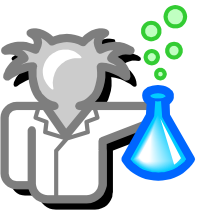


# Building the Internet's Largest Measurement System

Geoff Huston

APNIC Labs



# Israeli ISPs

## Visible ASNs: Customer Populations (Est.)

| Rank | ASN      | AS Name   | CC                 | Users (est.) | % of country | % of Internet | Samples |
|------|----------|---|--------------------|--------------|--------------|---------------|---------|
| 1    | AS12400  | PARTNER-AS  | <a href="#">IL</a> | 1,804,074    | 23.14        | 0.042         | 705,984 |
| 2    | AS1680   | NV-ASN CELLCOM Ltd.                               | <a href="#">IL</a> | 1,485,747    | 19.06        | 0.034         | 581,414 |
| 3    | AS12849  | HOTNET-IL AMS-IX Admin LAN                        | <a href="#">IL</a> | 1,030,062    | 13.21        | 0.024         | 403,092 |
| 4    | AS8551   | BEZEQ-INTERNATIONAL-AS Bezeqint Internet Backbone | <a href="#">IL</a> | 899,318      | 11.53        | 0.021         | 351,928 |
| 5    | AS16116  | Pelephone Communications                          | <a href="#">IL</a> | 670,854      | 8.6          | 0.016         | 262,524 |
| 6    | AS6810   | BEZEK   | <a href="#">IL</a> | 470,774      | 6.04         | 0.011         | 184,227 |
| 7    | AS21450  | MIRS-AS   | <a href="#">IL</a> | 403,761      | 5.18         | 0.009         | 158,003 |
| 8    | AS47956  | XFONE   | <a href="#">IL</a> | 271,871      | 3.49         | 0.006         | 106,391 |
| 9    | AS198484 | IL-GOLANTELECOM                                   | <a href="#">IL</a> | 138,157      | 1.77         | 0.003         | 54,065  |
| 10   | AS202940 | ITCNG ITC Internet Service Provider               | <a href="#">IL</a> | 114,037      | 1.46         | 0.003         | 44,626  |

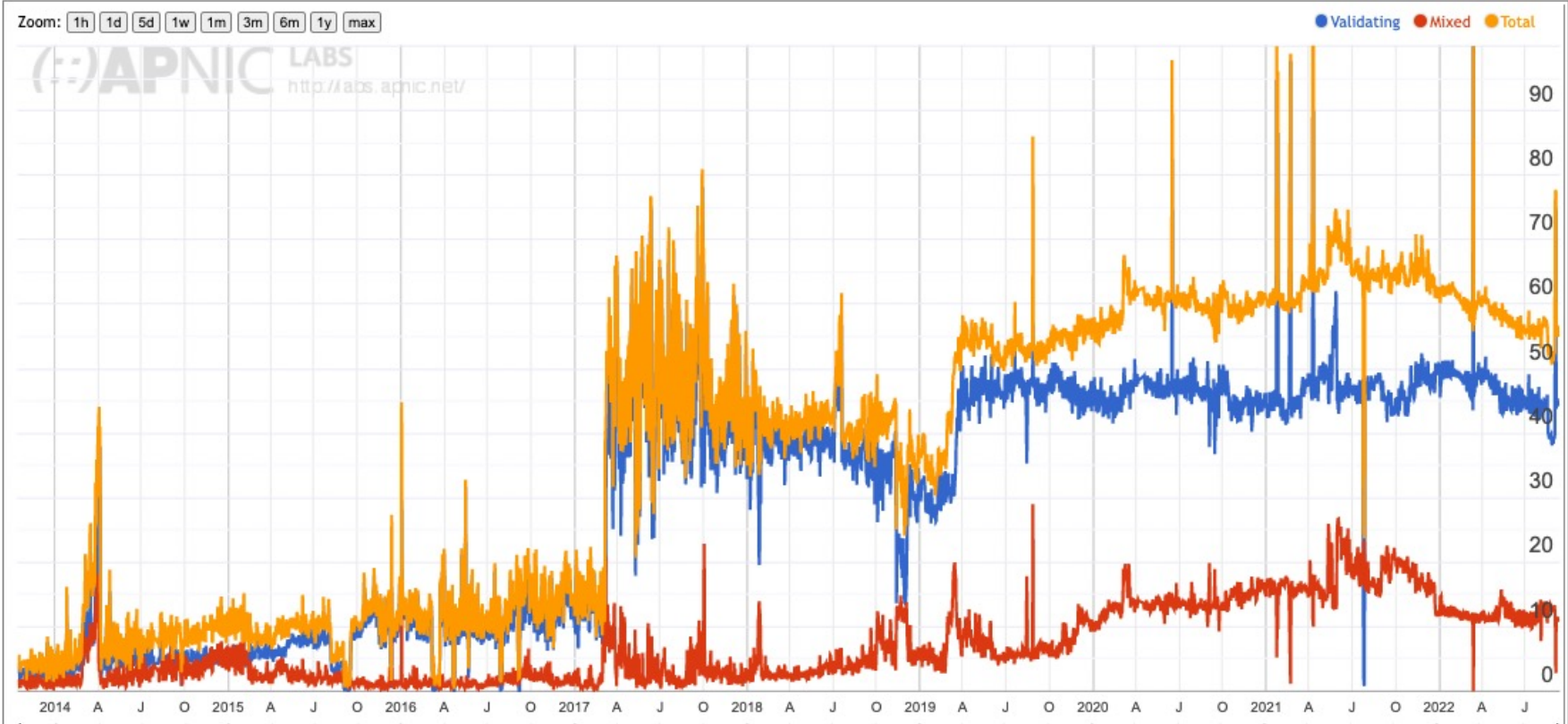
# Use of IPv6 in Israel

| ASN      | AS Name   | IPv6 Capable | IPv6 Preferred | Samples |
|----------|---|--------------|----------------|---------|
| AS12400  | PARTNER-AS  | 43.01%       | 42.33%         | 367,143 |
| AS1680   | NV-ASN CELLCOM Ltd.                               | 38.36%       | 37.70%         | 299,684 |
| AS12849  | HOTNET-IL AMS-IX Admin LAN                        | 59.07%       | 58.09%         | 215,383 |
| AS8551   | BEZEQ-INTERNATIONAL-AS Bezeqint Internet Backbone | 29.79%       | 28.55%         | 139,461 |
| AS16116  | Pelephone Communications                          | 73.21%       | 72.32%         | 127,087 |
| AS6810   | BEZEK   | 79.93%       | 73.43%         | 102,178 |
| AS21450  | MIRS-AS   | 59.33%       | 58.30%         | 76,539  |
| AS47956  | XFONE   | 58.43%       | 52.74%         | 53,123  |
| AS202940 | ITCNG ITC Internet Service Provider               | 39.46%       | 38.99%         | 22,911  |
| AS198484 | IL-GOLANTELECOM                                   | 57.86%       | 55.20%         | 20,453  |
| AS51825  | TELZAR-ASN  | 5.84%        | 5.62%          | 18,833  |
| AS8948   | PRIMO-099   | 0.44%        | 0.16%          | 8,564   |



