NLNETLABS

ANNUAL REPORT 2020

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About NLnet Labs

NLnet Labs is a not-for-profit foundation, founded in 1999. Over the past 20 years our mission remains to develop open source software and open standards for the benefit of the Internet, and to perform applied research on Internet protocols. We focus our efforts particularly on the Domain Name System and inter-domain routing. NLnet Labs work supports the robustness, security and reliability of the Internet and safeguards the privacy of its users.

To accomplish our mission, we collaborate with key players in the Internet around the world. Organisations we work with include the Internet Engineering Task Force (IETF), the Regional Internet Registries (RIRs), the Internet Corporation for Assigned Names and Numbers (ICANN), leading Top Level Domain (TLD) operators, the International Standards Organisation (ISO), the Internet Society (ISOC), as well as a wide variety of others in the field, ranging from individual researchers to major industry actors.

NLnet Labs plays a leading role in promoting technologies that stimulate trust, security, privacy, scalability and the global nature of the Internet. Our peers see us as a major stakeholder in the creation and use of open standards and open software. We are leading experts on core Internet technologies, specifically the DNS and routing.

We are a lightweight organisation with a team of around fifteen people, consisting almost exclusively of developers and researchers, with minimal overhead. We attract talented people who want to make a difference in the well-being of the Internet, with a profound belief in open source and open standards.

We develop open source software that is used across the Internet industry, ranging from DNS root servers at the core of the Internet to small embedded devices running a secure recursive resolver, or routing security software that helps protect the network of large network operators.

Our researchers pioneer new technologies, help define future standards and build prototypes of technologies that promise to improve the Internet. We increase understanding of the Internet by studying its fundamental building blocks. By actively participating in both worlds, we bridge the gap between academia and industry, and introduce innovative solutions.

We also contribute to policy and governance organisations. Our technical expertise and advice is widely recognised by policy-making bodies. We advise on public policy decisions that affect the security and privacy of Internet users across the globe, as well as the stability of the Internet itself.

Software Development

At a glance

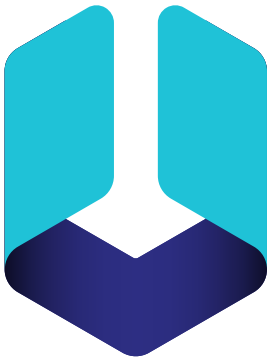
In 2020 we continued to develop and extend our existing DNS and RPKI software. For the DNS products, we've seen five releases for Unbound and NSD, and three for OpenDNSSEC. And for our routing security software, five releases of Routinator, which has become one of the premier RPKI relying party software in the industry, and five feature releases of Krill, our RPKI CA implementation.

Our DNS library LDNS has not seen an update in 2020. It is still widely used by DNS developers and gets our attention for maintenance and further development. There has been one release of the getdns library and Stubby stub resolver. The DNS library for Rust, called domain crate, started as a small project in 2018 and has seen community contributions ever since. In 2020, we made four releases of domain crate available to users.

The remainder of this section provides a more detailed overview of highlights for our various projects.

DNS(SEC) Software Projects

Unbound



In 2020 NLnet Labs again participated in a successful DNS Flag Day, a collaborative effort of the DNS implementers and operator community. As part of this, we released a version of Unbound (version 1.12.0) in October that sets the default EDNS buffer size such that it reduce packet fragmentation.

Key features introduced in 2020 include support for Response Policy Zones and "serve stale" as standardised in the IETF. Response Policy Zones (RPZ) is a functionality that makes it possible to express DNS response policies in a DNS zone. RPZ allows network administrators to monitor and manage DNS requests from their network to the global Internet. This allows one to specify and block malicious domains, for example websites known to distribute malware or servers used for command & control for botnets.

The other major feature is a new implementation to serve stale. Our initial implementation of serve stale behaviour in Unbound attempts to respond with expired cached items without waiting for the actual resolution to complete. This first implementation by NLnet Labs was introduced before serve stale was standardised in the IETF. In the new implementation that follows the standard, Unbound will try to resolve a domain name first before responding with expired cached data. Both options are available to users and make the DNS robust in the event of Internet outages or DDoS attacks on authoritative DNS servers.

