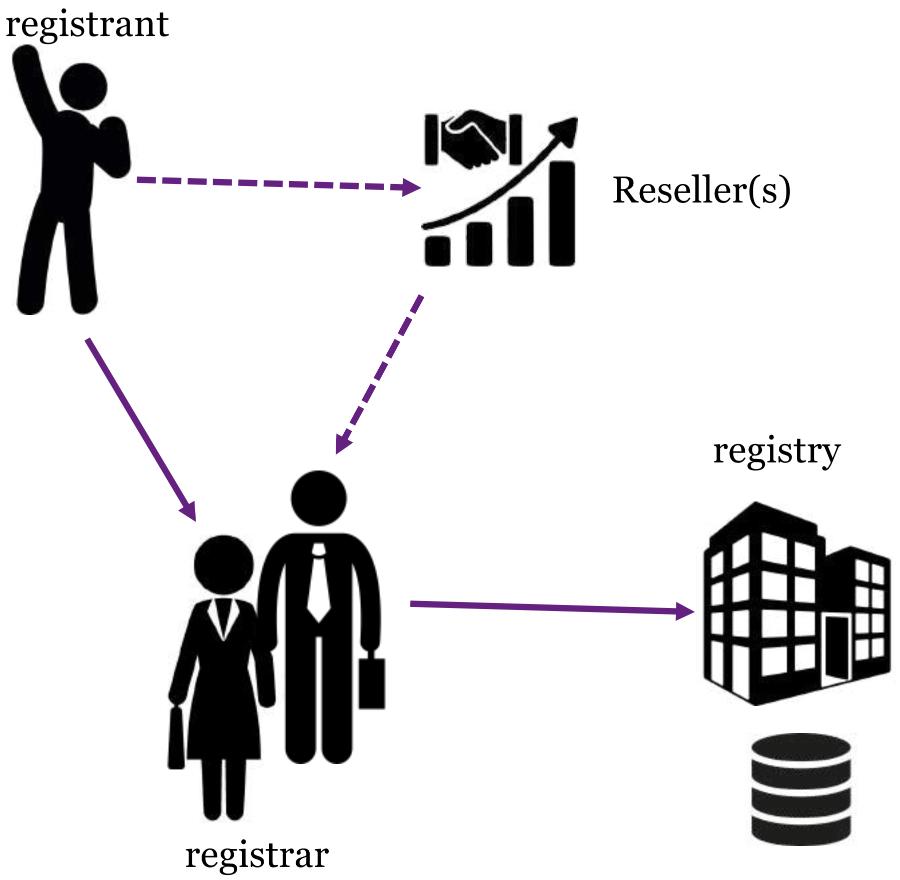
- The domain name is registered!



https://whois.nl/

Terminology

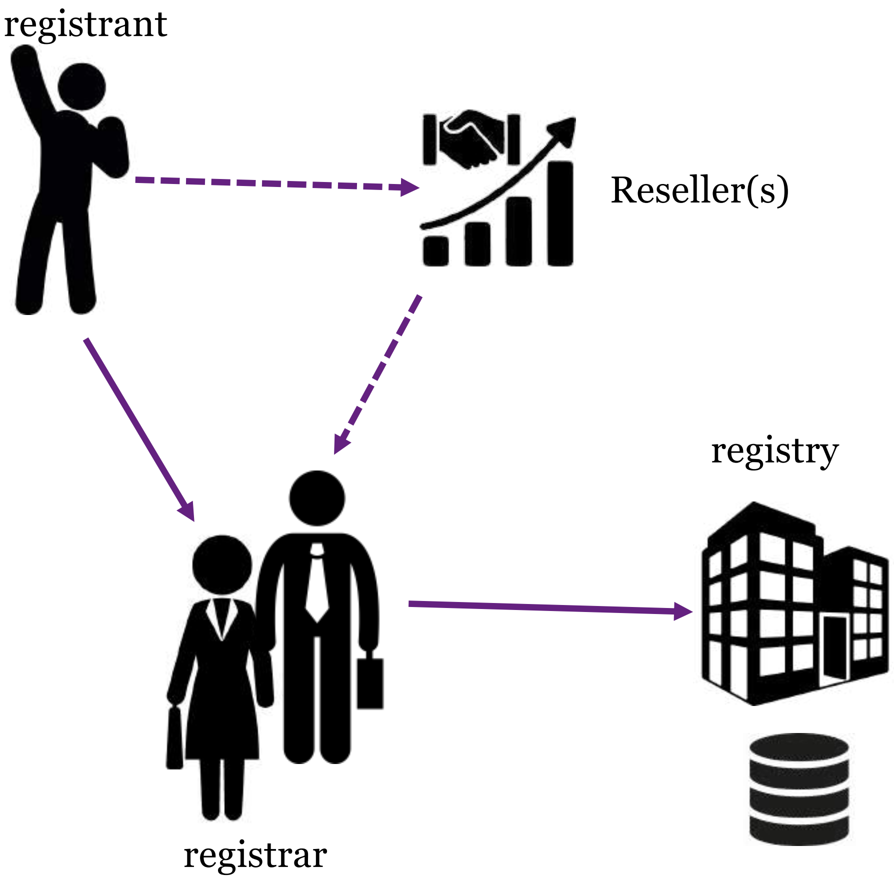
- 1 Registry (per TLD)
- ~1300 Registrars
- ??? Resellers
- ??? Unique registrants
- RRR model



https://whois.nl/

Terminology

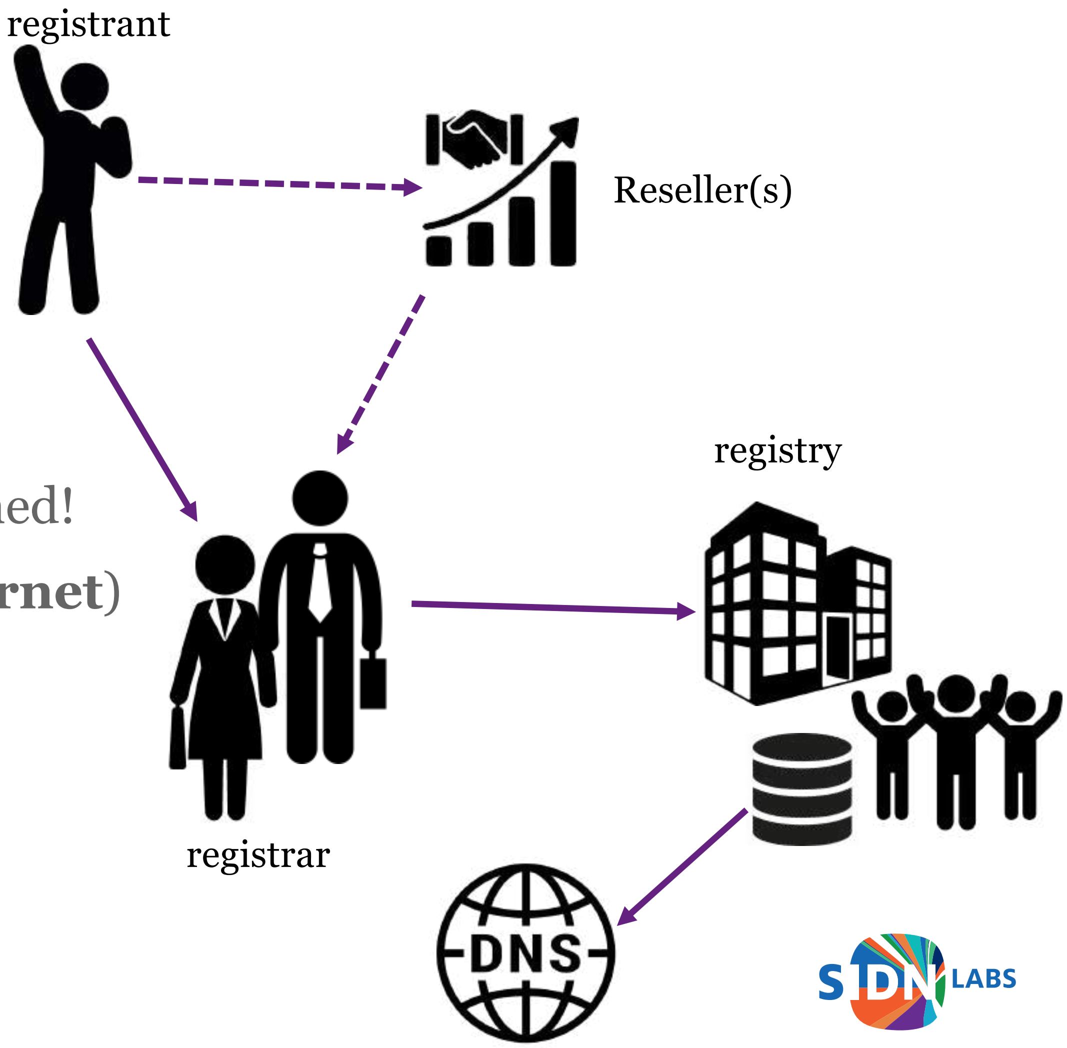
- The domain name is registered!



https://whois.nl/

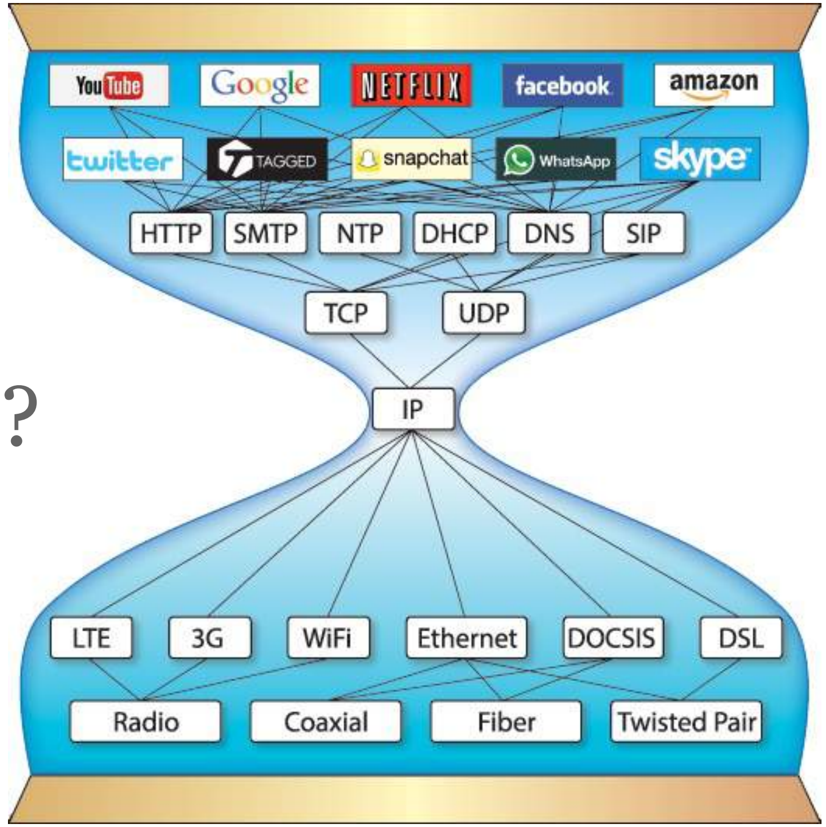
Terminology

- The domain name is registered
- The domain name has been published!
- (only then does it work on the **internet**)



The term 'internet'

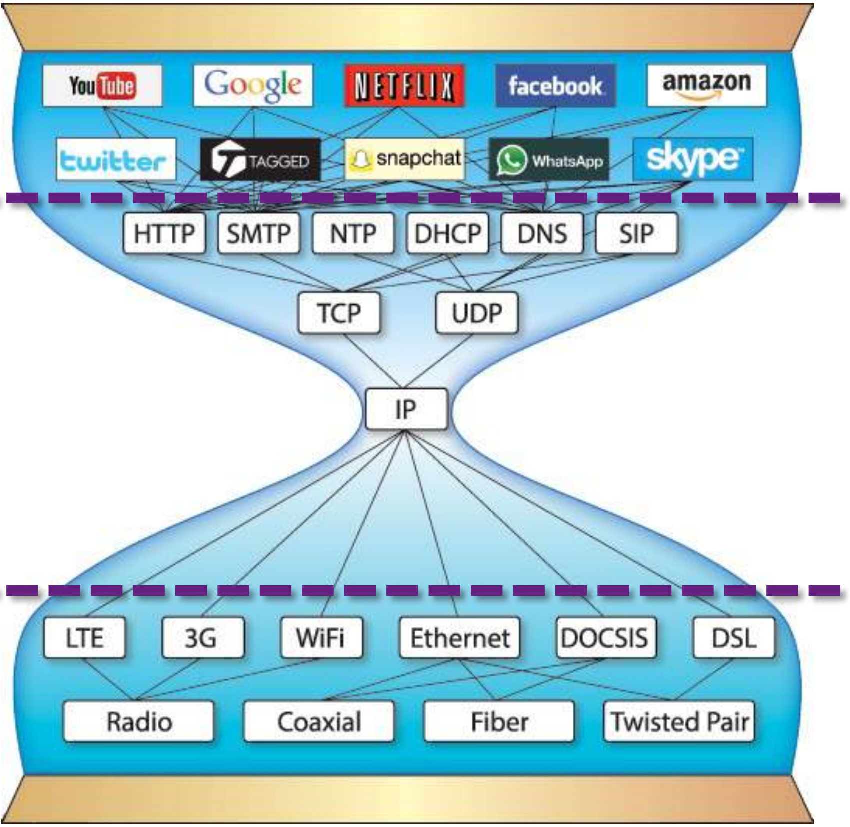
What do we mean by that?



The internet

Most people

Me



The internet

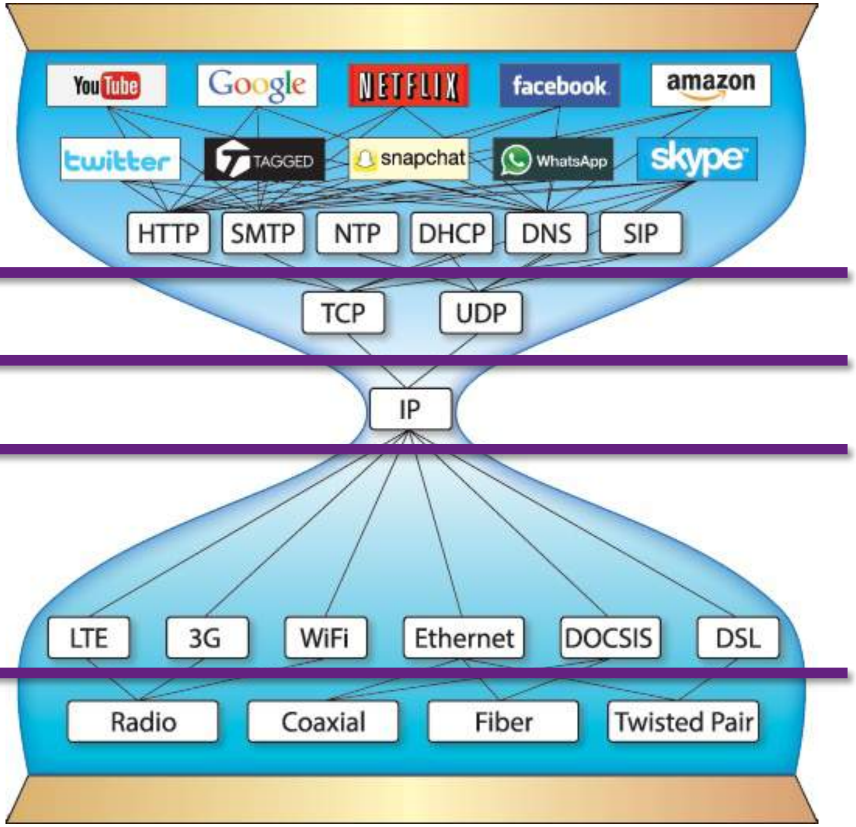
Application (Presentation / session)

Transport

Internet (network)

Link (datalink)

(Physical)



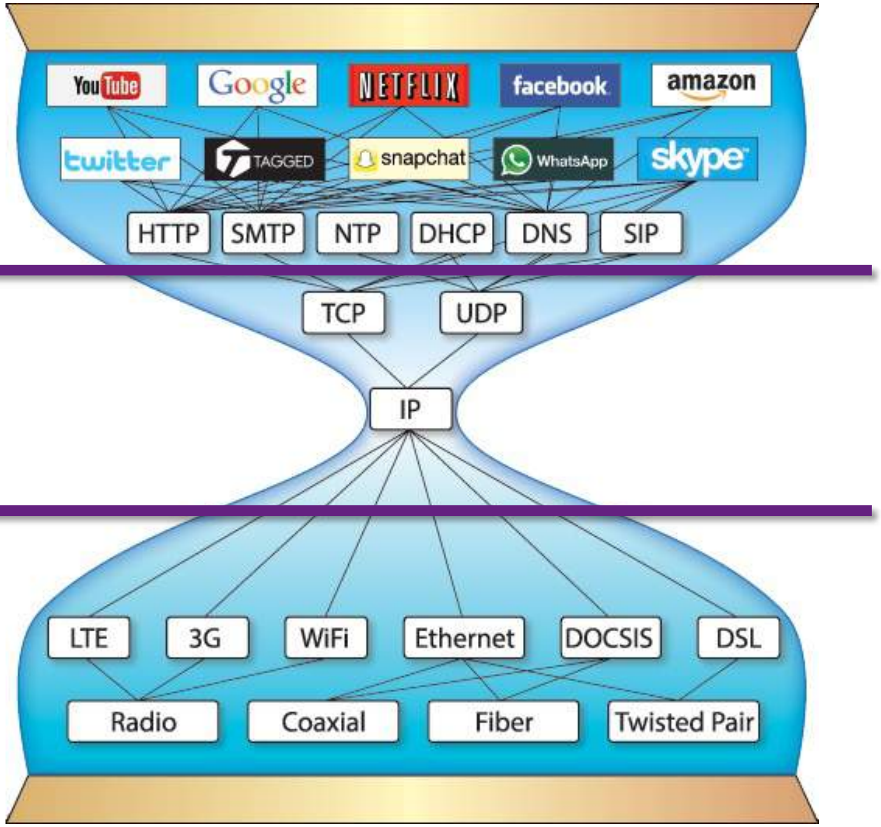
https://en.wikipedia.org/wiki/Internet_protocol_suite#Comparison_of_TCP/IP_and_OSI_layering

The internet

Fast

Slow!

Fast



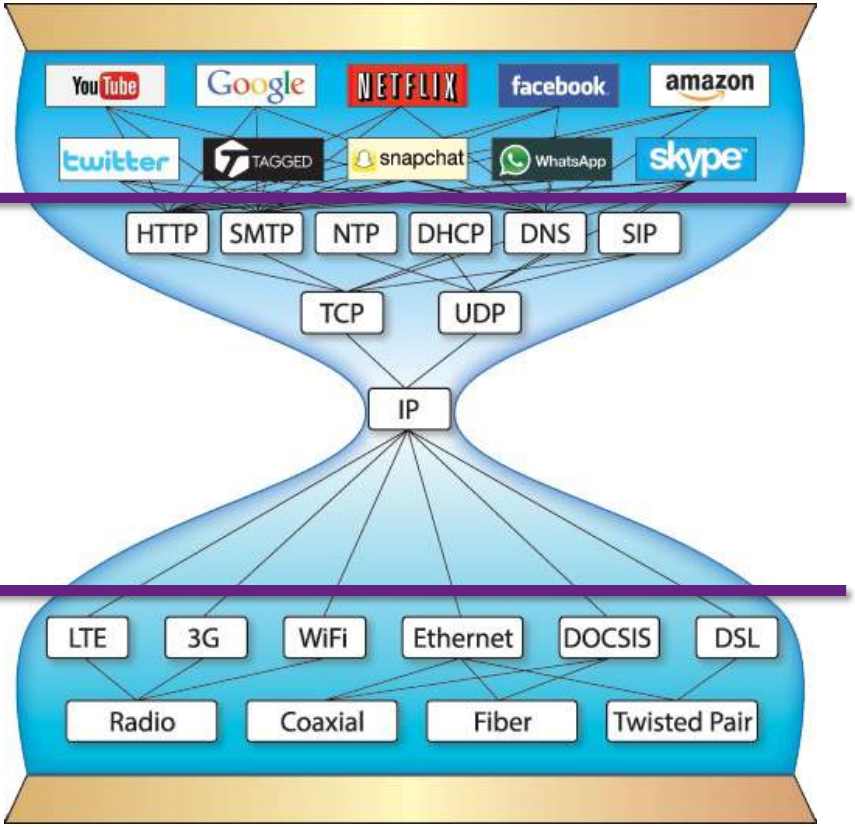
The internet

I E T F®

(and others, such as W3C®)

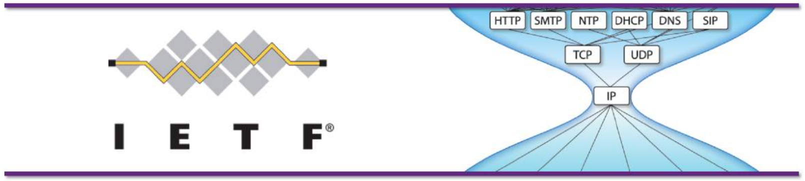
IEEE

(and others, such as Bluetooth®)



SIDN LABS

Internet Standards



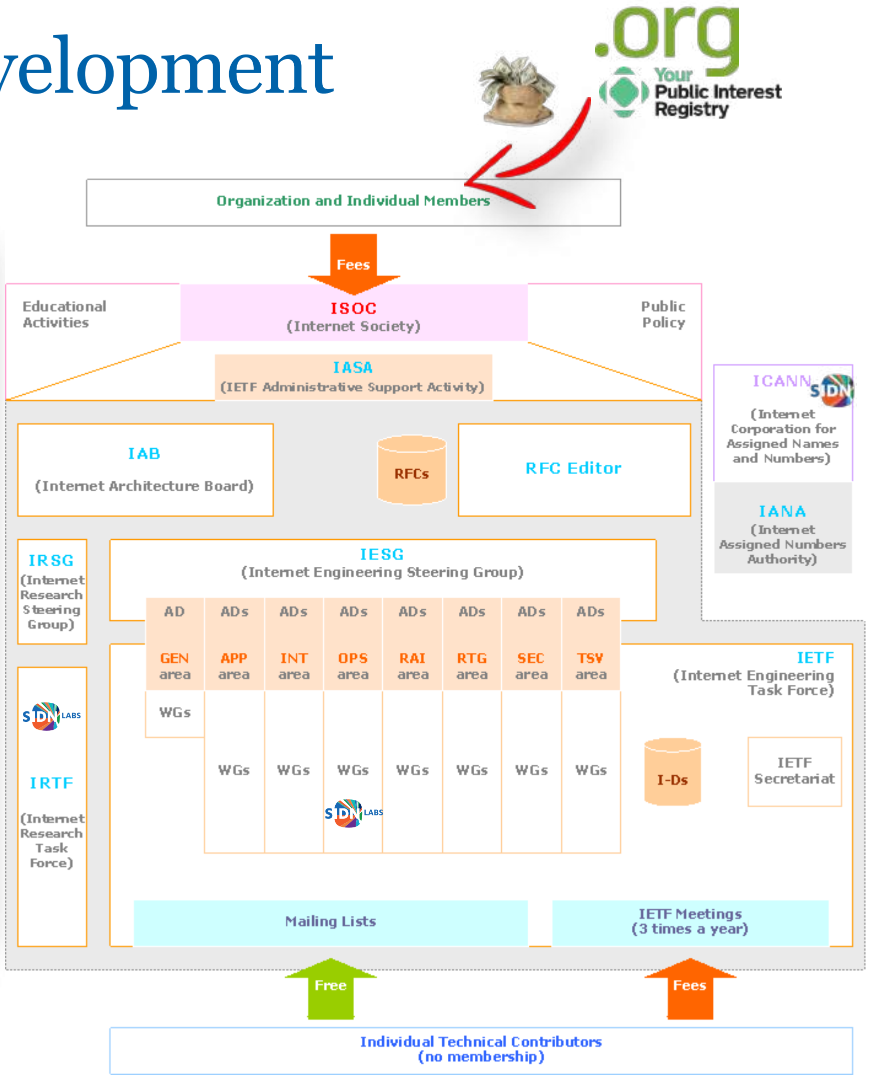
"We reject kings, presidents and voting.
We believe in rough consensus and running code”
-- David Clark

IETF, Internet Engineering Task Force:

- Open standards organization, without formal membership
- Everyone can participate (in person or via mailing lists)
- Under the auspices of the Internet Society (ISOC)
- Many working groups and informal discussions
- Rough consensus* is the primary basis for decision-making
- Often slow processes!
- But many RFCs ! About 9568 and a multitude of drafts

* https://www.rfc-editor.org/info/rfc7282

IETF: bottom-up standards development



.org Your Public Interest Registry

Organization and Individual Members

Fees

Educational Activities

ISOC (Internet Society)

Public Policy

IASA (IETF Administrative Support Activity)

IAB (Internet Architecture Board)

RFCs

RFC Editor

ICANN (Internet Corporation for Assigned Names and Numbers)

IANA (Internet Assigned Numbers Authority)

IRSG (Internet Research Steering Group)

IESG (Internet Engineering Steering Group)

AD	ADs	ADs	ADs	ADs	ADs	ADs	ADs
GEN area	APP area	INT area	OPS area	RAI area	RTG area	SEC area	TSV area
WGs	WGs	WGs	WGs	WGs	WGs	WGs	WGs

IETF (Internet Engineering Task Force)

I-Ds

IETF Secretariat

IRTF (Internet Research Task Force)

Mailing Lists

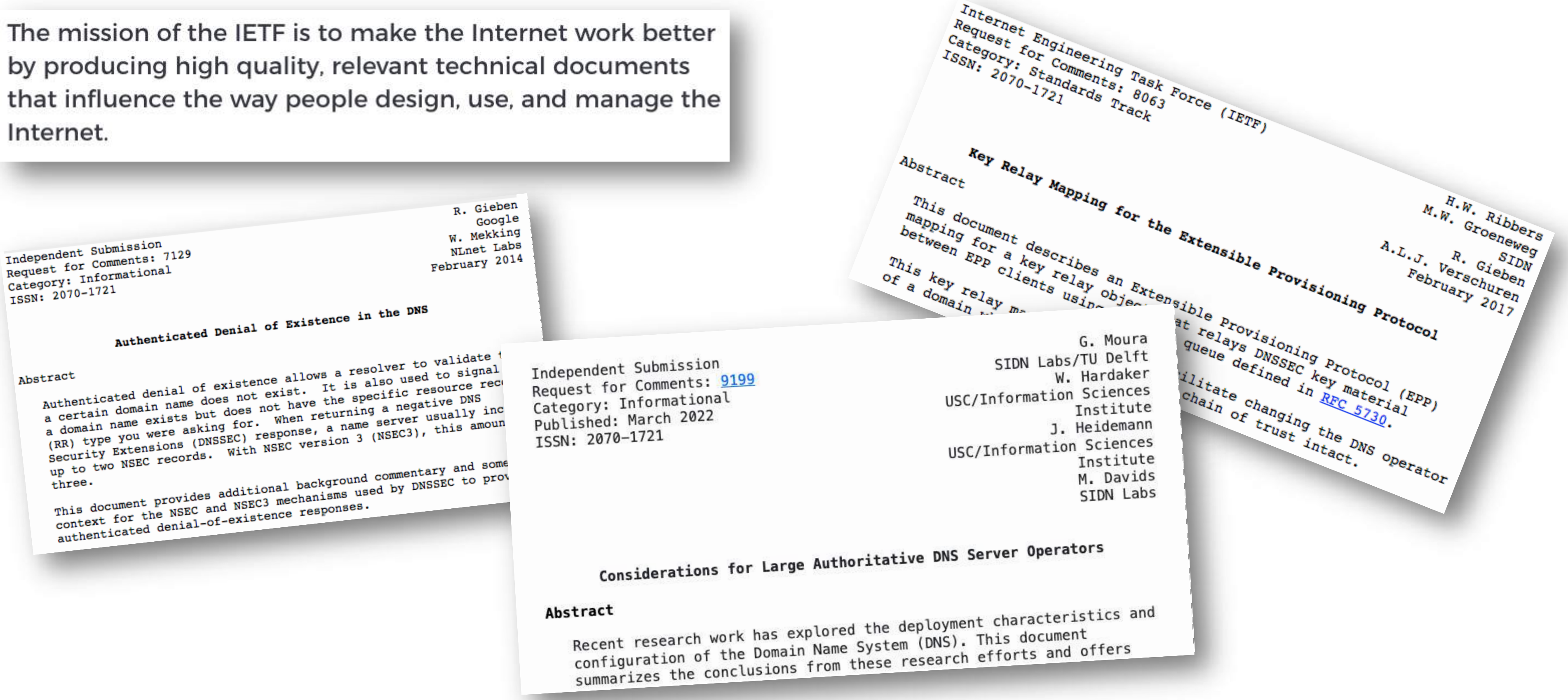
IETF Meetings (3 times a year)

Free

Fees

Individual Technical Contributors (no membership)

IETF: many RFC's



The mission of the IETF is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet.

Independent Submission
Request for Comments: 7129
Category: Informational
ISSN: 2070-1721

R. Gieben
Google
W. Mekking
NLnet Labs
February 2014

Authenticated Denial of Existence in the DNS

Abstract

Authenticated denial of existence allows a resolver to validate t
a certain domain name does not exist. It is also used to signal
a domain name exists but does not have the specific resource rec
(RR) type you were asking for. When returning a negative DNS
Security Extensions (DNSSEC) response, a name server usually inc
up to two NSEC records. With NSEC version 3 (NSEC3), this amoun
three.

This document provides additional background commentary and some
context for the NSEC and NSEC3 mechanisms used by DNSSEC to prov
authenticated denial-of-existence responses.

Internet Engineering Task Force (IETF)
Request for Comments: 8063
Category: Standards Track
ISSN: 2070-1721

H.W. Ribbers
M.W. Groeneweg
SIDN
R. Gieben
A.L.J. Verschuren
February 2017

Key Relay Mapping for the Extensible Provisioning Protocol

Abstract

This document describes an Extensible Provisioning Protocol (EPP)
mapping for a key relay objec at relays DNSSEC key material
between EPP clients usin queue defined in RFC 5730.

