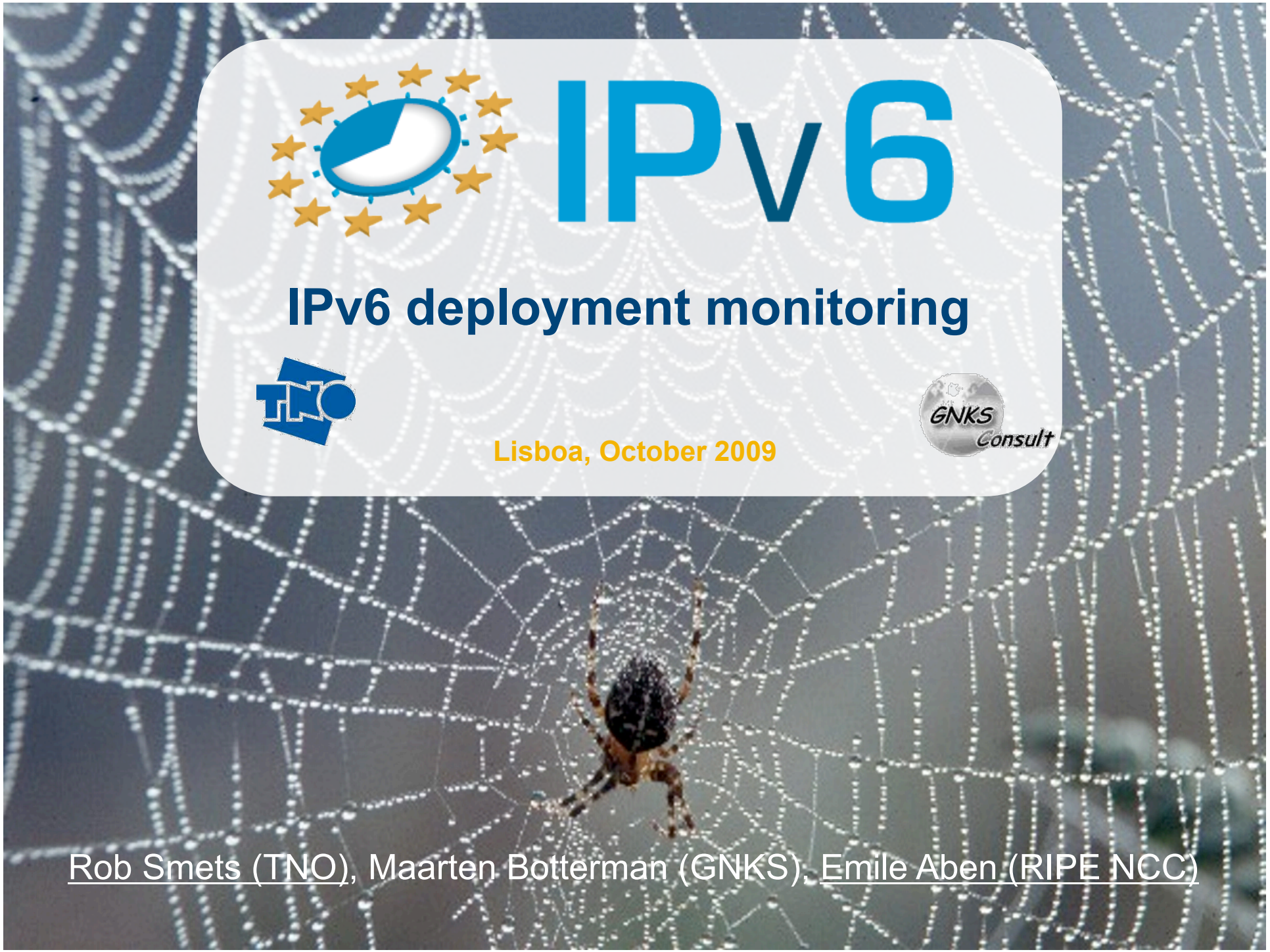

IPv6

IPv6 deployment monitoring

Lisboa, October 2009

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Content

- IPv6 deployment metrics
- Breakdown into sub-measurements
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  - Presentation of statistics
  - Accuracy
- Considerations on privacy, commercial-in-confidence, and retention
- Participate on www.ipv6monitoring.eu !

IPv6 deployment metrics

- **Existing metrics to estimate IPv6 deployment:**
  - Listing of assigned IPv6 address space.
  - Listing of advertised IPv6 address space.
  - Traffic volume measurements.
  - Measurement of IPv6 versus IPv4 web hits
  - DNS based measurements.
  - …
  - …
  - User oriented metric:

The percentage unique users that is able to connect to the IPv6 Internet and access their most important content and service providers without noticing a major difference compared to IPv4.