Other important contributions in 2020 include support for DNS-over-HTTPS (DoH for short) and use of inclusive language in our documentation (same for NSD and other documentation).

NSD

For NSD, we added CPU performance affinity. CPU affinity takes advantage of the fact that remnants of a process running on a given processor may remain in that processor's state (for example, data in the cache memory) after another process was run on that processor. Pinning a server process to a specific CPU, as well as having a separate network card for that CPU, and an interface address for that server process, increases throughput and ultimately improves the performance of the name server.

For the DNS Flag Day 2020, we made similar changes to NSD as for Unbound. The change sets the default EDNS buffer size to 1232, that should reduce fragmentation.

We also introduced support for a new RR type ZONEMD and over the year there was a CVE as well as numerous minor bug fixes.

New ideas to further improve NSD's performance have been published in a blog post.

OpenDNSSEC

In 2019, we ended support for OpenDNSSEC 1.4 and announced that version 2.1 would be the de-facto supported version. Due to our outreach activities, there is a huge adoption of OpenDNSSEC 2. Several parties have already upgraded or were in the final phase of the upgrade in 2020. NLnet Labs has been contacted to oversee the upgrade and received feedback to further improve OpenDNSSEC.

In 2020 there were three releases of OpenDNSSEC 2.1 over the course of the year, most of which focused on fixing minor issues discovered by our community after migrating to 2.1 from earlier versions of OpenDNSSEC.

SoftHSM

The SoftHSM project, to which NLnet Labs has contributed in the past, was incorporated in 2019 as a project under the Commons Conservancy. The long-term goal of this step is to keep the project sustainable and to allow new partners to make significant contributions to the project.

With help from the community, SoftHSM has seen two releases where bugs have been fixed, Botan has been updated and some miscellaneous features have been added.

DNS(SEC) Libraries

LDNS

Our general purpose C-language DNS library, LDNS, has not seen a new release in 2020. For 2021 we are preparing a release that will contain a long list of bug fixes, some of which have been contributed by our community. We will continue to maintain LDNS with no plans for major changes in the near future.

getdns and Stubby

The getdns project brings a modern DNS API to applications with a number of language bindings, and Stubby, which is based on getdns, provides a local privacy-aware DNS resolver on UNIX-like systems. A binary port of Stubby for Windows is also distributed by the project.

In 2020, getdns/Stubby had one release that, in addition to better TLS support, introduced the CMake build system. With CMake replacing the autotools build system, Windows becomes a first class build platform for getdns, increasing the ease of use of the getdns library in Windows applications. getdns and Stubby can now be built using a native Windows build toolchain, ideally via the Visual Studio project. This work will also facilitate the development of a User Interface for Stubby on Windows.

Net::DNS(::SEC)

NLnet Labs is a long time contributor and maintainer of the Net::DNS::(SEC) library that supports DNS functionality in the Perl scripting language. During 2020, six versions of Net::DNS::(SEC) were released, fixing several bugs and introducing the first implementations of new IETF RFCs and Internet-Drafts such as DNS cookies and SVCB/HTTPS resource records.

Domain Crate

Since 2018, NLnet Labs also has an experimental DNS(SEC) library for the Rust programming language: the domain crate. In 2020, the release of version 0.5.0 contained a major restructuring and refactoring of the entire library. The previous set of crates has been reassembled into one crate, with various modules being optional and available through functions. Minor additions and bug fixes have been included in later versions, including contributions by external parties.

Routing Software

In the summer of 2018 we announced our plans to develop a comprehensive toolset for Resource Public Key Infrastructure (RPKI), a technology aimed at making the Border Gateway Protocol (BGP) more secure.

