Internet security: what is it and where is it going?

Cristian Hesselman

Nacht van de digitale veiligheid, Leiden University

May 26, 2025

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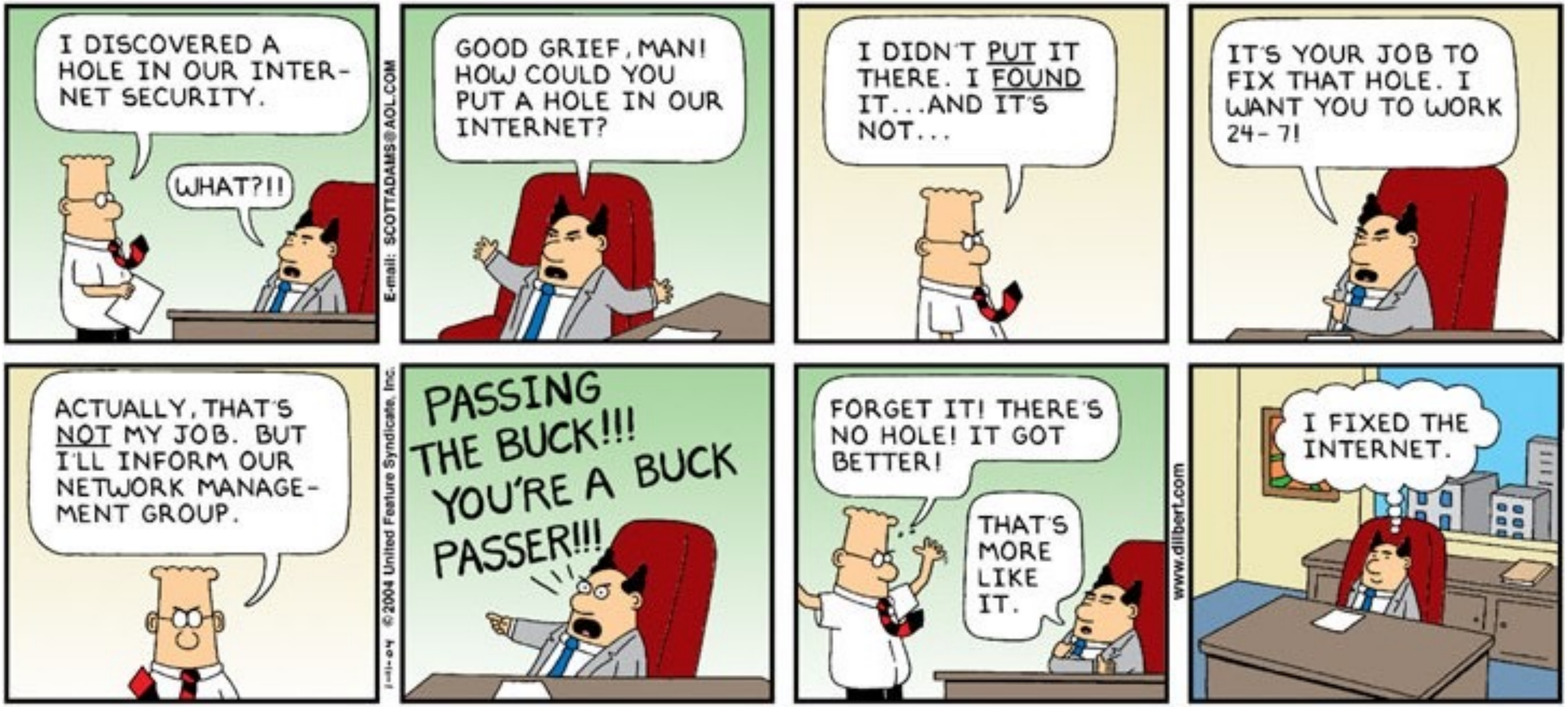
How difficult can Internet security be? ☺



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Today's objective

- Understand what Internet security is and where it might be going

- Enable you to impress your friends :-)

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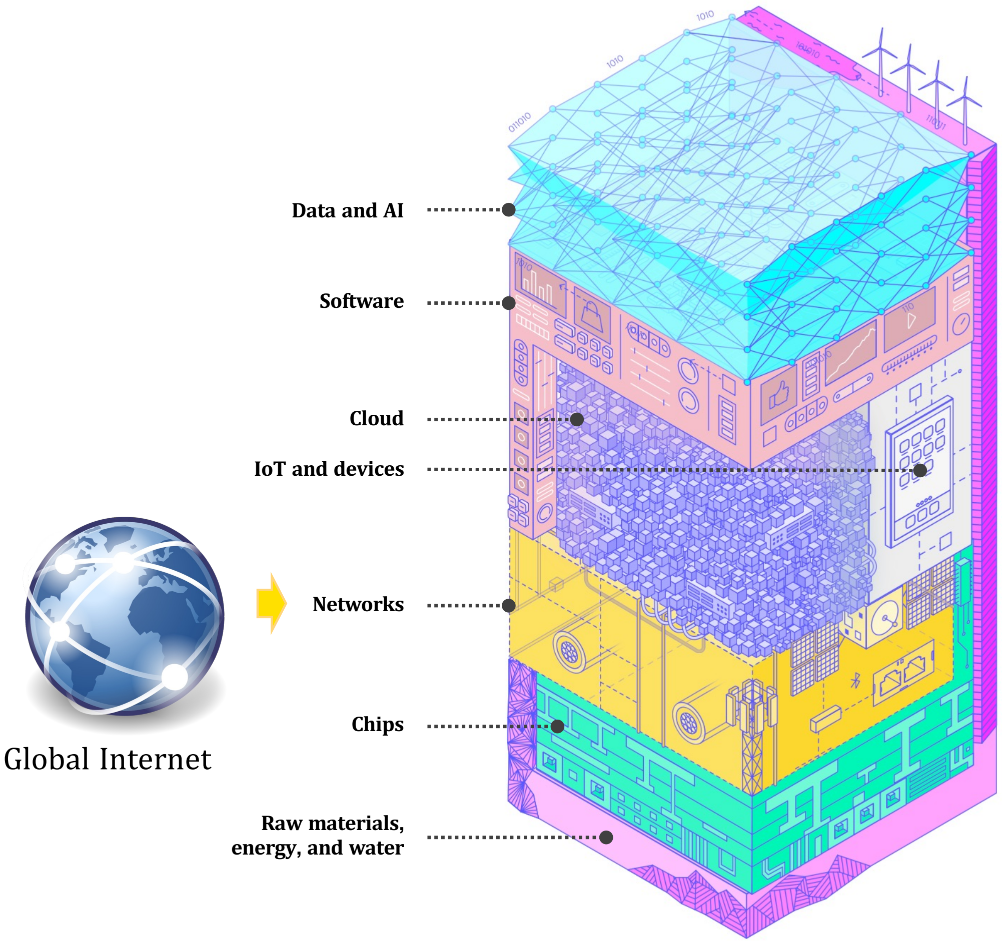
The Internet in our digital infrastructure