C

Breakdown into sub-measurements

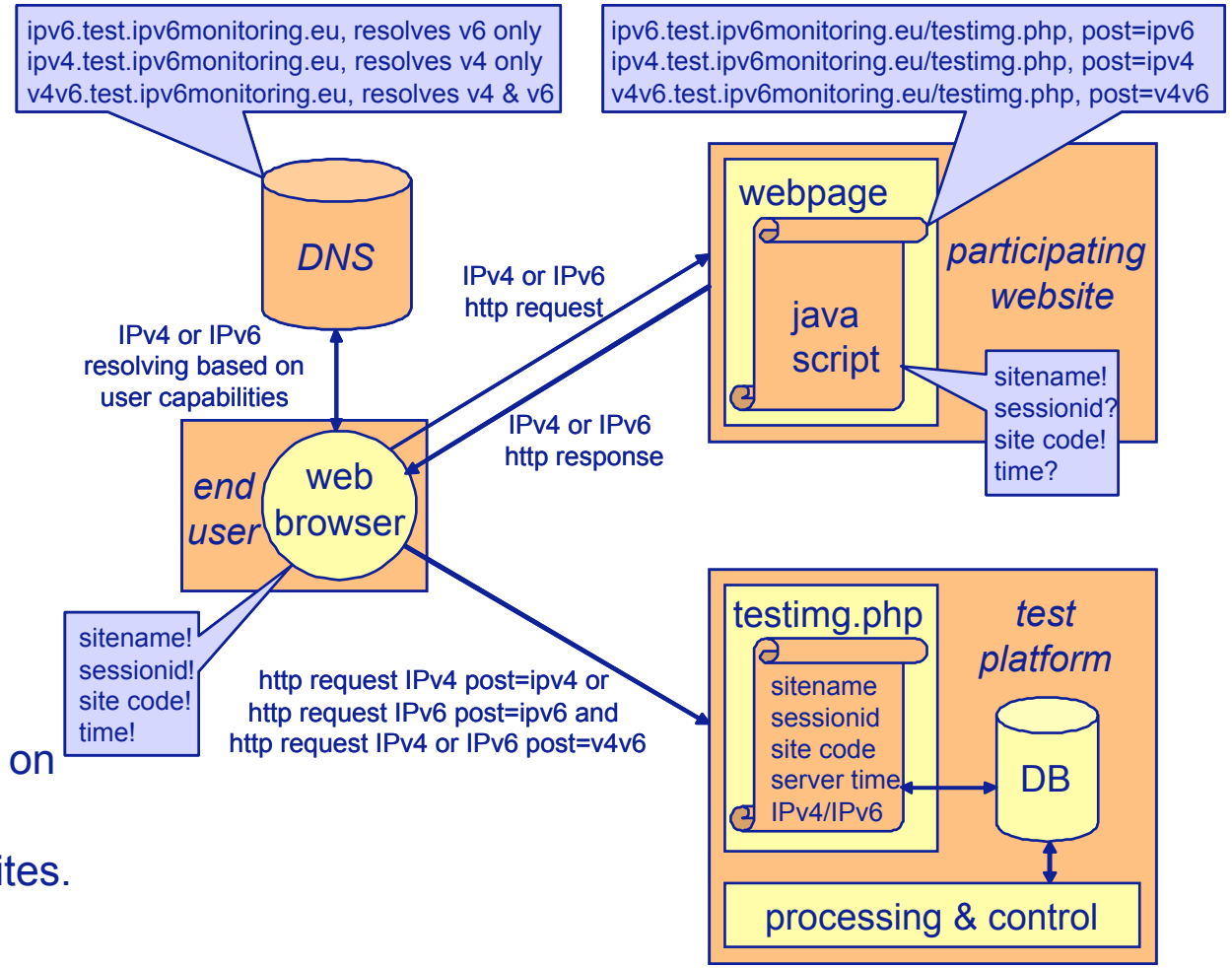
- ***unique users:***
  - The fraction of unique IPv6 users over unique IPv4 users → *U*
- ***most important content and service providers:***
  - The fraction of websites that can be accessed through IPv6 over those that can only be accessed through IPv4 → *C*
- ***major difference***
  - The user's experience of websites over IPv6 should be comparable to experiencing websites over IPv4 → *R*

$$M = U \bullet C \bullet R$$

- per EU state and EU aggregated
- for individual websites
- as a function of time

Methodology to measure IPv6 to IPv4 unique-user fraction, *U*

- Website visitors access a measurement platform in three different ways:
  - IPv4 only
  - IPv6 only
  - Browser / OS preferred (IPv4 or IPv6)
- In analogy to
  - ipv6test.max.nl
  - Google (RIPE 57)
- **but focused on:**
  - user capabilities, not on performance
  - use of multiple websites.



Collecting IPv4 and IPv6 requests

- Each requests contains the following data:
  - type of request (ipv4, ipv6, or browser / OS preferred (v4v6))
  - IP address
  - sessionID
  - site code (unique for the website and registered webmaster, generated by measurement platform)
  - referrer URL
  - site name
  - generation time stamp
  - reception time stamp
  - browser type

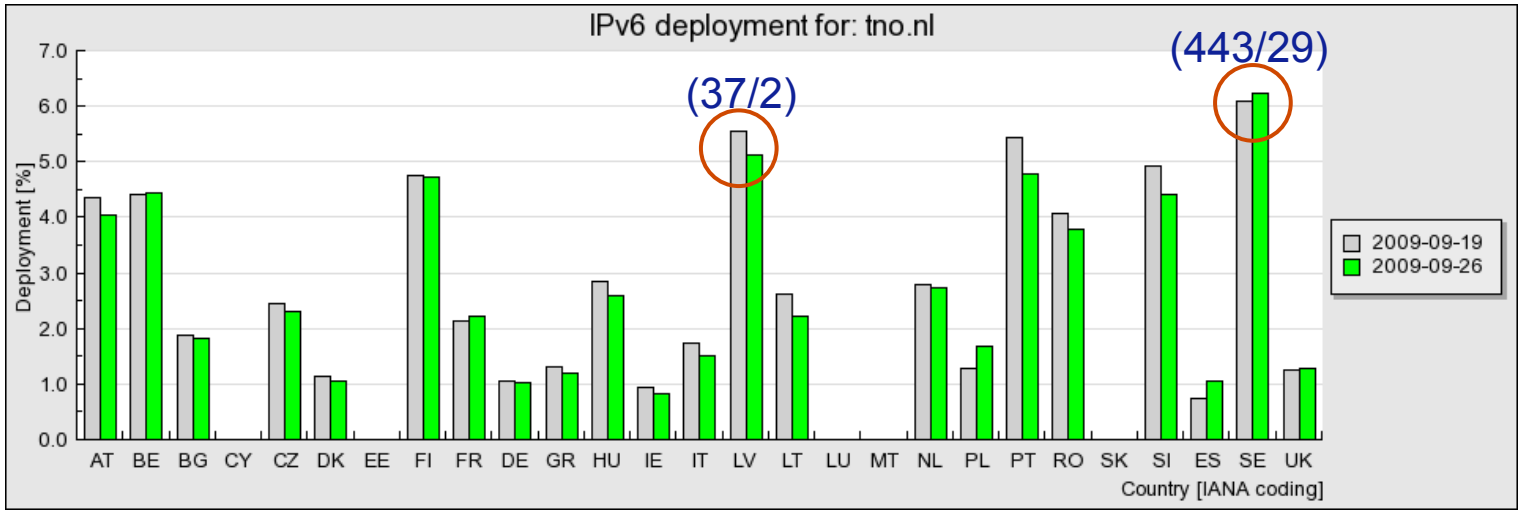
- Before request is placed in the database a sanity check on site name and referrer URL takes place.