This key relay ma ilitate changing the DNS operator
of a domain w chain of trust intact.

Independent Submission
Request for Comments: 9199
Category: Informational
Published: March 2022
ISSN: 2070-1721

G. Moura
SIDN Labs/TU Delft
W. Hardaker
USC/Information Sciences
Institute
J. Heidemann
USC/Information Sciences
Institute
M. Davids
SIDN Labs

Considerations for Large Authoritative DNS Server Operators

Abstract

Recent research work has explored the deployment characteristics and
configuration of the Domain Name System (DNS). This document
summarizes the conclusions from these research efforts and offers

🇳🇱 👍🏽 http://www.arkko.com/tools/allstats/thenetherlands.html

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Really a lot, maybe even too much...

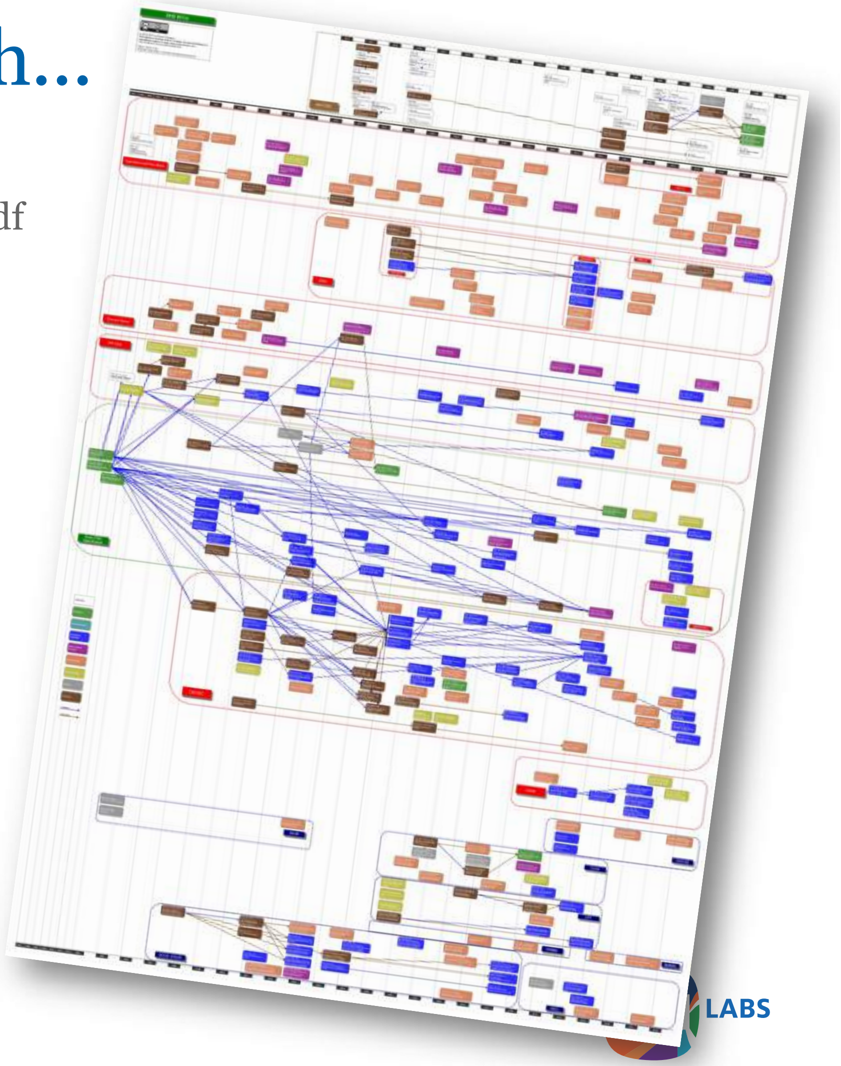
https://emaillab.jp/wp/wp-content/uploads/2017/11/RFC-DNS.pdf

185 RFC's
2781 pages
166891 lines
888233 words

This is 2 times "The C++ Programming Language" (4th ed.)

Some good words on this are in RFC 8324

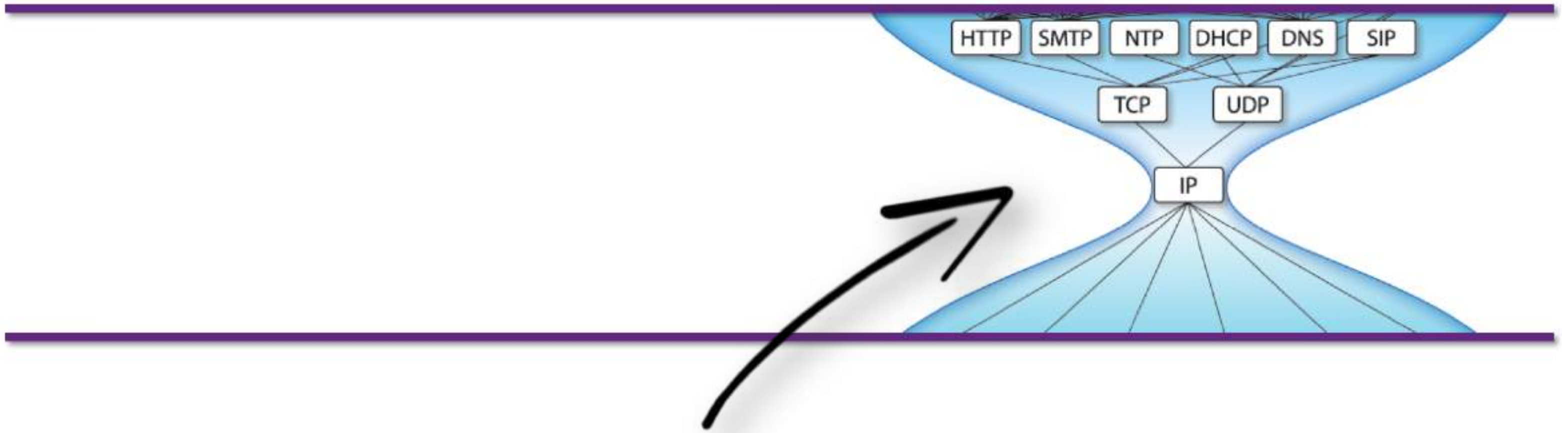
https://datatracker.ietf.org/meeting/101/materials/slides-101-dnsop-sessa-the-dns-camel-01



DNS(SEC)

See also: https://powerdns.org/dns-camel/

Names and numbers



Names and numbers

Do you recognize these?

192.168.0.1

192.168.1.1

192.168.100.1

192.168.2.1

https://www.rfc-editor.org/info/rfc1918

Names and number

198.51.100.123

A 'global' IP address

But this one?

2001:db8::198:51:100:123

Names and numbers

Good to know:

Every device connected directly to the Internet requires a unique IP address.*

* exception: anycast

Control of IP address space issuance

The mission of ICANN is to ensure the stable and secure operation of the Internet's unique identifier systems

ICANN (the Internet Corporation for Assigned Names and Numbers)

https://www.icann.org/resources/pages/governance/bylaws-en/

Control of IP address space issuance (and more)

DNS space

ICANN

AS numbers

IP space

The mission of ICANN is to ensure the stable and secure operation of the Internet's unique identifier systems

’Global number registries’

ICANN (the Internet Corporation for Assigned Names and Numbers)

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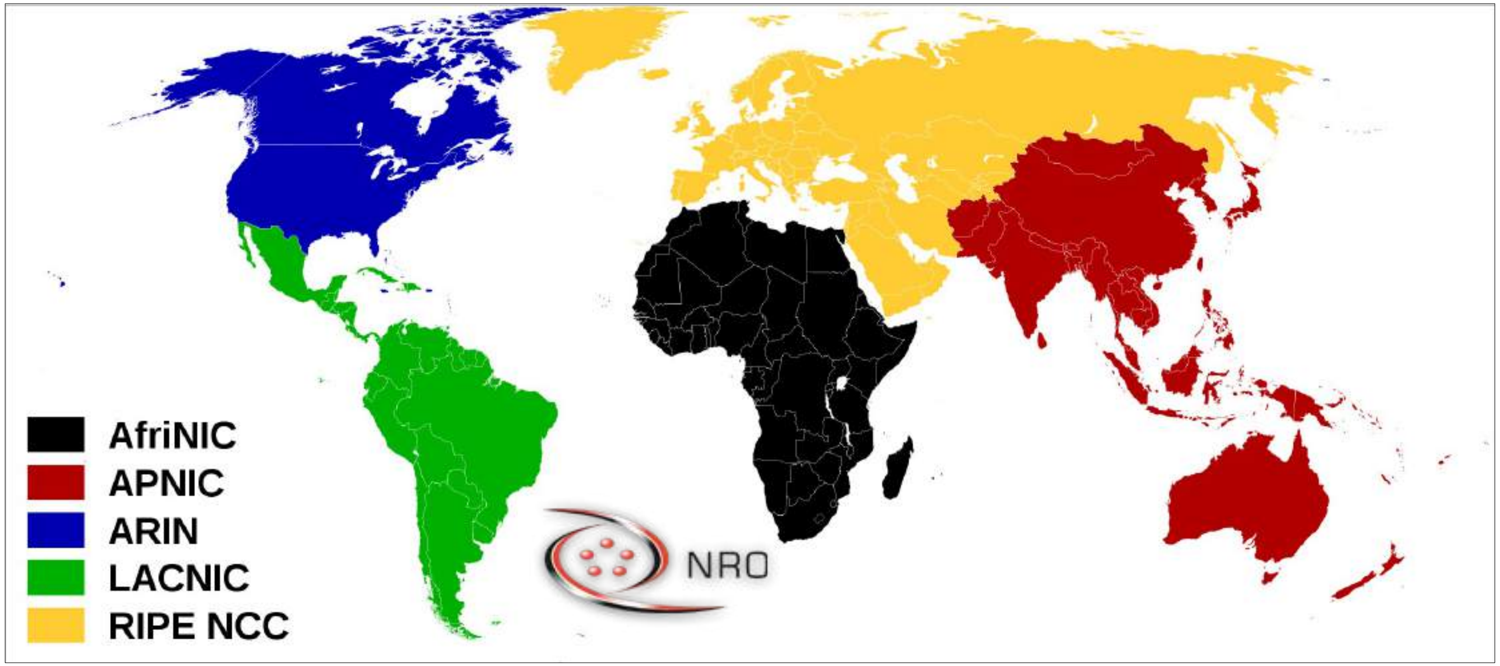
https://www.icann.org/

Issueance of IP address space

https://www.iana.org/assignments/ipv4-address-space/
https://www.iana.org/assignments/ipv6-address-space/

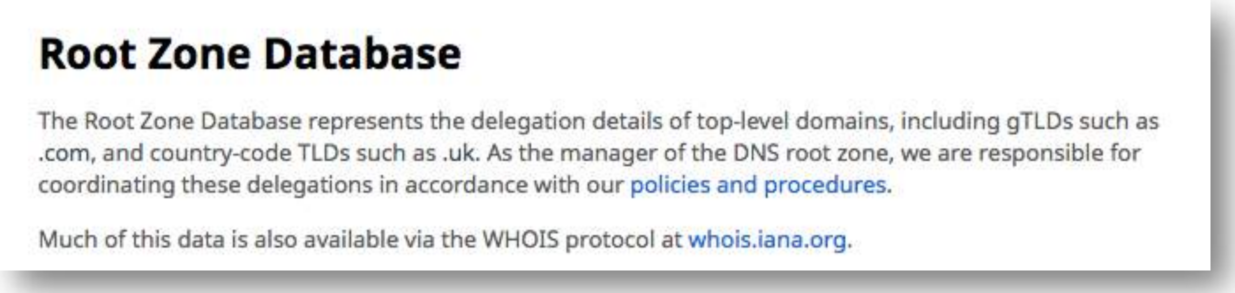


IANA (Internet Assigned Numbers Authority) → RIRs → LIRs

https://www.nro.net/

But ICANN does more (top level domains)

https://www.iana.org/domains/root/db



Root Zone Database

The Root Zone Database represents the delegation details of top-level domains, including gTLDs such as .com, and country-code TLDs such as .uk. As the manager of the DNS root zone, we are responsible for coordinating these delegations in accordance with our policies and procedures.

Much of this data is also available via the WHOIS protocol at whois.iana.org.

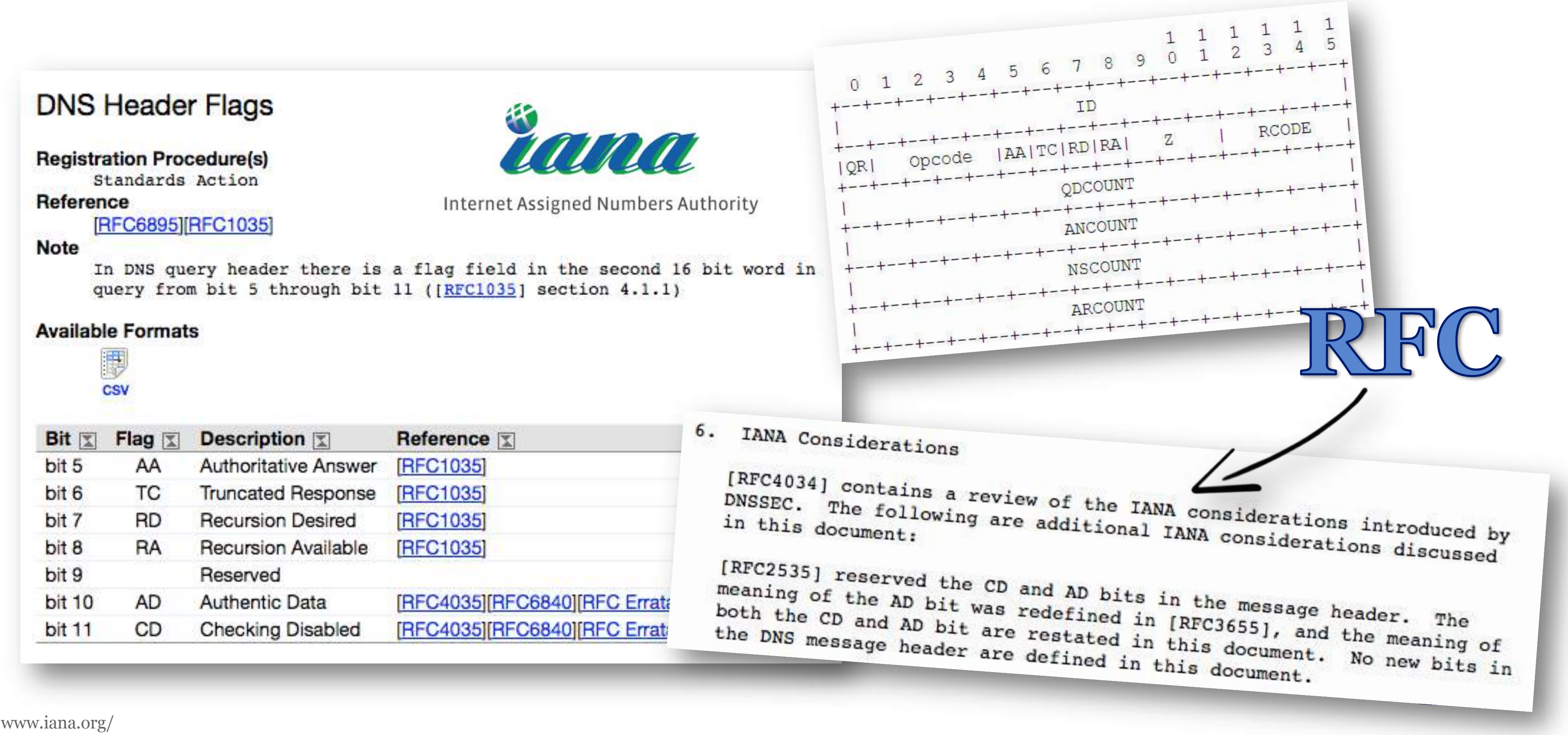
iana

Internet Assigned Numbers Authority

https://www.iana.org/

And ICANN does even more (protocol assignments)

https://www.iana.org/assignments/dns-parameters/dns-parameters.xhtml#dns-parameters-12



DNS Header Flags

Registration Procedure(s)

`Standards Action`

Reference

[RFC6895][RFC1035]

Note

`In DNS query header there is a flag field in the second 16 bit word in query from bit 5 through bit 11 ([RFC1035] section 4.1.1)`

Available Formats

CSV

Bit	Flag	Description	Reference
bit 5	AA	Authoritative Answer	[RFC1035]
bit 6	TC	Truncated Response	[RFC1035]
bit 7	RD	Recursion Desired	[RFC1035]
bit 8	RA	Recursion Available	[RFC1035]
bit 9		Reserved	
bit 10	AD	Authentic Data	[RFC4035][RFC6840][RFC Errata
bit 11	CD	Checking Disabled	[RFC4035][RFC6840][RFC Errat

```
                                1  1  1  1  1  1
  0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                      ID                       |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|QR|   Opcode  |AA|TC|RD|RA|   Z    |   RCODE   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    QDCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    ANCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    NSCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    ARCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

RFC

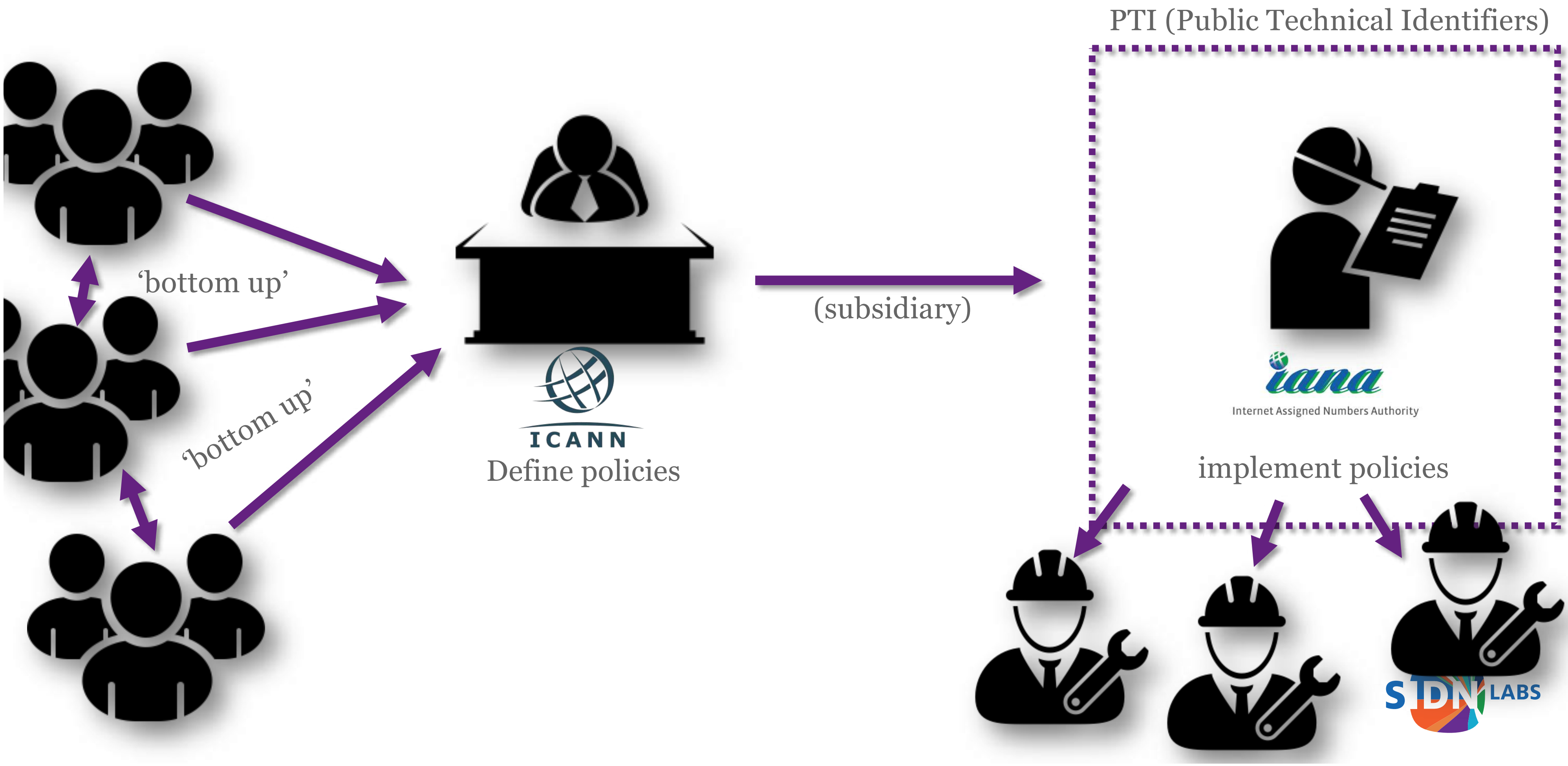
```
6.  IANA Considerations

   [RFC4034] contains a review of the IANA considerations introduced by
   DNSSEC.  The following are additional IANA considerations discussed
   in this document:

   [RFC2535] reserved the CD and AD bits in the message header.  The
   meaning of the AD bit was redefined in [RFC3655], and the meaning of
   both the CD and AD bit are restated in this document.  No new bits in
   the DNS message header are defined in this document.
```

https://www.iana.org/

Overview ICANN / IANA



(back to) Names and numbers

www.example.nl

This will be familiar.

And what do we see here?

www.sidn.team

(back to) Names and numbers

www.example.испытание

What about this one?

www.日本レジストリサービス.jp

(back to) Names and numbers

www.bücher.de

Allowed or…?

www.café.nl

www.café.be

Internationalized domain name (IDN)

www.bücher.de

www.xn--bcher-kva.de

IDNA / punycode / ACE-string

www.café.be

www.xn--caf-dma.be

Leestip: https://en.wikipedia.org/wiki/IDN_homograph_attack

Names ~~and numbers~~

And have you ever seen these ones?

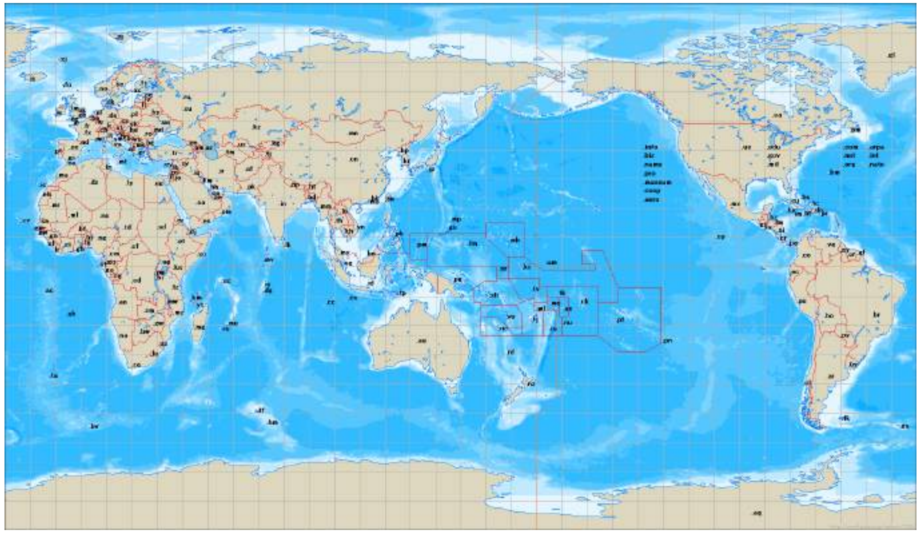
marco-gw.home.arpa

darknetsite.onion

e164.arpa

eat.kiwi

Top-level domains



±308

life
sport
school
llp
cruise
furniture
mba
help
store
style
security
website
media
deals
food
film
luxury
hot
wine
mls
city
video
data
fashion
merck
gay
soccer
construction
tube
team
corp
play
llc
inc
game
taxi
buy
green
cam
diet
garden
show
now
site
hotel
web
cpa
news
broadway
club
design
blogbook
health
yoga
cloud
gmbh
box
movie
property
phd
tech
marketing
pizza
band
salon
bank
bar
gold
music
art
shop
home
app
baby
online
group
world
casa
restaurant
love
golf
mail
vote
country
realestate
vip
insurance
spot
law
forum
search
beauty
tennis
wow
flowers
ltd
family
free
basketball
bet
sale
pay
tickets
sucks
map
memorial
live
cricket
latino
radio
网址
eco
wedding
poker
rip
energy
casino
cars
fishing
science
doctor
mobile
tires
webs
mom
red
theater
rugby
auto
hosting
yun
express
party
spa
fun
football
chat
racing
immo

±1241

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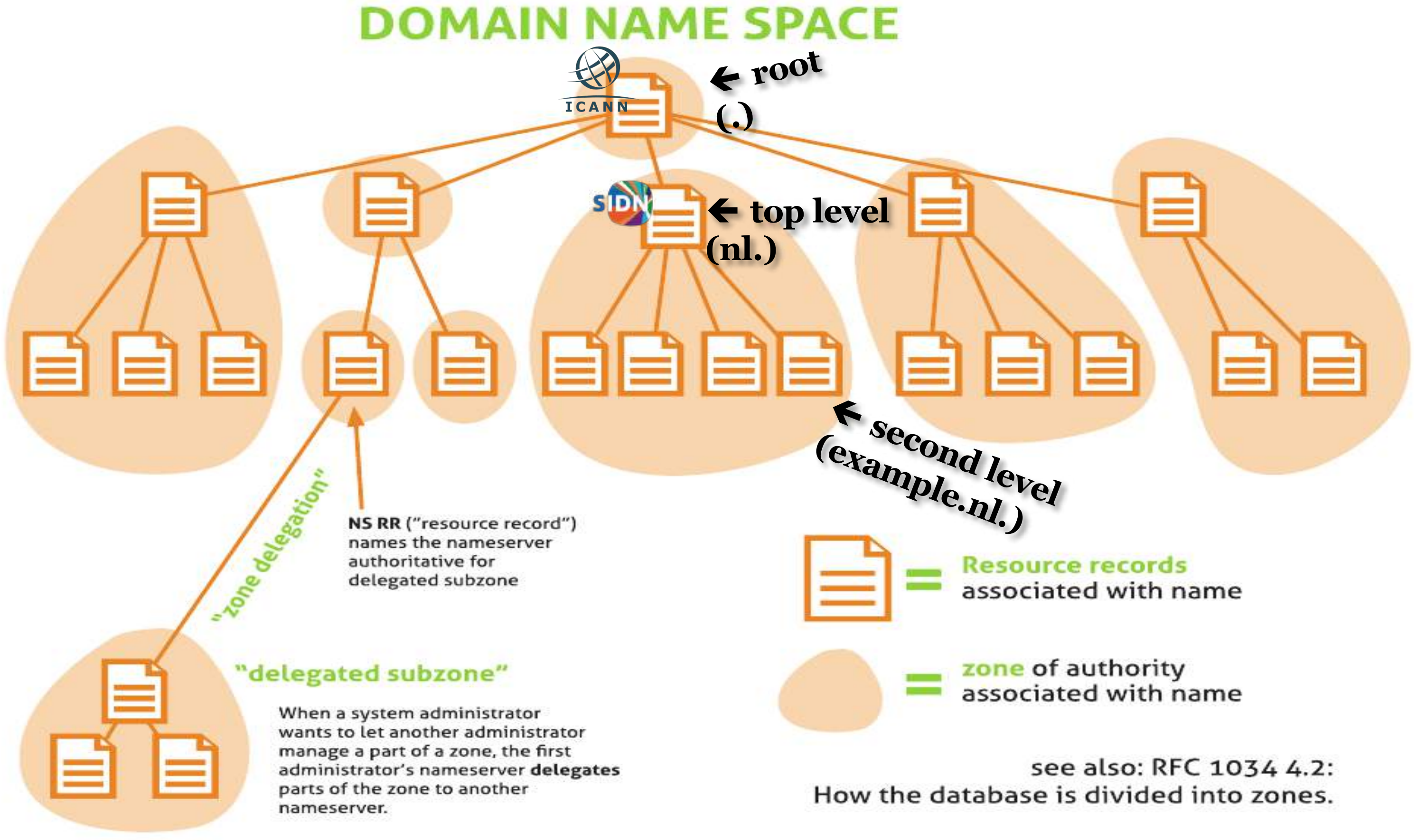
http://www.marco.panizza.name/dispenseTM/slides/TLD/ccTLD_worldmap.html
https://en.wikipedia.org/wiki/Country_code_top-level_domain

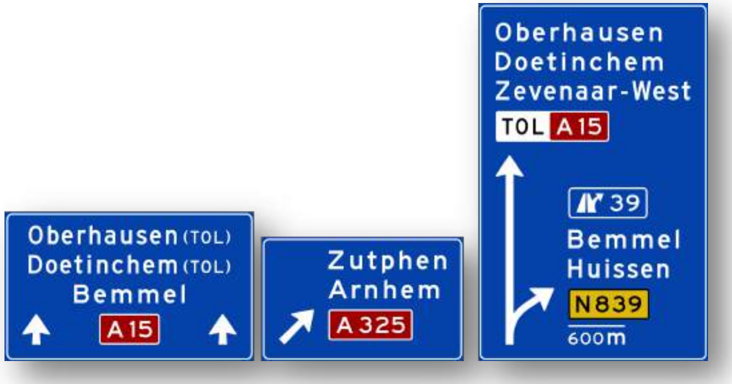
https://newgtlds.icann.org/en/program-status/statistics

Domain Name System (DNS)


DOMAIN NAME SPACE
ICANN
← root
(.)
SIDN
← top level
(nl.)
← second level
(example.nl.)
"zone delegation"
NS RR ("resource record") names the nameserver authoritative for delegated subzone
"delegated subzone"
When a system administrator wants to let another administrator manage a part of a zone, the first administrator's nameserver **delegates** parts of the zone to another nameserver.
= Resource records associated with name
= zone of authority associated with name

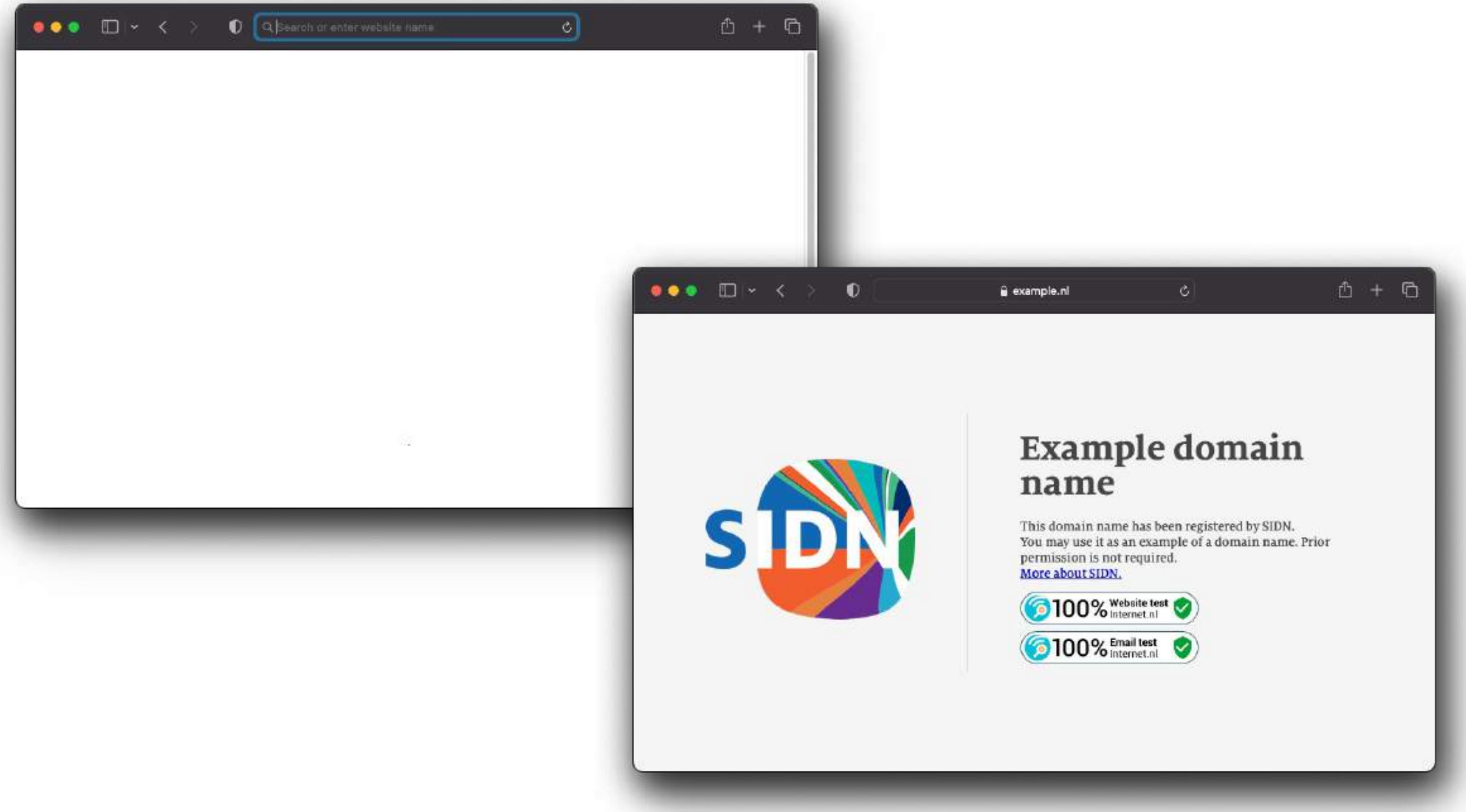
see also: RFC 1034 4.2:
How the database is divided into zones.

About DNS



- DNS is a kind of ‘internet signage’
- Some compare it with a telephone directory
- You know the name (sidn.nl), your browser can't do much with it
- Your browser wants the IP address (2600:1901:0:7947::0)
- DNS makes this possible

How do you get from blank page to website?

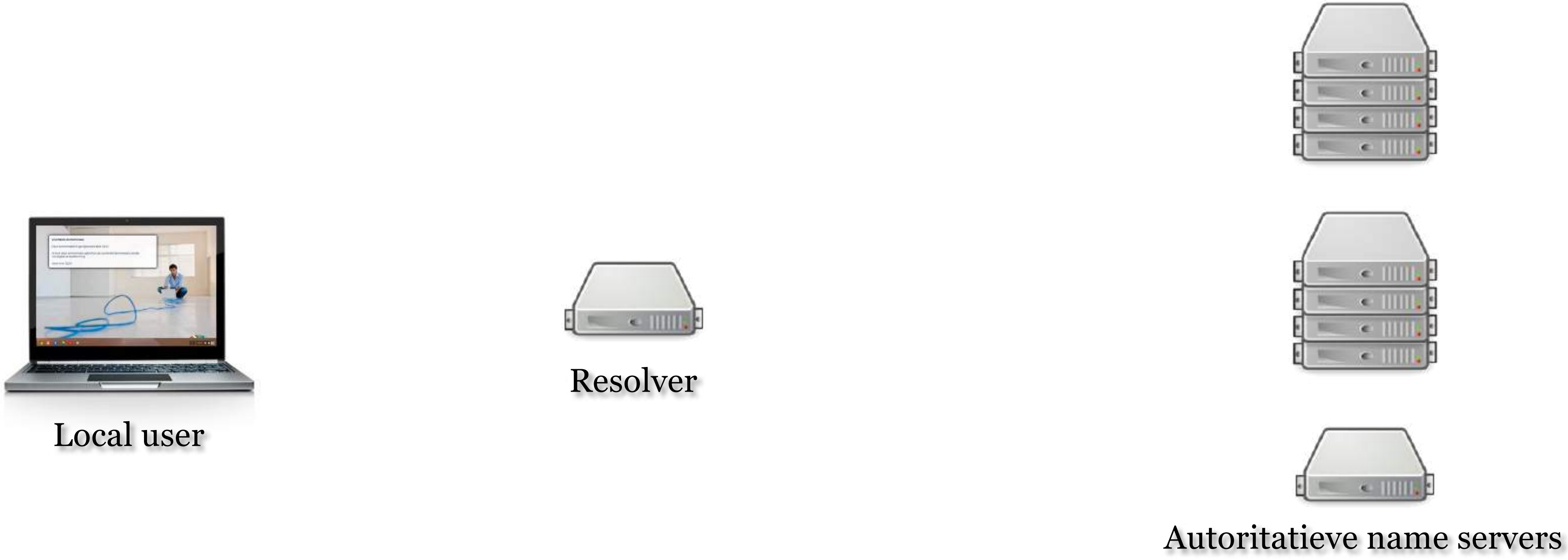

Search or enter website name
example.nl

Example domain name

This domain name has been registered by SIDN.