# Use of DNSSEC in Israel

## Use of DNSSEC Validation for Israel (IL)



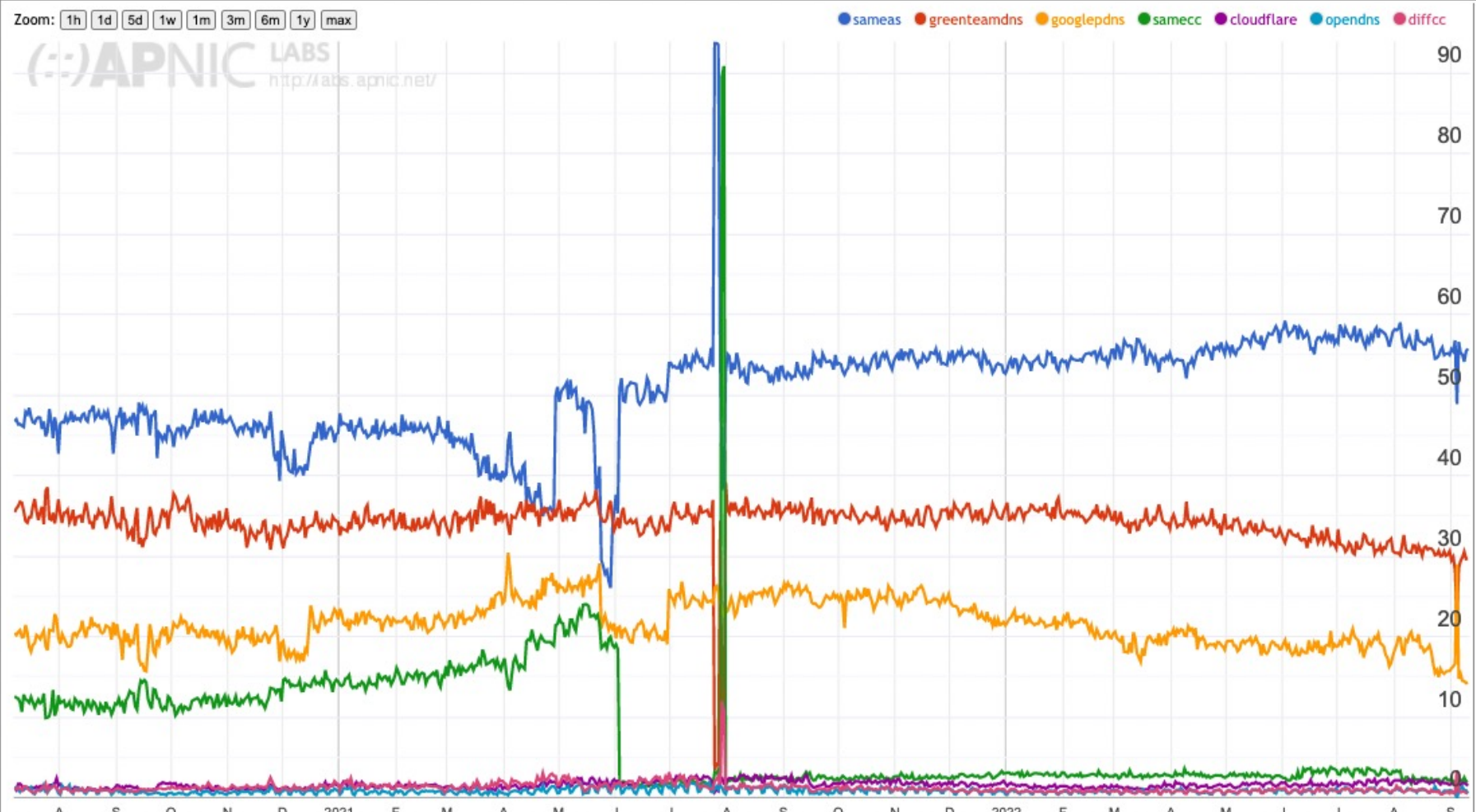
# Use of DNSSEC in Israel

## Use of DNSSEC Validation for Israel (IL)



| ASN      | AS Name   | DNSSEC Validates | Partial Validation | Samples |
|----------|---|------------------|--------------------|---------|
| AS12400  | PARTNER-AS  | 7.18%            | 24.59%             | 189,654 |
| AS1680   | NV-ASN CELLCOM Ltd.                               | 95.22%           | 4.37%              | 158,360 |
| AS12849  | HOTNET-IL AMS-IX Admin LAN                        | 21.09%           | 27.48%             | 109,988 |
| AS8551   | BEZEQ-INTERNATIONAL-AS Bezeqint Internet Backbone | 84.23%           | 11.57%             | 74,625  |
| AS16116  | Pelephone Communications                          | 1.29%            | 0.82%              | 70,651  |
| AS6810   | BEZEK   | 5.81%            | 1.88%              | 54,032  |
| AS21450  | MIRS-AS   | 1.16%            | 0.61%              | 42,782  |
| AS47956  | XFONE   | 97.72%           | 2.22%              | 28,554  |
| AS202940 | ITCNG ITC Internet Service Provider               | 93.42%           | 6.16%              | 11,972  |
| AS198484 | IL-GOLANTELECOM                                   | 97.12%           | 2.72%              | 11,038  |
| AS51825  | TELZAR-ASN  | 3.97%            | 8.49%              | 10,071  |
| AS42925  | RIMON1  | 24.90%           | 14.53%             | 5,080   |
| AS208905 | TAMARES-AS  | 94.22%           | 3.95%              | 4,380   |
| AS8048   | PRIMO 000   | 4.53%            | 4.88%              | 4,310   |

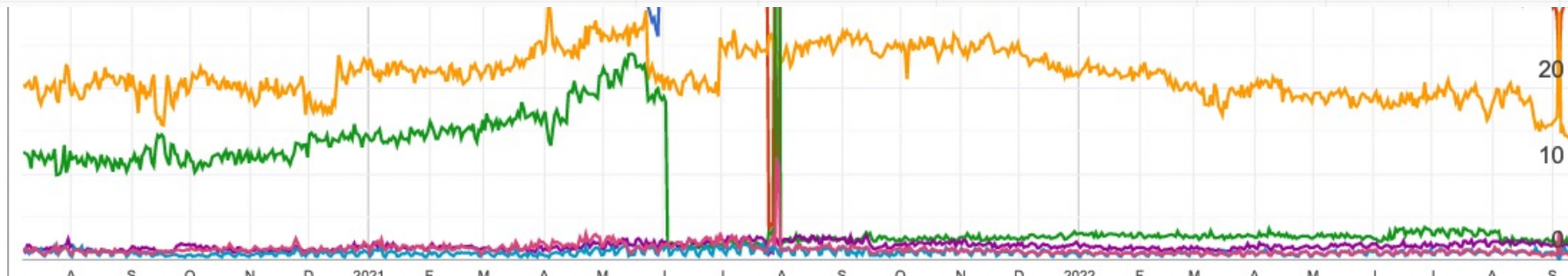
# DNS Resolver use in Israel



# DNS Resolver use in Israel



| ASN      | AS Name   | sameas  | greenteamdns | googlepdns | samecc  | cloudflare | opendns | diffcc | diffcceu | diffccneu | level3 | Samples |
|----------|---|---------|--------------|------------|---------|------------|---------|--------|----------|-----------|--------|---------|
| AS12400  | PARTNER-AS  | 89.001% | 0.135%       | 7.249%     | 1.881%  | 1.128%     | 0.403%  | 0.178% | 0.110%   | 0.068%    | 0.003% | 279,981 |
| AS1680   | NV-ASN CELLCOM Ltd.                               | 0.000%  | 94.021%      | 4.200%     | 0.317%  | 0.850%     | 0.403%  | 0.201% | 0.094%   | 0.107%    | 0.004% | 226,944 |
| AS12849  | HOTNET-IL AMS-IX Admin LAN                        | 49.945% | 0.043%       | 48.206%    | 0.145%  | 1.126%     | 0.319%  | 0.200% | 0.114%   | 0.085%    | 0.007% | 163,318 |
| AS8551   | BEZEQ-INTERNATIONAL-AS Bezeqint Internet Backbone | 0.000%  | 85.496%      | 11.290%    | 0.158%  | 1.600%     | 0.665%  | 0.752% | 0.276%   | 0.476%    | 0.033% | 162,377 |
| AS16116  | Pelephone Communications                          | 97.700% | 0.344%       | 0.982%     | 0.415%  | 0.415%     | 0.073%  | 0.070% | 0.027%   | 0.044%    | 0.001% | 96,525  |
| AS6810   | BEZEK   | 92.798% | 0.048%       | 5.846%     | 0.210%  | 0.891%     | 0.112%  | 0.092% | 0.029%   | 0.063%    | 0.002% | 83,996  |
| AS21450  | MIRS-AS   | 83.088% | 0.213%       | 1.000%     | 15.319% | 0.270%     | 0.047%  | 0.062% | 0.015%   | 0.046%    | 0.000% | 60,331  |
| AS47956  | XFONE   | 95.690% | 0.082%       | 2.912%     | 0.074%  | 0.551%     | 0.517%  | 0.166% | 0.022%   | 0.144%    | 0.000% | 40,623  |
| AS202940 | ITCNG ITC Internet Service Provider               | 78.198% | 0.118%       | 17.503%    | 0.276%  | 1.836%     | 0.949%  | 1.122% | 0.946%   | 0.176%    | 0.000% | 17,285  |
| AS198484 | IL-GOLANTELECOM                                   | 0.000%  | 66.218%      | 33.005%    | 0.278%  | 0.366%     | 0.061%  | 0.072% | 0.016%   | 0.056%    | 0.000% | 15,771  |
| AS51825  | TELZAR-ASN  | 89.012% | 0.147%       | 2.876%     | 0.138%  | 0.465%     | 7.194%  | 0.051% | 0.010%   | 0.041%    | 0.000% | 14,067  |



So much to measure...

so little time!



# How and what

- The basic questions are to figure out **what** measurement approach to use:
  - whole of network metrics vs sample measurements
  - system behaviour metrics vs user experience metrics vs component metrics
  - snapshot metrics vs time series measurements
- And then figure out **how** to perform the measurement:
  - Passive vs active
  - Dedicated probes vs enrolment
  - Deliberate and Intentional vs Opportunistic

# APNIC's path into measurement

2010:

IPv4 exhaustion is just around the corner - so how “ready” are we to operate an IPv6 Internet?

# "Measurable" IPv6 Questions

- How much traffic uses IPv6?
- How many connections use IPv6?
- How many routes are IPv6 routes?
- How many service providers offer IPv6?
- How many domain names have AAAA RRs?
- How many domain NS's use AAAA's?
- How many DNS queries are for AAAA RRs?
- How many DNS queries are made over IPv6?
- How many end devices have IPv6?
- How many end devices use IPv6?