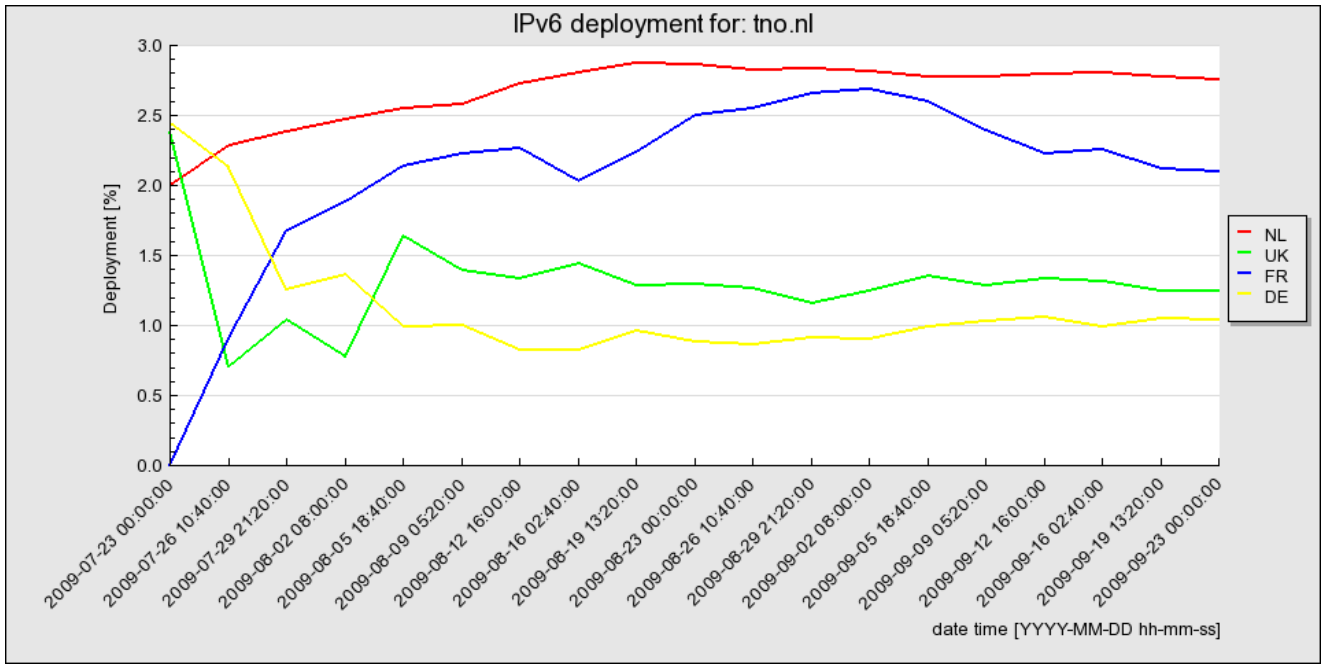
Processing v4 and v6 requests

- Retrieve from measurement DB next set of requests with same sessionID and timestamp
- Check site code with site code of registered websites
- Check site name with referrer URL for consistent domains
- Process for IPv4 requests
  - check if IPv4 request was received, if not go to Process for IPv6 requests
  - if IPv4 address is unique, get country code from geo-location database
  - if IPv4 address is not unique, get country code from own database
  - update v4 table by inserting new entry or updating existing one
    - *IP address*
    - *site name*
    - *country code*
    - *time first seen*
    - *time last seen*
    - *count*
    - *site code*
- Process for IPv6 requests
  - check if IPv6 request was received, if not go for next set of requests with same session ID
  - check if IPv6 address (/64) is unique
  - update v6 table by inserting new entry or update existing one

Presentation of statistics (C=R=1)

Real data for www.tno.nl !

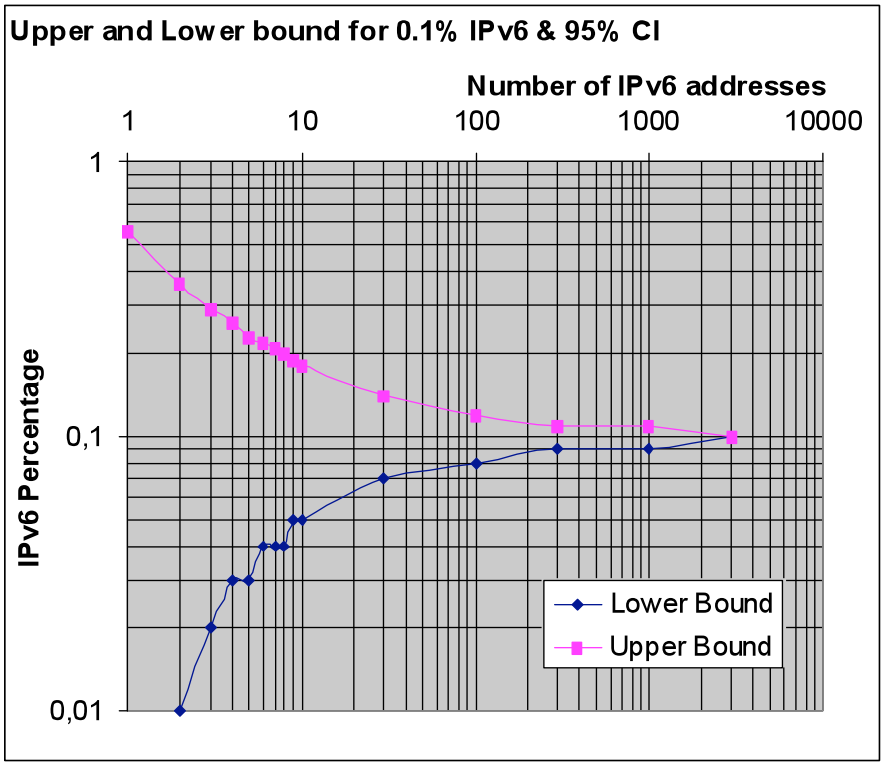




- IPv6/(IPv4+IPv6)*100%
- start date: **23-07-2009**
- only for www.tno.nl
- # for 4 countries (v4/v6) at **26-09-2009**:
  - NL: (71100/2018)
  - UK: (1900/24)
  - FR: (1844/43)
  - DE: (2764/30)
- Also global and EU aggregates possible

Accuracy

- Errors are introduced by:
  - Proxies
  - NAT (at least for v4)
  - Users with /48
  - DHCP
  - Tunnel configuration policies
  - Browsers without javascript
  - Too little diversity in websites
  - Too few unique addresses
  - …



(Clopper-Pearson, binomial tail evaluation)

Privacy, commercial-in-confidence, and retention

- Data retention

Unlimited data base
- scientifically desired
- error detection and correction
- geo-location for IPv6

Time-limited data base
- no correction possible
- data limited time in DB
- limited error detection
- which results to store?

- Privacy
  - Similar issues as with global Internet advertising solutions,
  - Not able to link IP addresses to persons.

- Commercial-in-confidence
  - Webmasters have only access to data related to their own website.
  - No data will be disclosed to third parties at any time that would allow identification of persons or websites.