	KEY COUNTRIES	KEY FIRMS
Data and artificial intelligence	US, China	OpenAI, Microsoft, Google, Meta, Anthropic, XAI, Amazon, Baidu, Tencent, Alibaba, DeepSeek
Software	US, China, Germany	Microsoft, Apple, Alphabet, Meta, Amazon, Salesforce, SAP, ByteDance, Tencent
Cloud	US, China	Amazon, Microsoft, Alphabet, Alibaba
Internet of things & devices	US, China, Korea, Germany	Amazon, Google, Apple, Samsung, Huawei, Bosch, Siemens, Xiaomi
Networks	US, China, Europe, Japan	Huawei, Nokia, Ericsson, ZTE, SpaceX, NEC
Chips	Taiwan, Korea, US, Netherlands	TSMC, Samsung, Intel, NVIDIA, AMD, ASML
Raw materials, energy, and water	US, China, Russia	Chinese government (through SOEs e.g., China Rare Earth Group), ExxonMobil, Gazprom

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https://www.euro-stack.info

Agenda

- What is the Internet and what is Internet security?
- Two current threats: routing hijacks and quantum computers
- Internet security measurements
- Two future Internet security concepts
- Key takeaways

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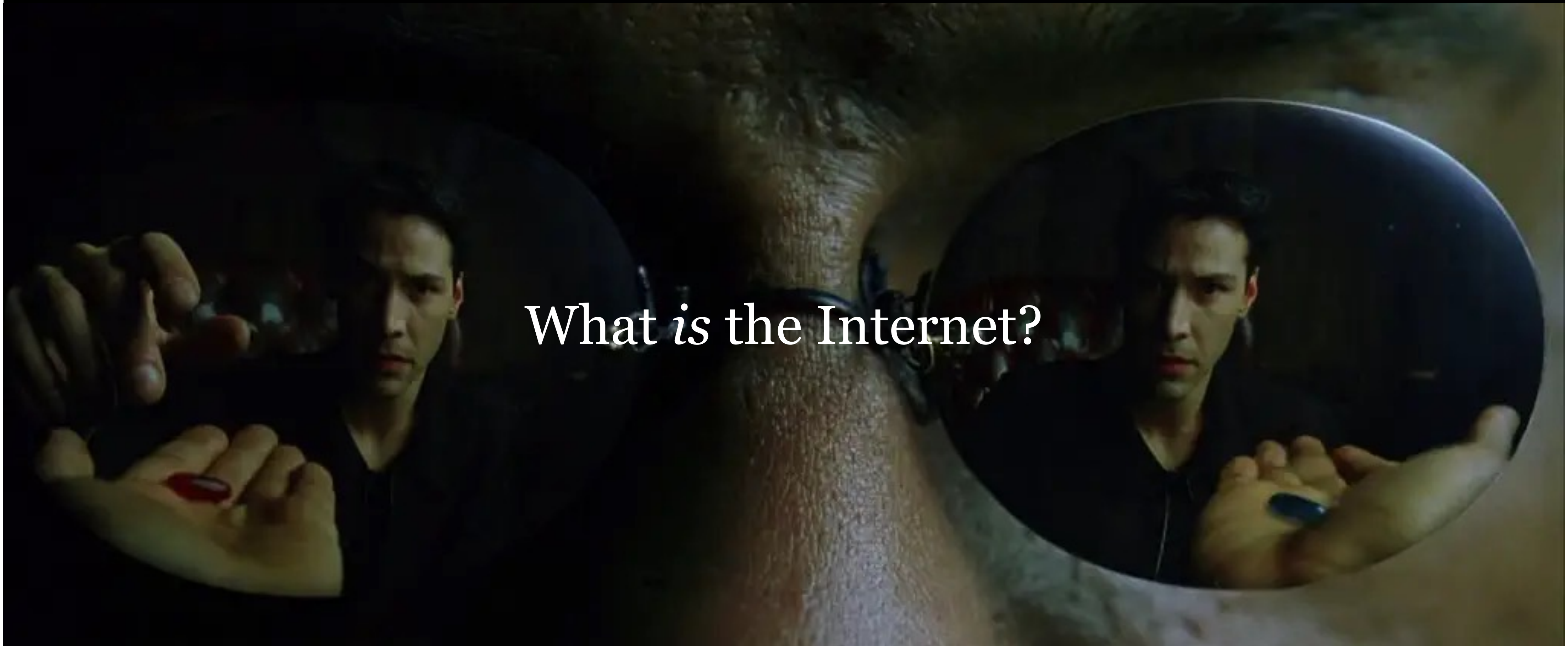
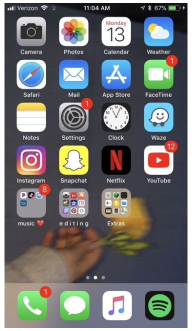
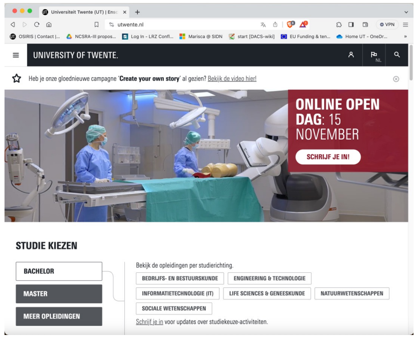
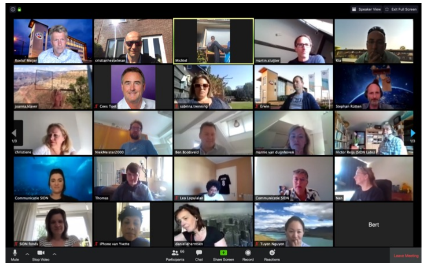
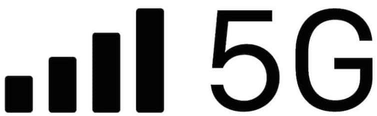

What *is* the Internet?