...

# Close, but

- None of these specific measurement questions really embrace the larger question of IPv6 “readiness” for the Internet as a whole
  - They are all aimed at measuring IPv6 within particular facets of the network infrastructure, but they don’t encompass all of the infrastructure of the network at once

# What's the question?

- To make an IPv6 connection everything else (routing, forwarding, DNS, transport) has to work with IPv6

- So can we measure:

**How many connected devices on today's Internet are capable of making IPv6 connections?**

- What if we use scripting on a web server to test the capabilities of clients via a scripted set of related web object fetches

# Scale of Measurement

- We really need to use a massively popular web service to conduct this experiment
  - But “massively popular web services” worry constantly about service resiliency and privacy of their data regarding users
  - They tend to be extremely suspicious of adding script elements to their service that performs third party dual stack tests with their clients (and I can't blame them!)
- So, we need to rethink this approach...

# How to conduct measurements at scale

Be Google



# How to conduct measurements at scale

Or get Google to place your measurement code on millions of end user's systems, all of the time



# How to conduct measurements at scale

How?

# Online Ads



**REMINDER: SOMETIMES YOU NEED TO LET THE WILD OUT (remember to breathe)**



should not profit from region's name

80 comments

### Cutting cord too early 'risks health'



**Exclusive:** Childbirth experts query policy after research suggests early clamping of umbilical cord can lead to iron deficiency anaemia

46 comments

- Mother sings praises of delayed clamping

### Chinese official sacked for excess



Communist boss in Jiangsu province begs in vain for forgiveness after campaigners gatecrash lavish dinner

17 comments

### Measles cases rise to 942 in Wales



Figure for greater Swansea area rises by 56 as experts warn epidemic shows no sign of easing

- Big drive to halt measles outbreak
- Measles vaccination campaign begins
- Outbreak triggers fresh emphasis on vaccination
- The story behind the MMR scare
- Measles and MMR: the essential guide

### PM handed press regulation dilemma



Cross-party plans rejected as papers launch audacious bid to set up own royal charter-backed body

197 comments

- Read the draft alternative royal charter
- Alternative regulation plans: the key differences
- Editorial: time for a ceasefire

### Ukip election candidate suspended



Antisemitic comments were allegedly posted on conspiracy theory website under Anna-Marie Crampton's name but she says she is hacking victim

- Farage: Ukip candidates may have BNP past
- Clegg kills 'snooper's charter' bill
- Nick Thornby: Clegg reminded he is a liberal
- MPs question David Cameron

### 10 of the worst



### George Monbiot

My search for a smartphone that isn't soaked in blood



### Spare Rib

Back for more



### Box set gold

Big Train



### Measles & MMR


Essential guide



### Turner prize

### Ballads of a thin man

★★★☆☆



Iggy and the Stooges can still make a racket, but the best songs on Ready to Die are the ballads, writes Alexis Petridis

17 comments

### On a Low Rate Credit Card



with an ongoing purchase rate of 13.49% p.a. (variable).

Apply now

### Top videos



### The price of resistance in DRC

Plagued by an armed militia, villagers in the Democratic Republic of the Congo have fought back - but at a cost



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Guardian mobile

travelalberta.com

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# Ads use scripts

- Each time an ad is loaded the ad server loads creative content and scripts on to the client's browser
- The script can include action items to fetch 'network assets'
  - Typically used to load alternate images, sequences
  - Its not a generalized network stack, subject to constraints such as limited to certain object loads, reduced run-time library
- There are on-Load, on-Hover and on-Click actions
- We want to minimise interactions so we use on-Load scripting

# This can work

- We can instrument the target host via an ad script
  - we can constrain the ad script to talk to our server(s)
  - And if we instrument the servers we can infer the target host properties
- Ads try to deliver to new users all of the time
  - We want to measure new sample points all of the time to avoid implicit repeat bias in the measurement set
- Ads are biased towards 'clicks'
  - We are not interested in clicks
  - We just want impressions
  - Impressions are far cheaper than clicks!

# Advertising placement logic

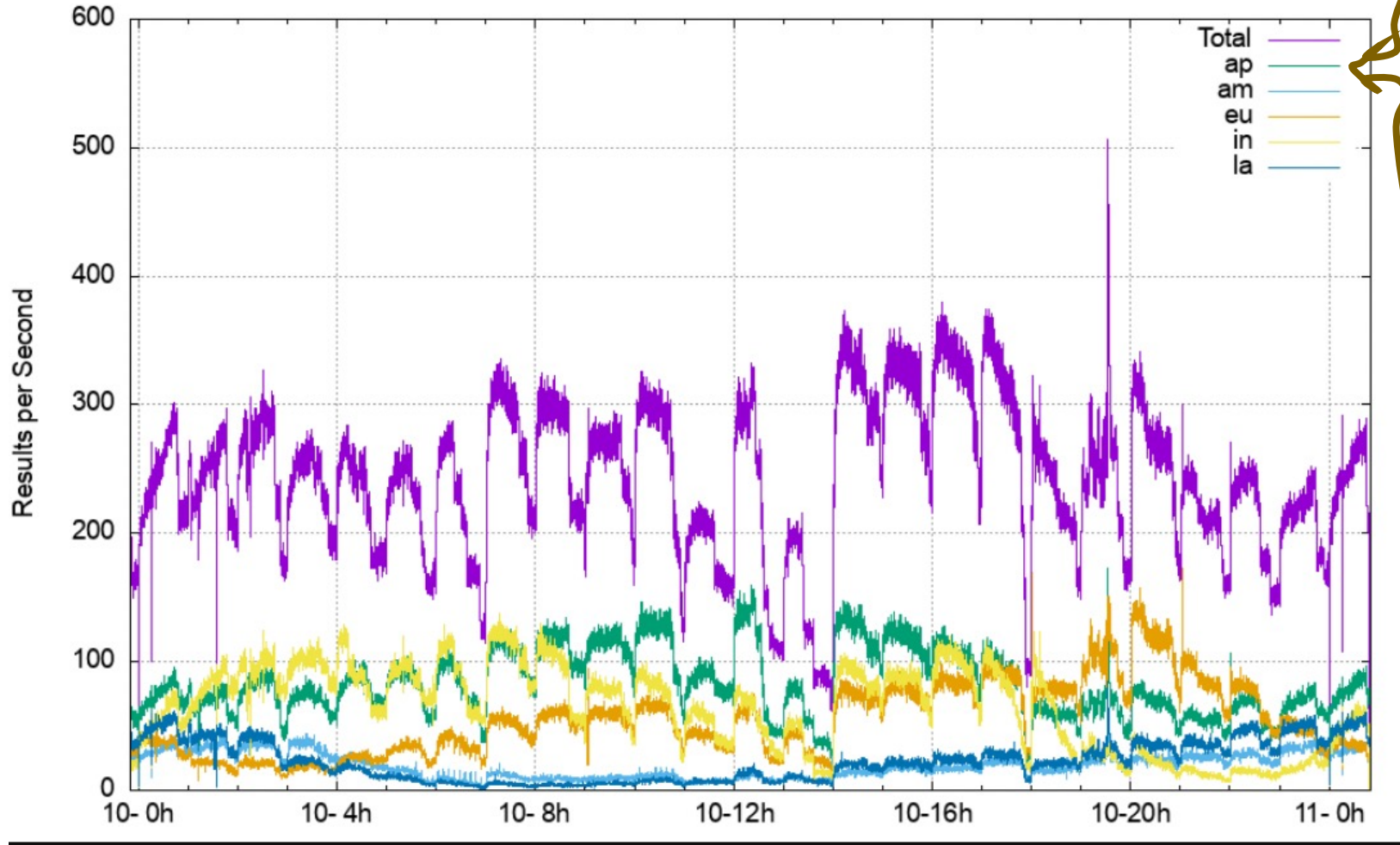
- Fresh Eyeballs == Unique endpoints
  - We have good evidence the advertising channel is able to sustain a constant supply of unique endpoints
- Pay by click, or pay by impression
  - If you select a preference for impressions, then the channel tries hard to present your ad to as many unique endpoints as possible
- Time/Location/Context tuned
  - Can select for time of day, physical location or keyword contexts (for search-related ads)
  - But if you don't select, then placement is generalized
- Aim to fill budget
  - If you request \$100 of ad placements per day, then inside 24h the algorithm tries hard to even placement but in the end the ad placement algorithm will ramp up your ad to achieve enough views, to bill you \$100

# Advertising placement logic

- Set a 'CPM' bid in the ad
  - Clicks Per Millepressions: bid rate to pay per thousand impressions
- Uneven distribution of ads throughout the day
  - But we can compensate for this by running 24 x 1-hour campaigns per day
- Use multiple campaigns each with a constrained locale
  - That way we can 'encourage' the ad system to give the ad a broad placement
- Outcome: 25M placements per day, on a mostly even placement model with end of day 'soak' to achieve budget goal

# Advertising placement logic

- $S_i$
  - $U$
  - $U$
  - $O$
- Completed Measurement per second



Asia (Singapore)  
America (Dallas)  
Europe (Frankfurt)  
Asia (Mumbai)  
S America (Sao Paulo)

ns per day

id placement

ement

← 26 hours →

# What can be scripted in an Ad

Not much:

- `http.FetchImg()`  
i.e. attempt to retrieve a URL

But that's enough!