- Additional measures:
  - Anonymising IPv4 addresses (IPv6 addresses are truncated to /64)

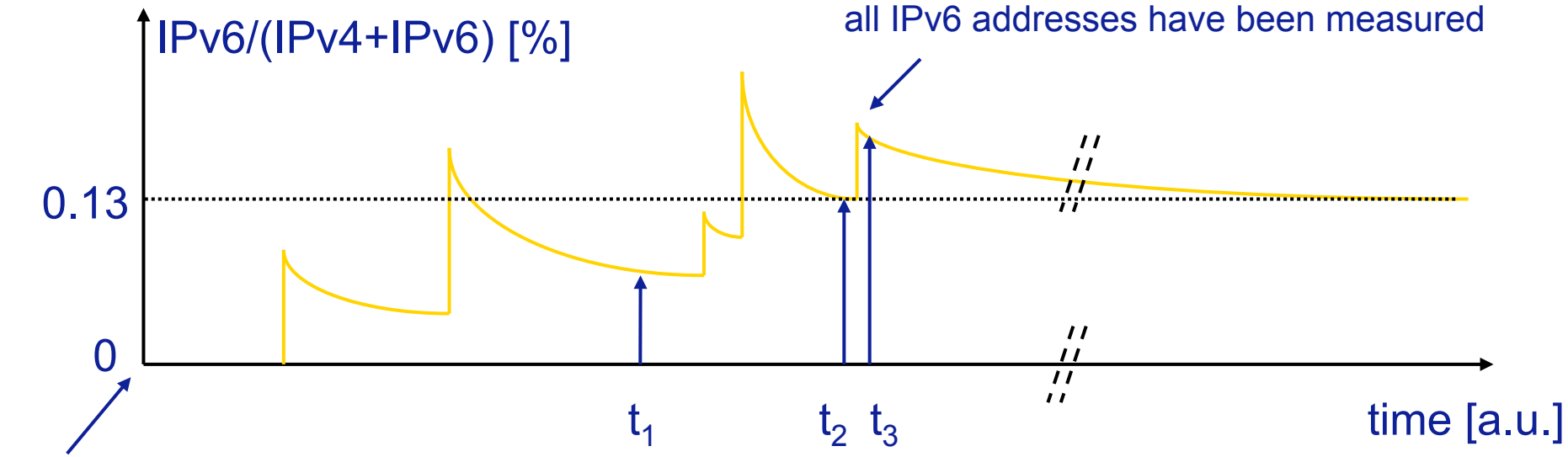
Participate on www.ipv6monitoring.eu !

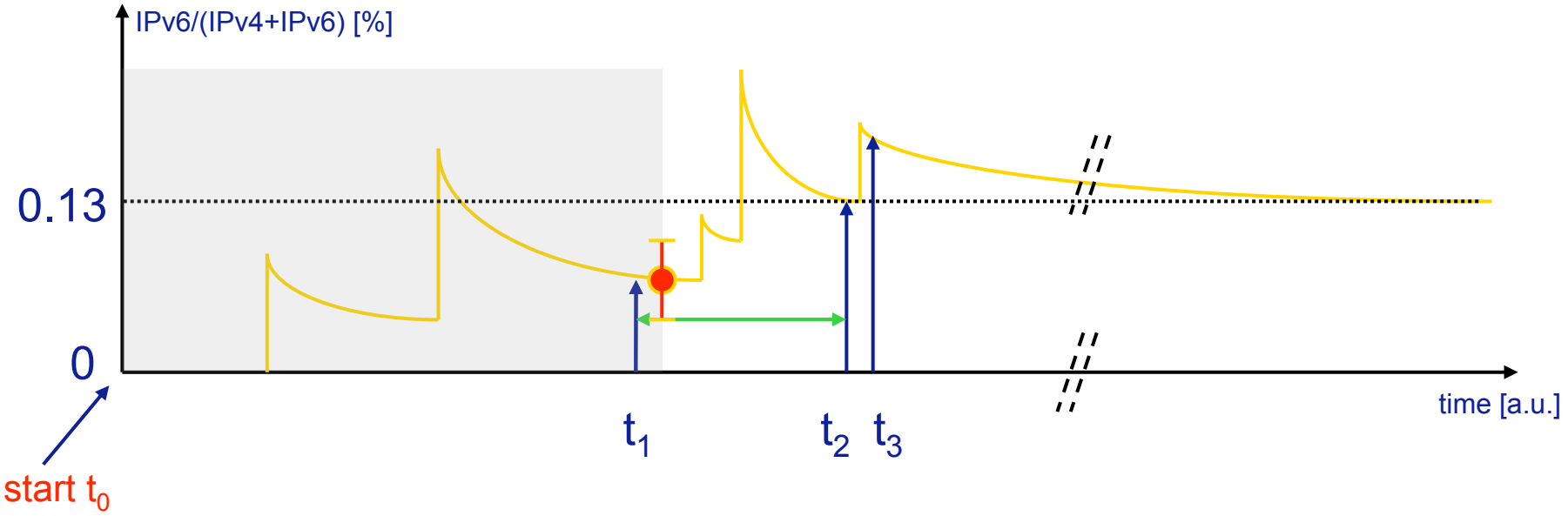
Backup

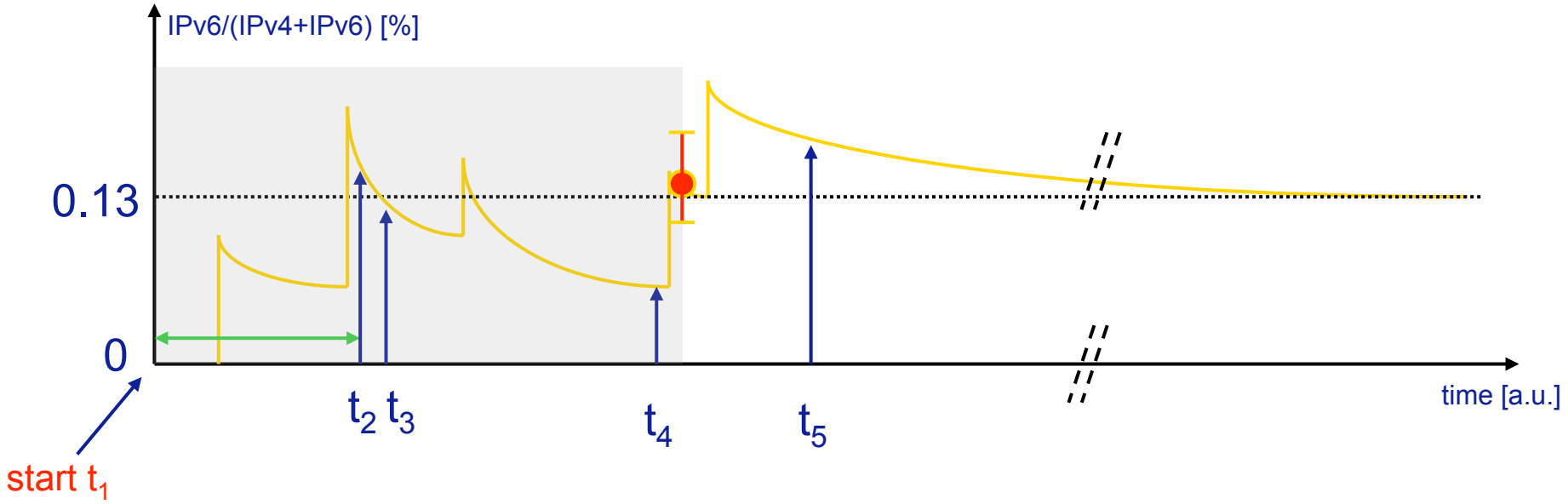
Time dependency of IPv6/IPv4 ratio

- Measurement parameters
  - Sample size
  - Measurement time window
  - Measurement repetition rate
  - Number of participating websites