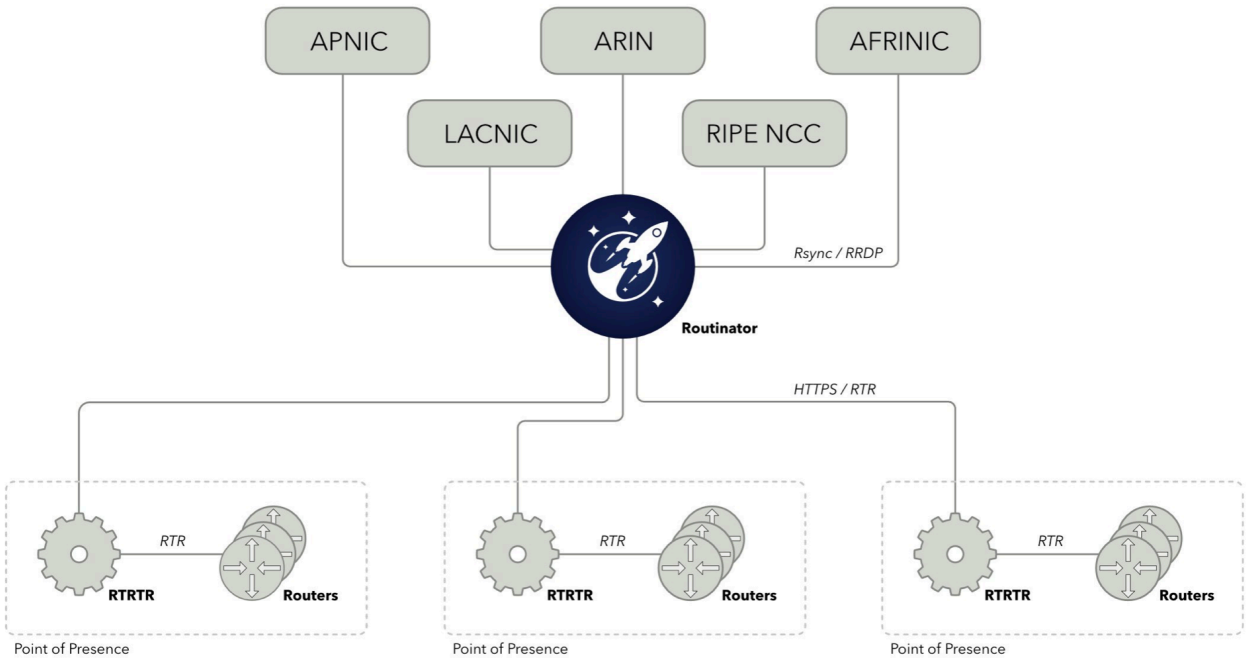
In 2019, the development of our routing software portfolio made good progress and in 2020 we continued to make great strides to improve our products with five releases for both RPKI Relying Party software Routinator and for RPKI Certificate Authority software Krill.

Routinator

Routinator is Relying Party software, also known as an RPKI Validator. Operators can use it to download and validate the global RPKI data set and feed the result into their routers, or use it elsewhere in the BGP decision making process.

Routinator connects to the Trust Anchors of the five Regional Internet Registries (RIRs) – APNIC, AFRINIC, ARIN, LACNIC and RIPE NCC – downloads all of the cryptographic material in their repositories and validates the signatures. It can feed the validated information to hardware routers supporting Route Origin Validation such as Juniper, Cisco and Nokia, as well as serving software solutions like BIRD and OpenBGPD. Alternatively, Routinator can output the validated data in a number of useful formats, such as CSV, JSON and RPSL.

In 2019, Routinator got off to a flying start with quite a number of releases and widespread adoption of the software by a large number of network operators and other organisations that run networks. Routinator is feature complete, but continued improvements have been made in 2020 to ease the integration of Routinator into operation with routers and routing software such



as BIRD or OpenBGPD. The development of IETF Internet-Drafts and RFCS is also closely followed and implementations of the new standards find their way into the software.

In 2020, we developed a missing piece of the puzzle of RPKI deployment with network routers. RTRTR is an RPKI data proxy, designed to collect Validated ROA Payloads from one or more sources in multiple formats and dispatch it onwards. It provides the means to implement multiple distribution architectures for RPKI such as centralised RPKI validators that dispatch data to local caching RTR servers.

For larger networks, RTRTR is an ideal companion to Routinator. For example, it is possible to centralise validation performed by Routinator and have RTRTR running in various locations around the world to which routers can connect.