You may use it as an example of a domain name. Prior permission is not required.
More about SIDN.

100% Website test Internet.nl
100% Email test Internet.nl

DNS: What happens when you surf to http://example.nl?

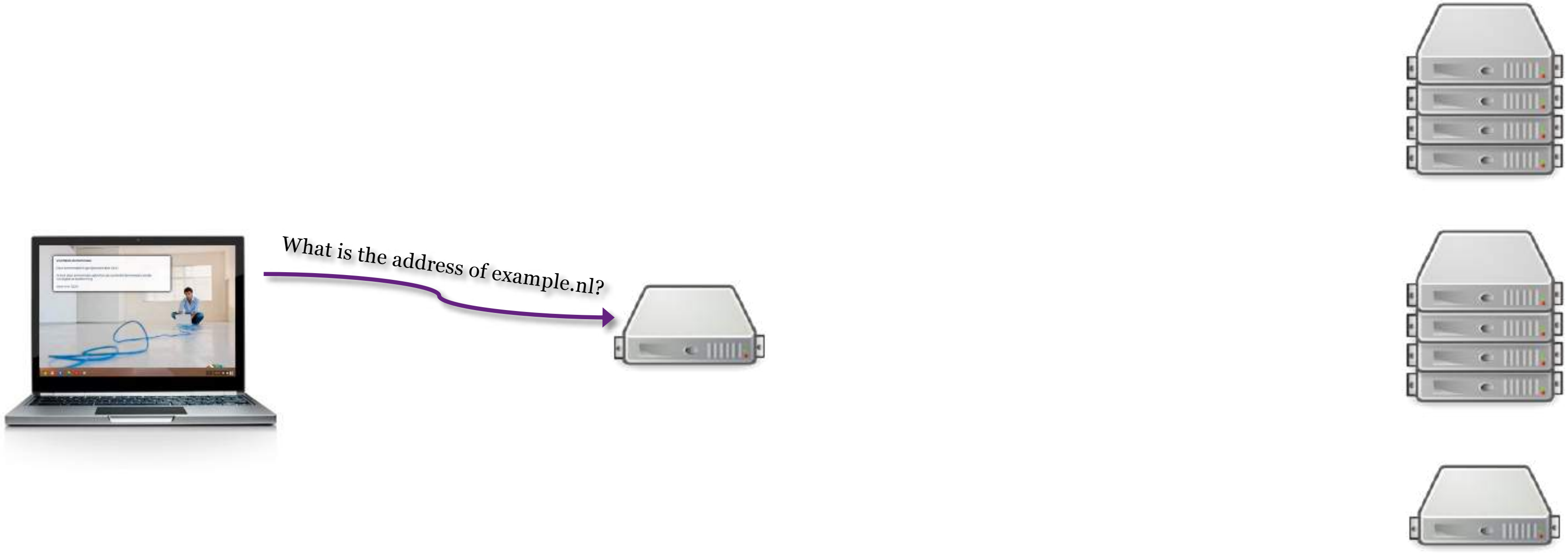


Local user

Resolver

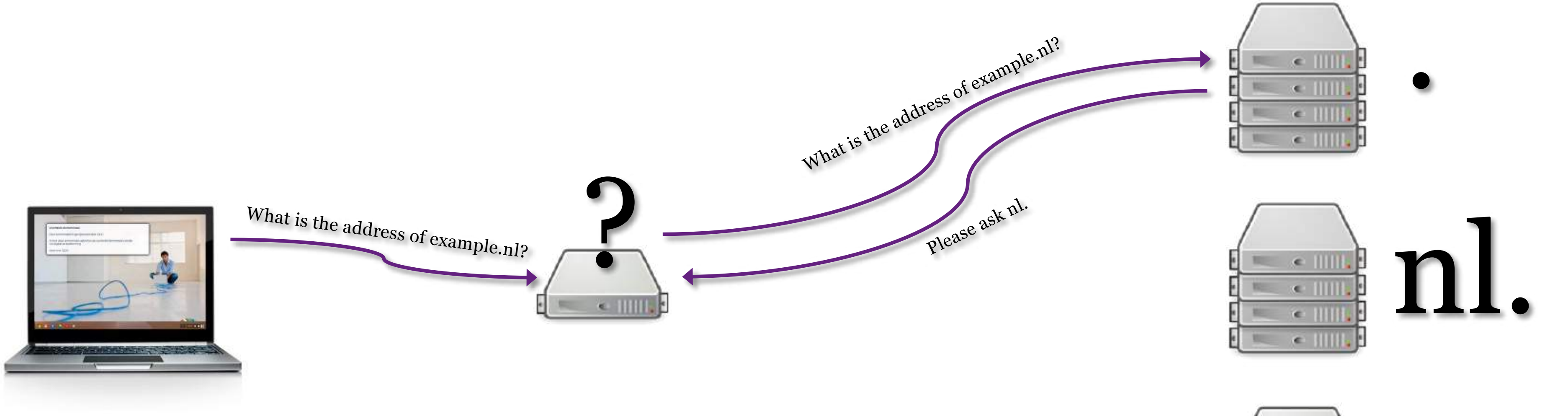
Autoritatieve name servers

DNS: The 'stub-resolver' asks a question to the 'resolver'...



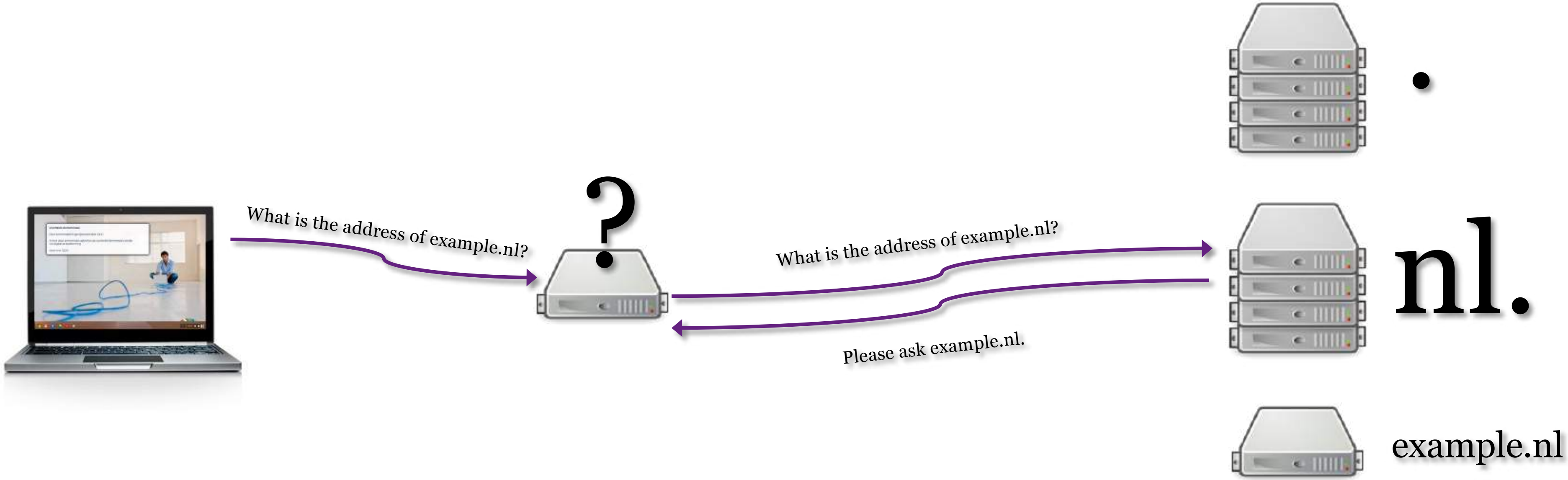
What is the address of example.nl?

DNS: The resolver starts looking for the answer…

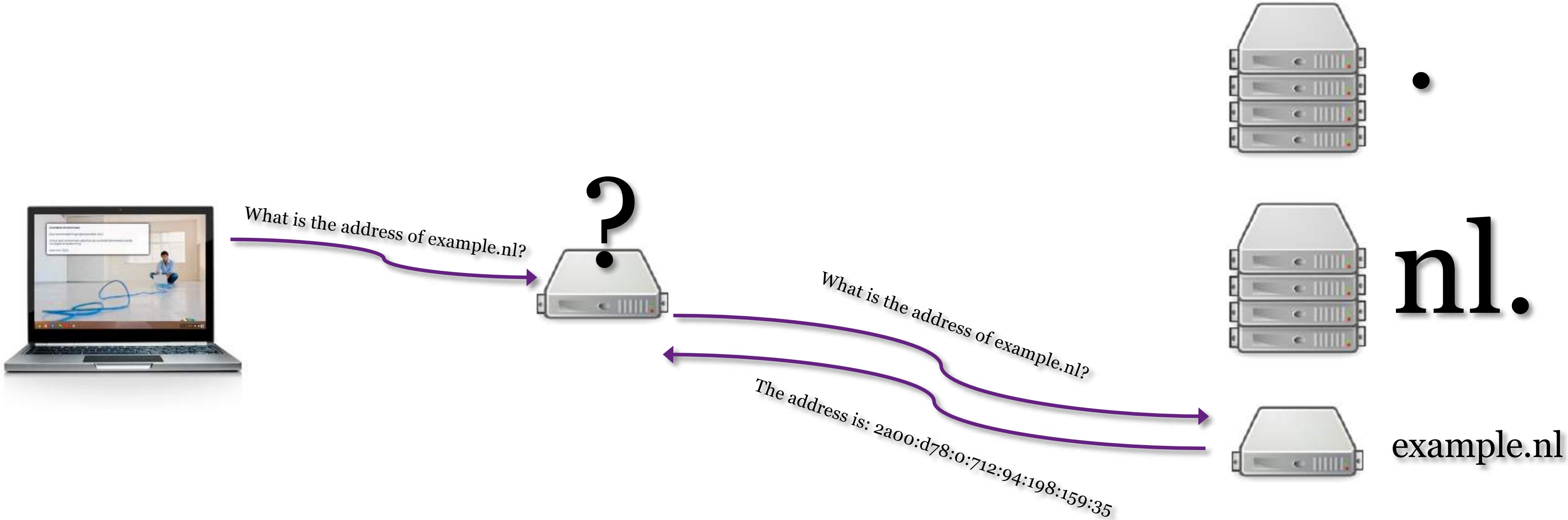

What is the address of example.nl?
?
What is the address of example.nl?
Please ask nl.
.
nl.
example.nl

SIDN LABS

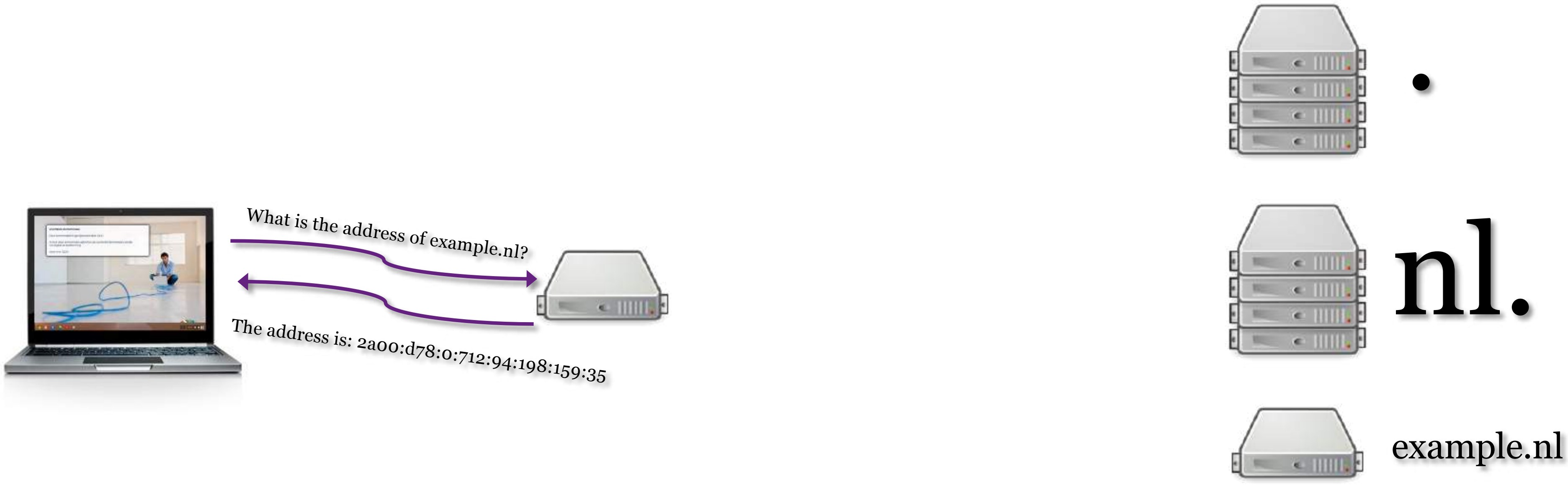
DNS: The resolver starts looking for the answer…


What is the address of example.nl?
?
What is the address of example.nl?
Please ask example.nl.
.
nl.
example.nl

DNS: The resolver starts looking for the answer…


.
What is the address of example.nl?
?
nl.
What is the address of example.nl?
The address is: 2a00:d78:0:712:94:198:159:35
example.nl

DNS: The resolver starts looking for the answer…



What is the address of example.nl?

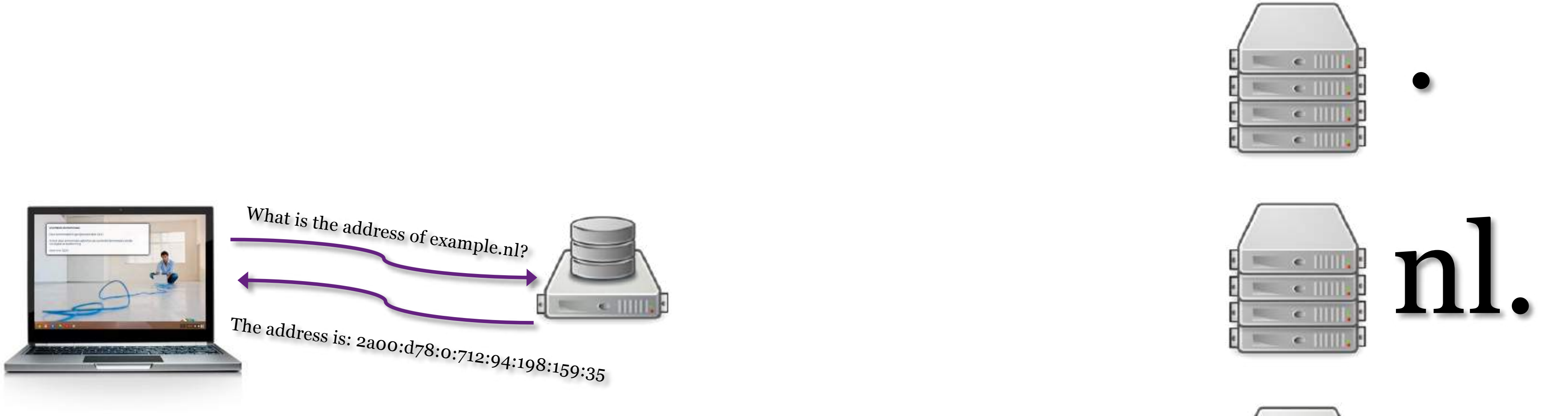
The address is: 2a00:d78:0:712:94:198:159:35

.

nl.

example.nl

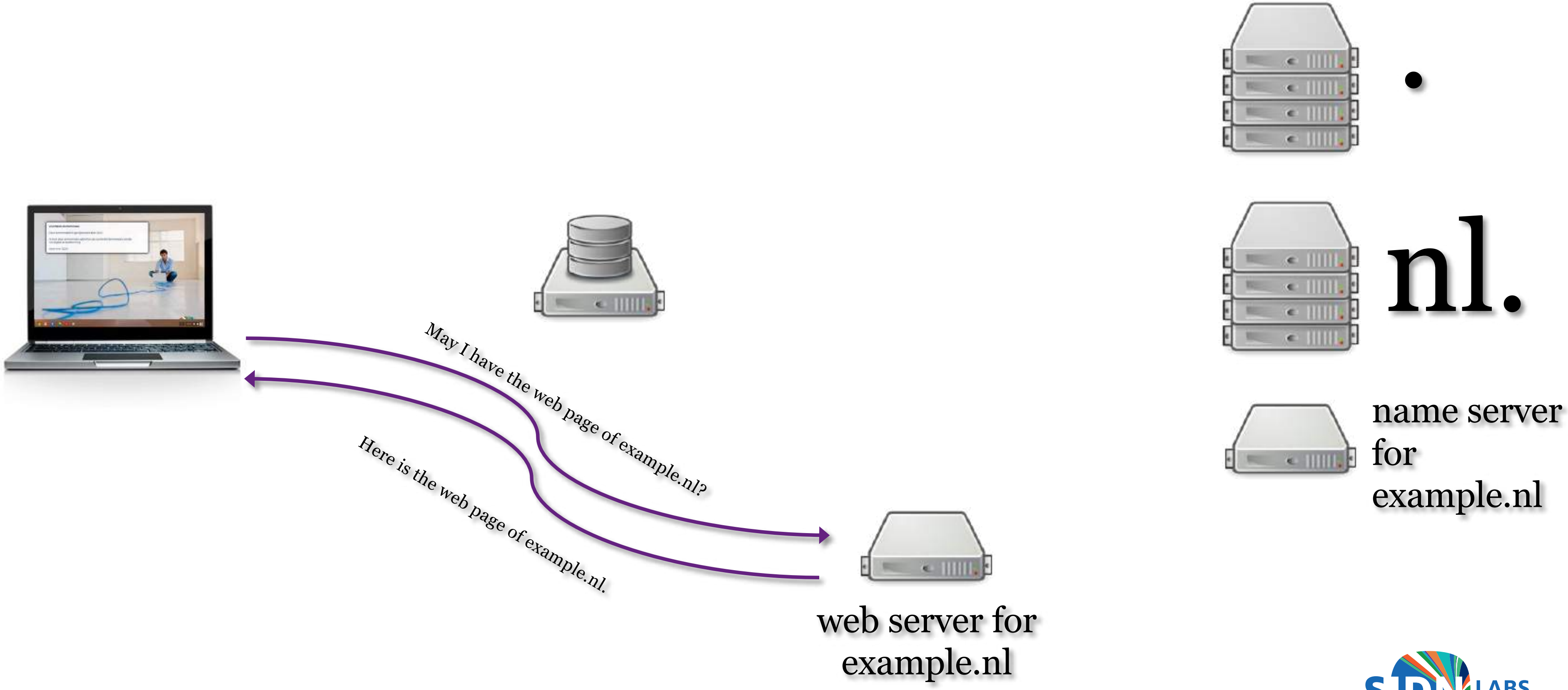
DNS: The resolver starts looking for the answer…



What is the address of example.nl?

The address is: 2a00:d78:0:712:94:198:159:35

DNS: The resolver starts looking for the answer…



.
nl.
name server for example.nl
May I have the web page of example.nl?
Here is the web page of example.nl.
web server for example.nl

SIDN LABS

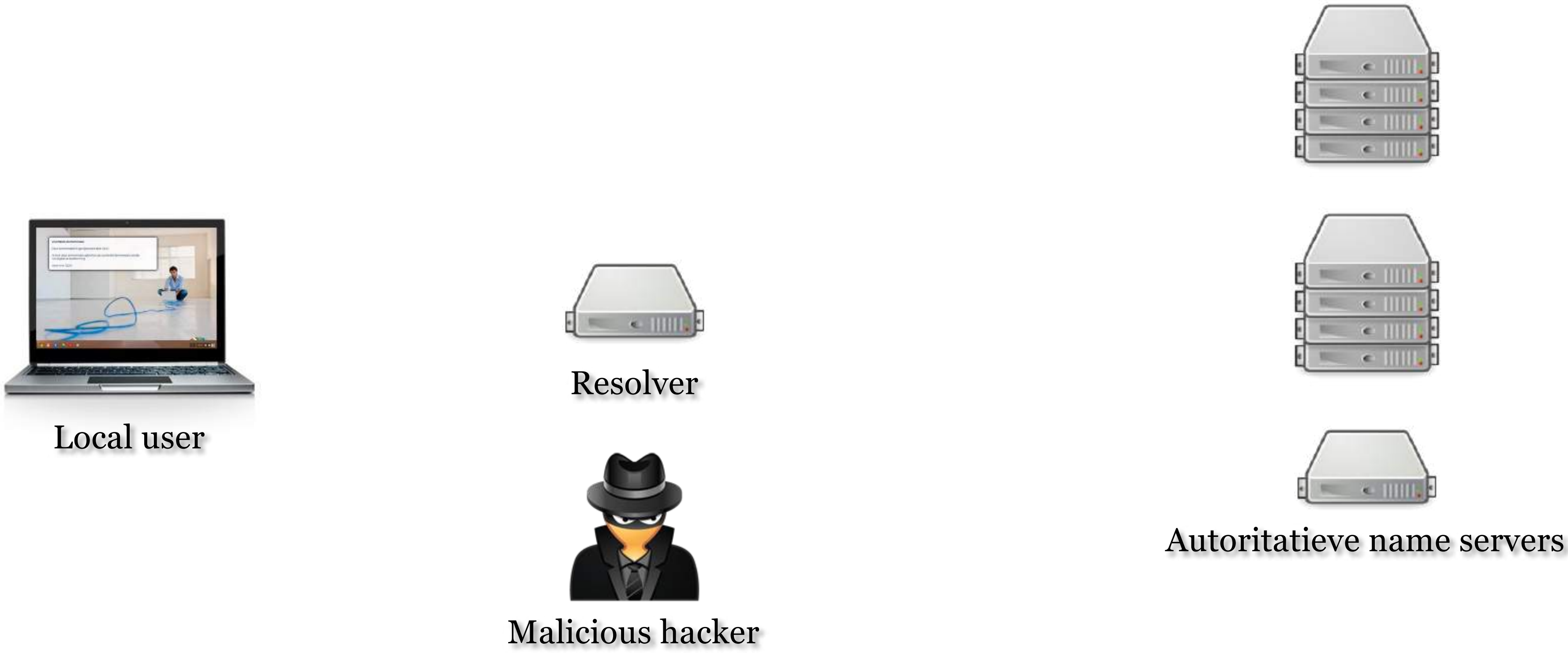
DNSSEC

About DNSSEC

Workings:

- DNS responses are digitally signed
- These digital signatures are checked by the resolver
- If the answer has been tampered with, the signature is incorrect

What could go wrong?



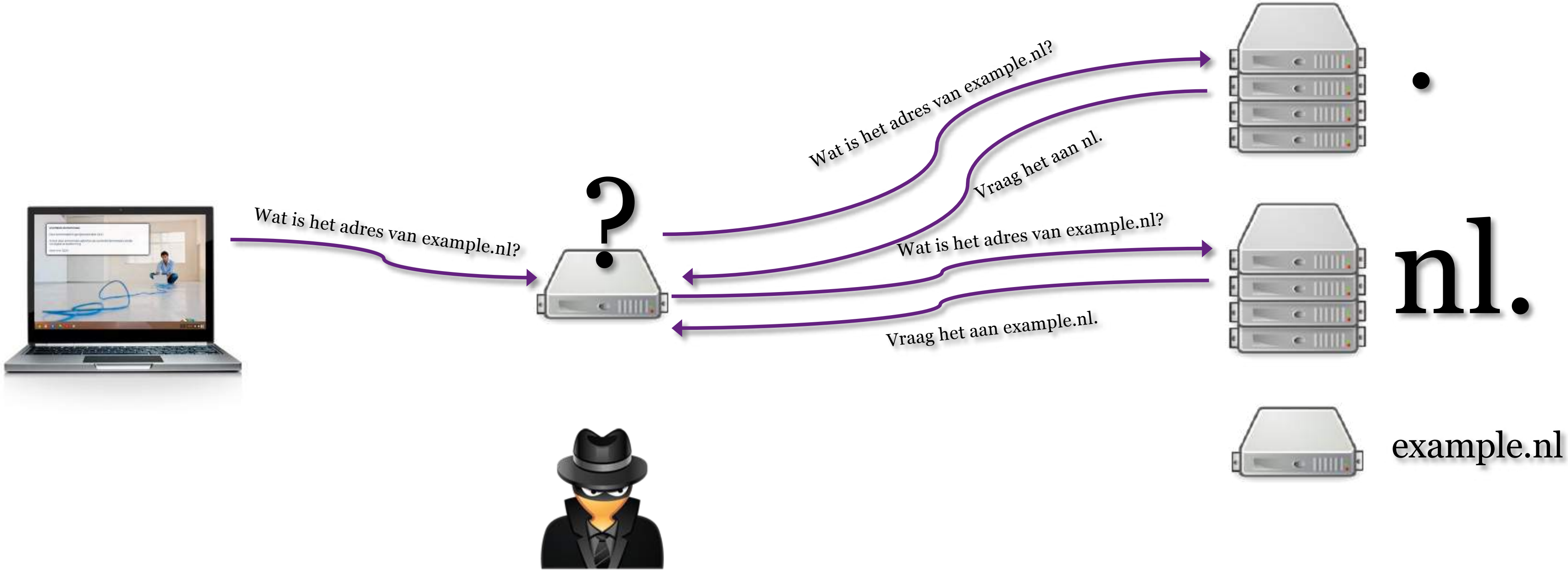
Local user

Resolver

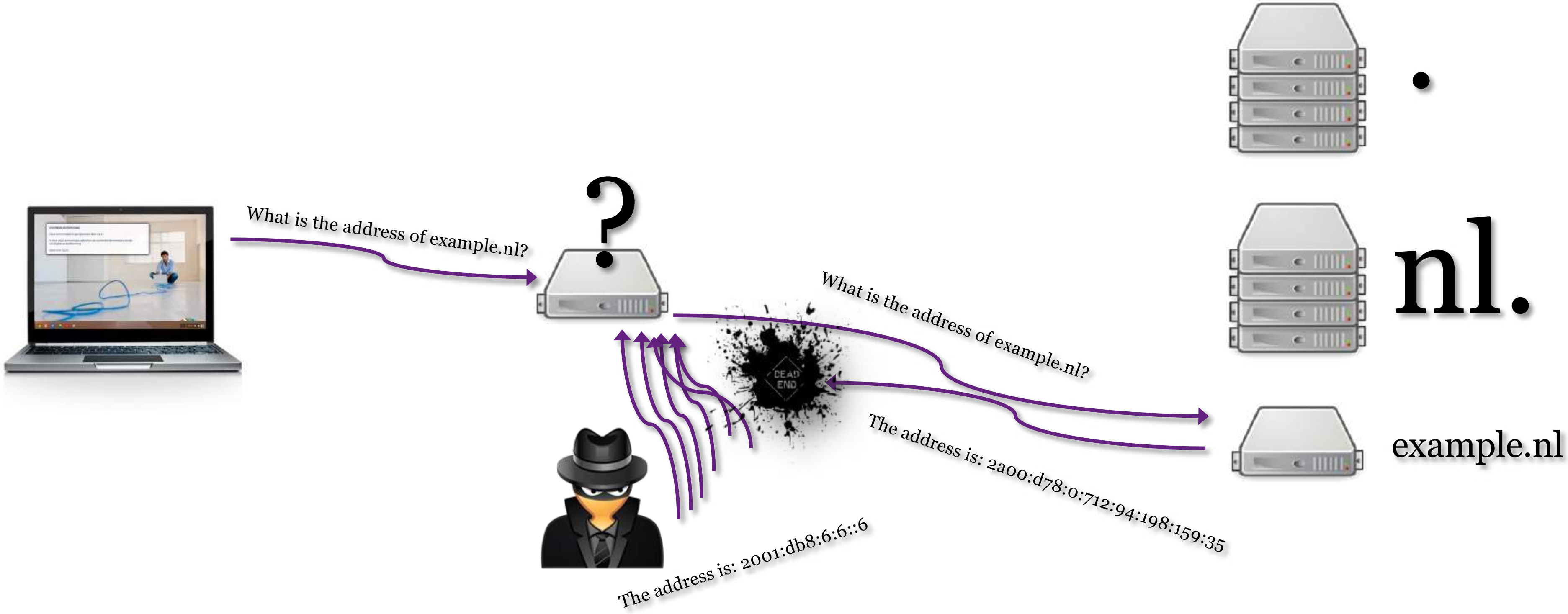
Malicious hacker

Autoritatieve name servers

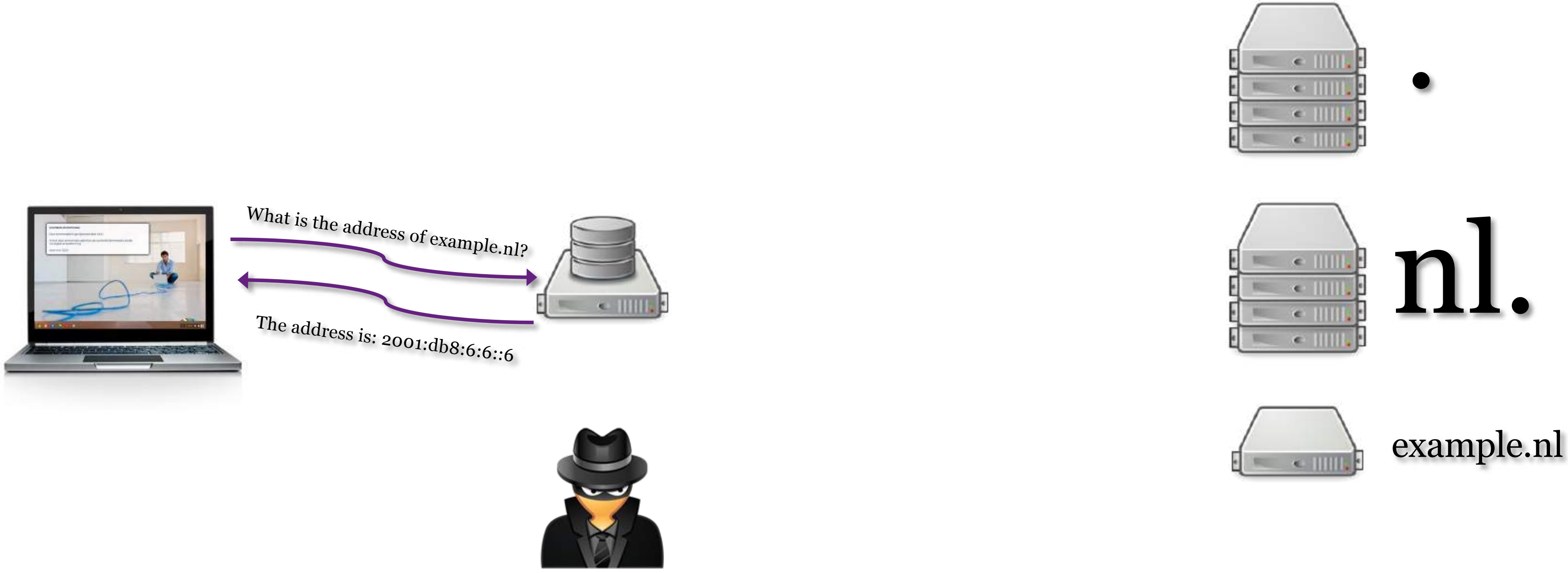
De resolver gaat op zoek naar het antwoord…


Wat is het adres van example.nl?
?
Wat is het adres van example.nl?
Vraag het aan nl.
Wat is het adres van example.nl?
Vraag het aan example.nl.
.
nl.
example.nl

Lots of fake answers!


.
nl.
example.nl
What is the address of example.nl?
?
What is the address of example.nl?
DEAD END
The address is: 2a00:d78:0:712:94:198:159:35
The address is: 2001:db8:6:6::6

The resolver has fallen for a false answer…



What is the address of example.nl?

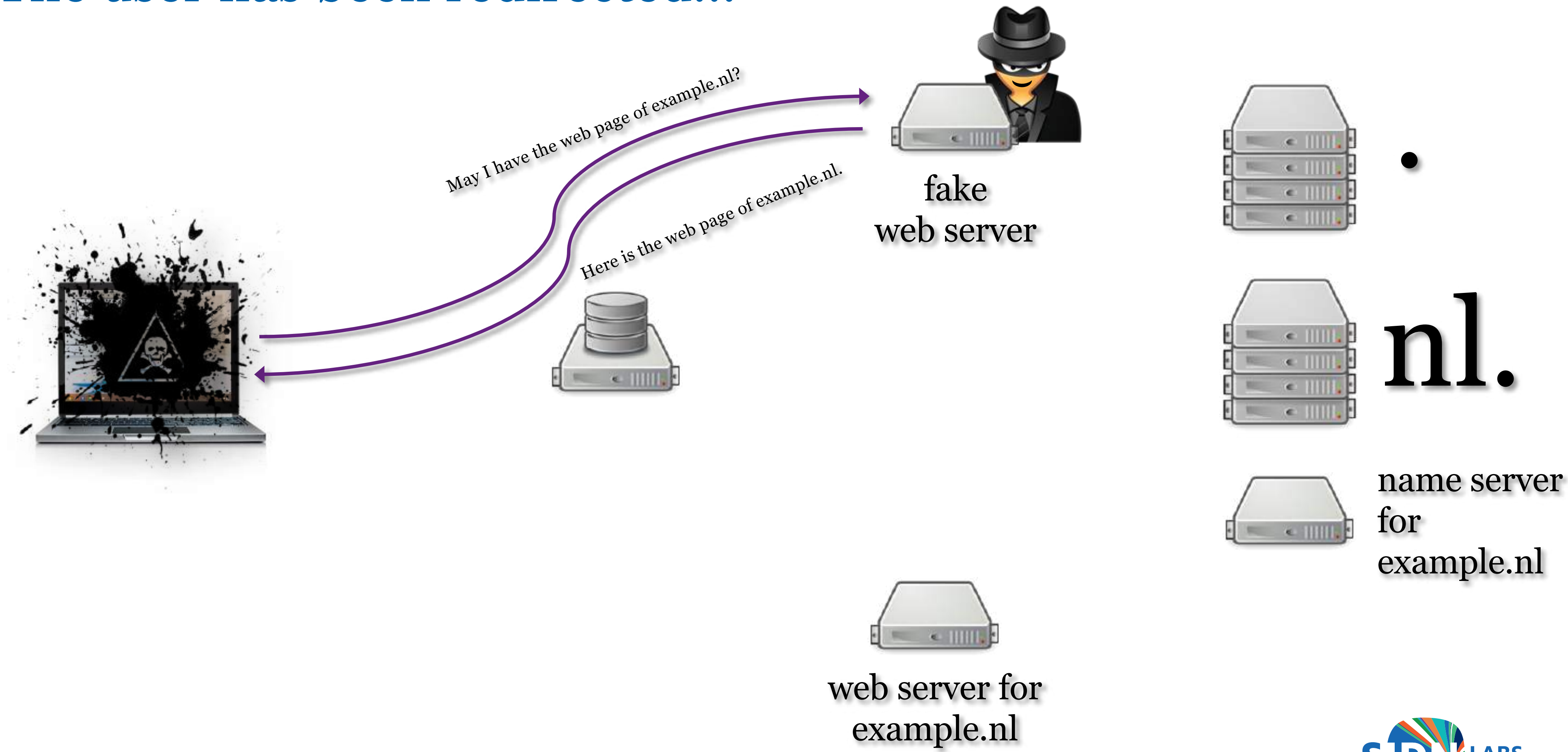
The address is: 2001:db8:6:6::6

.

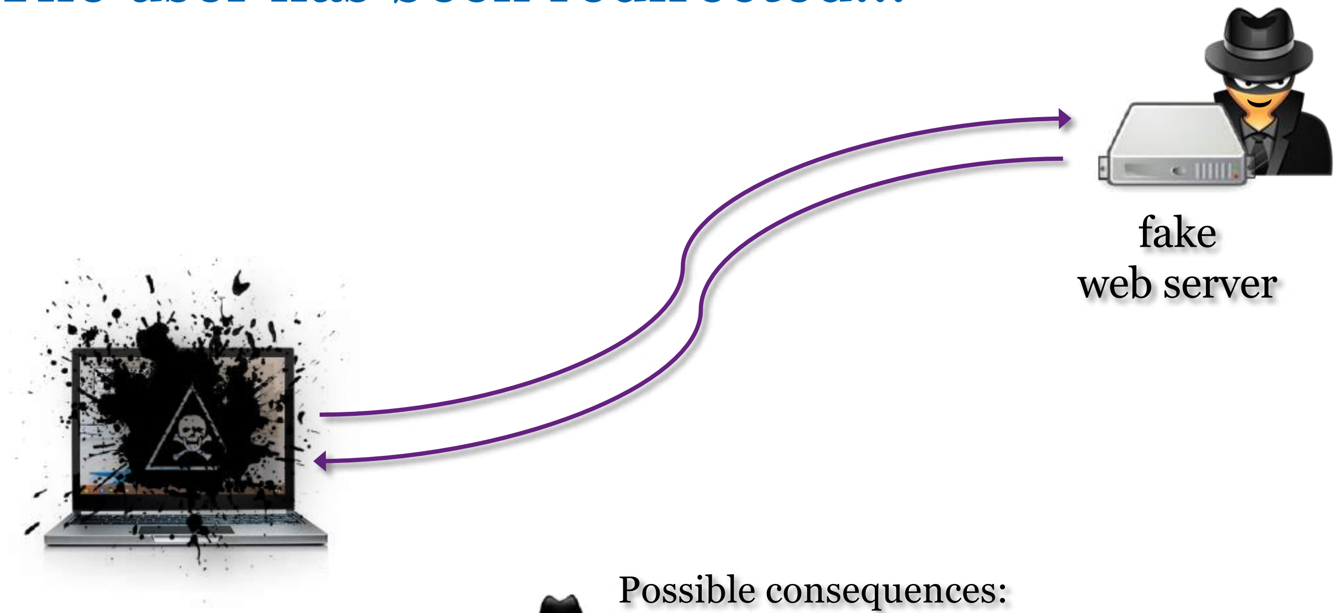
nl.

example.nl

The user has been redirected...


May I have the web page of example.nl?
Here is the web page of example.nl.
fake web server
.
nl.
name server for example.nl
web server for example.nl

The user has been redirected…

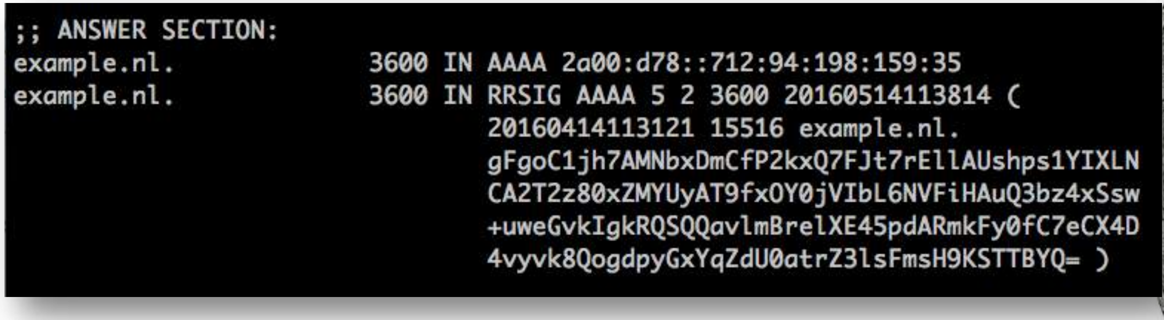


fake
web server

Possible consequences:

- Interception (such as emails or passwords)
- Presenting fake content (including malware)
- All the consequences as a result
  - (financial damage, reputational damage, etc.)

About DNSSEC

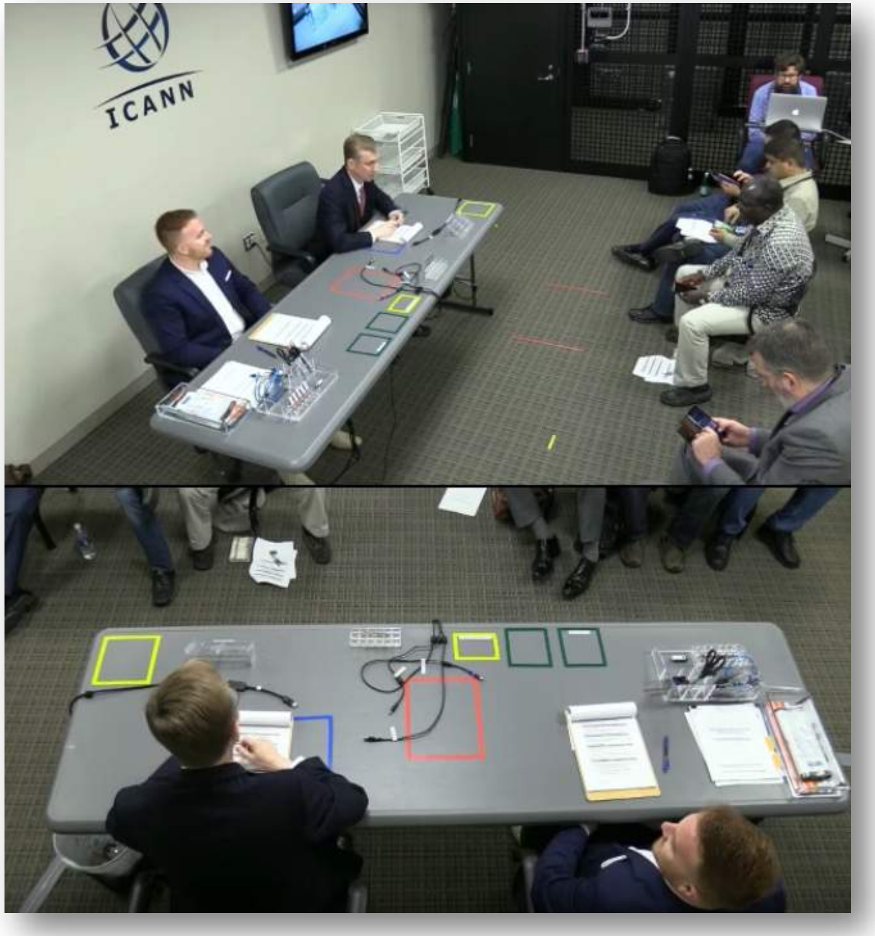