assumption:
- no new IPv6 addresses




IPv6/(IPv4+IPv6) [%]
0.13
0
time [a.u.]
t1
t2 t3
start t0


IPv6/(IPv4+IPv6) [%]
0.13
0
time [a.u.]
t2 t3
t4
t5
start t1

Activation and access of website statistics

IPv6 deployment monitoring in Europe

Introduction

In the near future IPv4 address space will be fully allocated and new Internet users may not be able to access the Internet using IPv4 in the same way as is customary today, but they will have to rely on a set of different techniques to achieve connectivity. Amongst existing technologies to achieve this are, IPv6 to IPv4 translation, translation on application layer by using an application layer gateway, carrier grade NAT, and the deployment of IPv6. Migration to IPv6 is considered, effective, durable and sustainable and it is technologically feasible to implement IPv6 on a large scale. In contrast to the present focus on the remaining IPv4 address space is the absence of IPv6 take up monitoring. This whitepaper touches on an effort by TNO and GNKS Consulting with help and feedback from RIPE NCC to measure and monitor IPv6 deployment in relation to the current use of IPv4. We will focus on websites as they are of importance to almost all Internet users. Moreover, when websites can be accessed either over IPv4 or IPv6 there is from a connectivity point of view no reason why peer-to-peer or other web-based applications (assuming they support IPv6) would not work on IPv6.

Metrics for determining IPv6 deployment

Today several metrics exist that aim to provide an indication of IPv6 deployment. Among these are:

- Listing of assigned IPv6 address space. By counting the address blocks that have been assigned by IANA and the RIRs an impression exists on the take up rate of IPv6. However it does not imply actual usage of these addresses.
- Listing of advertised IPv6 address space. When IPv6 addresses appear in BGP router advertisements one often concludes that these addresses are in use, while in reality an arbitrary fraction of these addresses are scheduled to become in use.
- Traffic volume measurements. Measuring traffic volumes does not allow an accurate conclusion on IPv6 deployment. Changes in peering agreements make centralized measurements at e.g. Internet Exchanges not representative.
- Measurement of IPv6 versus IPv4 hits on dual stack websites. This only works for websites that are on IPv6 and on IPv4. It provides more information on website deployment, rather than end-user IPv6 deployment. In addition robots aiming at increasing website hits for improved advertisement volume tend to trouble these measurements.
- DNS based measurements. Several options exist but they all face the problem of unknown multiplication factors in the name resolving tree, unless lifetime is kept short.

In an attempt to provide a more realistic metric that is not anted on already available high-level data, the following definition of IPv6 deployment is introduced [1]:

> *The percentage unique users that is able to connect to the IPv6 Internet and access their most important content and service providers without noticing a major difference compared to IPv4.*

This definition contains three components that are addressed individually:

- *unique users:* the fraction of unique IPv6 users versus unique IPv4 and IPv6 users, expressed by U .
- *most important content and service providers* : the fraction of websites that can be accessed through IPv6, versus websites that can only be accessed through IPv4, expressed by C .
- *major difference:* the user experience of accessing websites over IPv6 should be comparable to accessing websites over IPv4, expressed by R ,as the fraction of

websites where user experience over IPv6 does not differ from user experience over IPv4.

The metric of interest, M, aimed at describing the IPv6 deployment more realistically and from a user perspective becomes $M = U \cdot C \cdot R$.

Methodologies for determining U, C, R

Measurement of U

In order to measure the fraction U of the number of unique IPv6 capable users and the number of unique IPv4 and IPv6 users is determined using the setup below, which is similar to the diagnostic tool as implemented by [2] and [3], but focuses solely on determining the IP capabilities of end-users.
Compared to measurements performed by Google in [4], this methodology relies on a variety of participating websites which allows IPv6 deployment results to be further broken down to e.g. community level like, academic, industry, consumer, etc... In addition measurements will allow IPv6 deployment analysis per European state instead of providing a global view.