Krill

With Krill, operators can generate and publish RPKI cryptographic material to authorise their BGP announcements. Up until recently, operators were largely dependent on the hosted RPKI systems that each of the five Regional Internet Registries (RIRs) provide. Krill lets organisations run RPKI on their own systems as a child of one or more RIRs. It can also run under a different parent, such as a National Internet Registry (NIR), and, in turn, act as a parent for other organisations.

Krill is intended for:

- Organisations which do not want to rely on the web interface of the hosted systems that the RIRs offer, but require RPKI management that is integrated with their own systems
- Organisations that need to be able to delegate RPKI to their customers or different business units, so that that they can run their own CA and manage ROAs themselves
- Organisations that manage address space from multiple RIRs. Using Krill, they can manage all ROAs for all resources seamlessly within one system
- Organisations who want to be operationally independent from their parent RIR, such as NIRs or Enterprises

The five Krill releases in 2020 introduced many features to improve usability and provide users with feedback on the impact of creating and publishing ROAs. A user interface called Lagosta was introduced and shortly afterwards we offered multilingual support for the user interface. Efforts have also been made to facilitate migration from one Krill version to another. In later versions released that year, we added further refinements to the ROA management interface to give users confidence that their authorisations accurately reflect their BGP announcements. This means that Krill would give stronger suggestions and even outright refused to make certain corner cases.

In addition to this we made an implementation for “Resource Tagged Attestations” in collaboration with APNIC. We worked on a proposal in the IETF sidrops WG. This work is a bit stalled, but not lost, at the moment following the WG's insistence on adopting a simplified

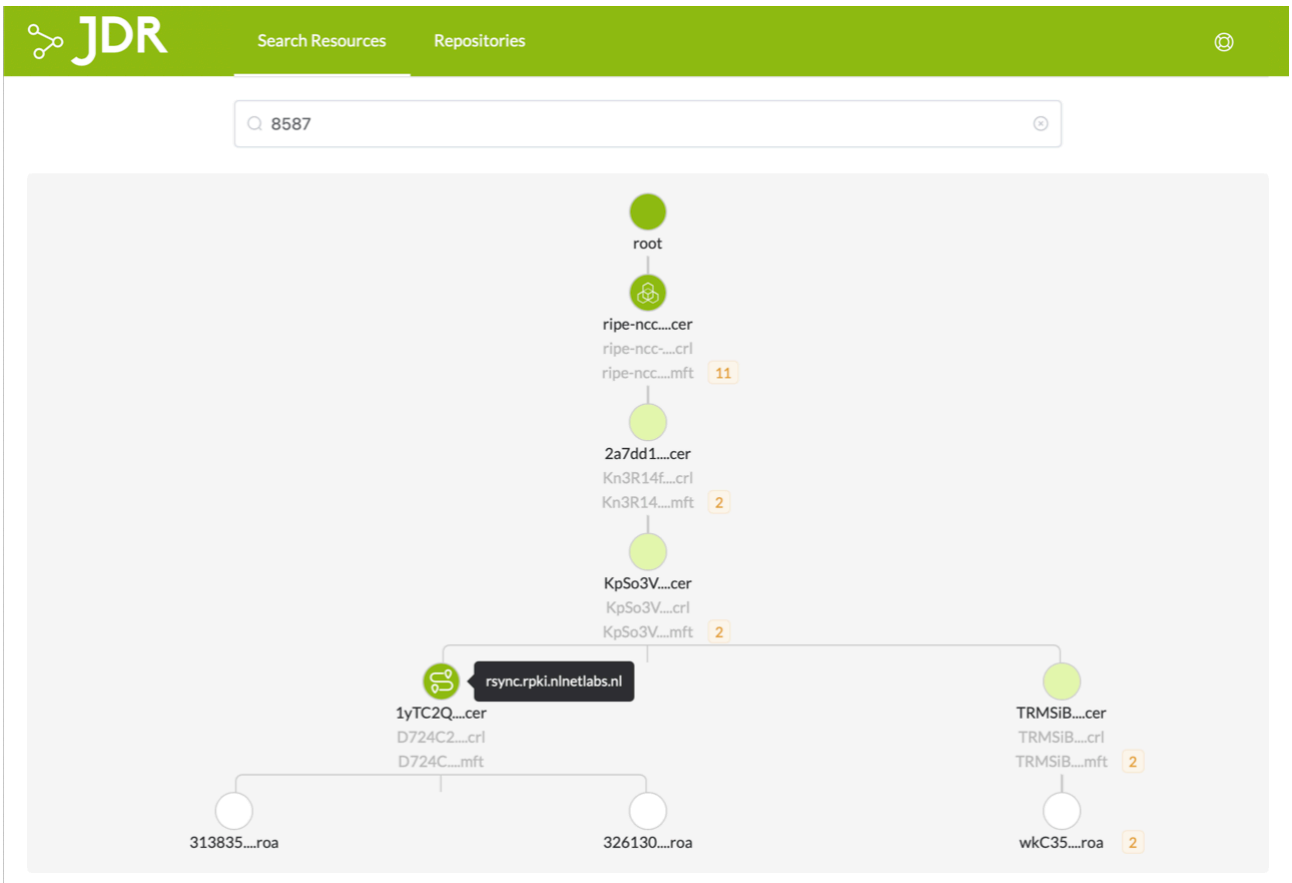
version of this proposal (excluding certain use cases explicitly desired by APNIC). We are following the WG developments and can add or modify our code accordingly.