Today’s dependence on the Internet









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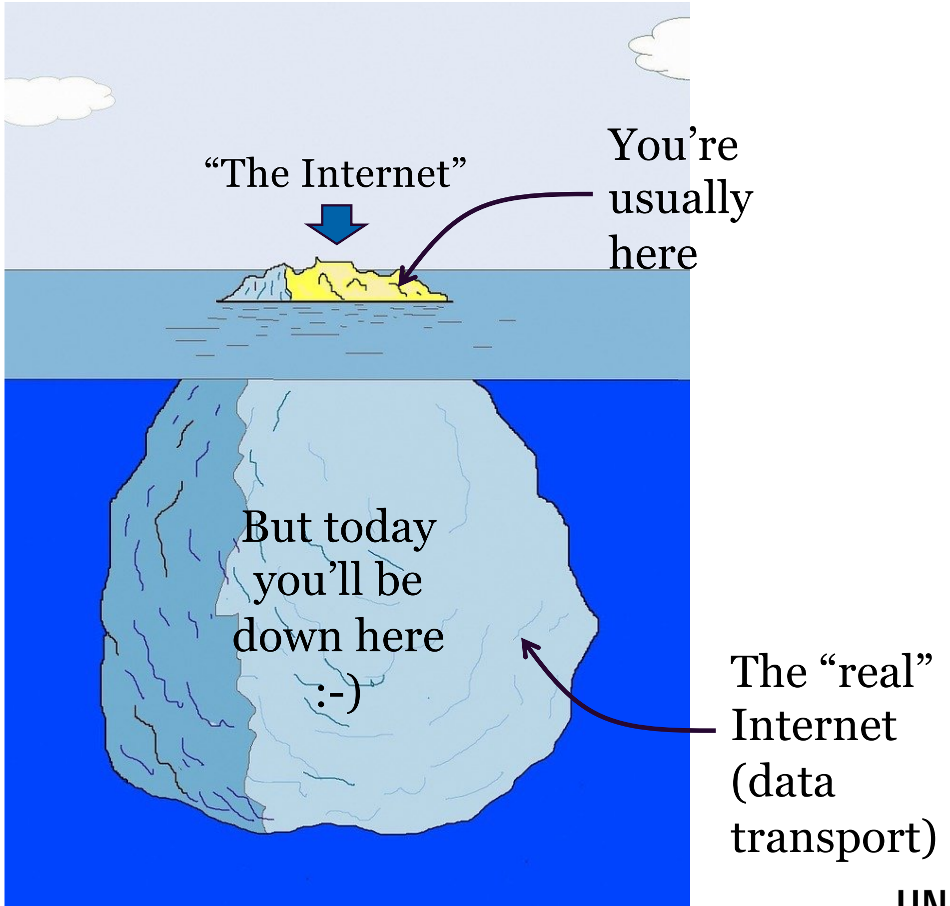
But that’s just the tip of the iceberg



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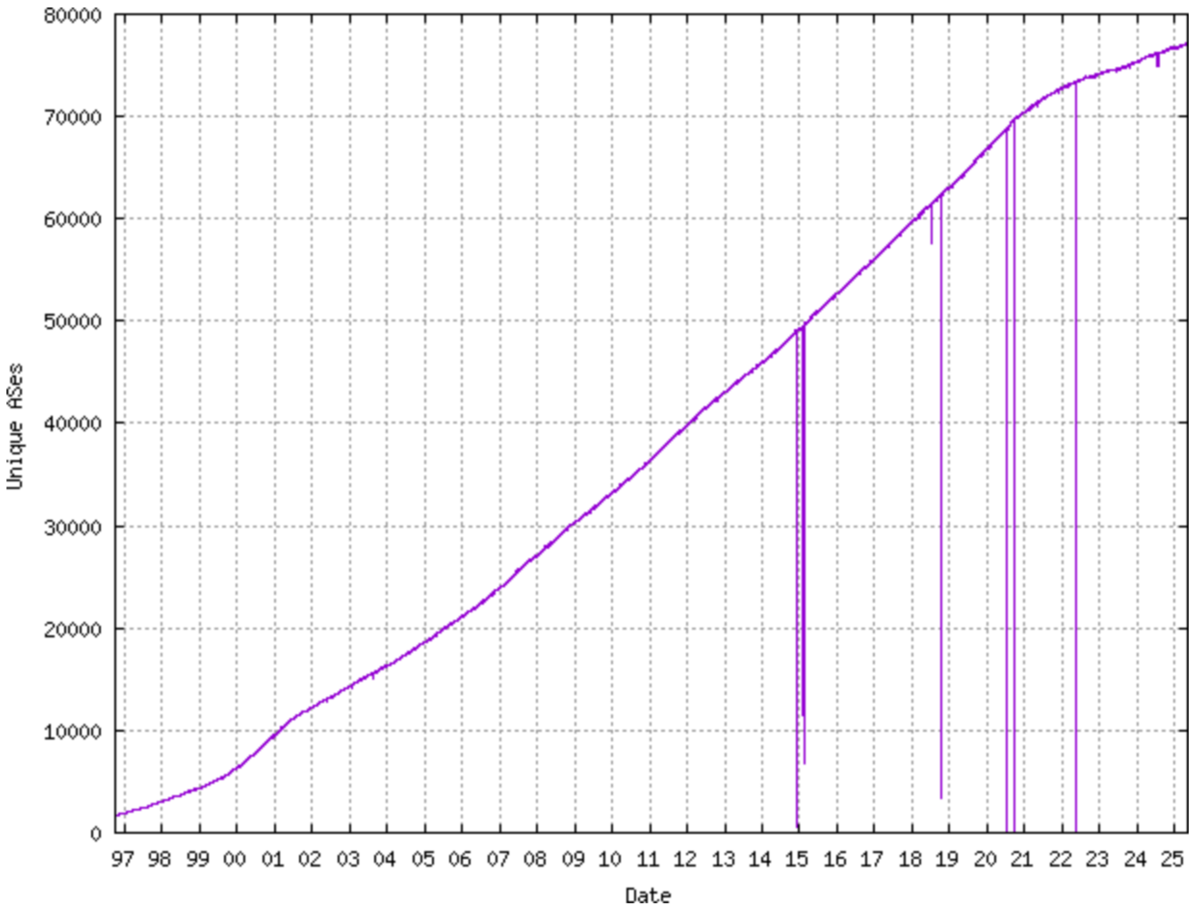
Barrett Lyon / The Opte Project
Visualization of the routing paths of the Internet
https://www.opte.org/the-internet

A complex and ever-changing
network of networks
(hence *inter*net)

Internet growth 1996-2025



https://www.cidr-report.org/as2.0/

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First packet ever: Oct 29, 1969