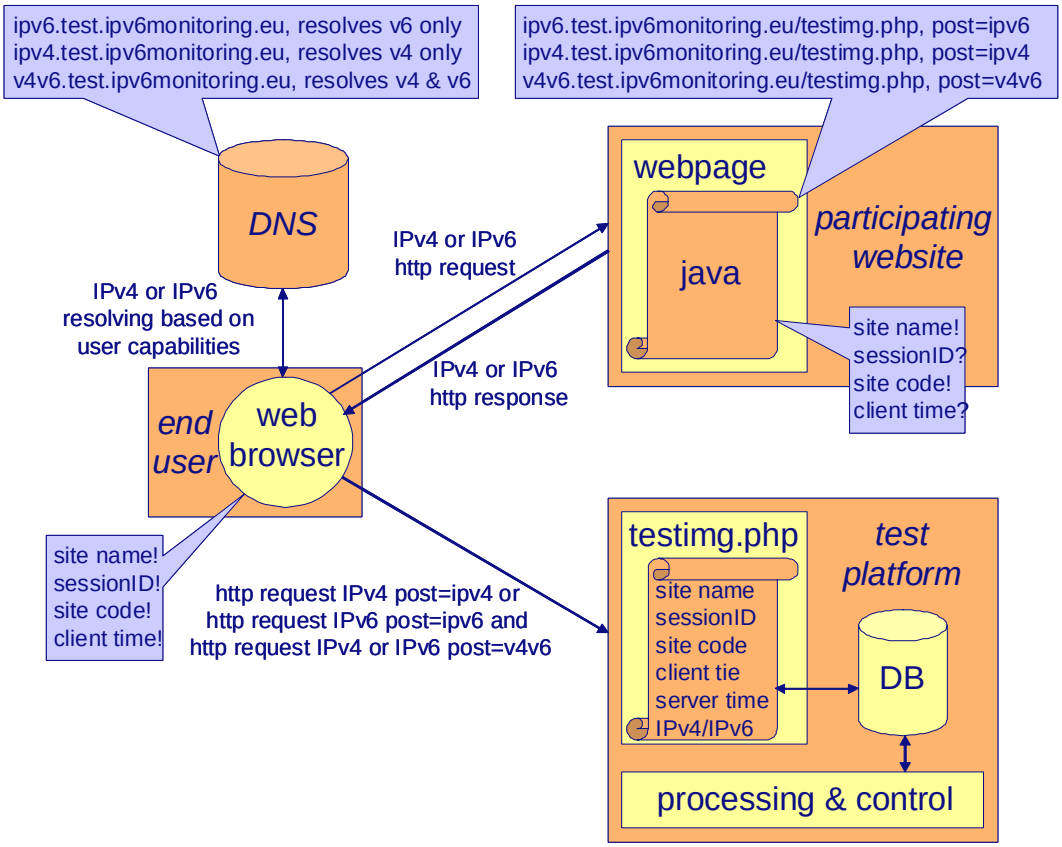


Figure 1: Measurement scheme for determining fraction *U*

Participating websites are asked to place a small java script on one of their frequently visited public web pages. When a user visits the web page a small java script is executed which tries to access the test platform in three different ways: (1) only via IPv4, (2) only via IPv6 and (3) using it's preferred way, IPv4 or IPv6. It can do so as DNS resolving is selective on the domain name to be resolved.
When a request is made to the test platform, a script is executed that logs relevant information of the incoming requests. The *site name*, is configured in the java script by the webmaster of the participating website, and a *site code* which is generated when the webmaster subscribed his website. The site code is used later by processing and control to

be able to link the rightful webmaster to the measurement results and exclude registrants who may have erroneously or falsely submitted the domain. The site name also needs to match the referrer URL obtained from the incoming request for the same obvious reason. During execution the end-user adds a *session id* and the *local time* the script was executed. This information is important to correlate the incoming requests. At the end the script stores the IP address, the type of request (IPv4 only, IPv6 only, preferred), the time the request was received, the session id, the time the script was executed, the site name, the referrer URL, and the code.

Processing of the data occurs on a regular interval. The following actions take place: 1. Individual requests (ipv4, ipv6, and v4v6) will be grouped by correlating the session id and local time. 2. Checks are made to determine if the IPv4 address has not been measured before. If this is the case the country code will be looked up in a database or web service and a new entry is made in the database recording the IP address, time the IP address was first seen (this is the time the request that was processed was logged), the country code. If an ipv6 request was received with the same session id and time the country code of the accompanying IPv4 address is looked up in the database. A new entry is made in the database for the highest 64 bits of the IPv6 address (the lowest 64 bits are discarded), associated country code, time the IP address was first seen.
In addition also the last time an IP address was observed is recorded as well as the number of times the address has been observed. The reason for this is that this information will help detecting e.g. proxies. Proxies limit the number of unique IPv4 addresses that the measurement system observes and introduces errors. The count and time difference between time of first observation and time of last observation may at a later time be used to introduce a correcting factor, or estimate the inaccuracy caused by e.g. proxies.
3. based on the code that was received the rightful registrant can be granted access to the IPv6 deployment measurement results of only his website.

Measurement of C

Content and service providers is interpreted as the fraction of Internet websites accessible via IPv6 compared to IPv4. Most important websites are websites considered popular by the majority of Internet users. In this definition most important is also linked to frequently used. Not-frequently used websites that are important are not taken into account. For example the governmental website for submitting ones yearly tax declaration is at some point in time an important website, perhaps even the most important website for some individuals. Yet these websites generally do not appear in charts published by for example Alexa [5].

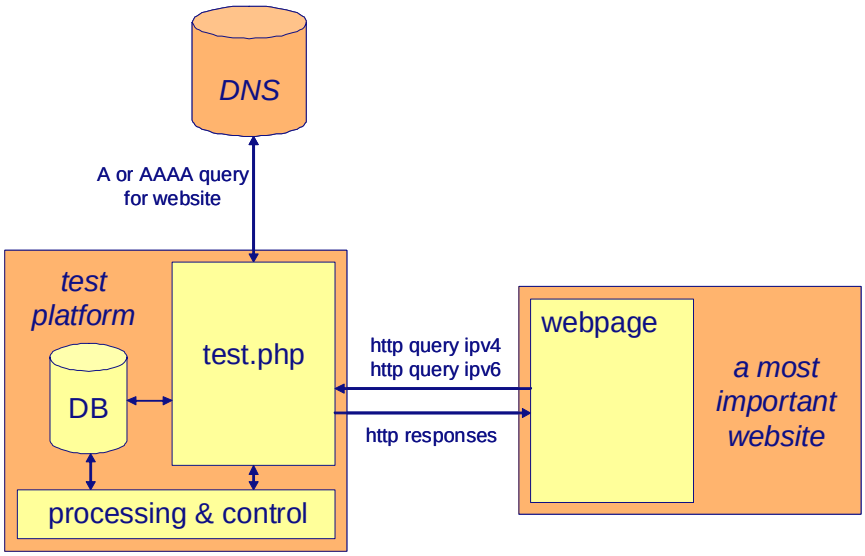


Figure 2: Measurement scheme for determining fraction *C*

A script is run that reads websites from a database and tries to resolve to IPv4 and IPv6 after which the script performs http requests over IPv4 and IPv6 and verifies the responses of the website. Based on the results of the DNS queries and http responses a conclusion is drawn on the IPv6 and IPv4 availability of the website and the result is stored in the database.

Measurement of R

This methodology describes how differences in website performance are determined. End-users make use of a wide variety of terminals (e.g. PCs), broadband access technologies, and Internet service providers in their website downloading activities.
ITU-T defines in G.1030 [7] (based on the work also described in [8]) a framework of tools to estimate the performance of websites from a user perspective and determines end-user experience satisfaction by establishing a mean opinion score (MOS). In this way it is possible to assess the performance of websites via IPv6 and IPv4.