JDR: Explore, Inspect and Troubleshoot RPKI

JDR helps you explore, inspect and troubleshoot anything RPKI. It interprets certificates and signed objects in the RPKI and annotates everything that could somehow cause trouble. You can search for Autonomous System Numbers, IP prefixes and browse RPKI repositories to analyse them.

When things do not work as expected, it can be a challenge to find the cause because there are so many (moving) parts involved. The RPKI is a distributed repository of possible delegations, containing objects created with various pieces of software, transported via one of several ways, to be interpreted by yet another plethora of libraries and software. And while most software will try to provide the user with concise logging in the event of an unexpected situation or error, often the focus of this software is not on troubleshooting.

JDR interprets certificates and signed objects in the RPKI, but instead of producing a set of Verified ROA Payloads (VRPs) to be fed to a router, it annotates everything that could somehow cause trouble. It will go out of its way to try to decode and parse objects: even if a file is clearly violating the standards and should be rejected by RP software, JDR will try to process it and present as much troubleshooting information to the end-user afterwards.



Research

Introduction

Research is an essential part of NLnet Labs' mission (read our research vision for more information). As in previous years, we continued our research efforts in collaboration with both the academic community and industry. In this section, we discuss our key research highlights of 2020.

Supporting DNSSEC Key Signing Ceremonies

Over the past decade, uptake of DNSSEC has grown significantly. The vast majority of top-level domains (TLDs) is now DNSSEC-signed. As you can imagine, the cryptographic keys used by TLDs and the root of the DNS are highly valuable, since if those keys were stolen, an attacker could effectively impersonate the operator of the TLD and manipulate the information for any domain under it. For this reason, many TLD operators closely guard their key material by storing it in a so-called Hardware Security Module (HSM). The same is true for the keys used to sign the root of the DNS, managed by the IANA and Verisign.

Such a setup, in which keys are protected by storing them in an HSM, is even more secure if the most important signing key – the Key Signing Key (KSK) – is in an HSM that is air-gapped. This is, for example, the case for the KSK of the root. But air-gapping also creates a conundrum: you need a special ceremony in which the air-gapped HSM is used to periodically create new signatures that sign records in the zone.

While key signing ceremonies are now deployed in many places in the DNSSEC community, what is lacking is a common approach, especially related to tooling. Many ceremonies are highly custom, both in the process followed and in the tools used. This may be a barrier to more operators implementing good security practices, and a dependence on highly custom tools can make these ceremonies fragile. Therefore, with help of a grant from the NGI0 PET project, NLnet Labs has built a prototype standardised DNSSEC Key Signing Ceremony, consisting of both documentation to help design a ceremony and tooling to integrate the ceremony in a DNSSEC signing toolchain.