```
;; ANSWER SECTION:
example.nl.             3600 IN AAAA 2a00:d78::712:94:198:159:35
example.nl.             3600 IN RRSIG AAAA 5 2 3600 20160514113814 (
                                20160414113121 15516 example.nl.
                                gFgoC1jh7AMNbxDmCfP2kxQ7FJt7rEllAUshps1YIXLN
                                CA2T2z80xZMYUyAT9fxOY0jVIbL6NVFiHAuQ3bz4xSsw
                                +uweGvkIgkRQSQQavlmBrelXE45pdARmkFy0fC7eCX4D
                                4vyvk8QogdpyGxYqZdU0atrZ3lsFmsH9KSTTBYQ= )
```

CERTIFICATE • OF • AUTHENTICITY • CERTIFICATE • OF • AUTHENTICITY •

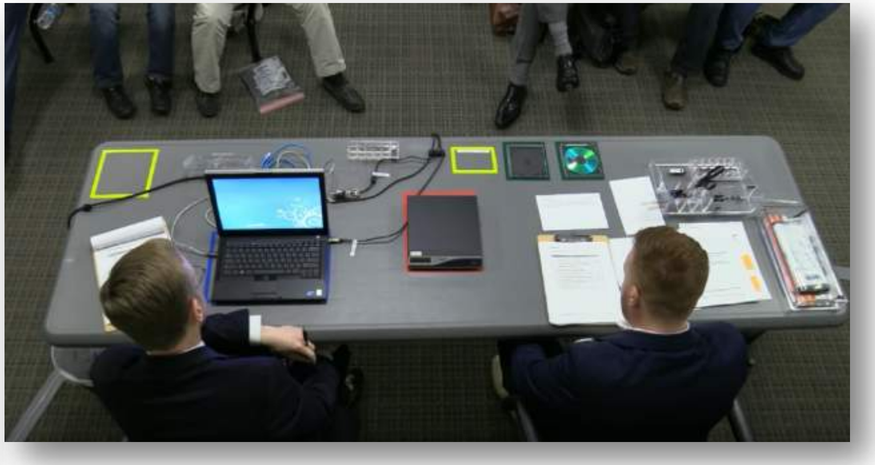
With DNSSEC,
every DNS response is provided with a digital signature,
so that the content can be checked for authenticity.

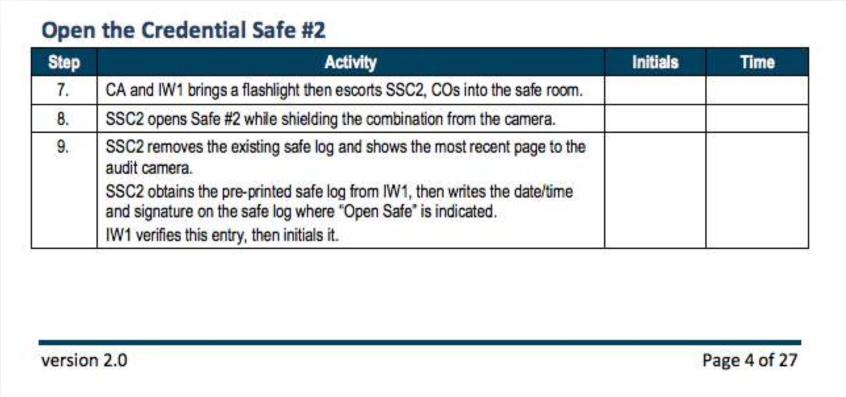
DNSSEC Key Signing Ceremony



https://www.youtube.com/watch?v=ZTxweLGjZSU

DNSSEC Key Signing Ceremony





Open the Credential Safe #2

Step	Activity	Initials	Time
7.	CA and IW1 brings a flashlight then escorts SSC2, COs into the safe room.		
8.	SSC2 opens Safe #2 while shielding the combination from the camera.		
9.	SSC2 removes the existing safe log and shows the most recent page to the audit camera. SSC2 obtains the pre-printed safe log from IW1, then writes the date/time and signature on the safe log where "Open Safe" is indicated. IW1 verifies this entry, then initials it.		

version 2.0 Page 4 of 27

https://www.youtube.com/watch?v=ZTxweLGjZSU

Part 2: Routing

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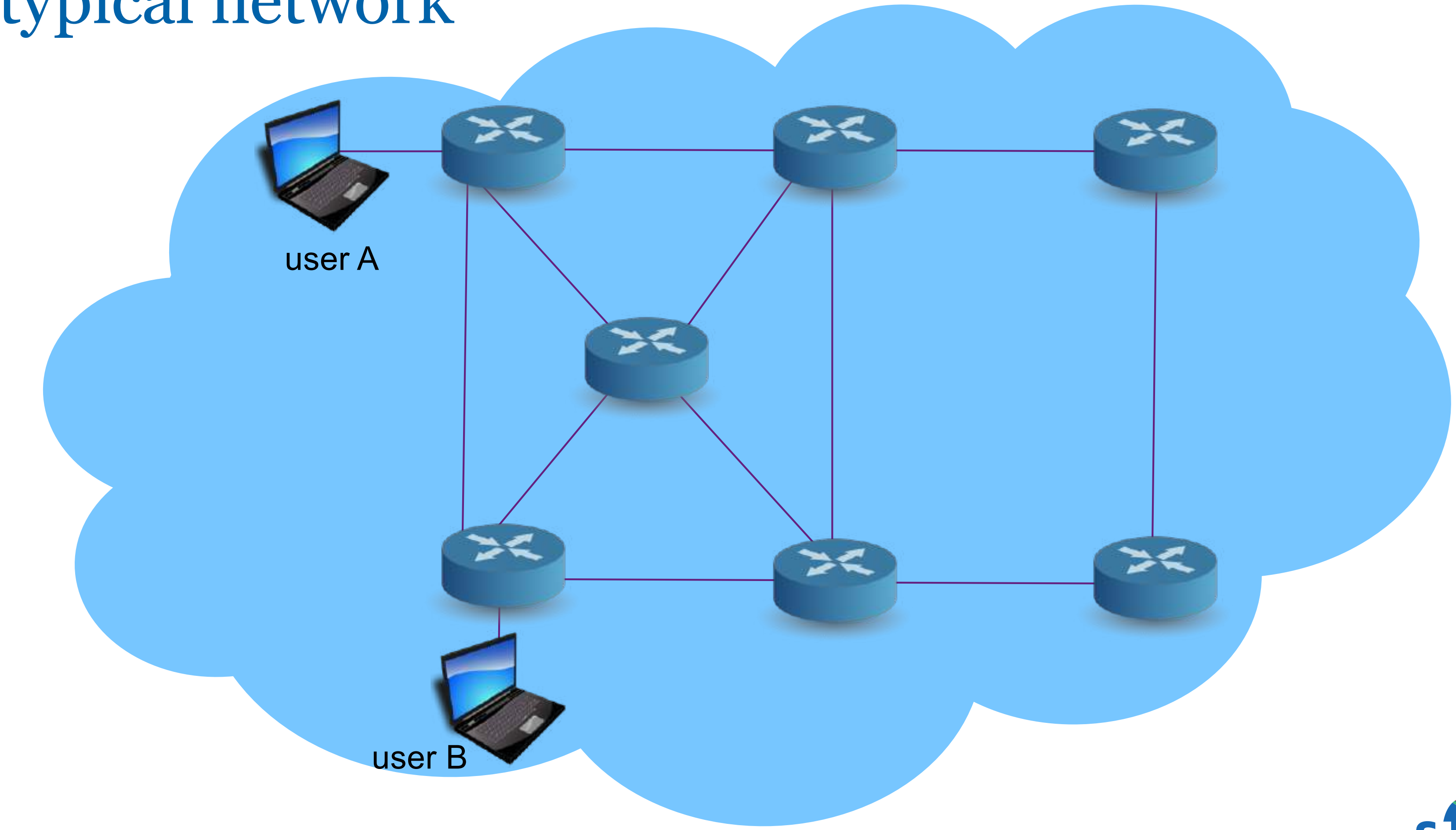
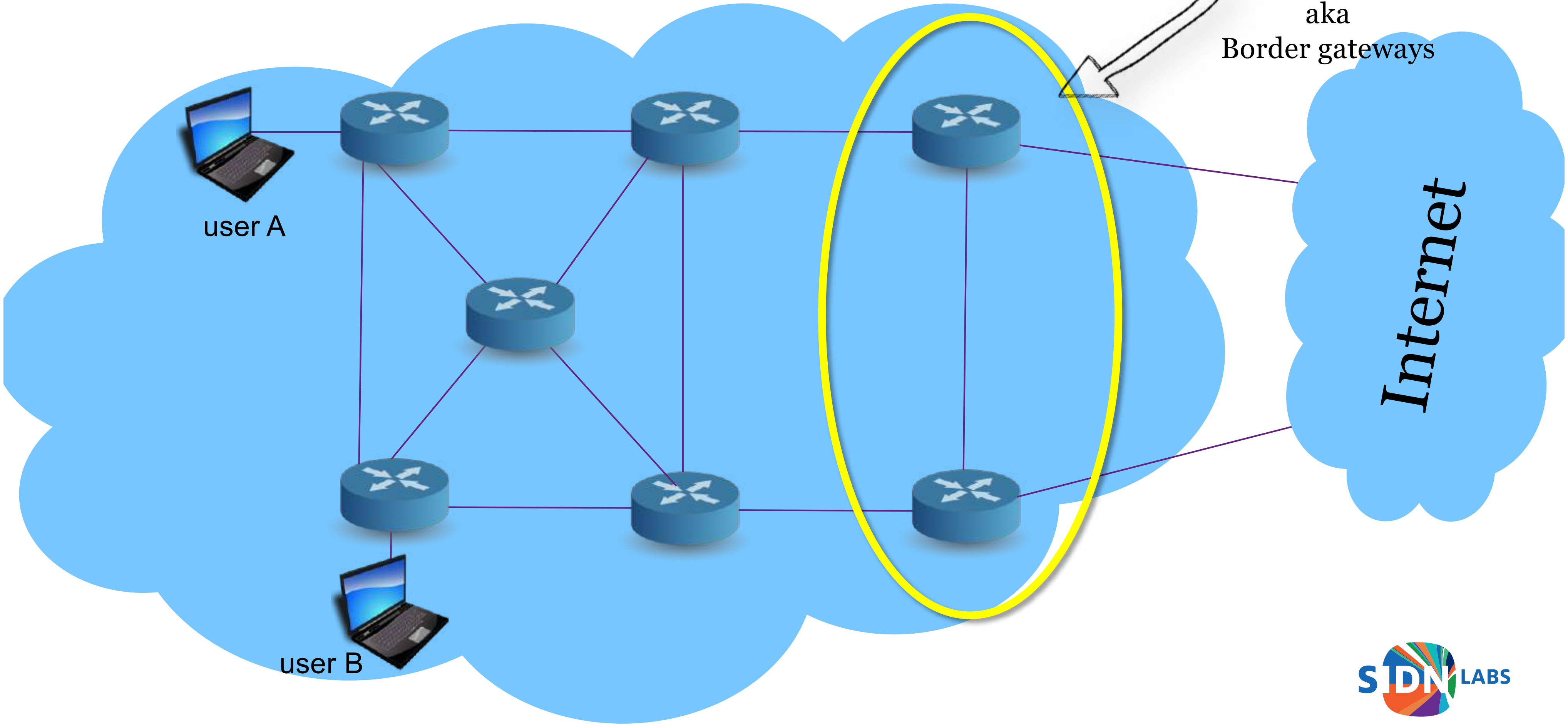
A typical network

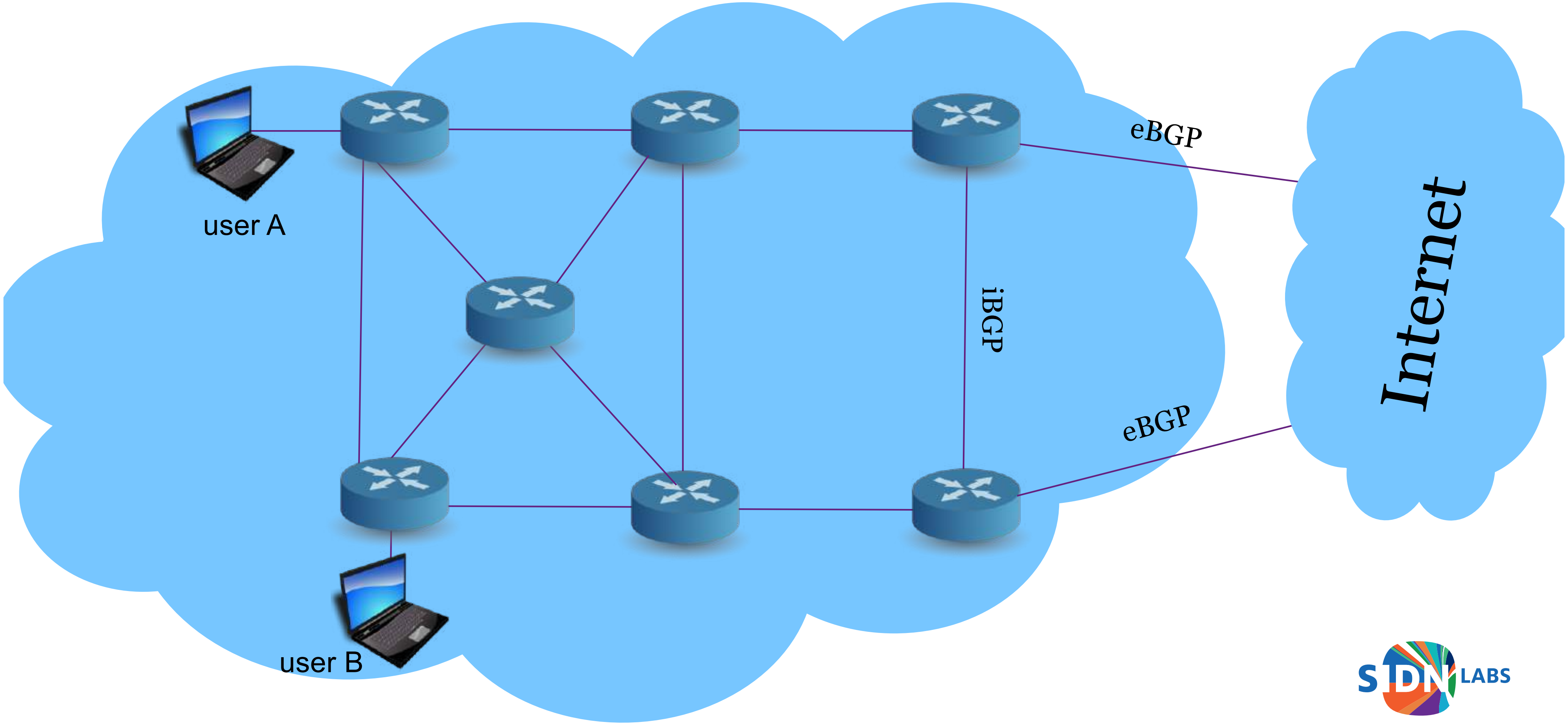


A typical network

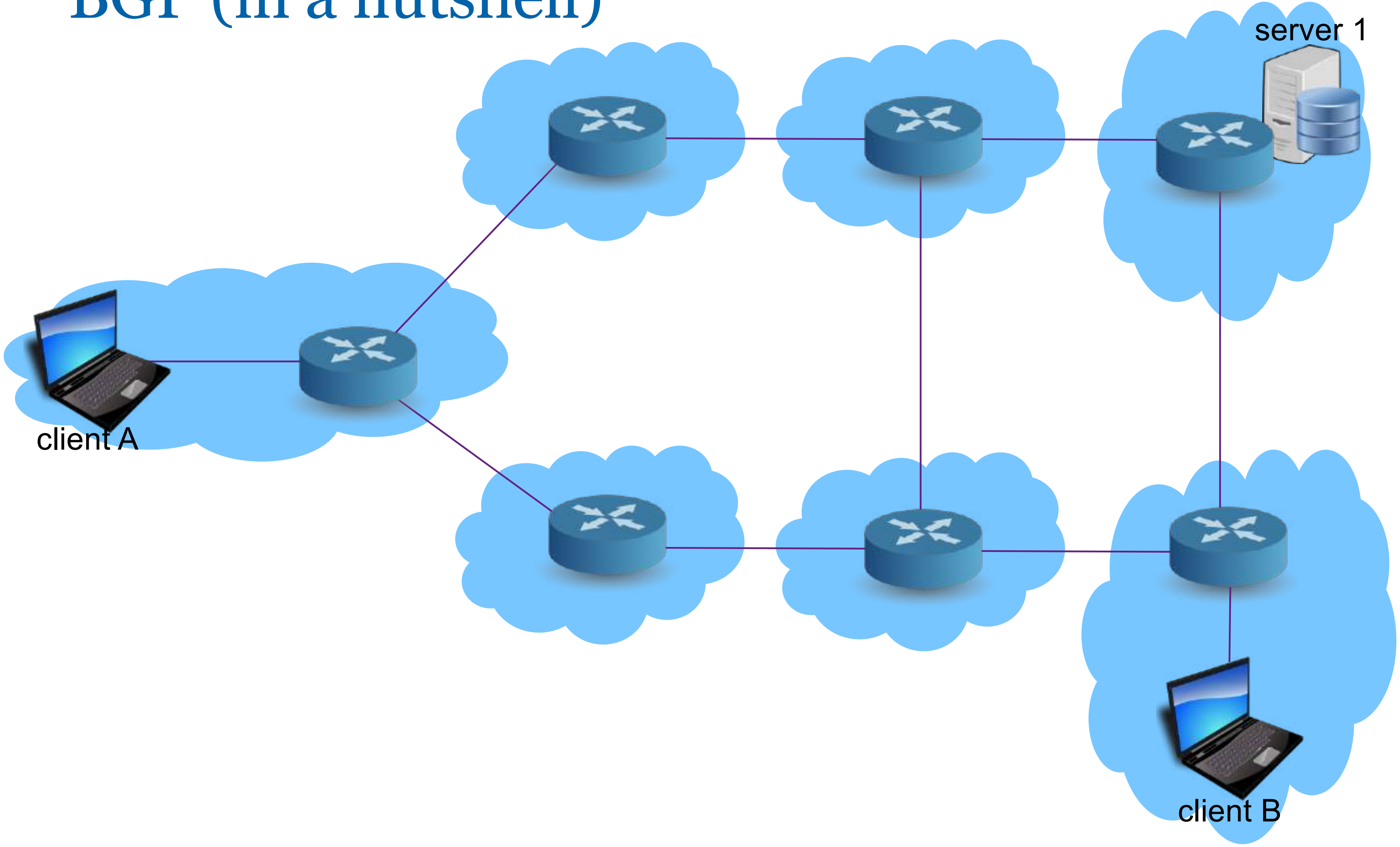


Edge routers
or
Border routers
aka
Border gateways

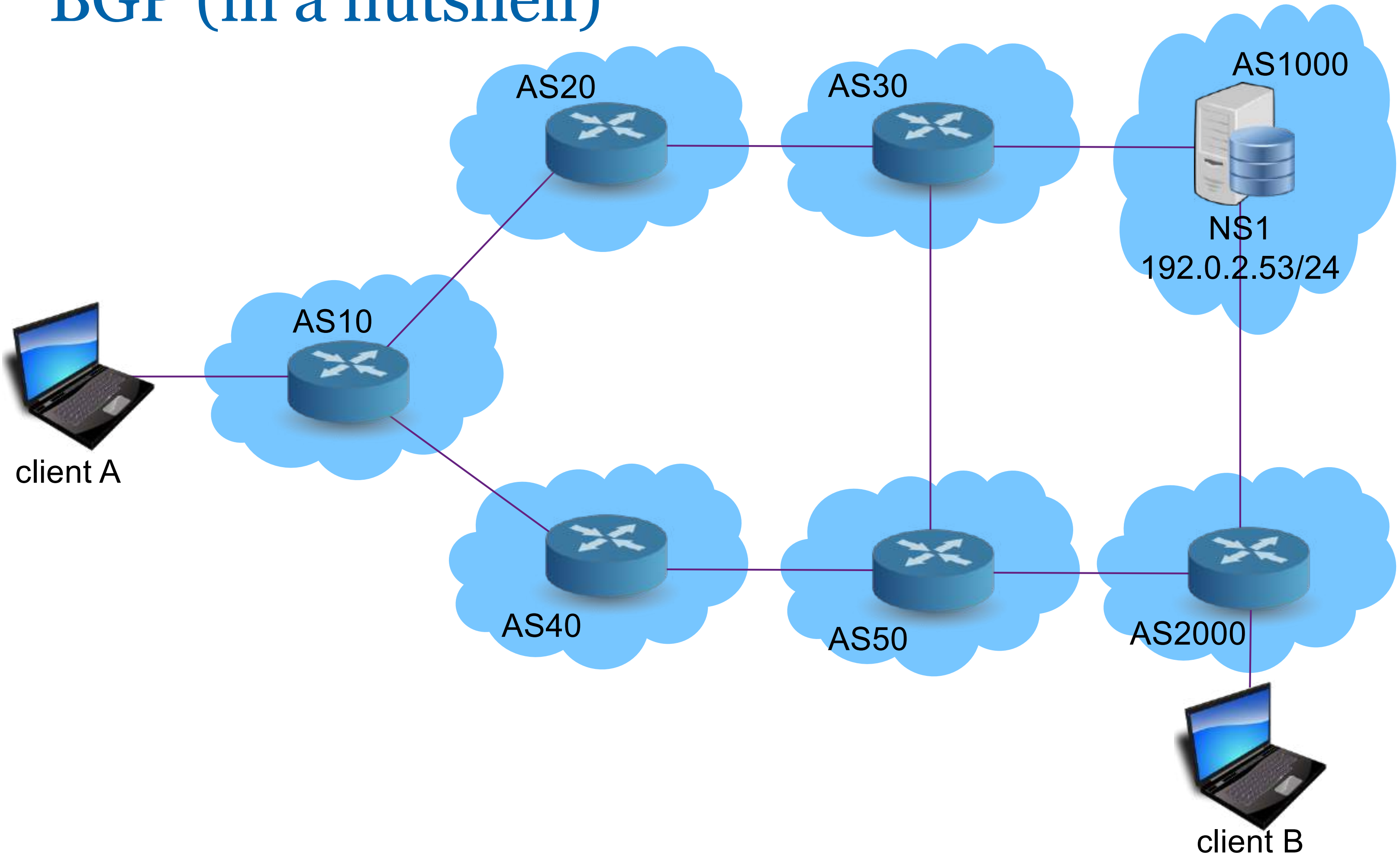
Average network



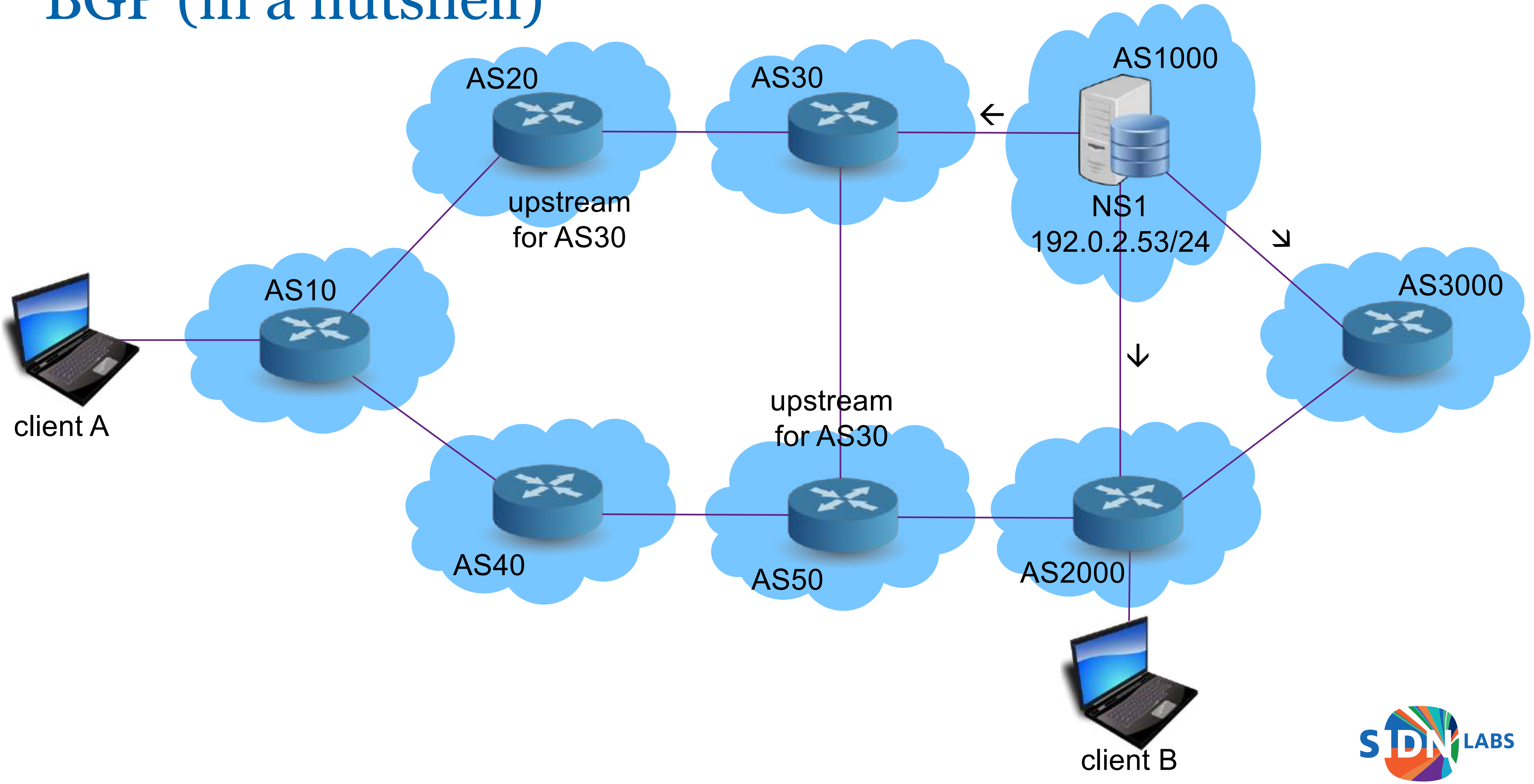
BGP (in a nutshell)



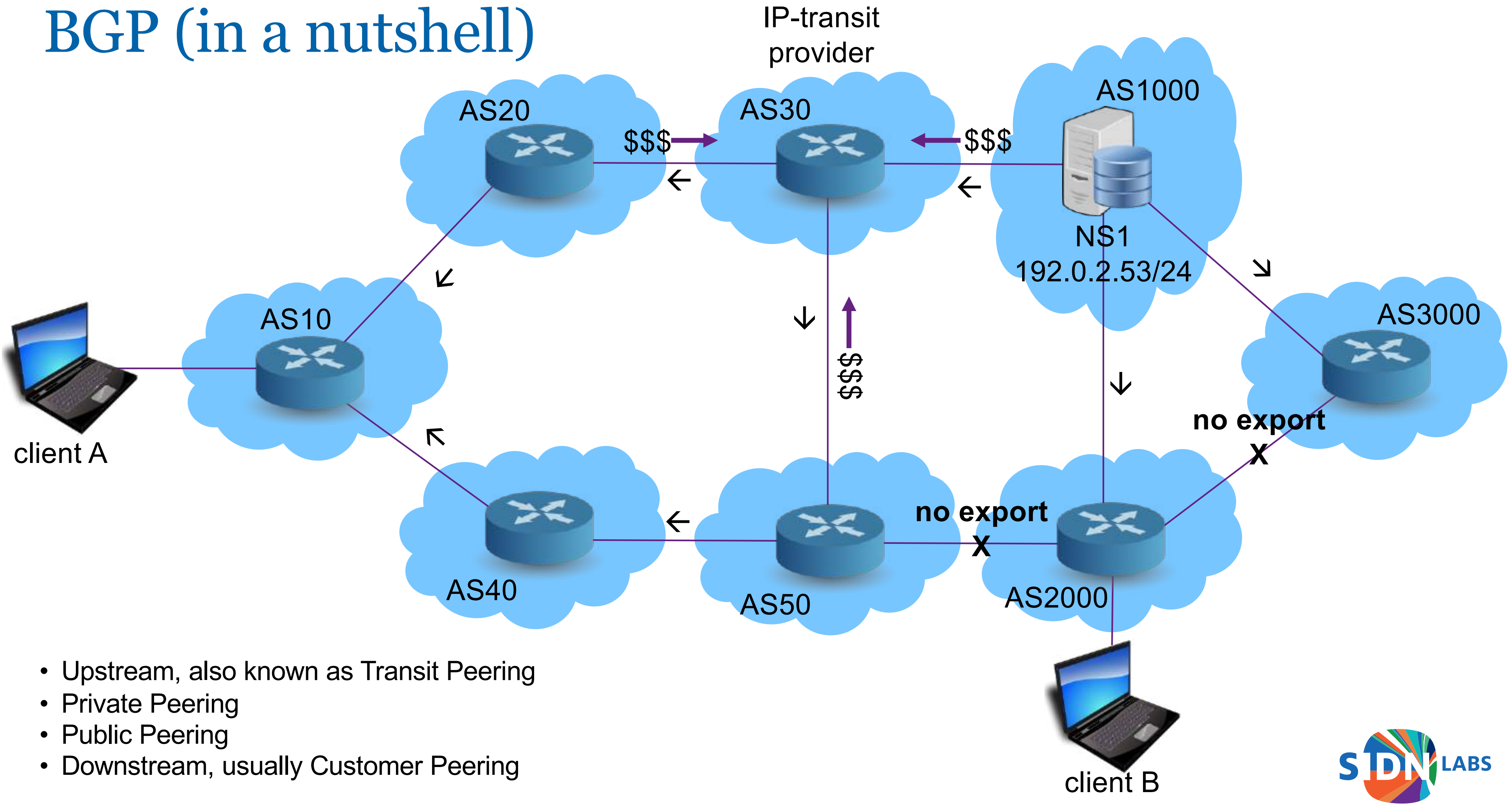
BGP (in a nutshell)



BGP (in a nutshell)

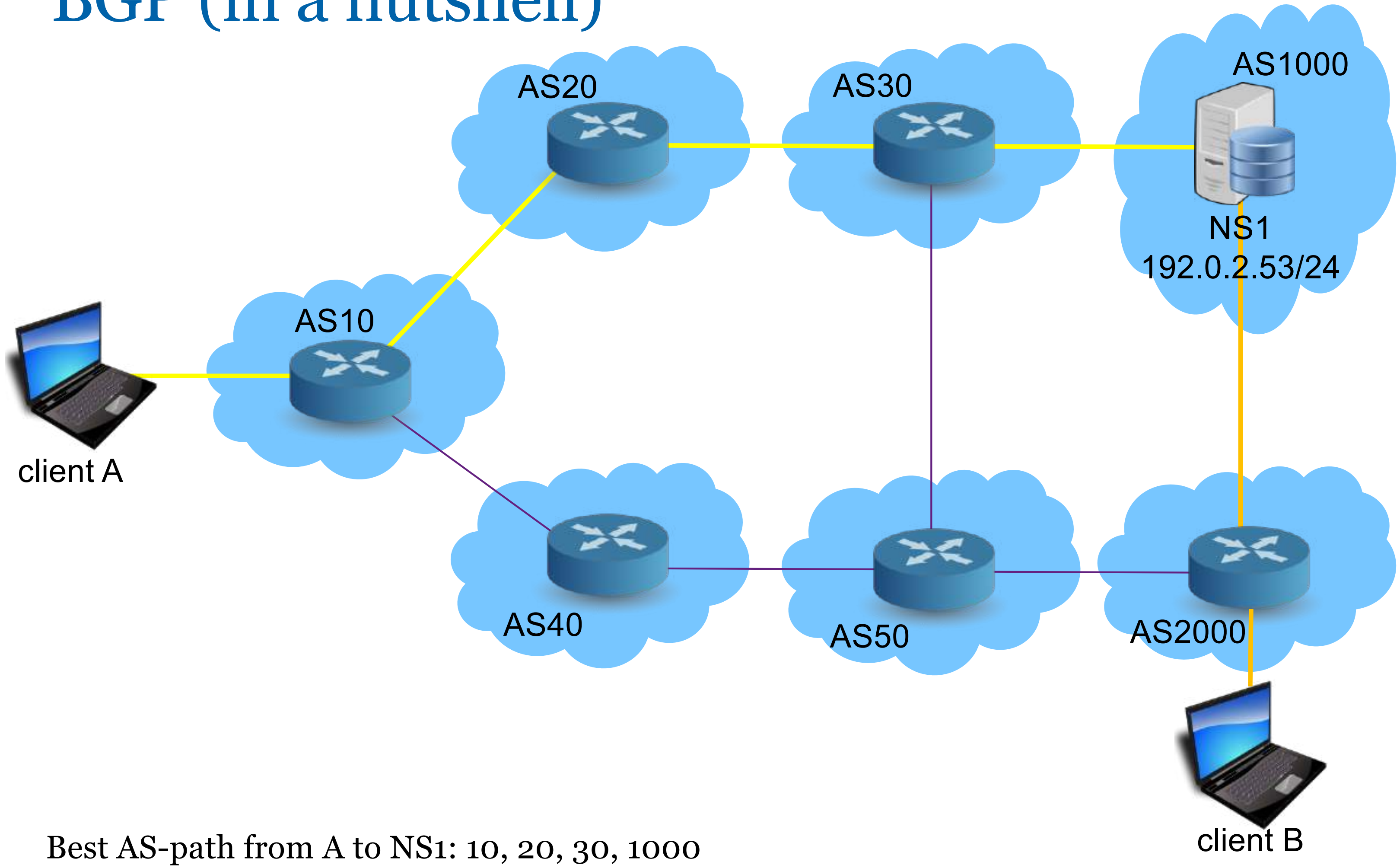


BGP (in a nutshell)



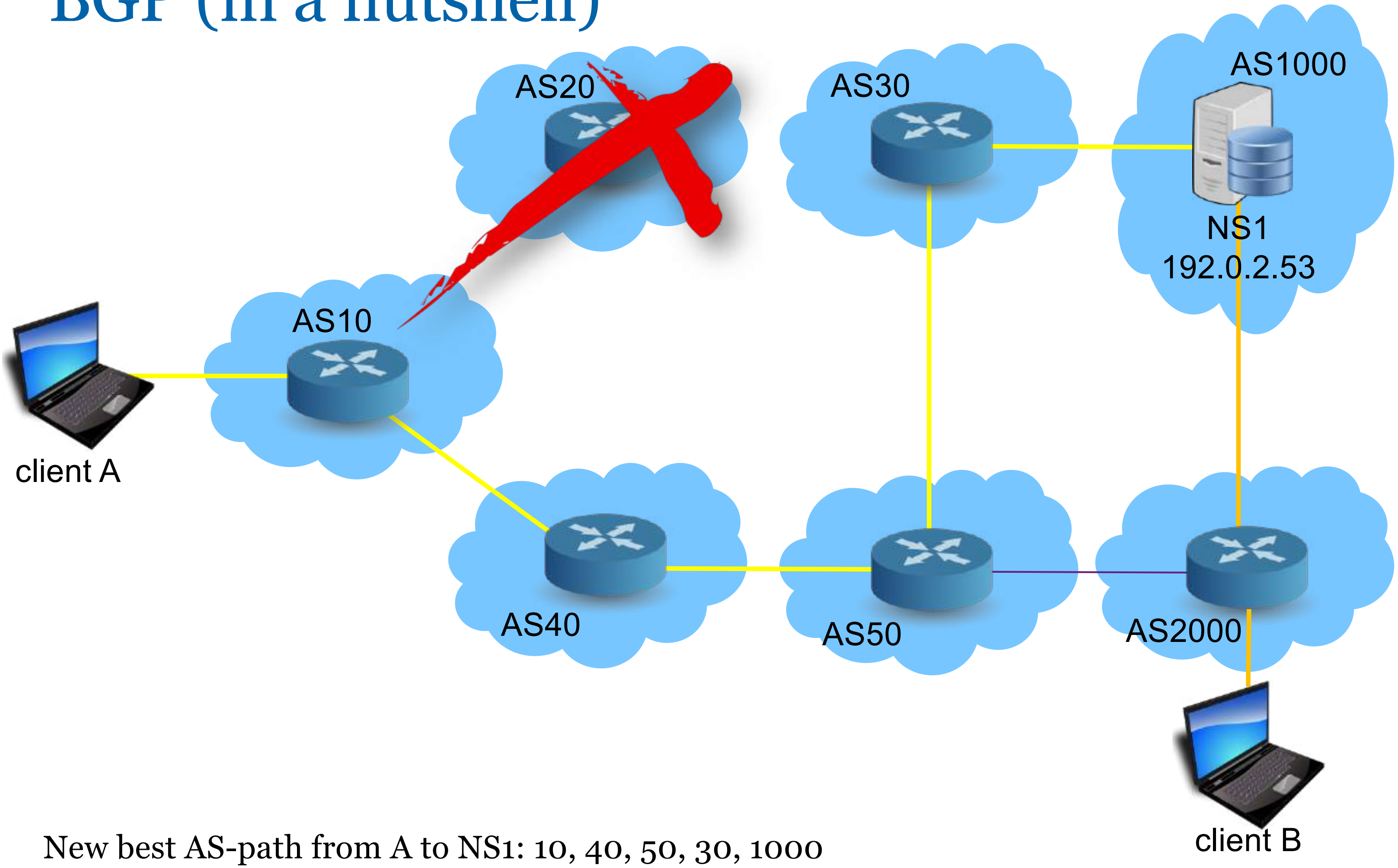
- Upstream, also known as Transit Peering
- Private Peering
- Public Peering
- Downstream, usually Customer Peering

BGP (in a nutshell)



Best AS-path from A to NS1: 10, 20, 30, 1000