- It's EXACTLY what users do!
- A URL consists of a DNS question and an HTML question
- What if we point both the DNS and the HTML to servers we run?
- As long as each Ad execution uses unique DNS names we can push the user query back to our servers and avoid the use of caching



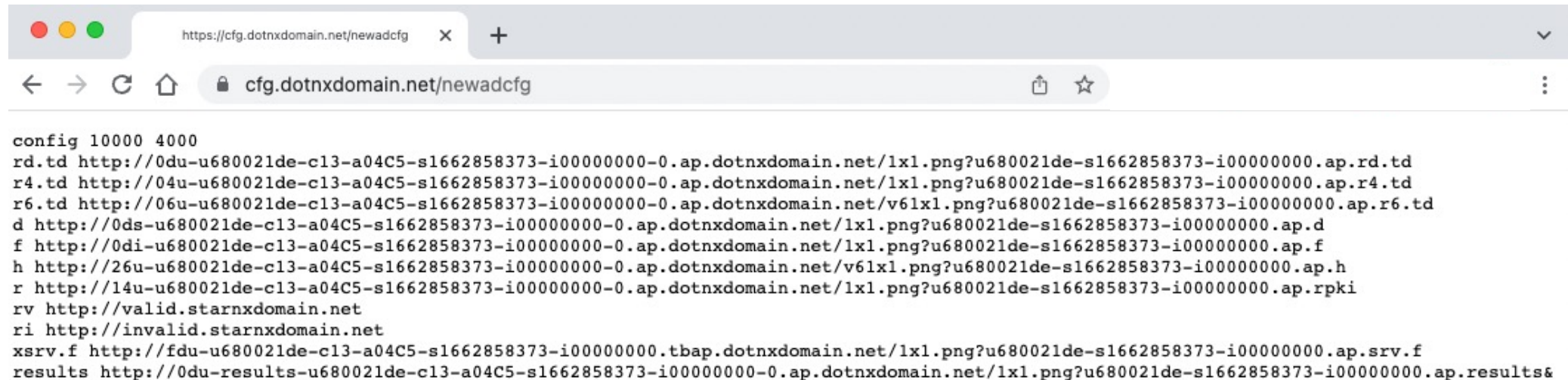
# Measuring IPv6 via Ads

- Use HTML5 code that is executed on ad impression
  - Client retrieves set of “tests” from an ad-controller
  - Client is given 10 URLs to load, including:
    - Dual Stack object
    - V4-only object
    - V6-only object
    - Result reporting URL (10 second timer)

All DNS is dual stack

All URLs use a unique DNS label

# For Example

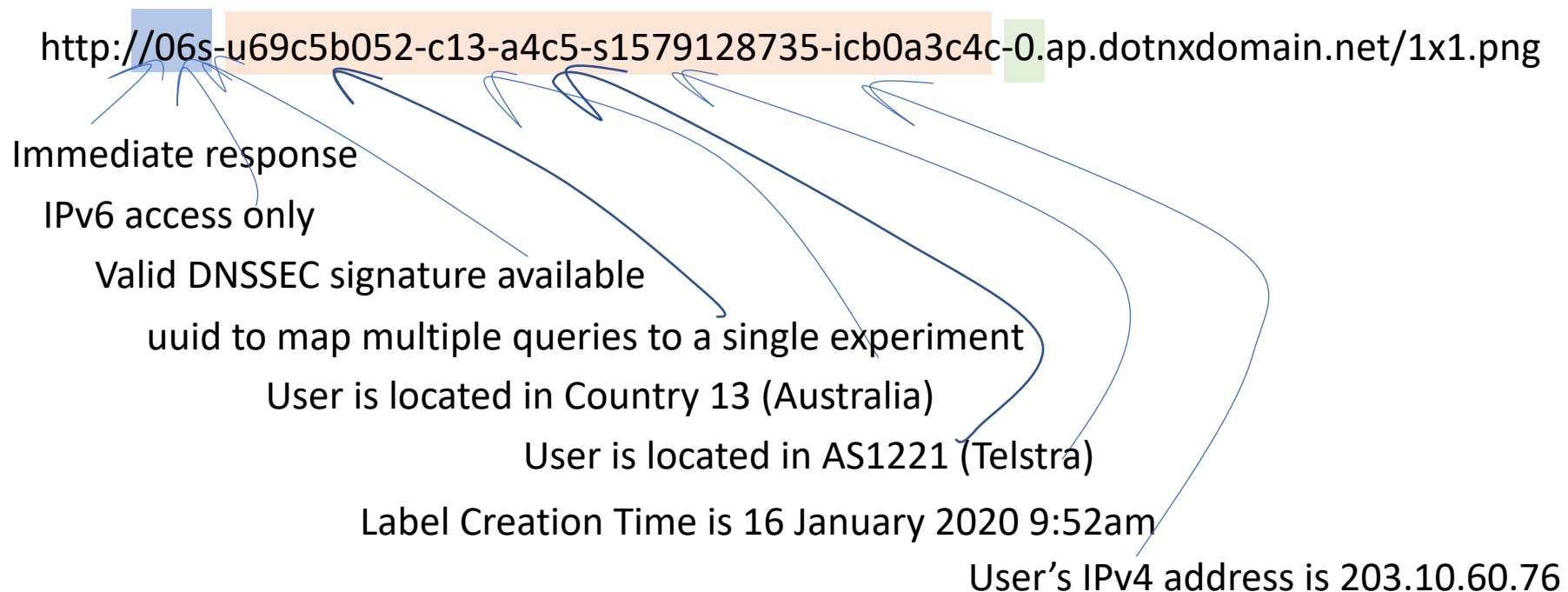


The image shows a browser window with the address bar displaying `https://cfg.dotnxdomain.net/newadcfg`. The page content is a list of DNS records:

```
config 10000 4000
rd.td http://0du-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/lx1.png?u680021de-s1662858373-i00000000.ap.rd.td
r4.td http://04u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/lx1.png?u680021de-s1662858373-i00000000.ap.r4.td
r6.td http://06u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/v6lx1.png?u680021de-s1662858373-i00000000.ap.r6.td
d http://0ds-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/lx1.png?u680021de-s1662858373-i00000000.ap.d
f http://0di-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/lx1.png?u680021de-s1662858373-i00000000.ap.f
h http://26u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/v6lx1.png?u680021de-s1662858373-i00000000.ap.h
r http://14u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/lx1.png?u680021de-s1662858373-i00000000.ap.rpki
rv http://valid.starnxdomain.net
ri http://invalid.starnxdomain.net
xsrv.f http://fdu-u680021de-c13-a04C5-s1662858373-i00000000.tbap.dotnxdomain.net/lx1.png?u680021de-s1662858373-i00000000.ap.srv.f
results http://0du-results-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/lx1.png?u680021de-s1662858373-i00000000.ap.results&
```

# DNS Label Encoding

Think of a URL name as a micro-coded instruction set directed to programmable DNS and HTTP servers ...



# Experiment Server config

- There are five server sets, identically configured in VMs in DCs (Frankfurt, Singapore, Dallas, Sao Paulo, Mumbai)
- The experiment script directs the client to the “closest” server set (based on geolocation of the client IP address)
- Server set has dedicated DNS and web content server VMs

# Collected Data

## Per Server, Per Day:

- HTTP access log  
(successfully completed fetches)
- DNS query log  
(incoming DNS queries)
- Packet capture  
All packets!