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The tangible Internet in the 1960s/70s

Birthplace of the Internet @UCLA

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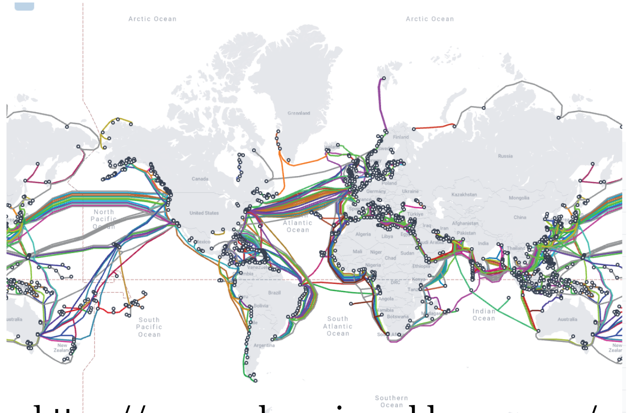
The tangible Internet today

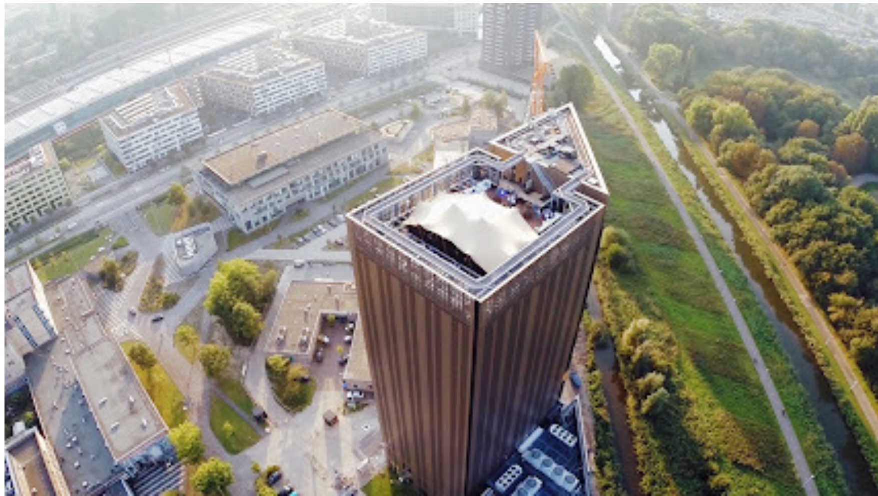
Nokia router

GL-iNet mini router



https://www.submarinecablemap.com/

Nikhef data center, Amsterdam



Data Tower, Amsterdam Science Park

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The Internet is our newest civil infrastructure

- Large, built over multiple generations
- Continual improvement, no replacement
- Interacting components with interfaces
- Foundation for other civil infrastructures

Henning Schulzrinne, “Networking: The Newest Civil Engineering Challenge”, SIGCOMM Lifetime Achievement Award keynote, SIGCOMM 2022, Amsterdam, August 2022, https://www.youtube.com/watch?v=5lvXIqI_mQ4

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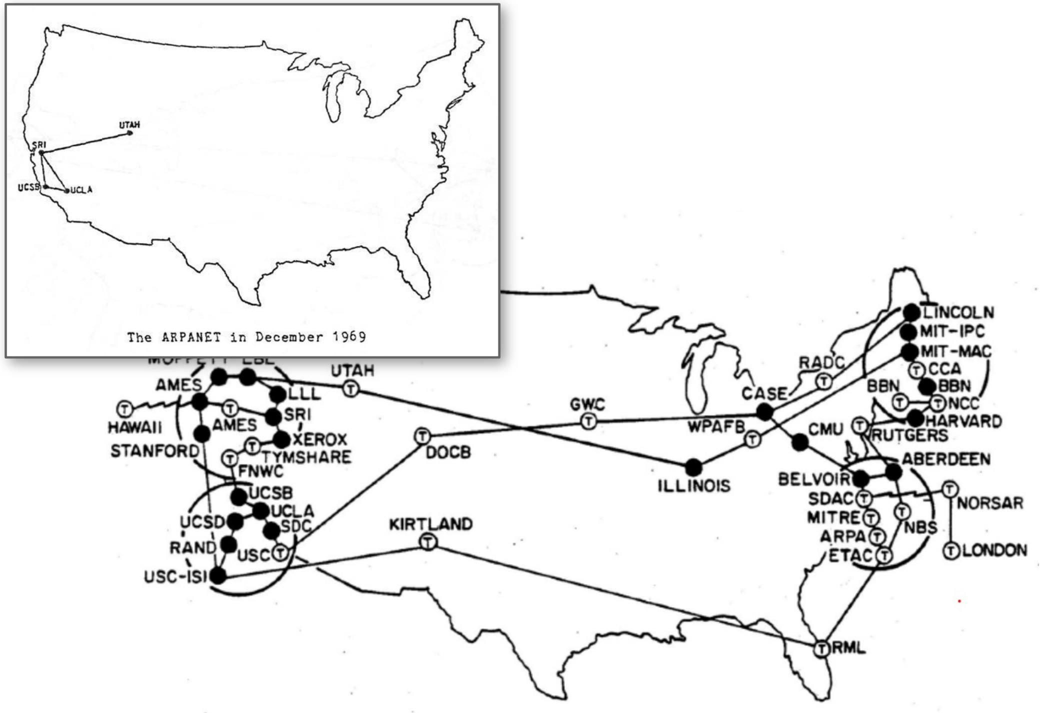
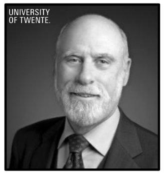
What is Internet security?