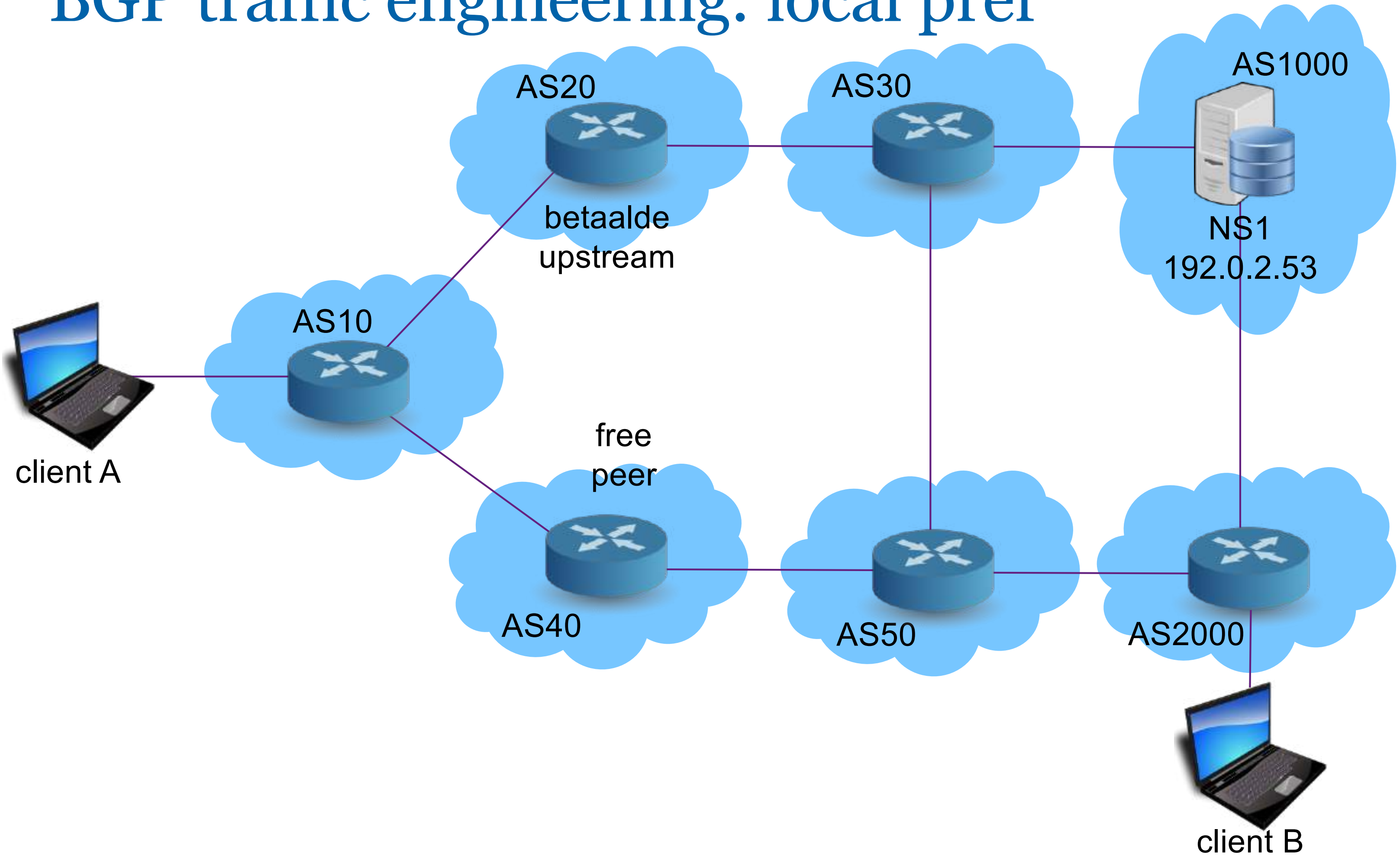
BGP (in a nutshell)



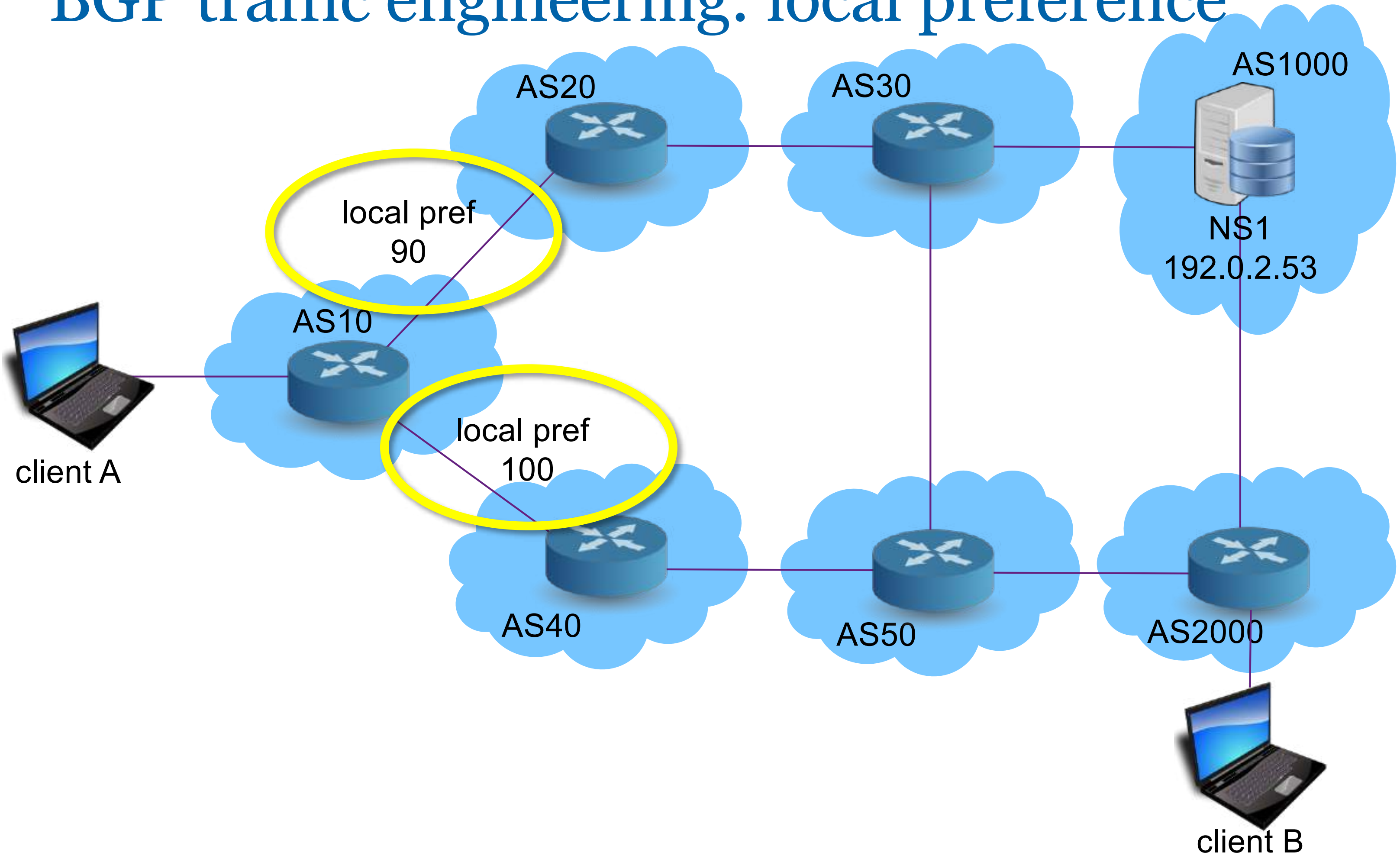
New best AS-path from A to NS1: 10, 40, 50, 30, 1000

Traffic engineering

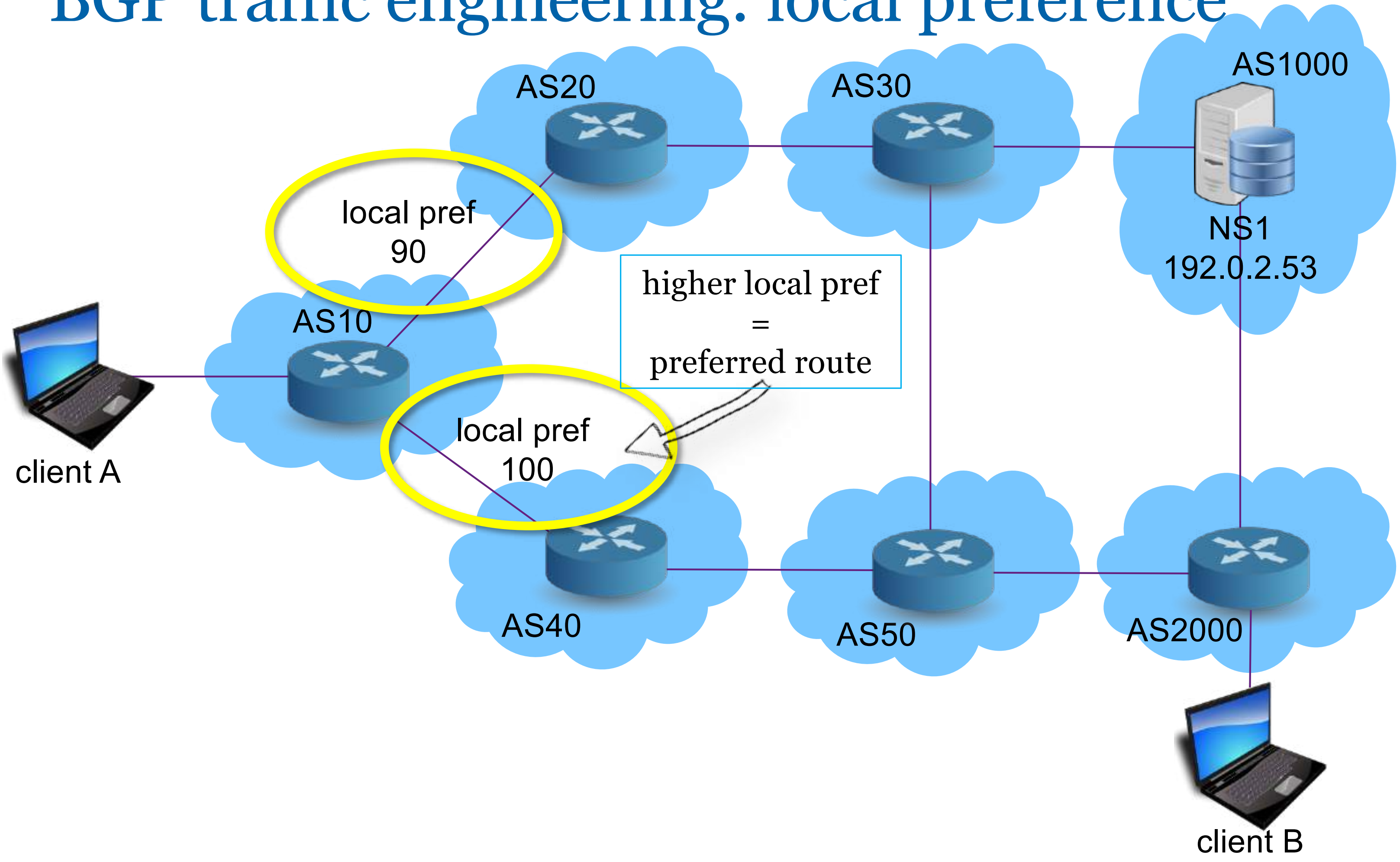
BGP traffic engineering: local pref



BGP traffic engineering: local preference

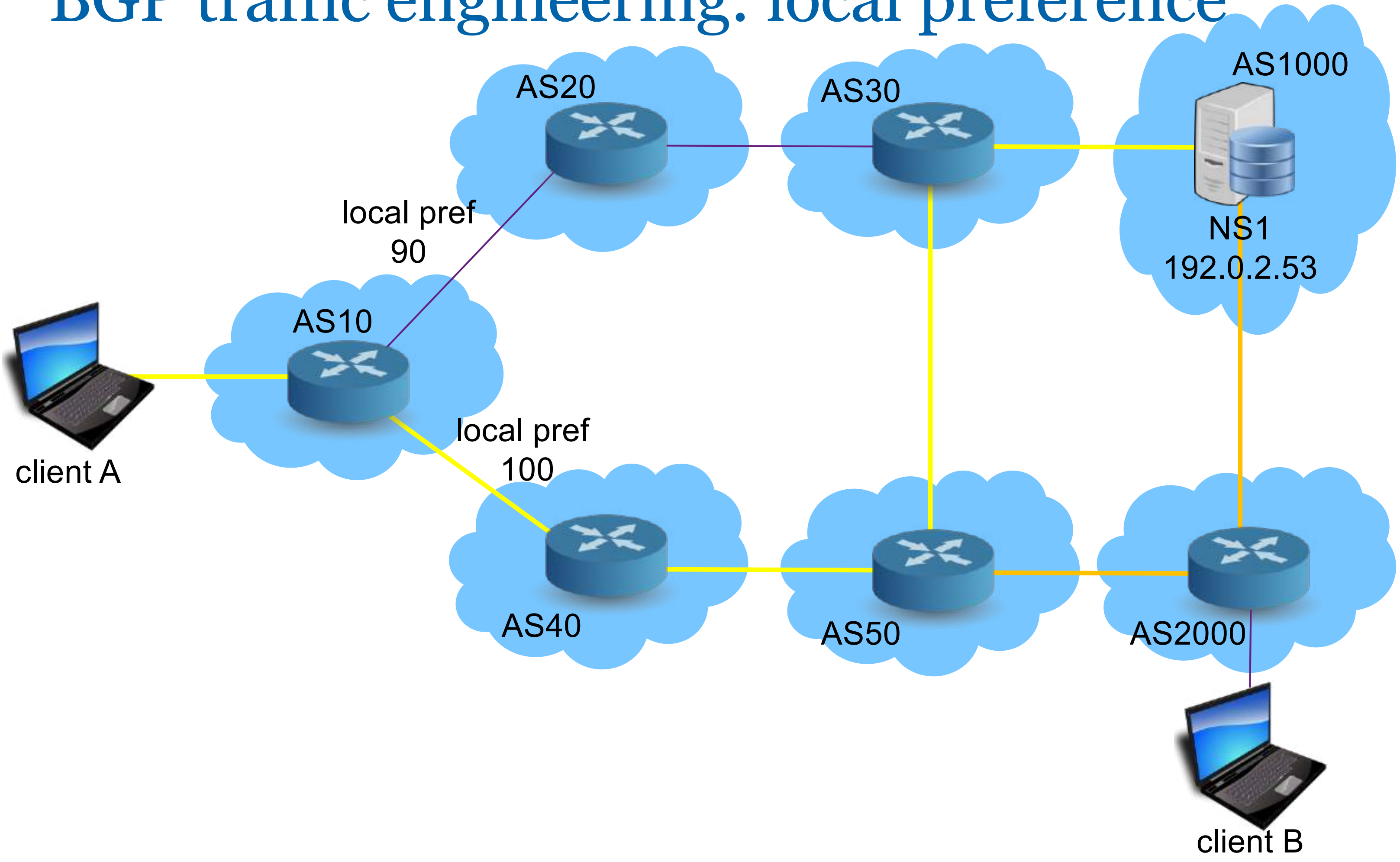


BGP traffic engineering: local preference

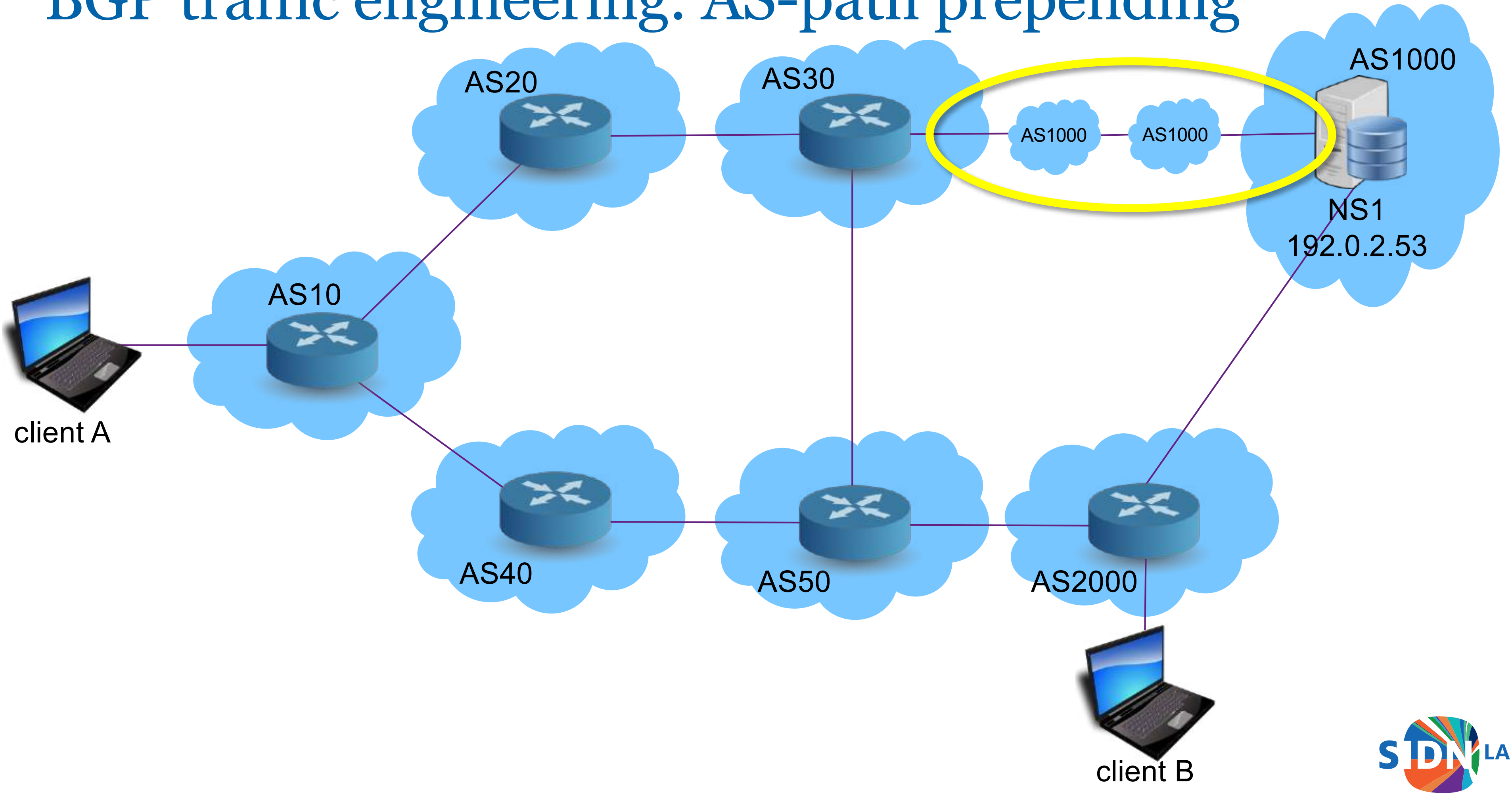


higher local pref
=
preferred route

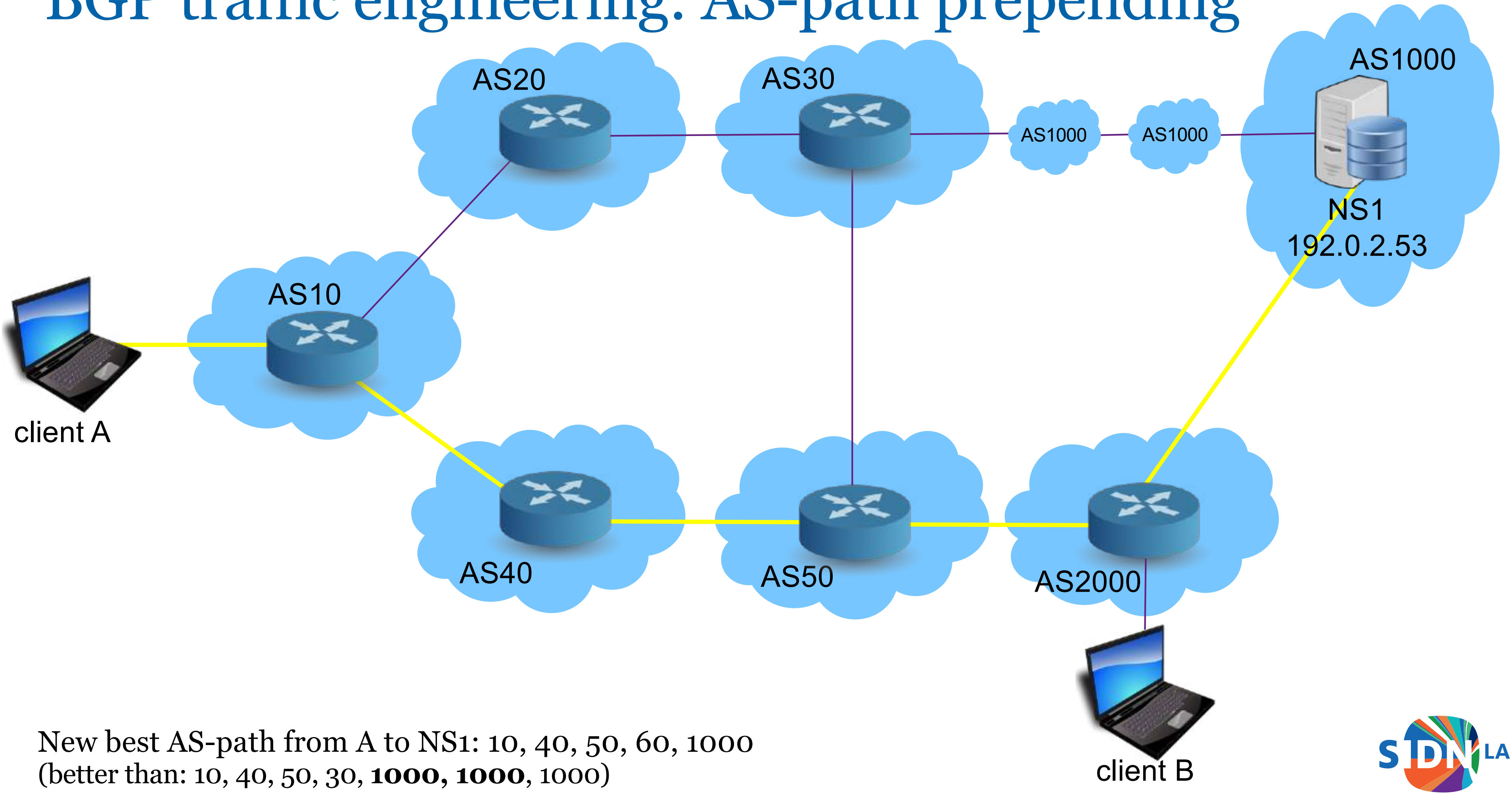
BGP traffic engineering: local preference



BGP traffic engineering: AS-path prepending

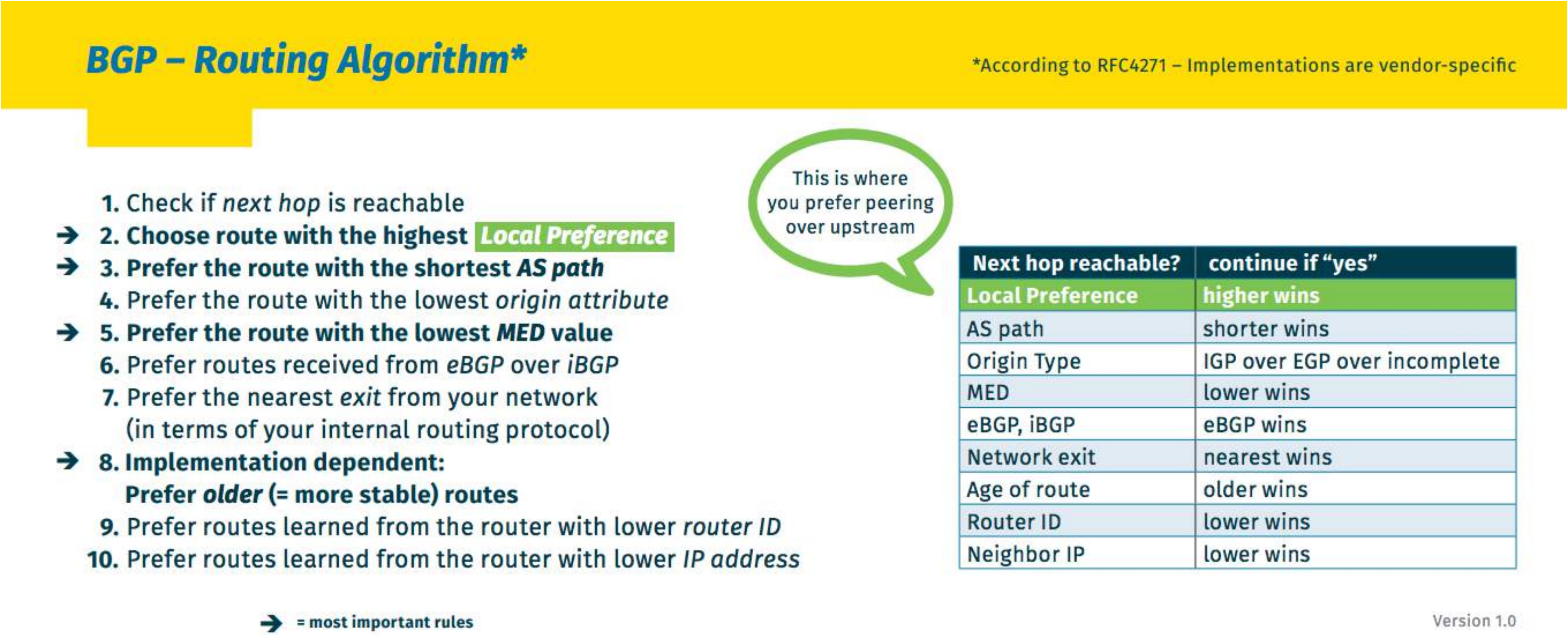


BGP traffic engineering: AS-path prepending



New best AS-path from A to NS1: 10, 40, 50, 60, 1000
(better than: 10, 40, 50, 30, **1000, 1000**, 1000)

BGP Best Path Selection Algorithm



BGP – Routing Algorithm*

*According to RFC4271 – Implementations are vendor-specific

1. Check if *next hop* is reachable
2. ➔ **Choose route with the highest *Local Preference***
3. ➔ **Prefer the route with the shortest *AS path***
4. Prefer the route with the lowest *origin attribute*
5. ➔ **Prefer the route with the lowest *MED* value**
6. Prefer routes received from *eBGP* over *iBGP*
7. Prefer the nearest *exit* from your network (in terms of your internal routing protocol)
8. ➔ **Implementation dependent: Prefer *older* (= more stable) routes**
9. Prefer routes learned from the router with lower *router ID*
10. Prefer routes learned from the router with lower *IP address*

This is where you prefer peering over upstream

Next hop reachable?	continue if “yes”
Local Preference	higher wins
AS path	shorter wins
Origin Type	IGP over EGP over incomplete
MED	lower wins
eBGP, iBGP	eBGP wins
Network exit	nearest wins
Age of route	older wins
Router ID	lower wins
Neighbor IP	lower wins

➔ = most important rules

Version 1.0

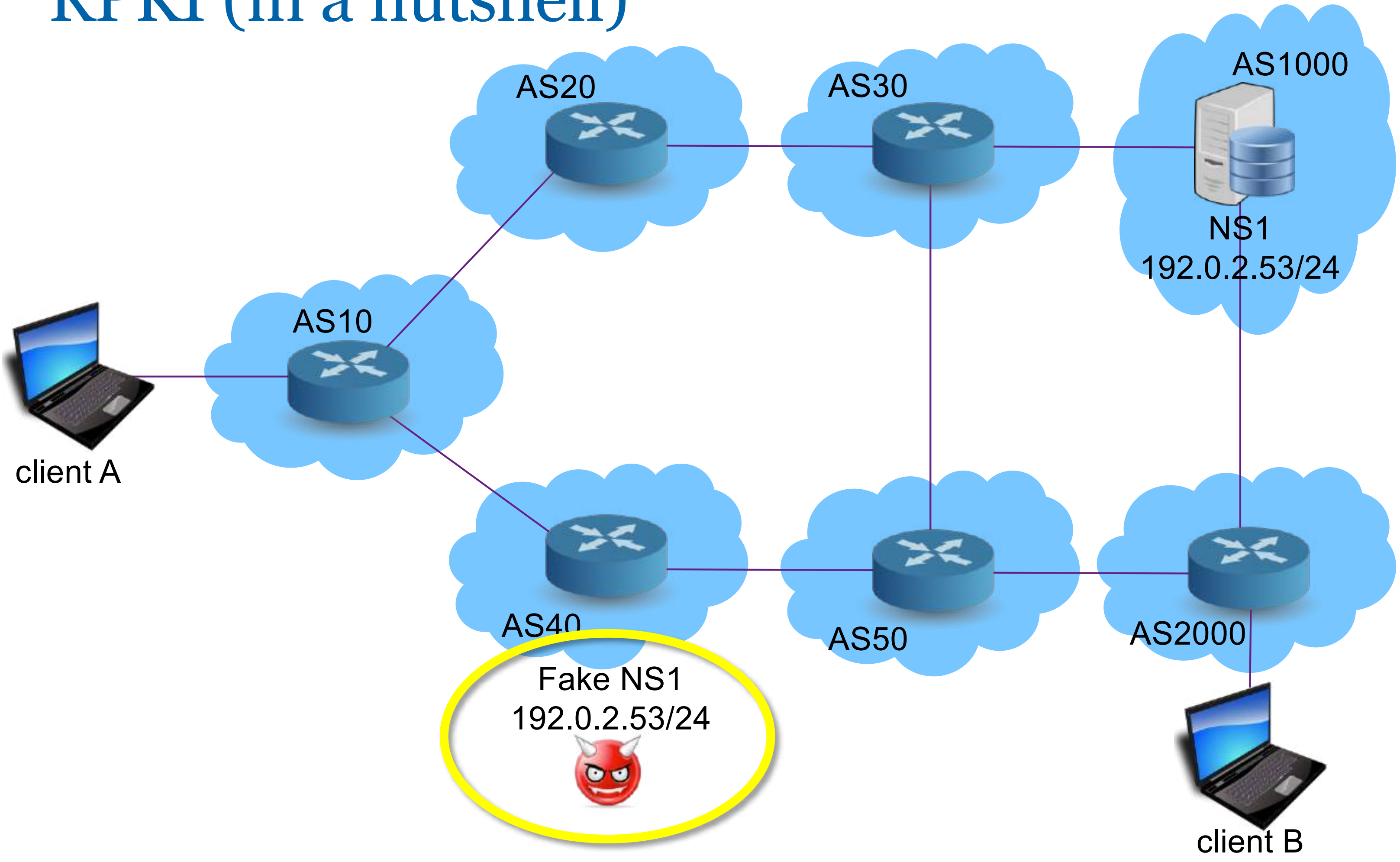
Source: https://www.de-cix.net/en/resources/bgp-basics

Traffic engineering with BGP communities

- *Transitive attribute tags* that can be applied to inbound or outbound prefixes to achieve a particular goal.
- For example: local pref adjustments, geographical adjustments, AS-path prepending or blackholing.
- No universal definitions, except the so-called *well-known*