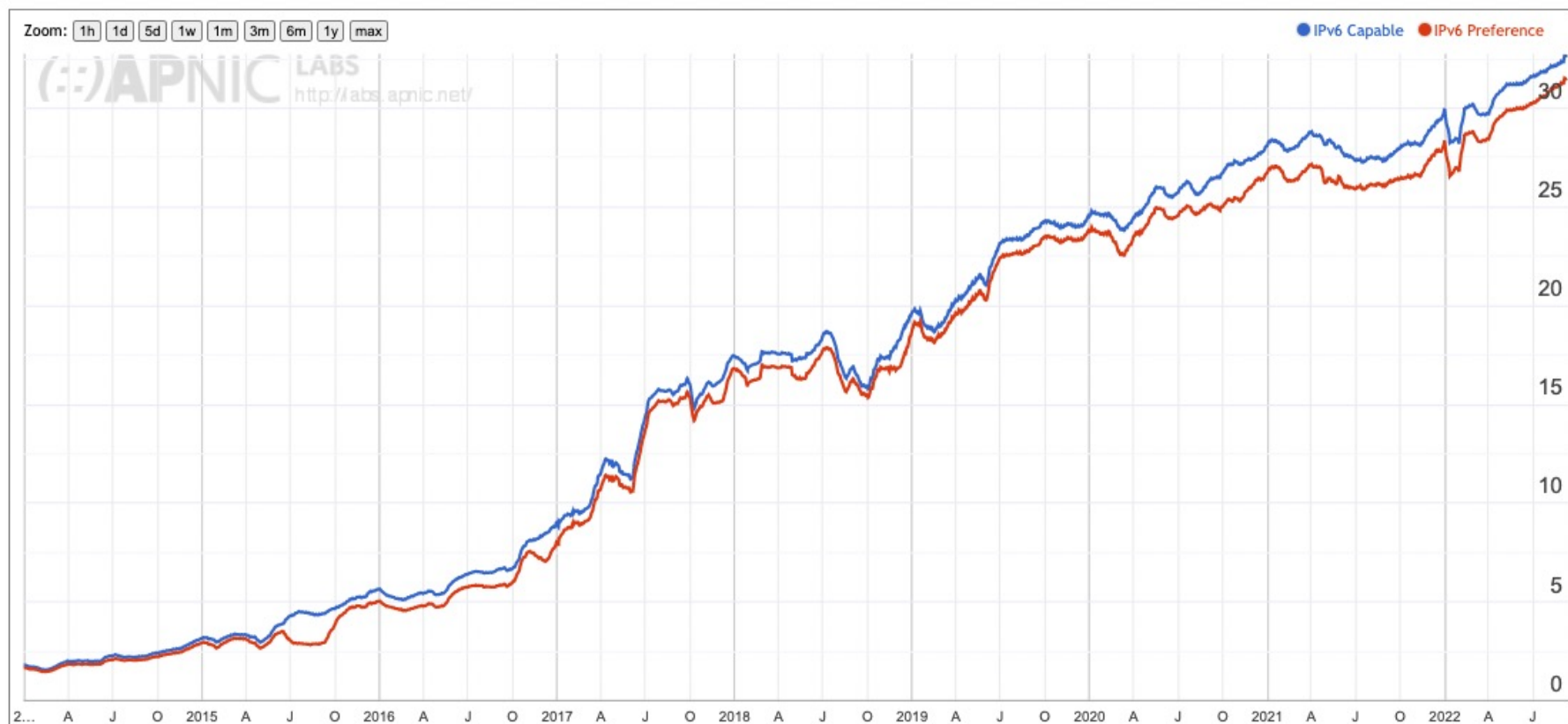
# Data Analysis

For example – IPv6 measurement

- IPv6 “capable” means that the client successfully fetched the URL target that is only accessible using IPv6
- IPv6 “preferred” means that the client used IPv6 to fetch the dual stack URL target
- Aggregate data by origin AS and by geolocation CC
- “Normalise” the country data against estimates of national user populations (to compensate for aD placement bias at a national level)
- Generate IPv6 daily report and data to data set

# V6 Time Series

## Use of IPv6 for World (XA)



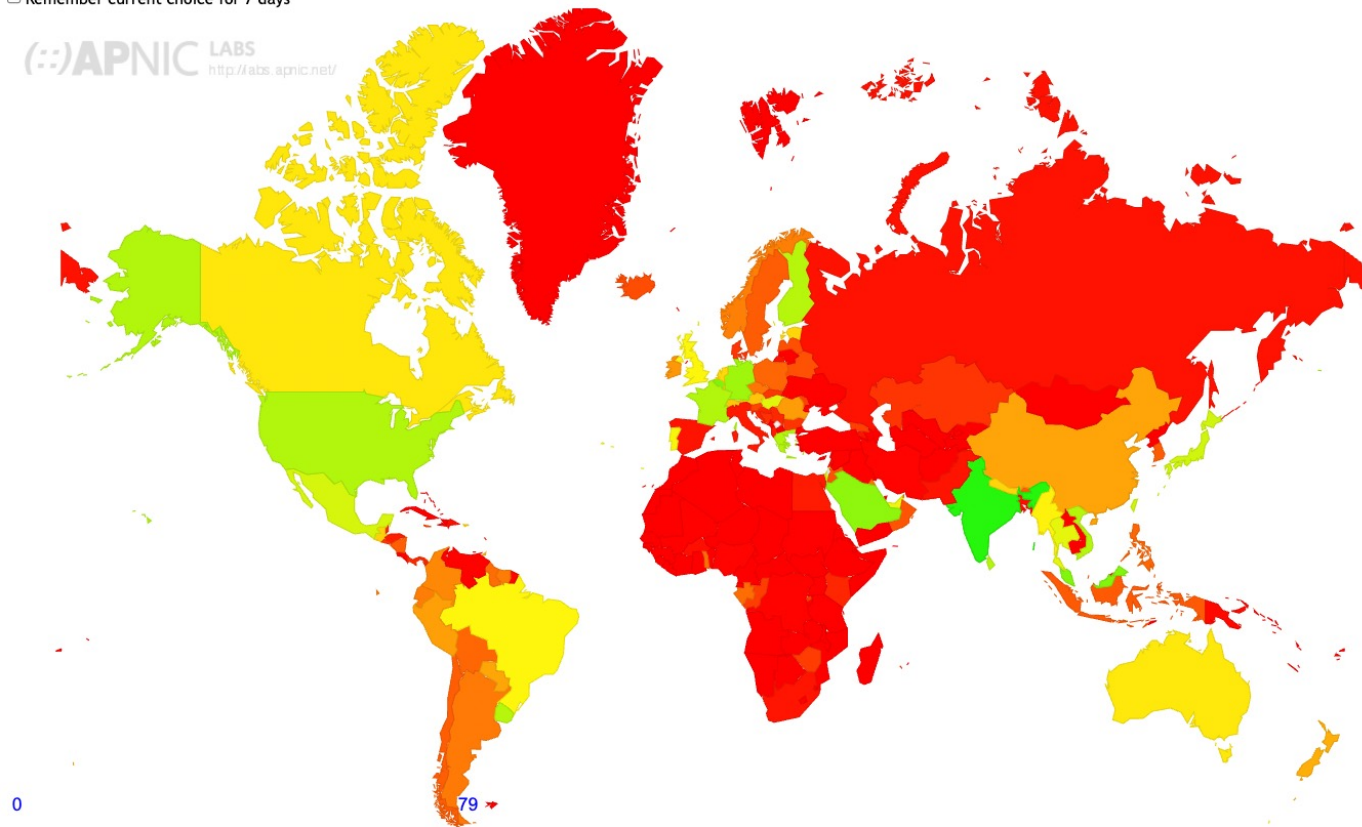
# IPv6 Report

## IPv6 Capable Rate by country (%)

[Click here for a zoomable map](#)

Remember current choice for 7 days

 APNIC LABS  
<http://labs.apnic.net/>



<https://stats.labs.apnic.net/ipv6>



# IPv6 Report

## IPv6 Capable Rate by co

[Click here for a zoomable map](#)