Early days: personal trust and no “bad actors”



INTERNET HALL of FAME


Vint Cerf


Steve Crocker

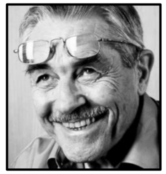

Robert Kahn


Jon Postel


Leonard Kleinrock


Paul Mockapetris


Kc Claffy


Louis Pouzin


Kees Neggers


Jaap Akkerhuis


Erik Huizer


Daniel Karrenberg

https://en.wikipedia.org/wiki/ARPANET
https://www.internethalloffame.org/

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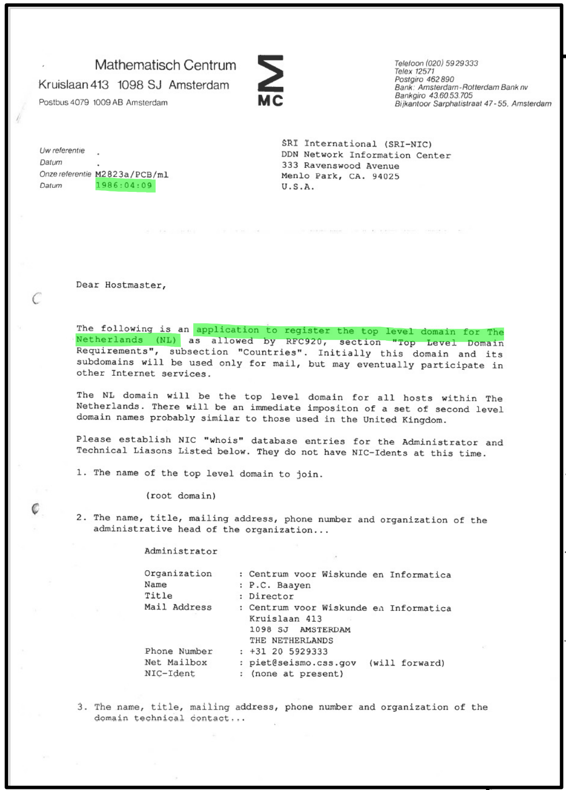
Example: .nl delegation (April 25, 1986)



Mathematisch Centrum
Kruislaan 413 1098 SJ Amsterdam
Postbus 4079 1009 AB Amsterdam

MC

Telefoon (020) 5929333
Telex 12571
Postgiro 462890
Bank: Amsterdam-Rotterdam Bank nv
Bankgiro 43.60.53.705
Bijkantoor Sarphatistraat 47-55, Amsterdam

Uw referentie .
Datum .
Onze referentie M2823a/PCB/ml
Datum 1986:04:09

SRI International (SRI-NIC)
DDN Network Information Center
333 Ravenswood Avenue
Menlo Park, CA. 94025
U.S.A.

Dear Hostmaster,

The following is an application to register the top level domain for The Netherlands (NL) as allowed by RFC920, section "Top Level Domain Requirements", subsection "Countries". Initially this domain and its subdomains will be used only for mail, but may eventually participate in other Internet services.

The NL domain will be the top level domain for all hosts within The Netherlands. There will be an immediate impositon of a set of second level domain names probably similar to those used in the United Kingdom.

Please establish NIC "whois" database entries for the Administrator and Technical Liasons Listed below. They do not have NIC-Idents at this time.

1. The name of the top level domain to join.

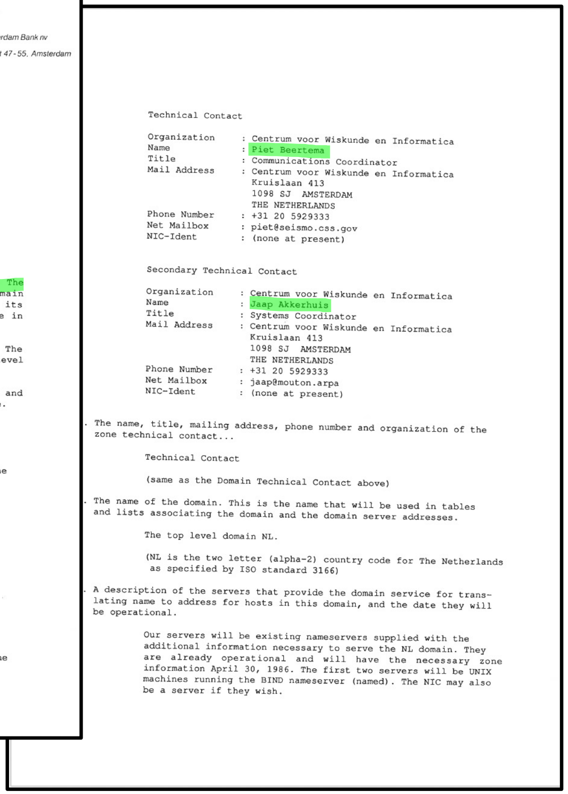
   (root domain)

2. The name, title, mailing address, phone number and organization of the administrative head of the organization...

   Administrator

   Organization : Centrum voor Wiskunde en Informatica
   Name : P.C. Baayen
   Title : Director
   Mail Address : Centrum voor Wiskunde en Informatica
   Kruislaan 413
   1098 SJ AMSTERDAM
   THE NETHERLANDS
   Phone Number : +31 20 5929333
   Net Mailbox : piet@seismo.css.gov (will forward)
   NIC-Ident : (none at present)

3. The name, title, mailing address, phone number and organization of the domain technical contact...



Technical Contact

Organization : Centrum voor Wiskunde en Informatica
Name : Piet Beertema
Title : Communications Coordinator
Mail Address : Centrum voor Wiskunde en Informatica
Kruislaan 413
1098 SJ AMSTERDAM
THE NETHERLANDS
Phone Number : +31 20 5929333
Net Mailbox : piet@seismo.css.gov
NIC-Ident : (none at present)

Secondary Technical Contact

Organization : Centrum voor Wiskunde en Informatica
Name : Jaap Akkerhuis
Title : Systems Coordinator
Mail Address : Centrum voor Wiskunde en Informatica
Kruislaan 413
1098 SJ AMSTERDAM
THE NETHERLANDS
Phone Number : +31 20 5929333
Net Mailbox : jaap@mouton.arpa
NIC-Ident : (none at present)

. The name, title, mailing address, phone number and organization of the zone technical contact...

Technical Contact

(same as the Domain Technical Contact above)

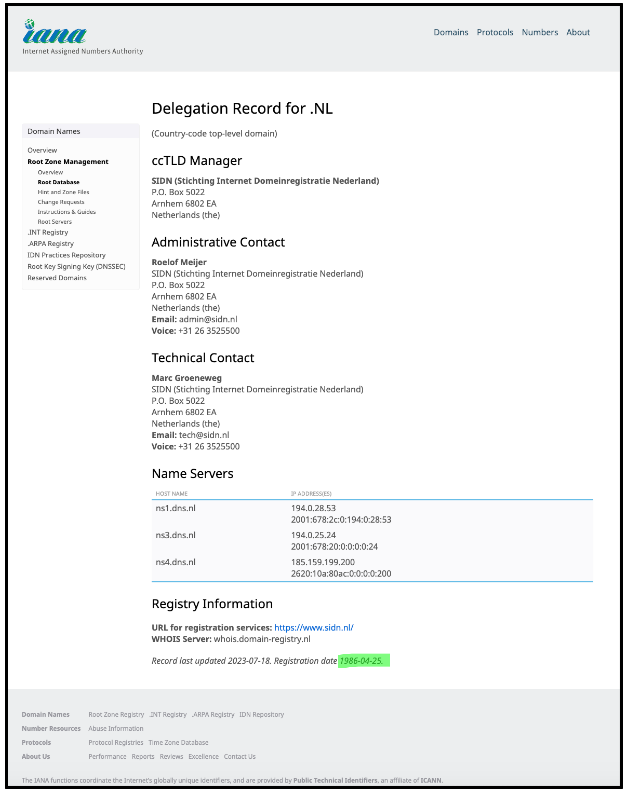
. The name of the domain. This is the name that will be used in tables and lists associating the domain and the domain server addresses.