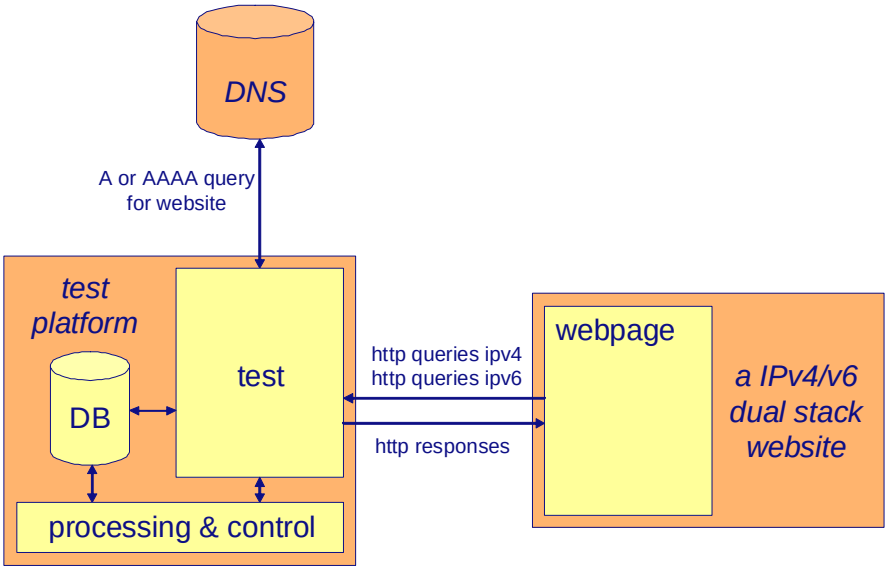


Figure 3: Measurement scheme for determining fraction *R*

A PERL script controls an Internet Browser to place requests at a selected set of websites obtained from [5], [6]. Response times and session times needed to download all data on a page are recorded and stored in a database. A processing script will use this data to compute the MOS (Mean Opinion Scores) as standardized in G.1030. When MOS values obtained over IPv6 are lower than MOS values obtained over IPv4 the particular website is considered to cause a major difference in user experience over IPv6 compared to IPv4.

Get Insight and participate in the measurement of IPv6 deployment

How does it work?

The IPv6 deployment monitoring team invites webmasters to participate through http://www.ipv6monitoring.eu/. The measurement platform can also be used by webmasters to gain insight on the IPv6 capabilities of their visitors. This may help them assess migration to IPv6 and choose a time line and strategy that is appropriate for this migration.

Figure 4: Participation in the measurements is possible via the website of the project.

After registration and logon it is possible to participate by entering the name of your website. You will receive a code that together with the name of your website must be pasted in a downloadable java script.
The java script should preferably be placed on a web page on your site that is frequently visited. Once the script is in place data collection begins.
In a few days data will become available. Once data is available a link, for obtaining measurements results will become active. When selecting the name of the website you entered during registration, measurement graphs will appear on IPv6 deployment pertaining to your website as you can see in the example below. The measurement graphs are constructed from the information in the database. As the data base contains only unique address, queries only need to count the number of entries that meet a set of country codes and a time of first observation.

What are the benefits for participating websites?
Figure 5 and Figure 6 are two examples of the type of information that will be made available to participating webmasters. Real measured data obtained by applying the methodology to the www.tno.nl website is presented in the graphs below.
It can be seen from Figure 5 that almost from all countries www.tno.nl has been visited. Almost 3% of the Dutch (NL) users visiting www.tno.nl are capable of accessing the Internet over IPv6. If, as indicated by 2009-09-26 data, IPv4 addresses are no longer available, then from every 100 new Internet users who would be on IPv6-only, 97 would not be able to visit www.tno.nl.

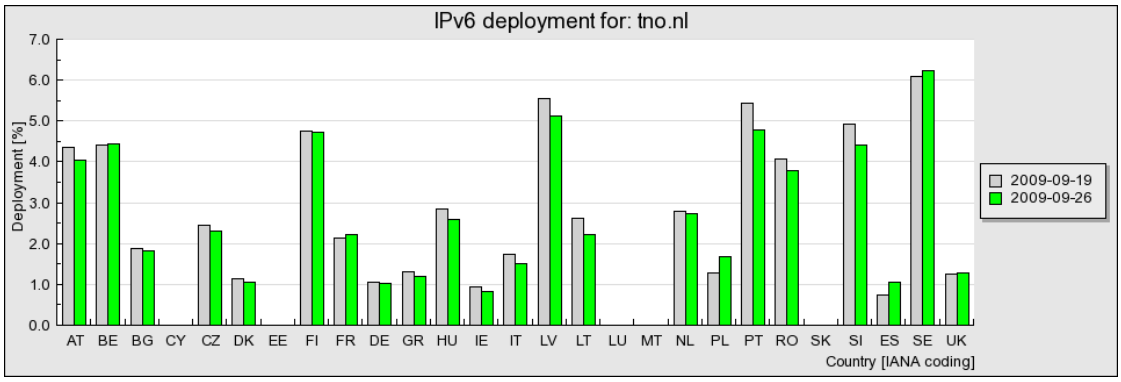


Figure 5: Percentage of users visiting www.tno.nl that are capable of accessing the Internet via IPv6, geo-located per EU country

Figure 6 shows how the deployment of IPv6 changes over a two months period. The red curve (Netherlands) is a curve compiled from more than a 100 times the number of visitors compared to the other three graphs.