Remember current choice for 7 da

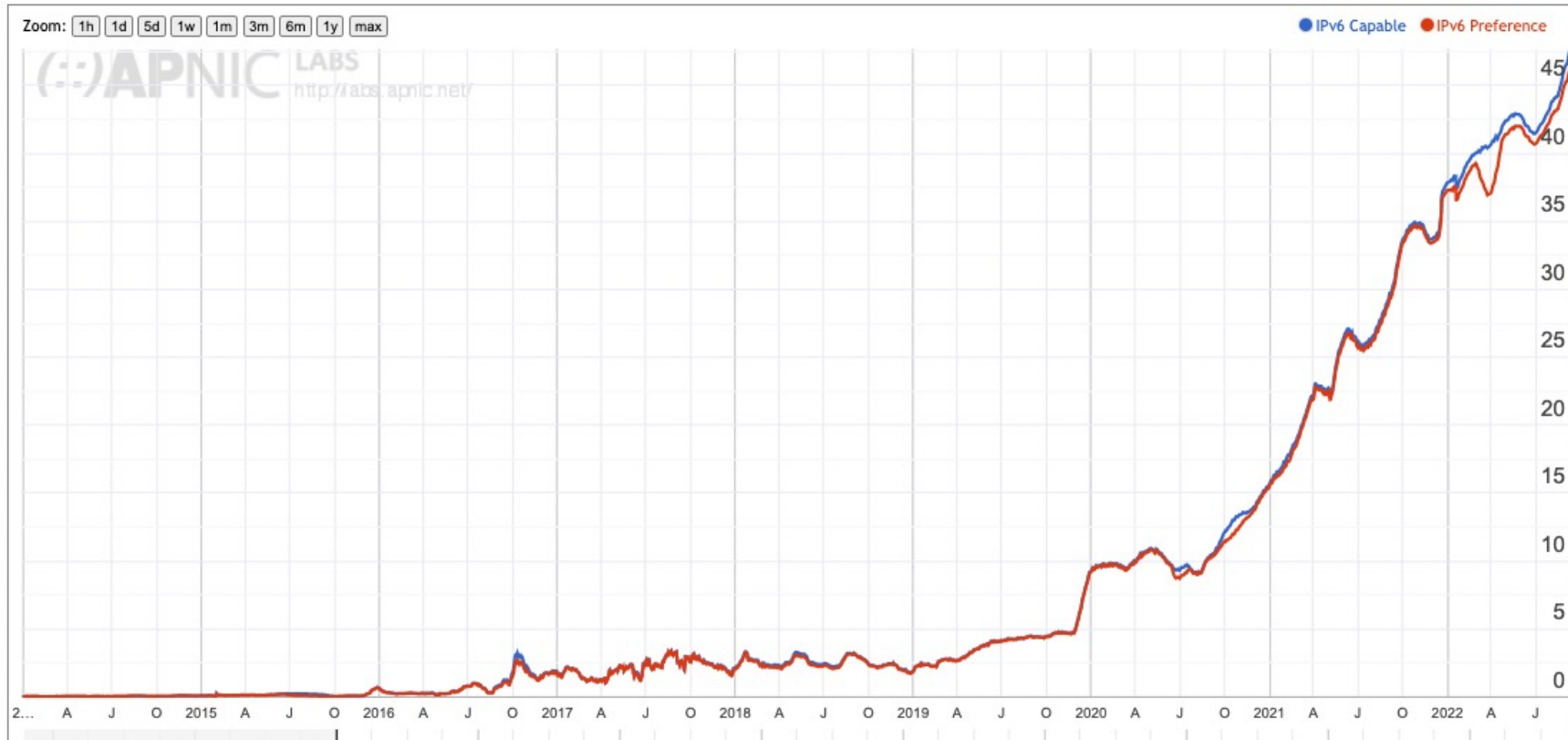


| CC | Country  | IPv6 Capable | IPv6 Preferred | Samples     |
|----|--|--------------|----------------|-------------|
| IN | India, Southern Asia, Asia                           | 78.63%       | 77.82%         | 153,680,002 |
| BL | Saint Barthelemy, Caribbean, Americas                | 75.04%       | 73.68%         | 661         |
| BE | Belgium, Western Europe, Europe                      | 63.44%       | 62.63%         | 1,281,187   |
| MY | Malaysia, South-Eastern Asia, Asia                   | 62.12%       | 61.54%         | 8,485,569   |
| SA | Saudi Arabia, Western Asia, Asia                     | 59.83%       | 58.62%         | 6,314,673   |
| DE | Germany, Western Europe, Europe                      | 56.75%       | 55.88%         | 3,908,561   |
| FR | France, Western Europe, Europe                       | 53.54%       | 52.99%         | 6,787,378   |
| US | United States of America, Northern America, Americas | 53.44%       | 52.13%         | 31,187,174  |
| GR | Greece, Southern Europe, Europe                      | 53.24%       | 52.94%         | 4,086,587   |
| LK | Sri Lanka, Southern Asia, Asia                       | 52.83%       | 52.11%         | 2,745,063   |
| VN | Vietnam, South-Eastern Asia, Asia                    | 52.79%       | 52.27%         | 9,420,147   |
| UY | Uruguay, South America, Americas                     | 52.61%       | 52.46%         | 724,175     |
| FI | Finland, Northern Europe, Europe                     | 52.47%       | 51.19%         | 596,829     |
| MS | Montserrat, Caribbean, Americas                      | 52.40%       | 51.59%         | 4,464       |
| JP | Japan, Eastern Asia, Asia                            | 47.96%       | 46.62%         | 6,560,313   |
| TW | Taiwan, Eastern Asia, Asia                           | 47.82%       | 46.82%         | 4,408,698   |
| IL | Israel, Western Asia, Asia                           | 47.59%       | 46.19%         | 1,516,479   |
| MX | Mexico, Central America, Americas                    | 46.86%       | 46.09%         | 18,675,047  |
| HU | Hungary, Eastern Europe, Europe                      | 44.92%       | 44.31%         | 2,644,651   |
| TH | Thailand, South-Eastern Asia, Asia                   | 44.08%       | 43.83%         | 6,736,827   |
| AX | Aland Islands, Northern Europe, Europe               | 42.54%       | 42.26%         | 2,847       |
| AE | United Arab Emirates, Western Asia, Asia             | 42.28%       | 41.90%         | 1,624,604   |

<https://stats.labs.apnic.net/ipv6>

# Per-Country Time Series - Israel

## Use of IPv6 for Israel (IL)



<https://stats.labs.apnic.net/ipv6/IL>

# Per-Country Time Series - Israel

## Use of IPv6 for I

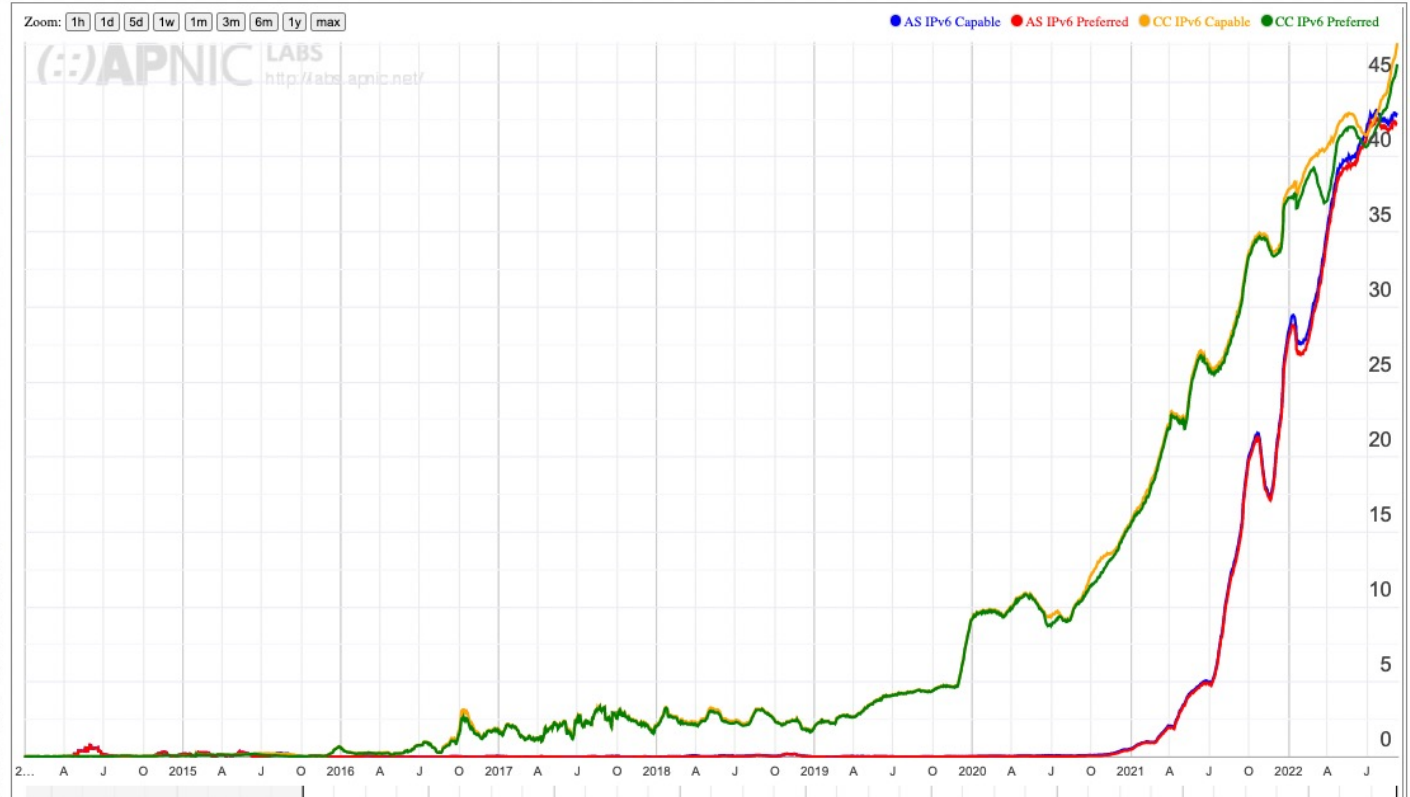
| ASN      | AS Name   | IPv6 Capable | IPv6 Preferred | Samples |
|----------|---|--------------|----------------|---------|
| AS12400  | PARTNER-AS  | 42.93%       | 42.28%         | 364,715 |
| AS1680   | NV-ASN CELLCOM Ltd.                               | 38.45%       | 37.82%         | 298,944 |
| AS12849  | HOTNET-IL AMS-IX Admin LAN                        | 58.93%       | 57.98%         | 213,606 |
| AS8551   | BEZEQ-INTERNATIONAL-AS Bezeqint Internet Backbone | 27.52%       | 26.32%         | 139,321 |
| AS16116  | Pelephone Communications                          | 73.23%       | 72.36%         | 126,952 |
| AS6810   | BEZEK   | 80.03%       | 73.62%         | 100,991 |
| AS21450  | MIRS-AS   | 59.30%       | 58.26%         | 76,453  |
| AS47956  | XFONE   | 58.25%       | 52.61%         | 53,013  |
| AS202940 | ITCNG ITC Internet Service Provider               | 39.13%       | 38.65%         | 22,862  |
| AS198484 | IL-GOLANTELECOM                                   | 58.00%       | 55.44%         | 21,019  |
| AS51825  | TELZAR-ASN  | 5.75%        | 5.54%          | 18,860  |
| AS208905 | TAMARES-AS  | 70.68%       | 69.21%         | 8,548   |
| AS8948   | PRIMO-099   | 0.43%        | 0.16%          | 8,546   |
| AS50463  | TRIPLEC-ASN                                       | 21.36%       | 20.56%         | 8,074   |
| AS42925  | RIMON1  | 26.64%       | 23.20%         | 7,688   |
| AS212238 | CDNEXT  | 0.20%        | 0.08%          | 6,570   |
| AS47962  | CONNECT972 Connect 972                            | 0.21%        | 0.14%          | 5,806   |
| AS47253  | AS-BNETSET  | 0.06%        | 0.03%          | 3,096   |
| AS60886  | AMIT  | 0.20%        | 0.07%          | 3,053   |
| AS13335  | CLOUDFLARENET                                     | 98.14%       | 85.65%         | 2,578   |
| AS200742 | IL-3SAMNET-AS                                     | 0.81%        | 0.12%          | 2,456   |