The top level domain NL.

(NL is the two letter (alpha-2) country code for The Netherlands as specified by ISO standard 3166)

. A description of the servers that provide the domain service for translating name to address for hosts in this domain, and the date they will be operational.

Our servers will be existing nameservers supplied with the additional information necessary to serve the NL domain. They are already operational and will have the necessary zone information April 30, 1986. The first two servers will be UNIX machines running the BIND nameserver (named). The NIC may also be a server if they wish.



iana
Internet Assigned Numbers Authority

Domains Protocols Numbers About

Domain Names
Overview
Root Zone Management
Overview
Root Database
Hint and Zone Files
Change Requests
Instructions & Guides
Root Servers
.INT Registry
.ARPA Registry
IDN Practices Repository
Root Key Signing Key (DNSSEC)
Reserved Domains

Delegation Record for .NL

(Country-code top-level domain)

ccTLD Manager

SIDN (Stichting Internet Domeinregistratie Nederland)
P.O. Box 5022
Arnhem 6802 EA
Netherlands (the)

Administrative Contact

Roelof Meijer
SIDN (Stichting Internet Domeinregistratie Nederland)
P.O. Box 5022
Arnhem 6802 EA
Netherlands (the)
Email: admin@sidn.nl
Voice: +31 26 3525500

Technical Contact

Marc Groeneweg
SIDN (Stichting Internet Domeinregistratie Nederland)
P.O. Box 5022
Arnhem 6802 EA
Netherlands (the)
Email: tech@sidn.nl
Voice: +31 26 3525500

Name Servers

HOST NAME	IP ADDRESS(ES)
ns1.dns.nl	194.0.28.53 2001:678:2c:0:194:0:28:53
ns3.dns.nl	194.0.25.24 2001:678:20:0:0:0:0:24
ns4.dns.nl	185.159.199.200 2620:10a:80ac:0:0:0:0:200

Registry Information

URL for registration services: https://www.sidn.nl/
WHOIS Server: whois.domain-registry.nl

Record last updated 2023-07-18. Registration date 1986-04-25.

Domain Names Root Zone Registry .INT Registry .ARPA Registry IDN Repository
Number Resources Abuse Information
Protocols Protocol Registries Time Zone Database
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The IANA functions coordinate the Internet's globally unique identifiers, and are provided by **Public Technical Identifiers**, an affiliate of **ICANN**.

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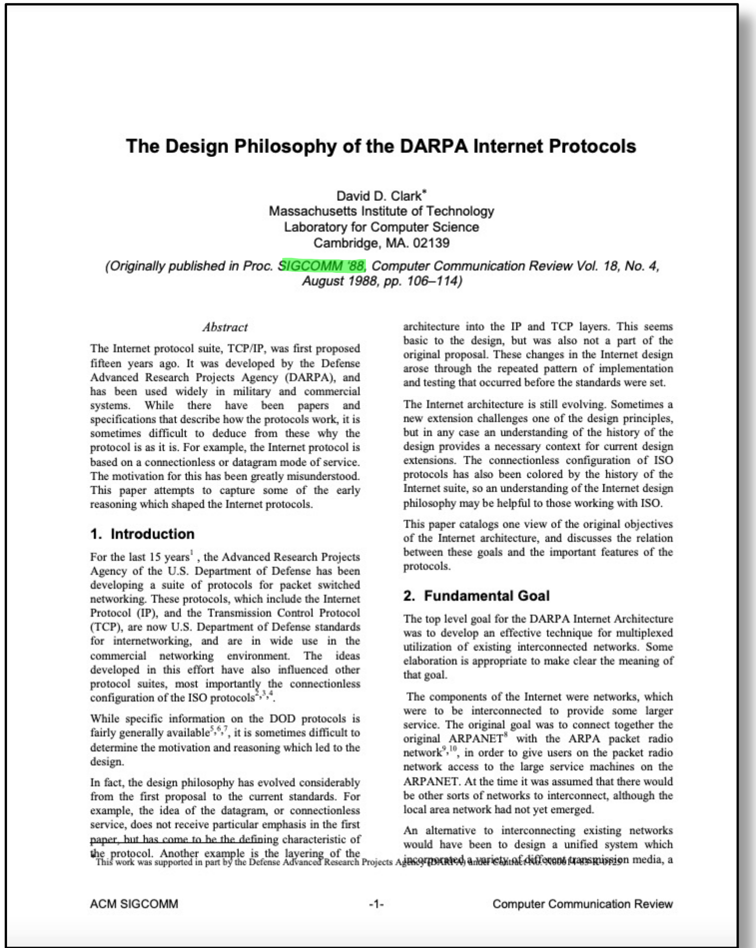
Initial design focused on survivability



The Design Philosophy of the DARPA Internet Protocols

David D. Clark*
Massachusetts Institute of Technology
Laboratory for Computer Science
Cambridge, MA. 02139

(Originally published in Proc. SIGCOMM '88, Computer Communication Review Vol. 18, No. 4, August 1988, pp. 106–114)

Abstract

The Internet protocol suite, TCP/IP, was first proposed fifteen years ago. It was developed by the Defense Advanced Research Projects Agency (DARPA), and has been used widely in military and commercial systems. While there have been papers and specifications that describe how the protocols work, it is sometimes difficult to deduce from these why the protocol is as it is. For example, the Internet protocol is based on a connectionless or datagram mode of service. The motivation for this has been greatly misunderstood. This paper attempts to capture some of the early reasoning which shaped the Internet protocols.

1. Introduction

For the last 15 years[1], the Advanced Research Projects Agency of the U.S. Department of Defense has been developing a suite of protocols for packet switched networking. These protocols, which include the Internet Protocol (IP), and the Transmission Control Protocol (TCP), are now U.S. Department of Defense standards for internetworking, and are in wide use in the commercial networking environment. The ideas developed in this effort have also influenced other protocol suites, most importantly the connectionless configuration of the ISO protocols[2,3,4].