The results of the project are available on our GitHub repository and have been presented at various meetings, including the CENTR Technical workshop and ICANN Tech Day where many TLD operators attended.

Route Origin Validation of DNS Resolvers

The Border Gateway Protocol (BGP) is responsible for routing on the Internet. BGP lacks built-in trust and security measures, making it vulnerable to IP prefix hijacking and route leaks. To

defend against these threats, the Resource Public Key Infrastructure (RPKI) standard has been developed in the IETF. RPKI secures the Internet's routing infrastructure by signing and validating prefix origin data.

There are, however, still situations that one may indirectly fall victim to prefix hijacks, even if their own AS is RPKI protected. A good example of this is the Amazon Route 53 BGP hijack. In this example, the prefixes of the Amazon authoritative DNS servers were hijacked. Any AS with a DNS resolver not protected by RPKI would receive a valid but malicious response from the hijacked authoritative DNS server, even if the AS from which the query originated was RPKI protected. For end-users to be fully protected, in addition to the network in which they reside, they must also have their DNS resolvers in RPKI protected networks.

In this research we will:

1. Measure the uptake of Route Origin Validation of DNS resolvers by scheduling long running measurements targeting authoritative name servers hosted on an RPKI beacon.
2. Measure the uptake of Route Origin Validation of authoritative name servers by sending queries to the authoritative name server operators (drawing up an inventory from OpenINTEL data) originating from an RPKI beacon.

We have started measuring the uptake of Route Origin Validation of DNS resolvers in January 2020 with a research project executed by two MSc students from the University of Amsterdam (see their report). Up to date results of the Route Origin Validation of DNS resolvers measurements can also be found on the DNSThought website (here for IPv4 and here for IPv6).

Our intention is to conduct ongoing measurements to monitor the state of RPKI protection of DNS resources over the long term. To that end, we are currently setting up an RPKI beacon under our own control to perpetuate this research.

Tinkering with DNS and XDP

Programmable network devices have seen much attention from both academia and industry in recent years, and affordable hardware is becoming increasingly available. We envision that such technologies, such as eBPF or P4, can be used to improve the performance of DNS resolvers and name servers.

In 2020, we started a SURF-sponsored Research on Networks (RoN) project to assess the potential that eBPF has to offer to improve the performance and stability of DNS name servers and resolvers. In the first phase, we explored the capabilities of the new technologies eBPF and eXpress Data Path (XPD). With a proof of concept implementation, we experimented how we can leverage the power of eBPF/XDP to improve resolver performance, increase name server versatility, as well as perform low-level measurements on high-speed connections. Our first experiences have been published as a blog post on our website and on the RIPE and APNIC blog websites.

In the second phase, we augmented existing DNS services with XDP programs to do some heavy lifting: returning the easy answers early on, but leveraging the smartness of existing name servers and resolvers for more complex tasks. The research project selected response rate limiting (RRL) as a use case for XDP. RRL mitigates against amplified denial-of-service attacks, where the attacker sends requests to a DNS server to soliciting large responses, spoofing the

source IP address of the request as the victim's, so that the victim is flooded with large answers. The RRL was extended to exclude resolvers with which the name server operators have an established long-term relationship. This resulted in a list of networks that are always exempt from any RRL, so service to these networks is guaranteed, while other networks have rate limiting applied to them. The project was part of a MSc thesis by Tom Carpay and the results have also been published in a blog post.

Other Research Highlights

OpenINTEL

In 2018, NLnet Labs joined the OpenINTEL project. The project's goal is to serve as the "long-term memory" of the DNS and performs daily measurements of over 60% of the global DNS name space. OpenINTEL is built on core NLnet Labs products (LDNS and Unbound). Other project partners are the University of Twente, SURFnet and SIDN.

The OpenINTEL project was extended in 2020 with a daily measurement of the IPv4 reverse DNS namespace. Different to other measurements that measure reverse DNS, this measurement has a high frequency (daily) and also contains specific code to map the delegation hierarchy of the reverse name space, including RFC 2317 delegations of blocks smaller than /24 using CNAMEs.