# Per-Network Time Series

## Use of IPv6 for

| ASN      | AS Name             | IPv6 Capable | IPv6 Preferred | Samples |
|----------|---------------------|--------------|----------------|---------|
| AS12400  | PARTNER-AS          | 42.93%       | 42.28%         | 364,715 |
| AS1680   | NV-ASN CELLCOM Ltd. | 38.45%       | 37.82%         | 298,944 |
| AS12849  | HOTNET              |              |                |         |
| AS8551   | BEZEC               |              |                |         |
| AS16116  | Peleph              |              |                |         |
| AS6810   | BEZEK               |              |                |         |
| AS21450  | MIRS-A              |              |                |         |
| AS47956  | XFONE               |              |                |         |
| AS202940 | ITCNG               |              |                |         |
| AS198484 | IL-GOL              |              |                |         |
| AS51825  | TELZA               |              |                |         |
| AS208905 | TAMAF               |              |                |         |
| AS8948   | PRIMC               |              |                |         |
| AS50463  | TRIPLE              |              |                |         |
| AS42925  | RIMON               |              |                |         |
| AS212238 | CDNE)               |              |                |         |
| AS47962  | CONN                |              |                |         |
| AS47253  | AS-BN               |              |                |         |
| AS60886  | AMIT                |              |                |         |
| AS13335  | CLOU                |              |                |         |
| AS200742 | IL-3SA              |              |                |         |

## IPv6 Per-Country Deployment for AS12400: PARTNER-AS, Israel (IL)



# What about DNSSEC Use?

- Can we use the same platform to measure the proportion of users who sit behind DNS resolvers that perform DNSSEC validation?

# What about DNSSEC Use?

- Can we use the same platform to measure the proportion of users who sit behind DNS resolvers that perform DNSSEC validation?



DNSSEC-signed  
DNS name



Invalidly-signed  
DNSSEC-signed  
DNS name

```
config 10000 4000
rd.td http://0du-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/1x1.png?u680021de-s1662858373-i00000000.ap.rd.td
r4.td http://04u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/1x1.png?u680021de-s1662858373-i00000000.ap.r4.td
r6.td http://06u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/v61x1.png?u680021de-s1662858373-i00000000.ap.r6.td
d http://0ds-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/1x1.png?u680021de-s1662858373-i00000000.ap.d
f http://0di-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/1x1.png?u680021de-s1662858373-i00000000.ap.f
h http://26u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/v61x1.png?u680021de-s1662858373-i00000000.ap.h
r http://14u-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/1x1.png?u680021de-s1662858373-i00000000.ap.rpki
rv http://valid.starnxdomain.net
ri http://invalid.starnxdomain.net
xsrv.f http://fdu-u680021de-c13-a04C5-s1662858373-i00000000.tbap.dotnxdomain.net/1x1.png?u680021de-s1662858373-i00000000.ap.srv.f
results http://0du-results-u680021de-c13-a04C5-s1662858373-i00000000-0.ap.dotnxdomain.net/1x1.png?u680021de-s1662858373-i00000000.ap.results&
```

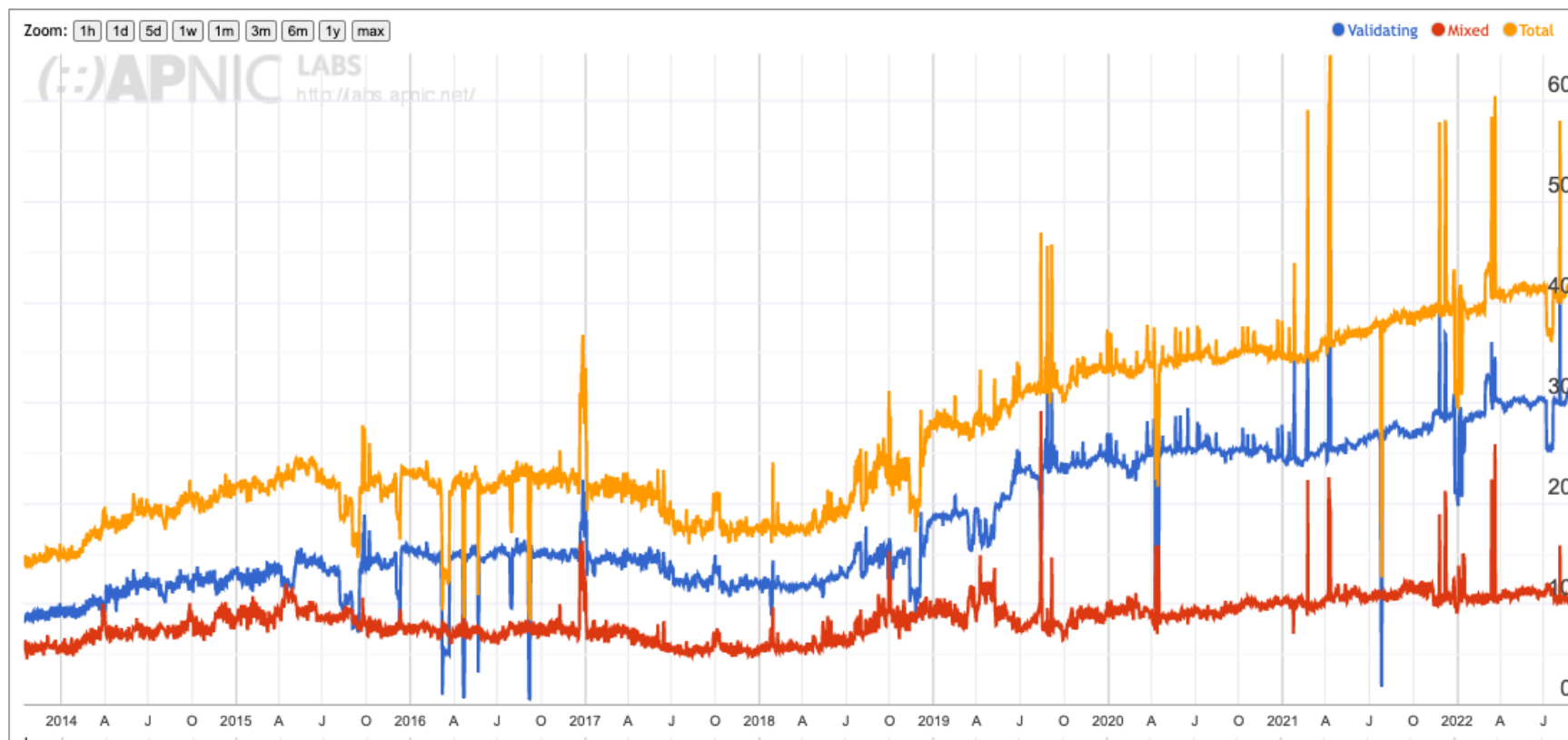
# DNSSEC Test

- A client is sitting behind DNSSEC validating resolvers if:
  - It fetches the validly-signed DNS URL
  - It does not fetch the invalidly-signed DNS URL
  - It queries for the address using EDNS0 DNSSEC OK field
  - It queries for the zone DNSKEY record for both DNS names \*
- A client “partially” validates if the validation failure causes the client to use an alternative non-validating resolver and resolve the name

\* This last one is a bit of a challenge as we want to see these queries at the authoritative server and not have them masked by caching – so we use a LDNS-based auth server to create a dynamic DNS server that constructs a DNSSEC signed delegated zone on the fly