While specific information on the DOD protocols is fairly generally available[5,6,7], it is sometimes difficult to determine the motivation and reasoning which led to the design.

In fact, the design philosophy has evolved considerably from the first proposal to the current standards. For example, the idea of the datagram, or connectionless service, does not receive particular emphasis in the first paper, but has come to be the defining characteristic of the protocol. Another example is the layering of the architecture into the IP and TCP layers. This seems basic to the design, but was also not a part of the original proposal. These changes in the Internet design arose through the repeated pattern of implementation and testing that occurred before the standards were set.

The Internet architecture is still evolving. Sometimes a new extension challenges one of the design principles, but in any case an understanding of the history of the design provides a necessary context for current design extensions. The connectionless configuration of ISO protocols has also been colored by the history of the Internet suite, so an understanding of the Internet design philosophy may be helpful to those working with ISO.

This paper catalogs one view of the original objectives of the Internet architecture, and discusses the relation between these goals and the important features of the protocols.

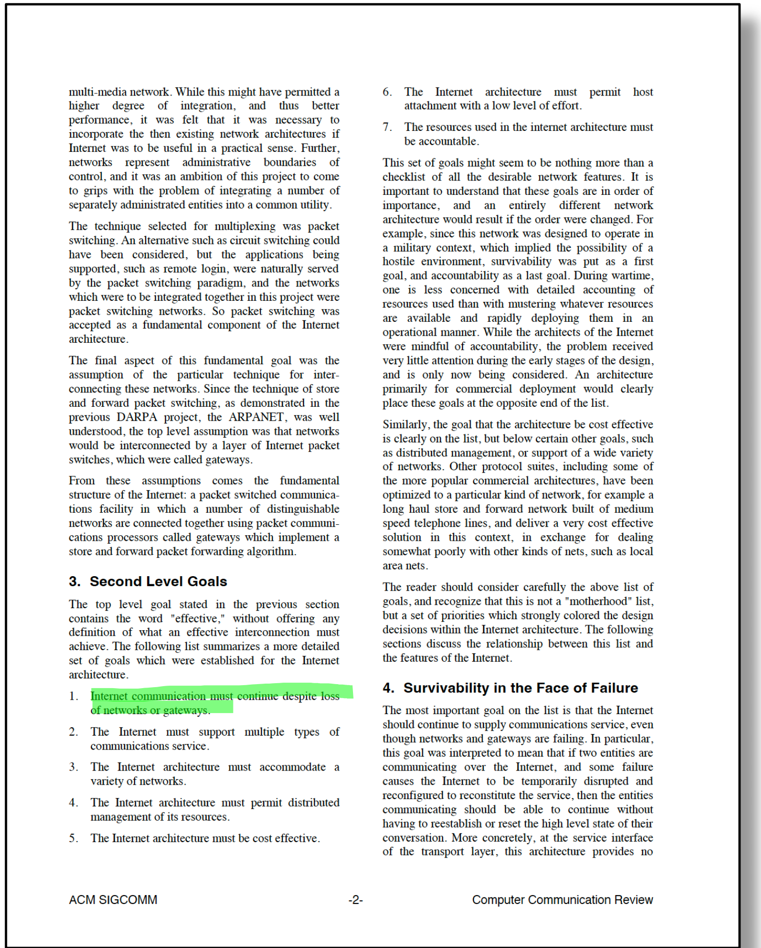
2. Fundamental Goal

The top level goal for the DARPA Internet Architecture was to develop an effective technique for multiplexed utilization of existing interconnected networks. Some elaboration is appropriate to make clear the meaning of that goal.

The components of the Internet were networks, which were to be interconnected to provide some larger service. The original goal was to connect together the original ARPANET[8] with the ARPA packet radio network[9,10], in order to give users on the packet radio network access to the large service machines on the ARPANET. At the time it was assumed that there would be other sorts of networks to interconnect, although the local area network had not yet emerged.

An alternative to interconnecting existing networks would have been to design a unified system which incorporated a variety of different transmission media, a

*This work was supported in part by the Defense Advanced Research Projects Agency



multi-media network. While this might have permitted a higher degree of integration, and thus better performance, it was felt that it was necessary to incorporate the then existing network architectures if Internet was to be useful in a practical sense. Further, networks represent administrative boundaries of control, and it was an ambition of this project to come to grips with the problem of integrating a number of separately administrated entities into a common utility.

The technique selected for multiplexing was packet switching. An alternative such as circuit switching could have been considered, but the applications being supported, such as remote login, were naturally served by the packet switching paradigm, and the networks which were to be integrated together in this project were packet switching networks. So packet switching was accepted as a fundamental component of the Internet architecture.

The final aspect of this fundamental goal was the assumption of the particular technique for inter-connecting these networks. Since the technique of store and forward packet switching, as demonstrated in the previous DARPA project, the ARPANET, was well understood, the top level assumption was that networks would be interconnected by a layer of Internet packet switches, which were called gateways.

From these assumptions comes the fundamental structure of the Internet: a packet switched communications facility in which a number of distinguishable networks are connected together using packet communications processors called gateways which implement a store and forward packet forwarding algorithm.

3. Second Level Goals

The top level goal stated in the previous section contains the word "effective," without offering any definition of what an effective interconnection must achieve. The following list summarizes a more detailed set of goals which were established for the Internet architecture.

1. Internet communication must continue despite loss of networks or gateways.
2. The Internet must support multiple types of communications service.
3. The Internet architecture must accommodate a variety of networks.
4. The Internet architecture must permit distributed management of its resources.
5. The Internet architecture must be cost effective.
6. The Internet architecture must permit host attachment with a low level of effort.
7. The resources used in the internet architecture must be accountable.

This set of goals might seem to be nothing more than a checklist of all the desirable network features. It is important to understand that these goals are in order of importance, and an entirely different network architecture would result if the order were changed. For example, since this network was designed to operate in a military context, which implied the possibility of a hostile environment, survivability was put as a first goal, and accountability as a last goal. During wartime, one is less concerned with detailed accounting of resources used than with mustering whatever resources are available and rapidly deploying them in an operational manner. While the architects of the Internet were mindful of accountability, the problem received very little attention during the early stages of the design, and is only now being considered. An architecture primarily for commercial deployment would clearly place these goals at the opposite end of the list.