Further Reading

Read more about all the research projects NLnet Labs participates in on our website.

Community Outreach

Standardisation

NLnet Labs actively participates in the Internet standardisation efforts of the IETF. In 2020, we contributed to several Internet drafts in the DNS-related working groups and in the SIDROPS working group. For example, to improve privacy, we contributed to DNS query name minimisation and for security and resilience, the so-called DNS server cookies to mitigate DDoS and spoofing attacks. In SIDROPS, we contributed to improve operational aspects and provide operational recommendations for delivering resilient RPKI services. Next to contributing to drafts, NLnet Labs is also an enthusiastic participant in IETF hackathons where the goal is to achieve the second half of the IETF's adagium of "rough consensus and running code".

Our further long-term commitment to open Internet standardisation is reflected in Benno Overeinder being appointed as one of the co-chairs of the IETF DNS Operations Working Group.

DNS Flag Day

NLnet Labs is a supporter of DNS Flag Day. This initiative that brings together leading organisations in open source DNS development and DNS operations, aims to encourage deployment of a more robust implementation of the DNS protocol.

The 2020 DNS Flag Day focused on the operational and security problems in DNS caused by Internet Protocol packet fragmentation.

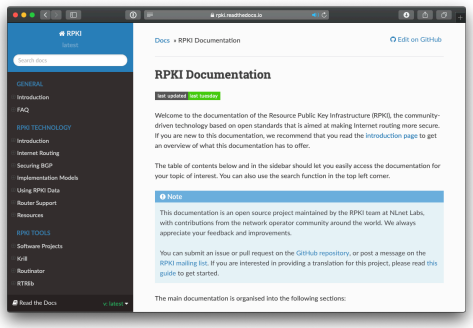
Internet.nl

NLnet Labs is a member of the Dutch Internet Standards Platform (Platform Internetstandaarden). Through this initiative various partners from the Internet community and the Dutch government collaborate to raise awareness about and increase the usage of modern Internet Standards, such as IPv6, DNSSEC, RPKI, TLS, SPF, DMARC and DKIM.

The website Internet.nl, launched in 2015, is used to educate and entice consumers and businesses to adopt modern Internet standards. NLnet Labs is responsible for the development and maintenance of Internet.nl. In 2020 we contributed to a number of maintenance release, but no major new features were introduced like last year.

RPKI Documentation Project

Started the end of 2018 and continued into 2020, NLnet Labs took the initiative to create a comprehensive documentation project for the RPKI ecosystem. This project brings together in-depth information about how RPKI works as well as documentation for tools from different open source organisations. The project has already received community contributions, for example from the developers of the RTRlib toolchain, as well as documentation for operational guidance.



Presentations

NLnet Labs regularly presents at national and international conferences and meetings. In 2020, we mainly attended online meetings and presented at the various IETF, ICANN, RIPE and DNS OARC meetings. A full overview and slide decks for our presentations can be found on our website.

Community Service

We fulfilled the following community positions in 2020:

Organisation	Role	Person
IETF DNSOP Working Group	Co-chair	Benno Overeinder
Forum Standaardisatie	Member	Benno Overeinder
ICANN	RSSAC Caucus member	Benno Overeinder
ICANN	SSAC member	Jaap Akkerhuis
ICANN	Various advisory roles	Jaap Akkerhuis
ISO	ISO 3166 MA member	Jaap Akkerhuis
Internet Society	Member advisory council	Jaap Akkerhuis
DNS-OARC	PC member	Ralph Dolmans

Team

NLnet Labs strives to achieve its goals with minimal management overhead. The organisation values diversity, aiming to employ staff members from a wide range of nationalities, cultures and backgrounds. Our goal is to be as open and inclusive as possible, with the love for open source and open standards binding us together.

Almost all of the staff is comprised of software developers and research engineers. The foundation strives to maintain a compact team, with a healthy mix of experience ranging from junior to senior and people who focus on software development or research. Other responsibilities such as management, product development, finance and auditing, staffing and recruiting, as well as sales and marketing are shared by two people.