```
route-server> show ip bgp 194.0.5.0/24
BGP routing table entry for 194.0.5.0/24
Paths: (23 available, best #18, table Default-IP-Routing-Table)
  Not advertised to any peer
  20473 210004
    206.53.202.75 from 216.218.252.190 (216.218.252.167)
      Origin IGP, metric 0, localpref 100, valid, internal
      Large Community: 6695:1000:1 20473:0:3021840115 210004:3000:1004
      Originator: 216.218.252.167, Cluster list: 216.218.252.190
      Last update: Wed Apr 15 16:06:36 2020
```

RPKI (in a nutshell)



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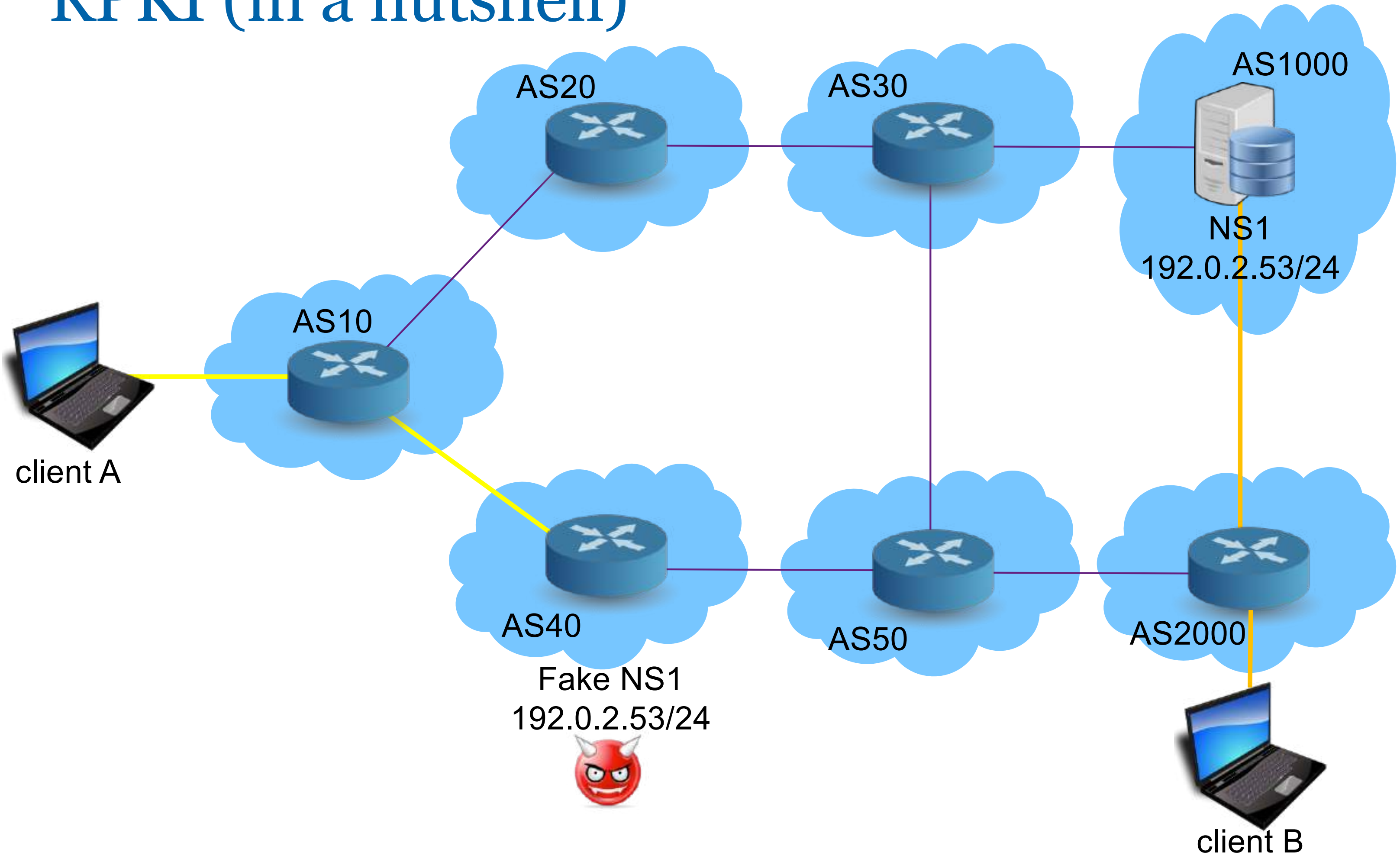
RPKI (in a nutshell)

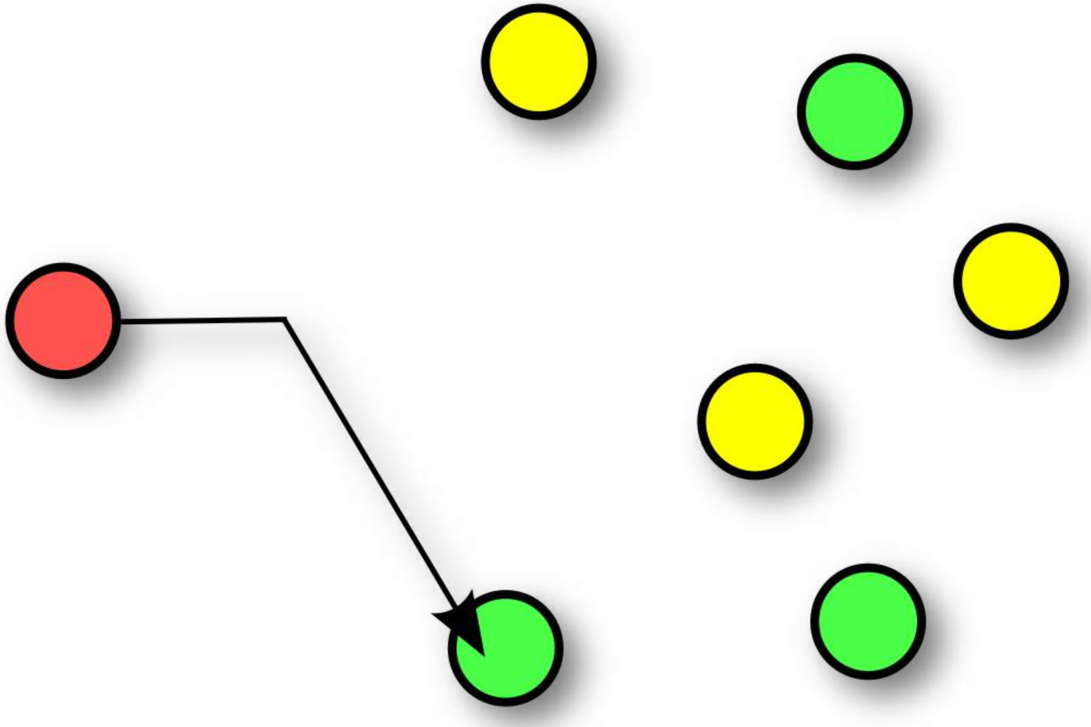


RPKI: Resource Public Key Infrastructure

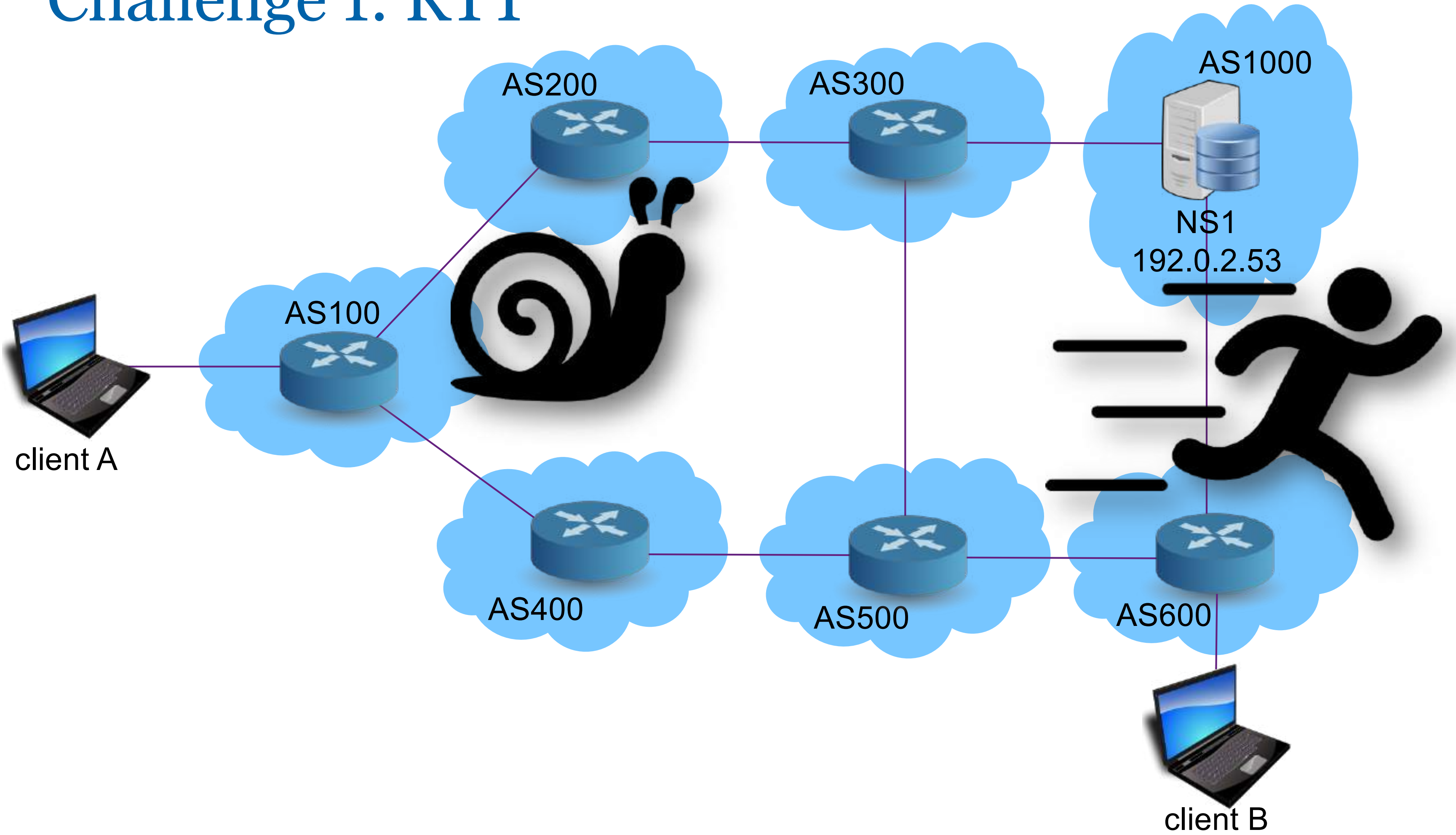
- A public key infrastructure to secure BGP
- Resource certification of IP prefixes / ASN combination
- Prevents (to some extent) route hijacking
- There are two sides: publishing ROAs and validating them
- Origin validation, **not** path validation (that's BGPSEC, still in the works)

Probeer je eigen ISP: https://isbgpsafeyet.com/

Anycast and why it's a good idea

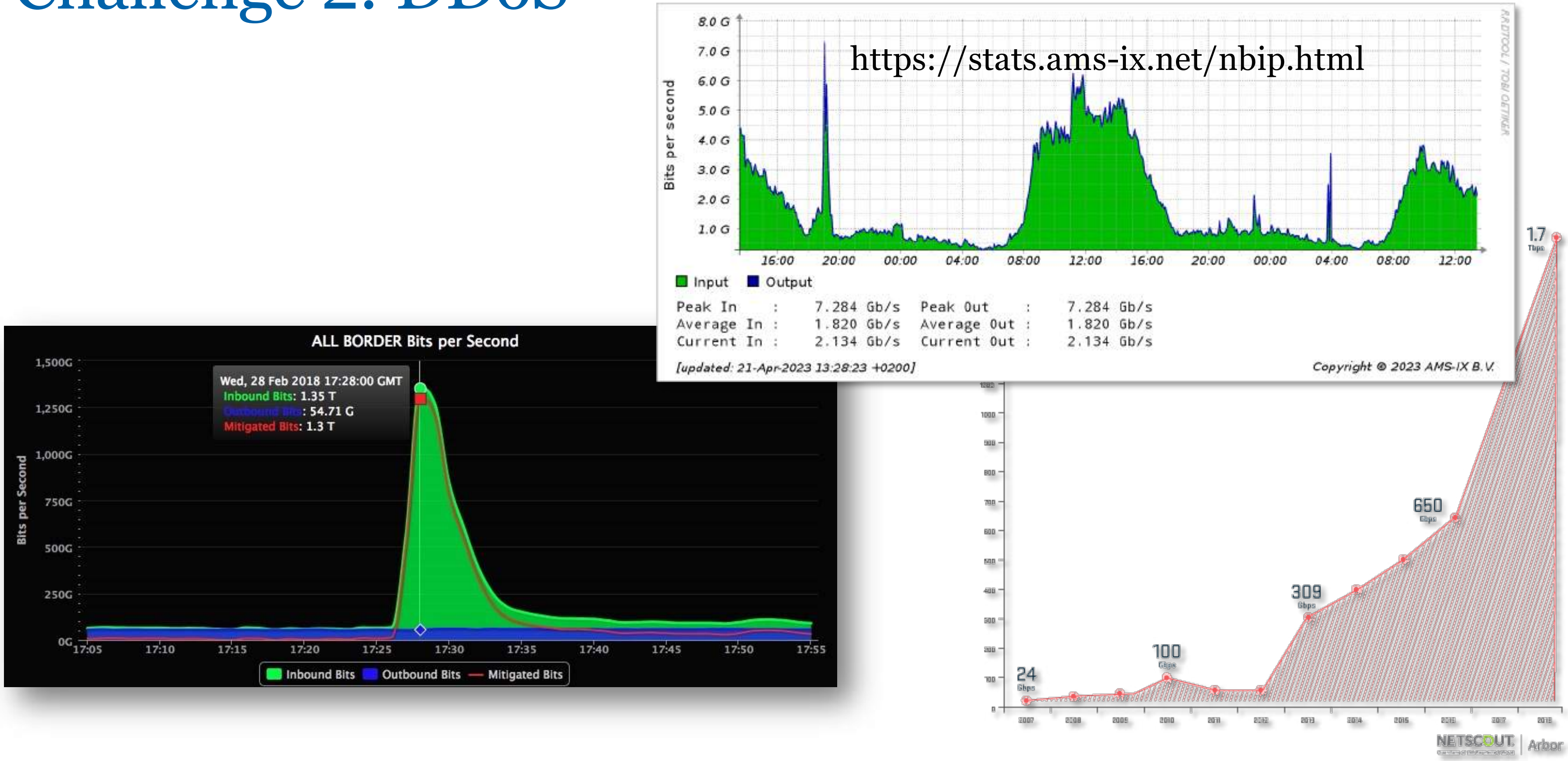


Challenge 1: RTT



Challenge 2: DDoS

https://stats.ams-ix.net/nbip.html