# DNSSEC Results

## Use of DNSSEC Validation for World (XA)



<https://stats.labs.apnic.net/dnssec/XA>

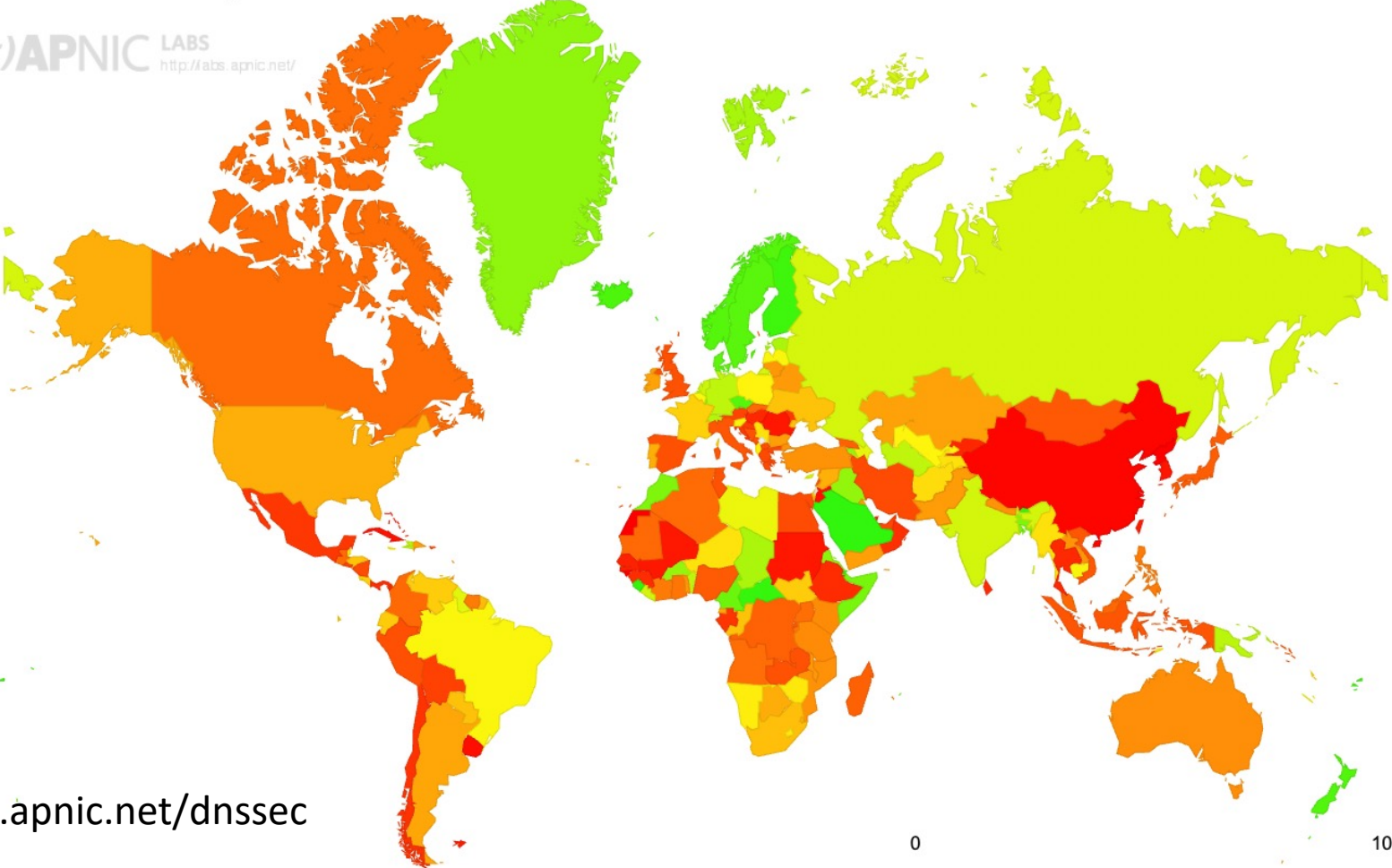


# DNSSEC Results

## DNSSEC Validation Rate by country (%)

[Click here for a zoomable map](#)  
 Remember current choice for 7 days

 APNIC LABS  
<http://labs.apnic.net/>



# DNSSEC Validation in Israel

| ASN      | AS Name   | DNSSEC Validates | Partial Validation | Samples ▼ |
|----------|---|------------------|--------------------|-----------|
| AS12400  | PARTNER-AS  |                  |                    | 189,654   |
| AS1680   | NV-ASN CELLCOM Ltd.                               | —————>           |                    | 158,360   |
| AS12849  | HOTNET-IL AMS-IX Admin LAN                        |                  |                    | 109,988   |
| AS8551   | BEZEQ-INTERNATIONAL-AS Bezeqint Internet Backbone | —————>           |                    | 74,625    |
| AS16116  | Pelephone Communications                          |                  |                    | 70,651    |
| AS6810   | BEZEK   |                  |                    | 54,032    |
| AS21450  | MIRS-AS   |                  |                    | 42,782    |
| AS47956  | XFONE   | —————>           |                    | 28,554    |
| AS202940 | ITCNG ITC Internet Service Provider               | —————>           |                    | 11,972    |
| AS198484 | IL-GOLANTELECOM                                   | —————>           |                    | 11,038    |
| AS51825  | TELZAR-ASN  |                  |                    | 10,071    |
| AS42925  | RIMON1  |                  |                    | 5,080     |
| AS208905 | TAMARES-AS  | —————>           |                    | 4,380     |
| AS8948   | PRIMO-099   |                  |                    | 4,212     |
| AS212238 | CDNEXT  | —————>           |                    | 4,107     |
| AS50463  | TRIPLEC-ASN                                       | —————>           |                    | 3,977     |
| AS47962  | CONNECT972 Connect 972                            | —————>           |                    | 2,868     |
| AS60886  | AMIT  | —————>           |                    | 1,544     |

<https://stats.labs.apnic.net/dnssec/IL>

# Other server side measurement techniques

We treat the DNS name (and the full URL) as a set of server instructions and use a combination of dynamic DNS, NGINX modules and 2-step packet processing to generate specific server-side behaviours that we want to measure

# Other server side measurement techniques - Glueless DNS

“Glueless” DNS delegation to provide explicit confirmation that a resolver has received a response

- The client is forced to resolve the name of the zone name servers before proceeding with the original resolution task
- If the name of the name servers is dynamically generated and unique then DNS caching won't help
- We've used this technique to measure:
  - IDN support
  - qname minimisation
  - DNS fragmentation management
  - DNS dual stack behaviour

# Other server side measurement techniques - Repeats

Explicitly directed repeat fetches to trigger content directives for HTTP/3

- Chrome relies on receiving an Alt-Svc: content directive before it will switch over to use HTTP for fetches from this server
- Which means it will only use HTTP/3 on the second (or subsequent) fetch
- To create this behaviour we have to allow the measurement script to schedule this fetch multiple times, with a small idle interval between fetches

# Other server side measurement techniques - SERVFAIL DNS

SERVFAIL responses to force the client resolver to cycle through all configured recursive resolvers

- This technique uses a LDNS path that responds with a SERVFAIL response for all DNS queries for this name set
- This is intended to cause the local resolver to cycle through all locally configured recursive resolvers to find a resolver that will respond to the query
- We used this is exposing the set of resolvers that a user may use to resolve a name

# Other server side measurement techniques - IPv6 Packet Mangling

- IPv6 packet manipulation to insert crafted IPv6 packets into an established TCP stream
  - To manipulate an IPv6 packet to manually control fragmentation and other forms of Extension Headers we use a “front end” unit to pick up incoming packets and pass them to a conventional back end server
  - The return packet is modified to add the appropriate Extension Header and/or Fragment before passing back to the end client

# Measurement Projects

- IPv6 Performance (connection reliability and relative speed)
- IPv6 Fragmentation
- IPv6 Extension Header loss Rates (HBH and DST)
- DNS: Use of ECDSA and EDDI DNSSEC signing algorithms
- DNS: Fragmentation Drop (and TCP support)
- DNS resolver use profile (use of open DNS resolvers)
- DNS KSK roll probes (RFC8509)
- Support for QUIC use (HTTP/3)
- Support for Route Origination Validation
- Zombies and tracking



# Server Side Measurement

- This approach complements client side measurements (CAIDA's ARK, RIPE NCC's Atlas) and network-level internal measurements by using a large scale server side measurement platform
- In this form of server-side measurement the client does what clients always do - fetch URLs
- We can test particular client behaviours and network behaviours by deliberately altering the server-side behaviour and triggering the behaviour in a measured behaviour
- The benefit of this approach is that rather than measuring the effect and inferring the cause, in this approach we trigger a cause and then correlate the observed outcomes against the known cause.

Thanks!

**Measurement Reports at APNIC Labs:  
<https://stats.labs.apnic.net>**