Funding

Income From Support and Development

A key goal for 2020 was to increase the turnover from support contracts and paid software development. Being a non-profit foundation, NLnet Labs is obliged to follow strict tax regulations and is not allowed to offer taxable services. Therefore, support and development contracts are offered through Open Netlabs B.V. This company is a wholly owned, taxable subsidiary of the NLnet Labs Foundation serving the non-profit public benefit goals of its parent, as well as being guided and managed according its charter.

Open Netlabs B.V. offers support contracts with a service level for our production-grade software packages, such as NSD and Unbound. In addition to receiving support and early access to security patches, the financial contribution also supports our mission to provide free and open software for all. Lastly, Open Netlabs provides training and software development in the area of Internet security standards, as well as consulting services such as installation and integration support, optimisation and auditing.

In 2020, Open Netlabs generated income from both support contracts and contracted software development. We are thankful that this contributes to letting us build free, open source software in a sustainable way. We would like to specifically thank NIC.br, Stichting NLnet, the RIPE NCC Community Projects Fund, as well as DigitalOcean for their investment in the development of our RPKI toolset.

Grants and Subsidies

Since 2012 NLnet Labs has received a generous subsidy from SIDN. This pledge was renewed in 2017 for another five years. We are also grateful for the substantial, long term grants that Infoblox, Verisign and Internetstiftelsen have donated.

Last but not least, we have also received numerous donations from both organisations and individuals.

Financial Results NLnet Labs

Income			
	2019 Actual (k€)	**2020 Actual (k€)**	**2020 Budget (k€)**
SIDN Subsidy	200	175	175
Other donations	498	314	168
Consultancy and other income	132	153	266
Research and projects	140	178	225
Income from Interest	7	5	4
Total	**977**	**825**	**838**

Expenditure			
	2019 Actual (k€)	**2020 Actual (k€)**	**2020 Budget (k€)**
Staff	677	699	700
Housing	55	60	44
Travel	51	12	48
Depreciation	1	1	
Project Costs	126		
Other Costs	55	28	40
Sub Total	965	800	832
Negative Result Open Netlabs B.V.	-5	-37	
Project Reservations	17	62	6
Total	**977**	**825**	**838**

Balance Sheet (k€)			
Assets		**Liabilities**	
Inventory	1	General Reserve	1298
Open Netlabs B.V. Stock and Loans	277	Special Purpose Reserves	100
Receivables	195	Current Liabilities and Accruals	93
Bank and Cash	1018		
Total	**1491**		**1491**

Governance

Stichting NLnet Labs was founded on 29 December 1999 by Stichting NLnet. Its board consists of four to seven members with staggered terms. The board's composition and most recent rotation schedule is shown below.

NLnet Labs Board in 2020		
Name	**Role**	**End of Term**
Cristian Hesselman	Chair	June 30, 2021
Marieke Huisman	Secretary	August 30, 2021
Sjoera Nas	Member	September 30, 2023
Andrei Robachevsky	Member	June 30, 2022
Jochem de Ruig	Treasurer	June 30, 2021

Four board meetings took place in the year 2020. Benno Overeinder participated in the board meetings in his role as director of NLnet Labs and as director of Open Netlabs BV.

Board members do not receive any compensation for their board work. Expenses may be reimbursed if necessary (€0 in 2020). The table below shows the additional functions held by board members and director of Stichting NLnet Labs.

Additional Functions Held By NLnet Lab Board Members and Directors in 2020	
Name	**Function(s)**
Cristian Hesselman	- Head of SIDN Labs - Member ICANN SSAC - Associate Professor University of Twente
Marieke Huisman	- Full Professor University of Twente
Sjoera Nas	- Senior Privacy Advisor, Privacy Company - Advisory Board SIDN Fonds
Benno Overeinder	- See the Community Service section for an overview
Andrei Robachevsky	- Technology Programma Manager Internet Society - Member EU MSP Standardisation
Jochem de Ruig	- Organic wine entrepreneur at Wilde Wijnen - Financial Director, Freedom Internet B.V.

Colophon

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