```
Peak In      :    7.284 Gb/s  Peak Out     :    7.284 Gb/s
Average In   :    1.820 Gb/s  Average Out  :    1.820 Gb/s
Current In   :    2.134 Gb/s  Current Out  :    2.134 Gb/s
```

[updated: 21-Apr-2023 13:28:23 +0200]

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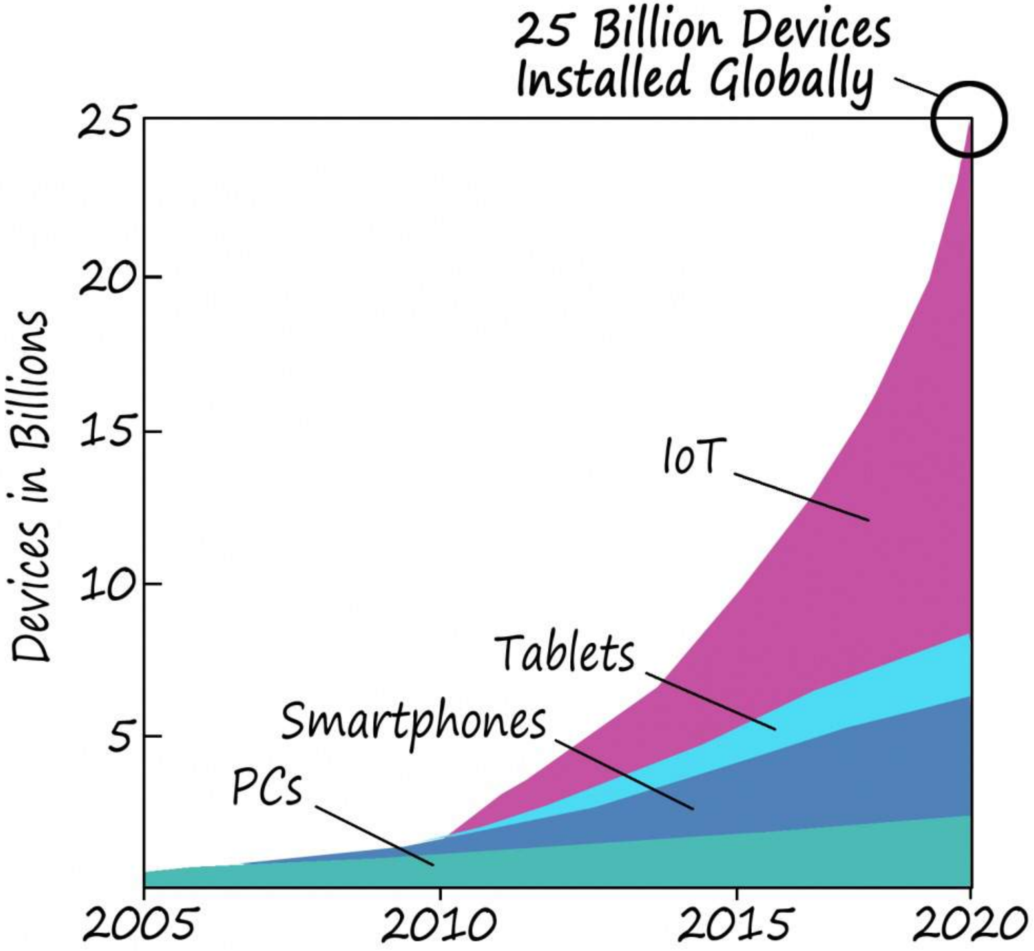
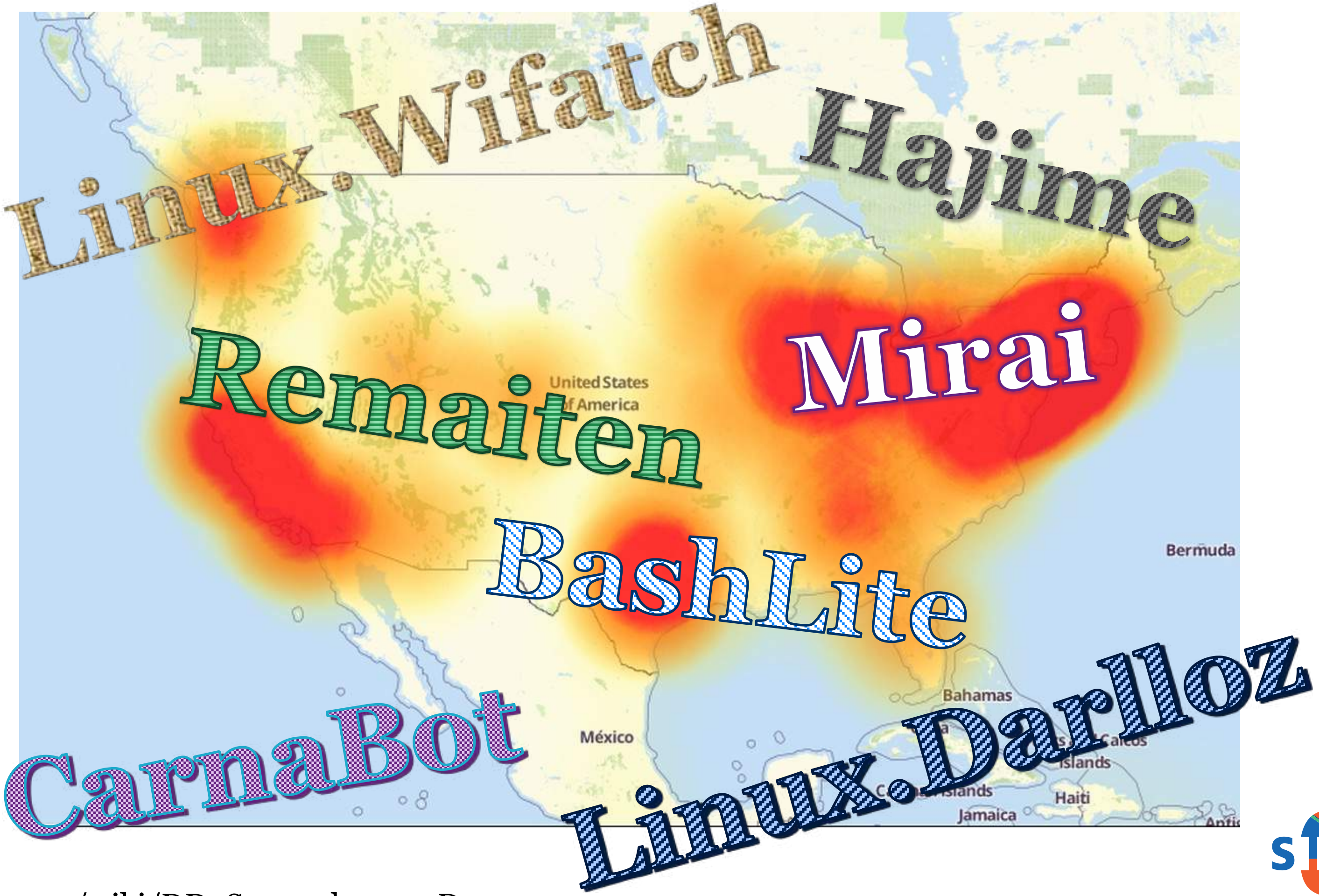
Main reason: IoT devices

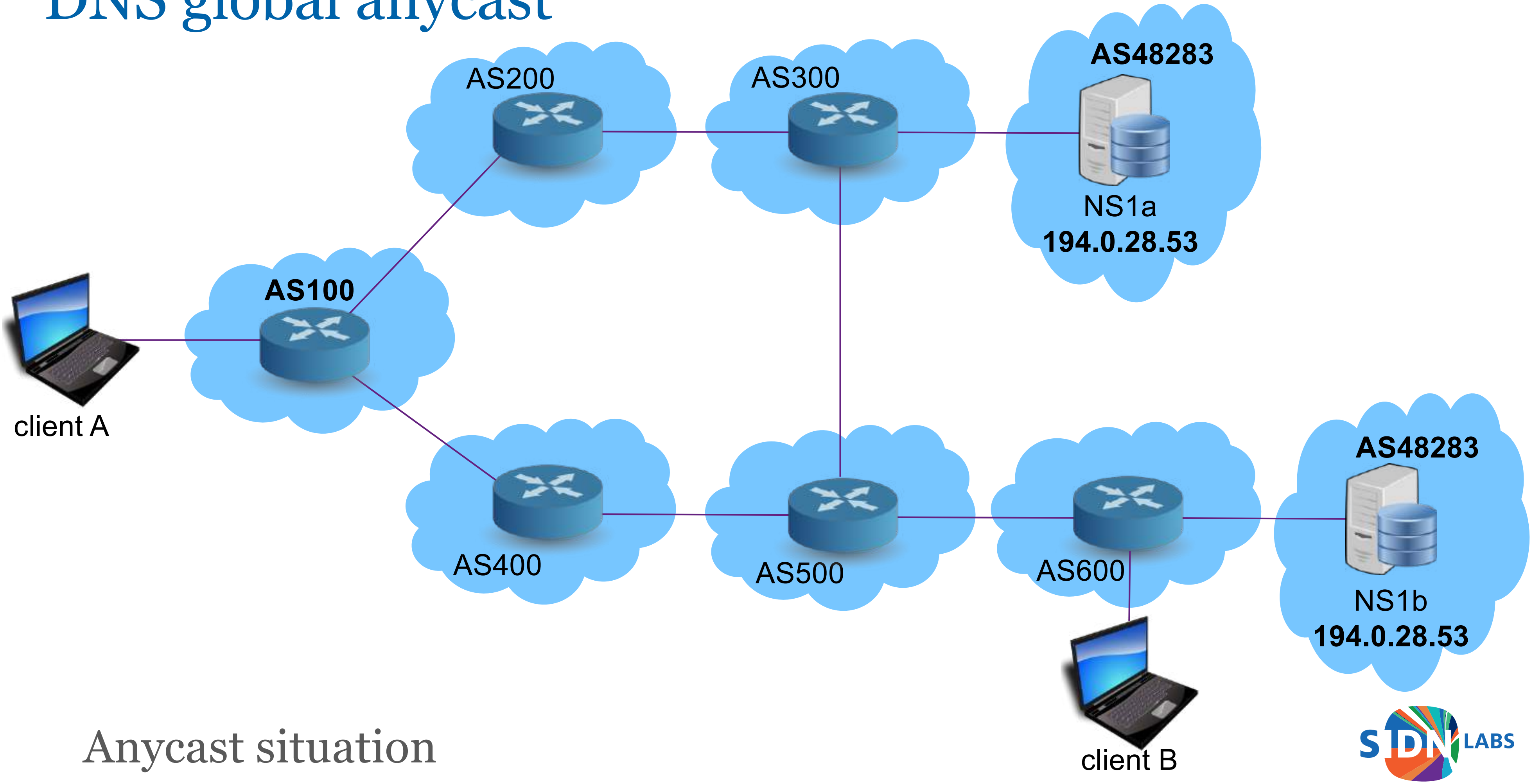


IoT botnets



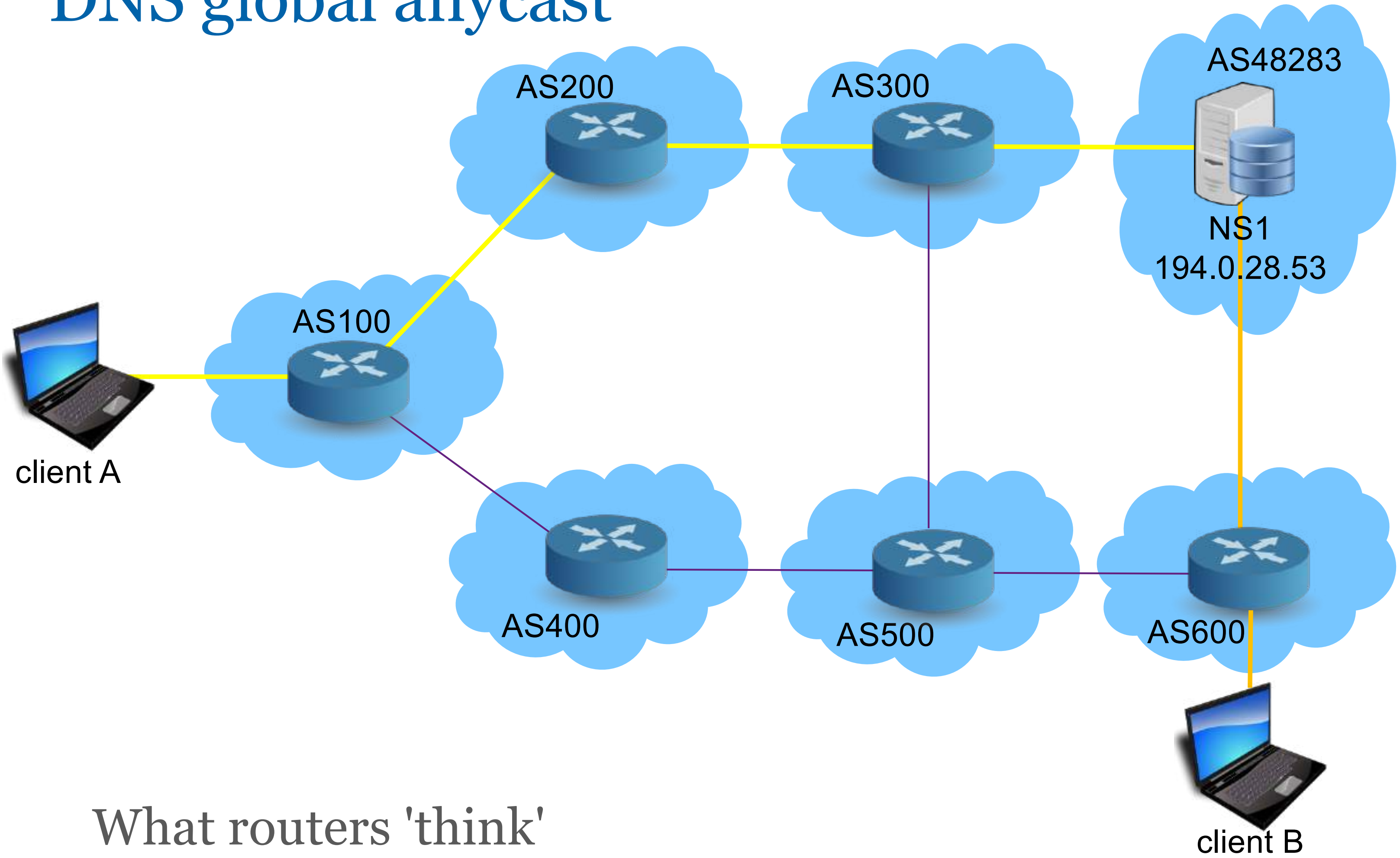
Bron: https://en.wikipedia.org/wiki/DDoS_attacks_on_Dyn

DNS global anycast



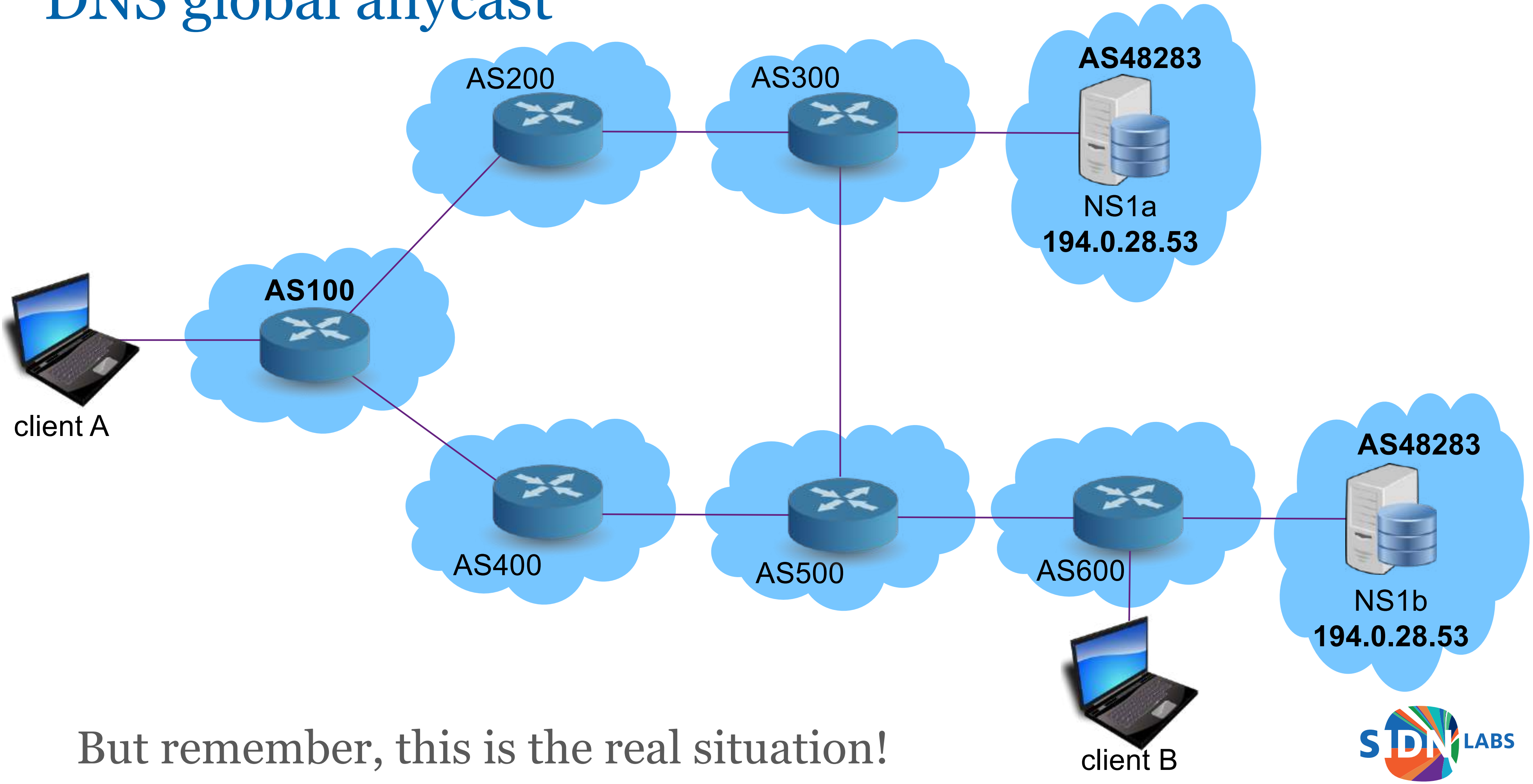
Anycast situation

DNS global anycast



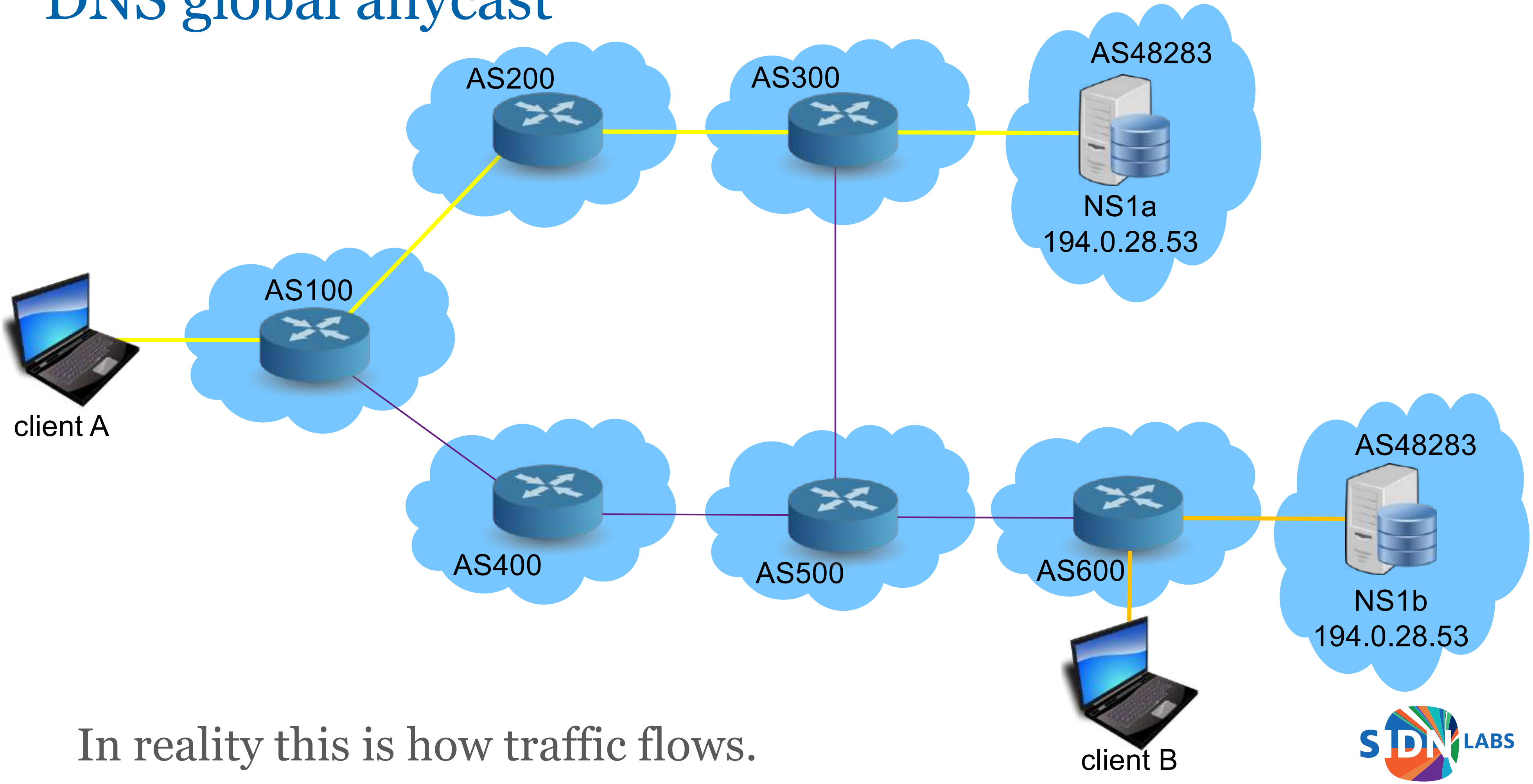
What routers 'think'

DNS global anycast



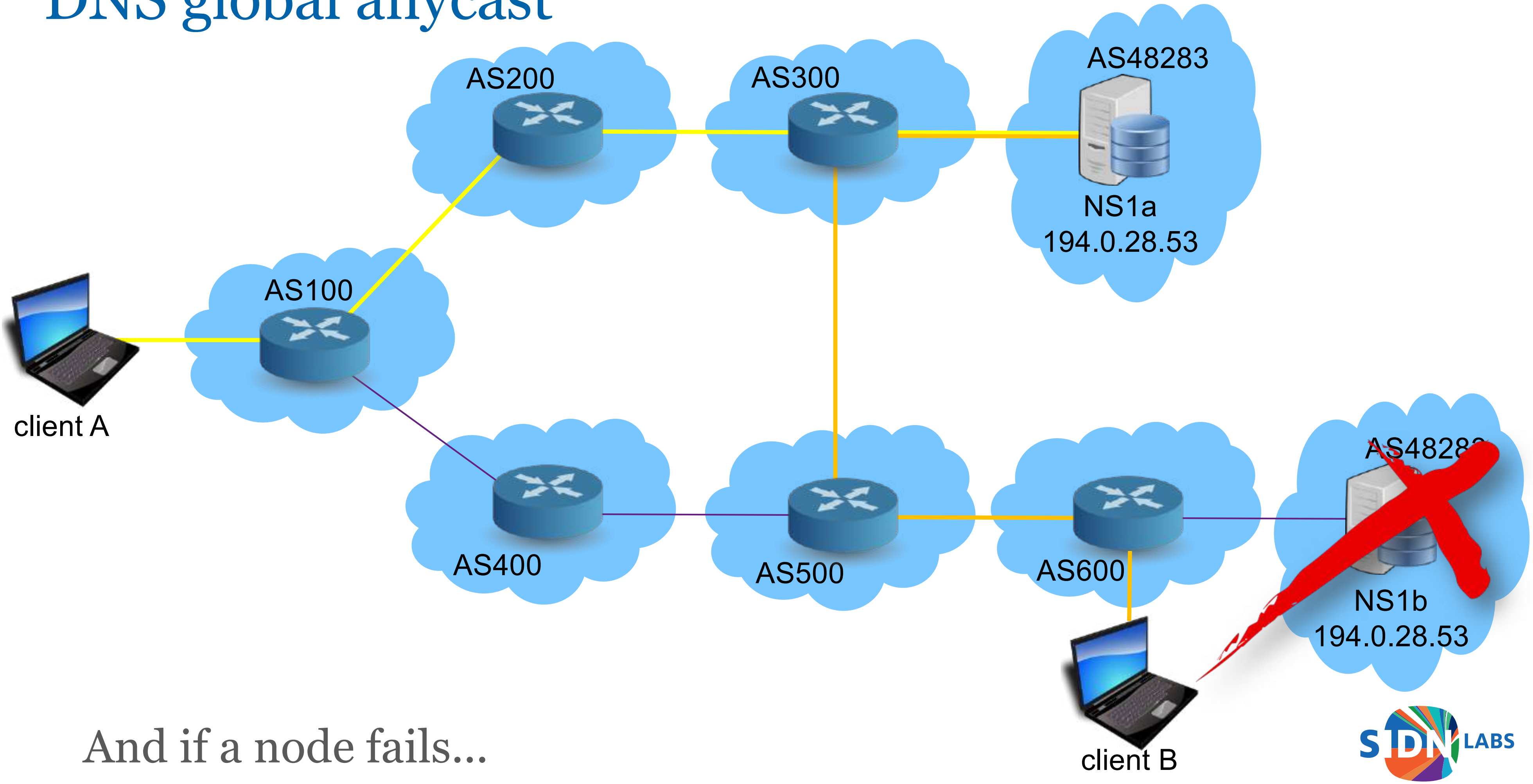
But remember, this is the real situation!

DNS global anycast



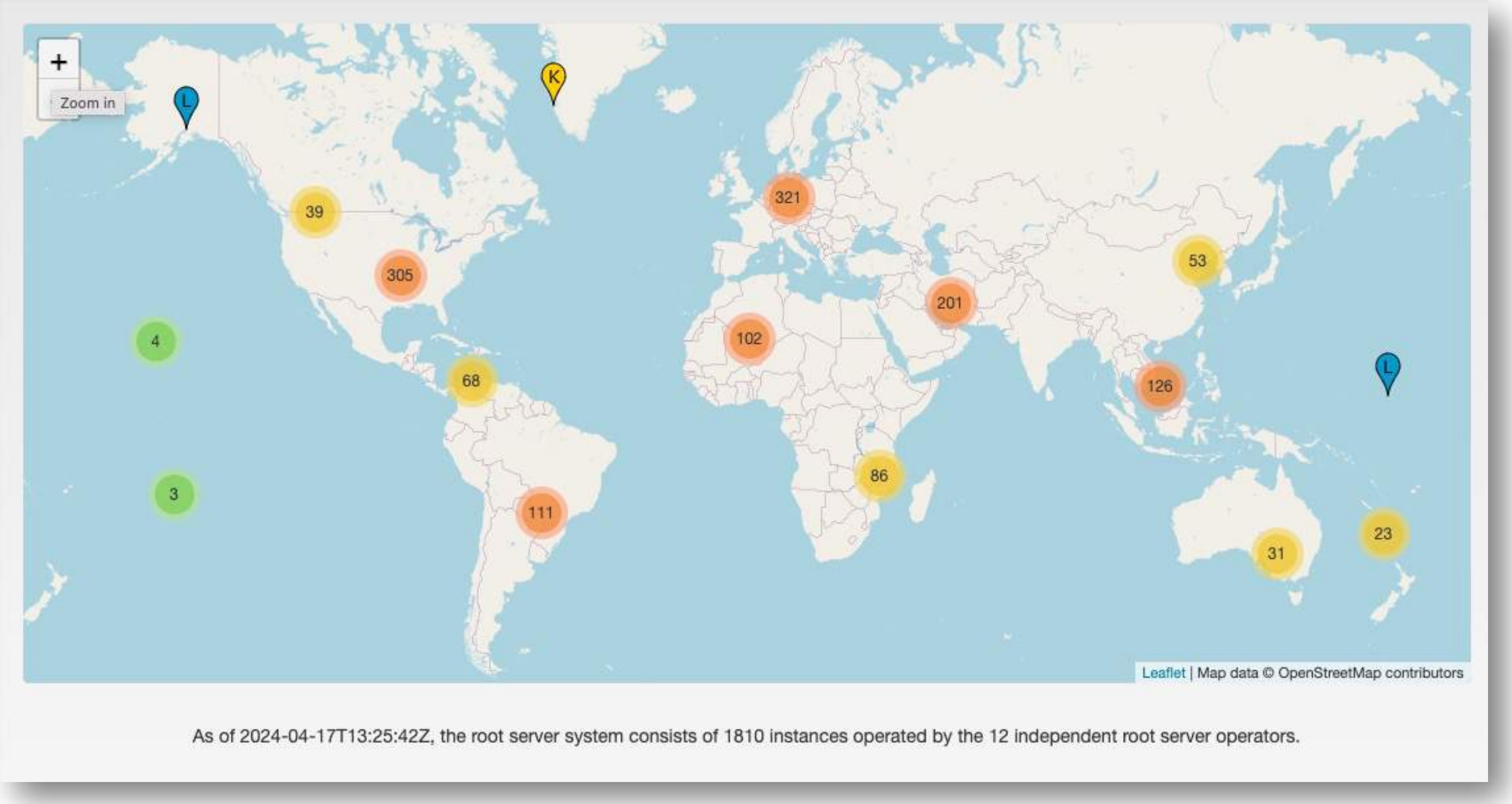
In reality this is how traffic flows.

DNS global anycast



And if a node fails...

DNS global anycast (for .)

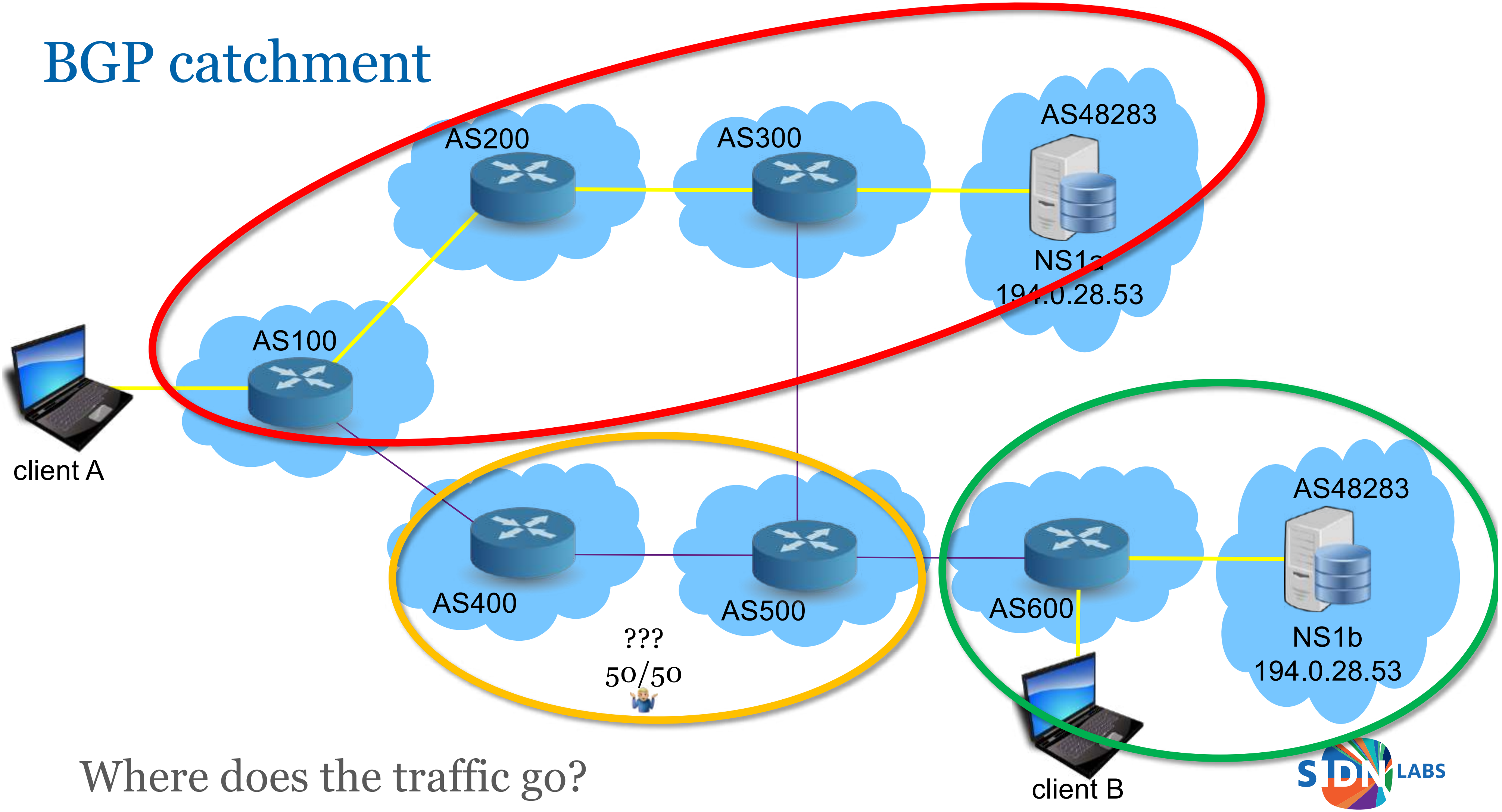


As of 2024-04-17T13:25:42Z, the root server system consists of 1810 instances operated by the 12 independent root server operators.

1810 servers!

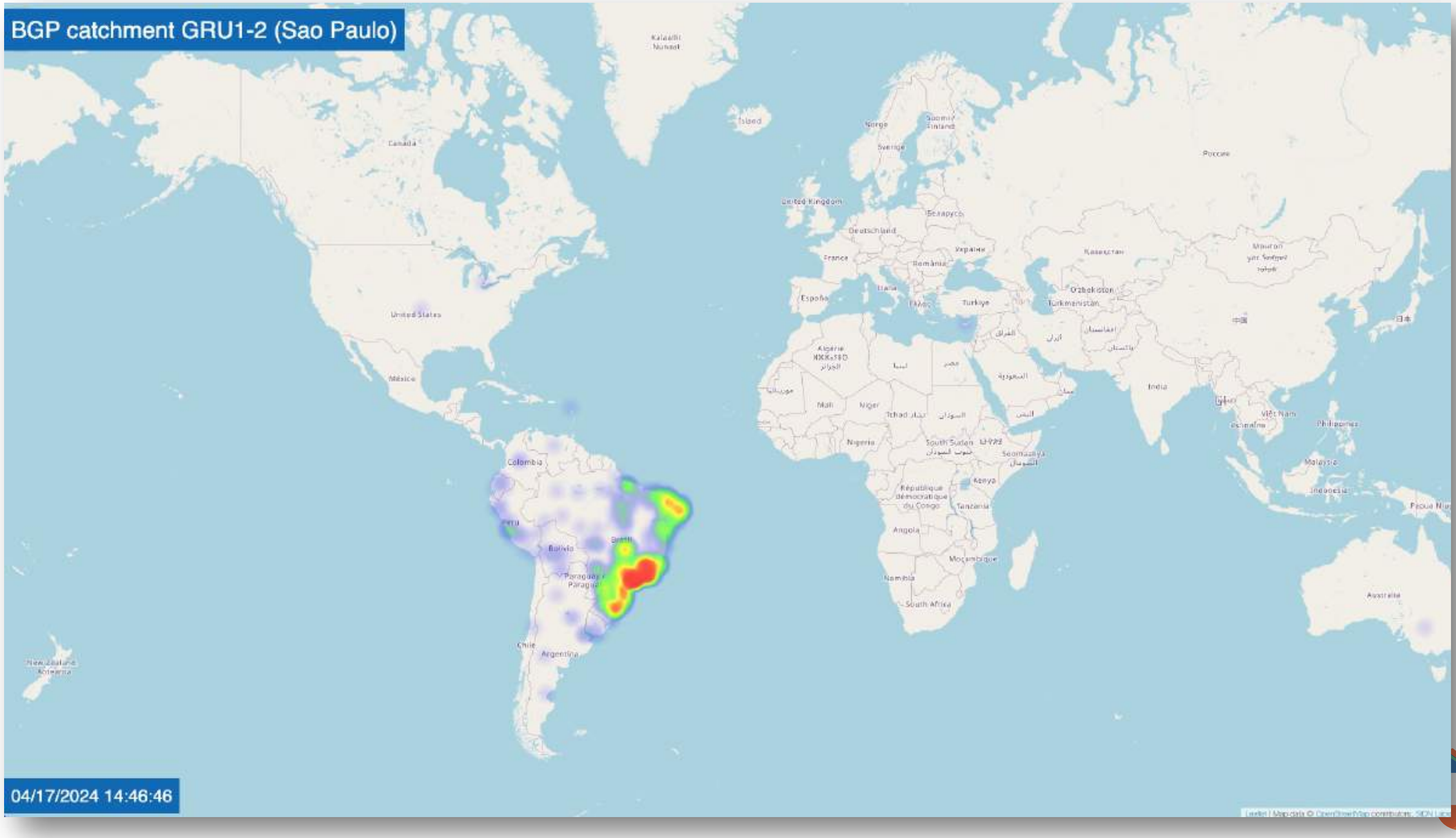
http://www.root-servers.org/

BGP catchment

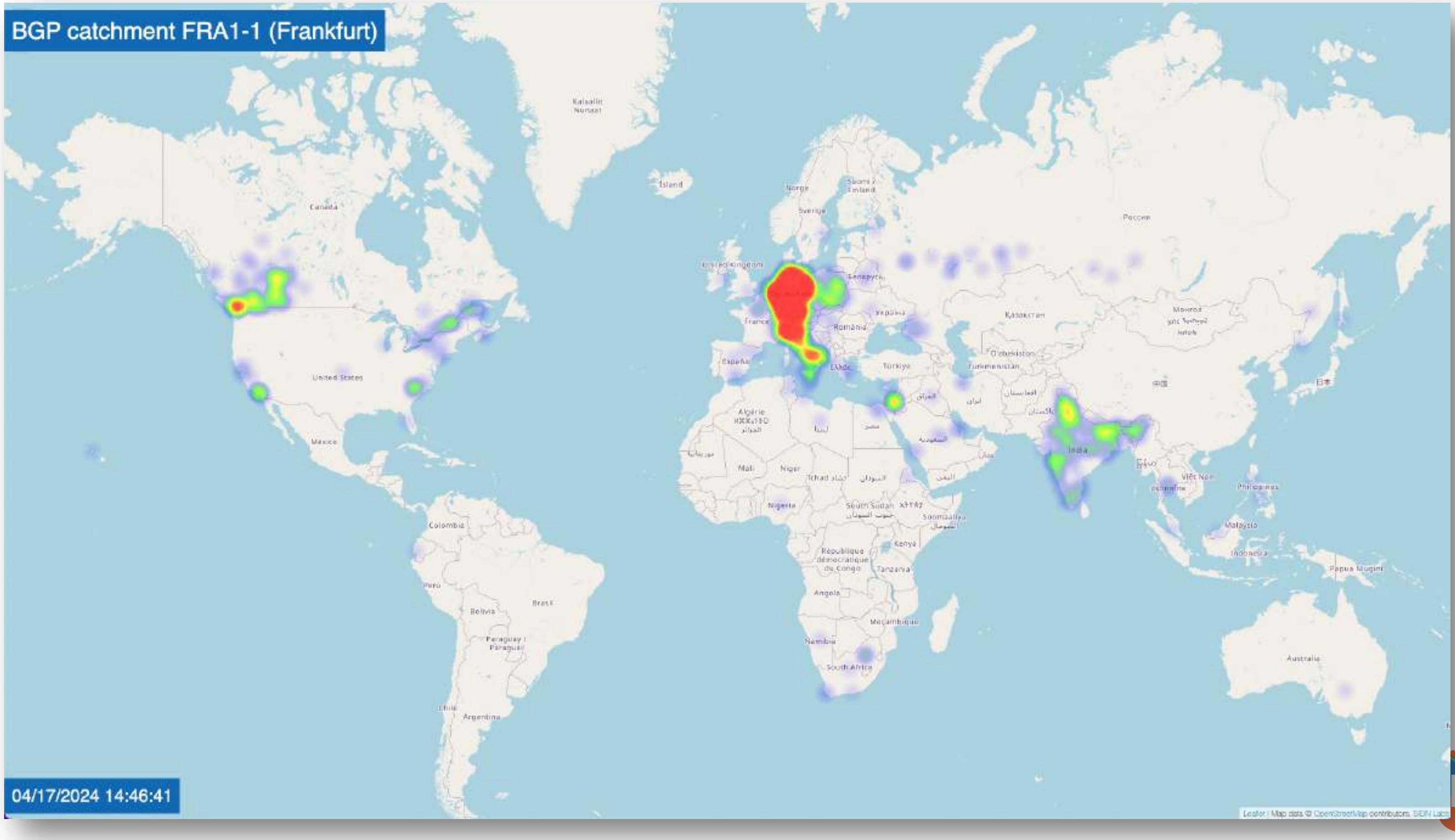


Where does the traffic go?

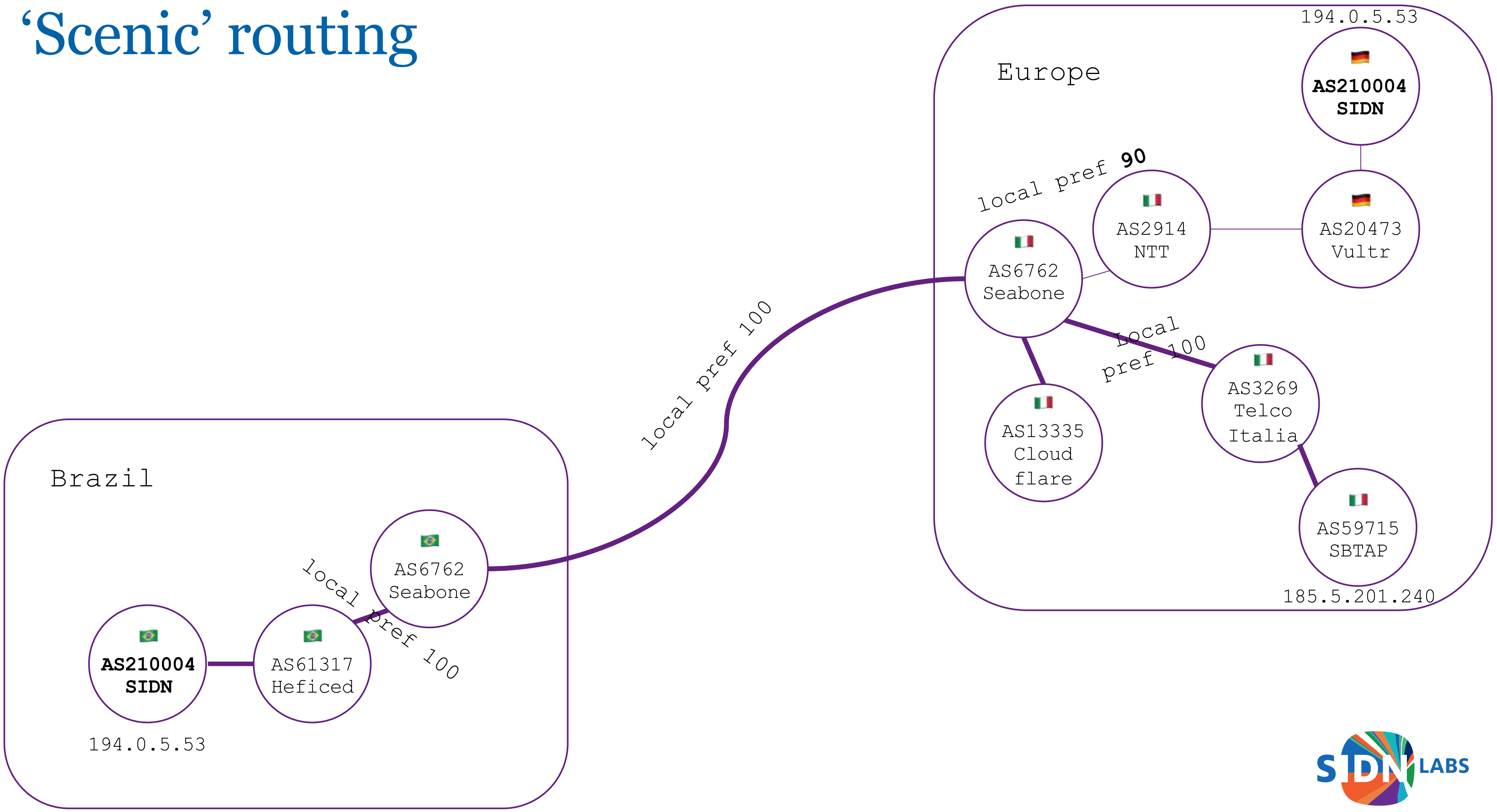
BGP catchment São Paulo ✅



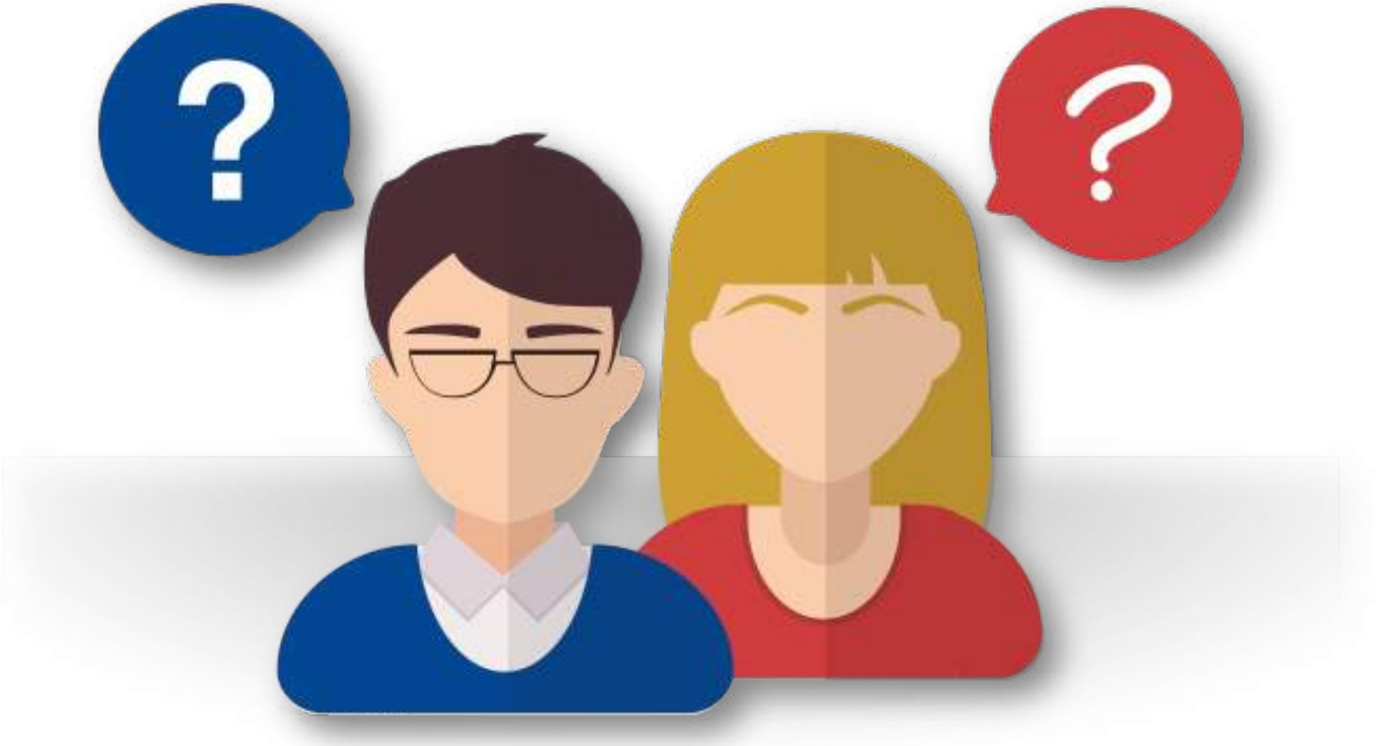
BGP catchment Frankfurt ⚠️


BGP catchment FRA1-1 (Frankfurt)
04/17/2024 14:46:41
Leaflet | Map data © OpenStreetMap contributors, SIDN Labs

‘Scenic’ routing



Questions, discussion



Thank you!