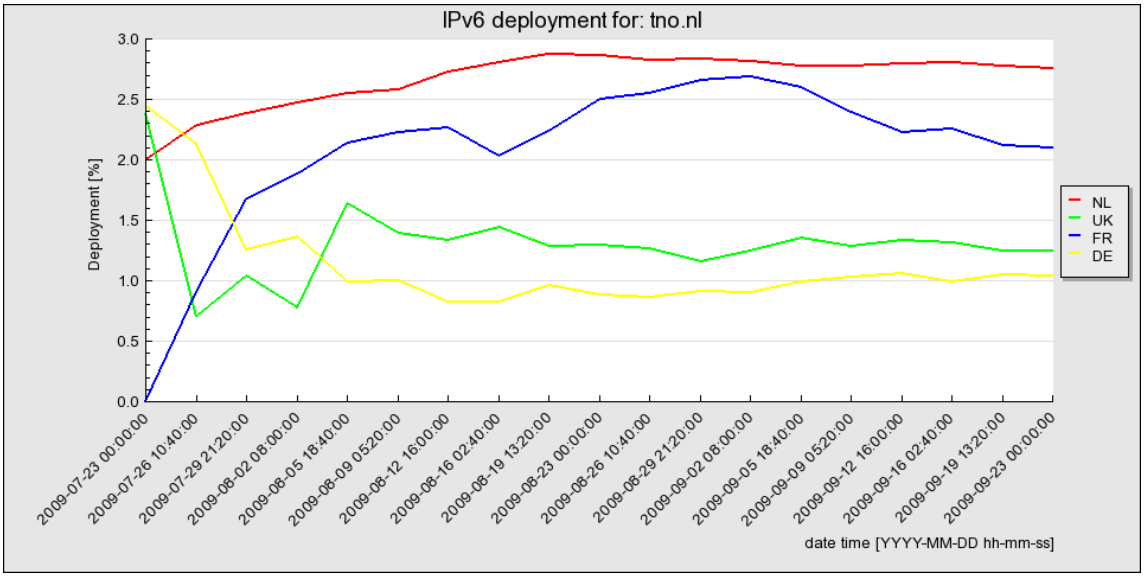


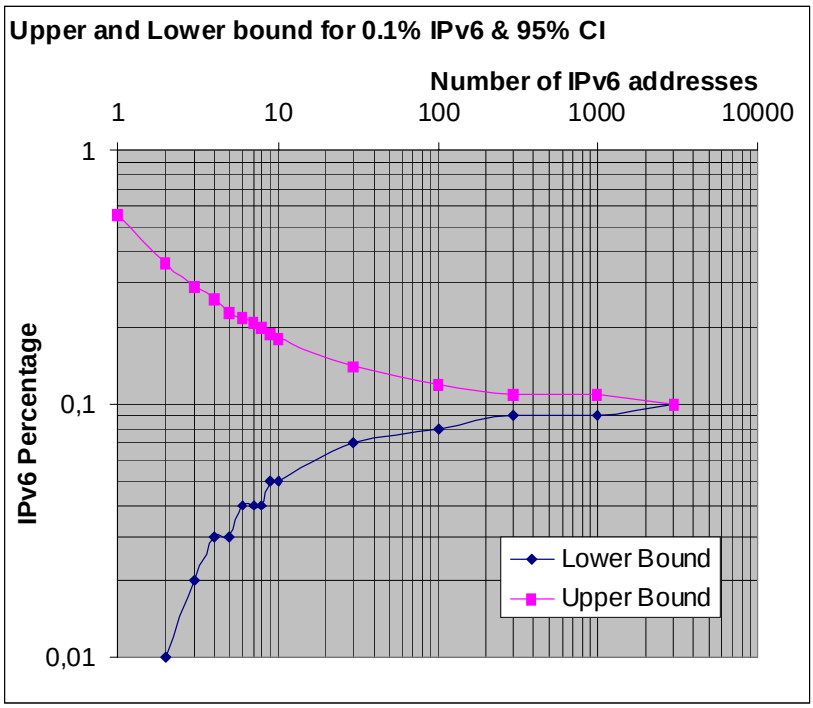
Figure 6: Percentage of users visiting www.tno.nl that are capable of accessing the Internet via IPv6, geo-located for NL, UK, FR, DE as a function of time.

It takes approximately three weeks to obtain a stationary state for the Dutch visitors. When the curve is in such a s state the ration of unique IPv6 and IPv4 users that are added is approximately the same when measured over a period of three weeks. In order to reduce the size of the database it is possible to apply a sliding filter and delete old measurements as new measurements are added and record the obtained metric U for each website and country. The size of this filter depends on the required sample size and therefore on the measured percentage and required confidence level. For practical and privacy reasons a time limit can be set on the lifetime of an IP address in the database.
In this example the sample size of the UK, FR, and DE curves is still low, and therefore these IPv6 deployment figures are not accurate yet and far from stationary.

Accuracy of the measurements

Accuracy of this measurement platform is impacted by several factors amongst which are (not exhaustive):

- Users behind NAT devices cause the methodology to count too few users. This occurs for IPv4, but does not always occur for IPv6. The methodology discards the lower 64 bit of the IPv6 address. This means that if residential routers are assigned a /64 address and terminals use auto configuration to set their IPv6 address then similar to IPv4, too few users are measured. If the gateway assigns a /64 address to each different terminal the exact number of IPv6 users is measured.
- Users behind proxies are not measured. Both for IPv4 and IPv6 too few users are measured.
- Users with e.g. a /48 on the Internet. For each terminal they operate on a /64 will be measured. This is similar to a corporate environment where /64 addresses are assigned to terminals in a /48 subnet. For a company this does not lead to inaccuracies, for individual subscribers, or single users, too many addresses are counted.
- A large number of users must be recorded in order to achieve desired accuracy and representativeness. Below is an example where the lower and upper bound is given for a data set where IPv6 deployment is 0.1% and a confidence interval of 95% is required. For a sample size of 10.000 (10 IPv6 addresses were measured) the error approximates to 100% which may even be acceptable as a deployment level of both 0.1% or 0.2% should be interpreted as virtually no IPv6 deployment.



- Representativeness of the selected websites is of importance. Differences exist between the early-adopting academic community where IPv6 is more common and the residential segment where IPv6 will be rolled out more as a need rather than for technological advancement.
- Tunnels: IPv4 users that are not able to connect to the Internet via native IPv6, may do so by creating a tunnel to IPv6 brokers. It depends on the broker's policy how they assign IP addresses to the tunnel end-points. When a small set of IPv6 addresses is reused, obviously the system counts too few unique IPv6 users. At best the broker uses a unique /64 IPv6 address for each new user. In this case the right number of users is counted. In this context is must be stated that in terms of desired end-situation native IP is the preferred option, so counting too few IPv6 tunnel users is

not dramatic. Tunneling is not a sustainable option if public IPv4 addresses must be used.

- Users who have turned off java scripting in their browsers are not measured. This will have negligible impact as both IPv4 count and IPv6 count are affected equally.

Information on the first time and last time an IP address is observed as well as the number of times an IP address is observed may be used to correct or estimate inaccuracies. This is not yet implemented and will become a topic for further study when more data is available and indications exist that justify further analysis.

Privacy, commercial-in-confidence, and data retention considerations

The methodology for determining U records IP addresses of end-users during a particular interval. Measurements are run until the ratio of IPv6 and IPv4 users does no longer change significantly in time, and conditions relating to sample size, accuracy and representativeness e.g. confidence intervals are met. After this time two options exist:

- either implement a sliding time-window that deletes recorded IP addresses that have aged beyond the size of the time-window (The optimum window size depends on the measured percentage and on the confidence interval required.), or
- maintain the database as is and let it grow.

From a scientific point of view one would like to have a large database as this allows the investigation of anomalies and could be used to reflect on IPv6 deployment at a later stage. From a data retention point of view limitation of the duration that addresses are stored in a database should be chosen as small as possible while saving IPv6 deployment figures per website, country and per époque.
Participating webmasters will only receive results relating to sites registered by them and based on requests received from users visiting only those websites maintained by the webmaster. Personal information pertaining to end-users and webmasters is stored only for the purpose of measuring IPv6 deployment and is treated as confidential information. This information will **not** be disclosed to third parties.

References

[1] The official "Action Plan" of the EU, http://www.ipv6.eu/admin/bildbank/uploads/Documents/Commision/COM_.pdf
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[6] http://sixy.ch/
[7] ITU-T, G.1030, http://www.itu.int/itudoc/itu-t/aap/sg12aap/history/g1030/g1030.html
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Information & contact

More information can be found on http://www.ipv6monitoring.eu. For additional information please contact:

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