Similarly, the goal that the architecture be cost effective is clearly on the list, but below certain other goals, such as distributed management, or support of a wide variety of networks. Other protocol suites, including some of the more popular commercial architectures, have been optimized to a particular kind of network, for example a long haul store and forward network built of medium speed telephone lines, and deliver a very cost effective solution in this context, in exchange for dealing somewhat poorly with other kinds of nets, such as local area nets.

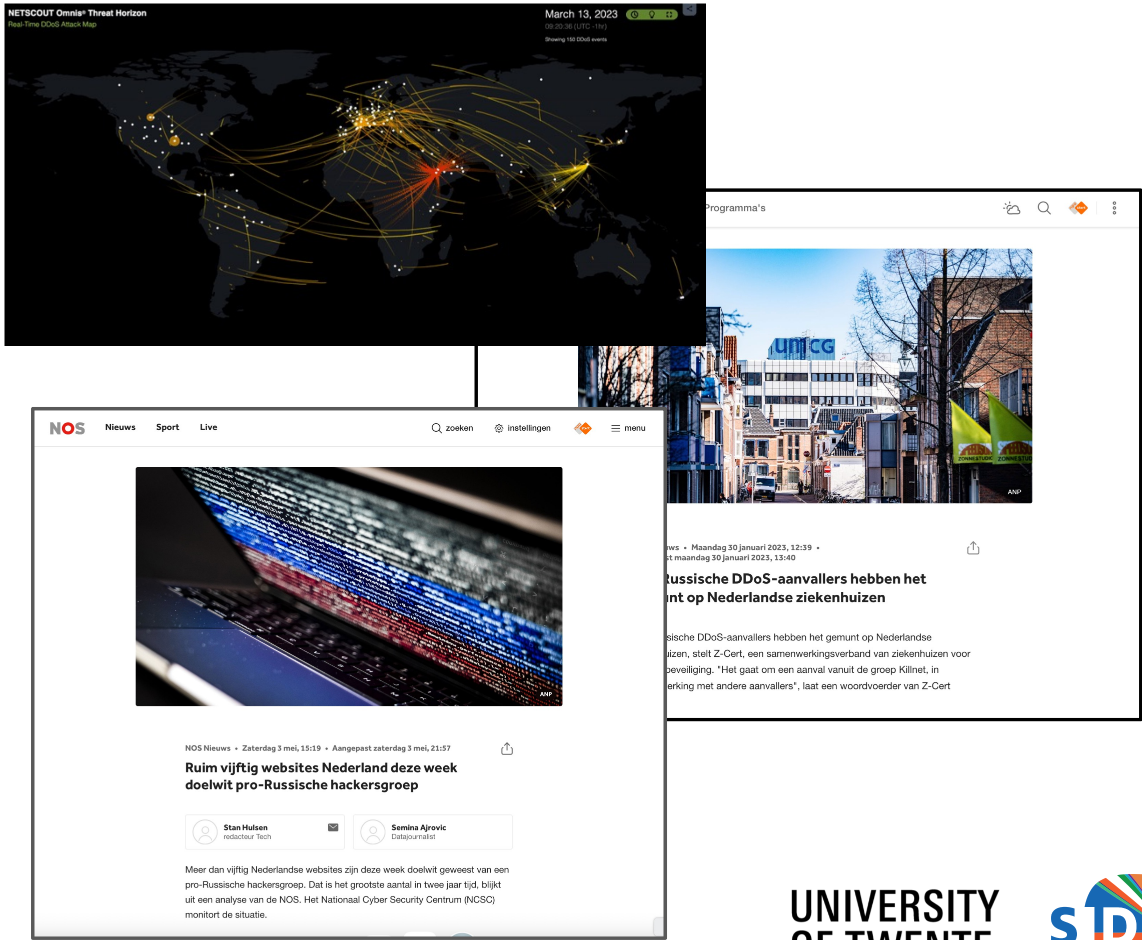
The reader should consider carefully the above list of goals, and recognize that this is not a "motherhood" list, but a set of priorities which strongly colored the design decisions within the Internet architecture. The following sections discuss the relationship between this list and the features of the Internet.

4. Survivability in the Face of Failure

The most important goal on the list is that the Internet should continue to supply communications service, even though networks and gateways are failing. In particular, this goal was interpreted to mean that if two entities are communicating over the Internet, and some failure causes the Internet to be temporarily disrupted and reconfigured to reconstitute the service, then the entities communicating should be able to continue without having to reestablish or reset the high level state of their conversation. More concretely, at the service interface of the transport layer, this architecture provides no

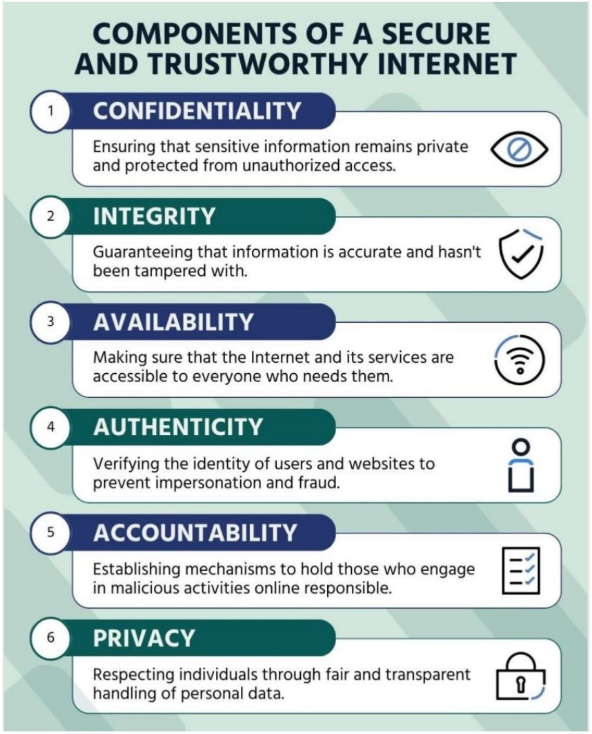
But growth introduced new security risks

- Phishing
- Fake webshops
- **DDoS attacks**
- Malware
- Routing hijacks



So, the community had to increase system trust

- Encryption so that only the receiver can read a message and not an adversary
- Signatures so that receivers can validate the source and message integrity
- Additional availability mechanisms, such as redundancy and "DDoS scrubbing"



https://www.internetsociety.org/blog/2025/04/internet-trust-why-we-need-it-and-how-to-achieve-it/

RESPONSIBLE INTERNET

7 TRANSPARENCY

8 CONTROLLABILITY

https://www.catrin.nl

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Threat #1: routing hijacks

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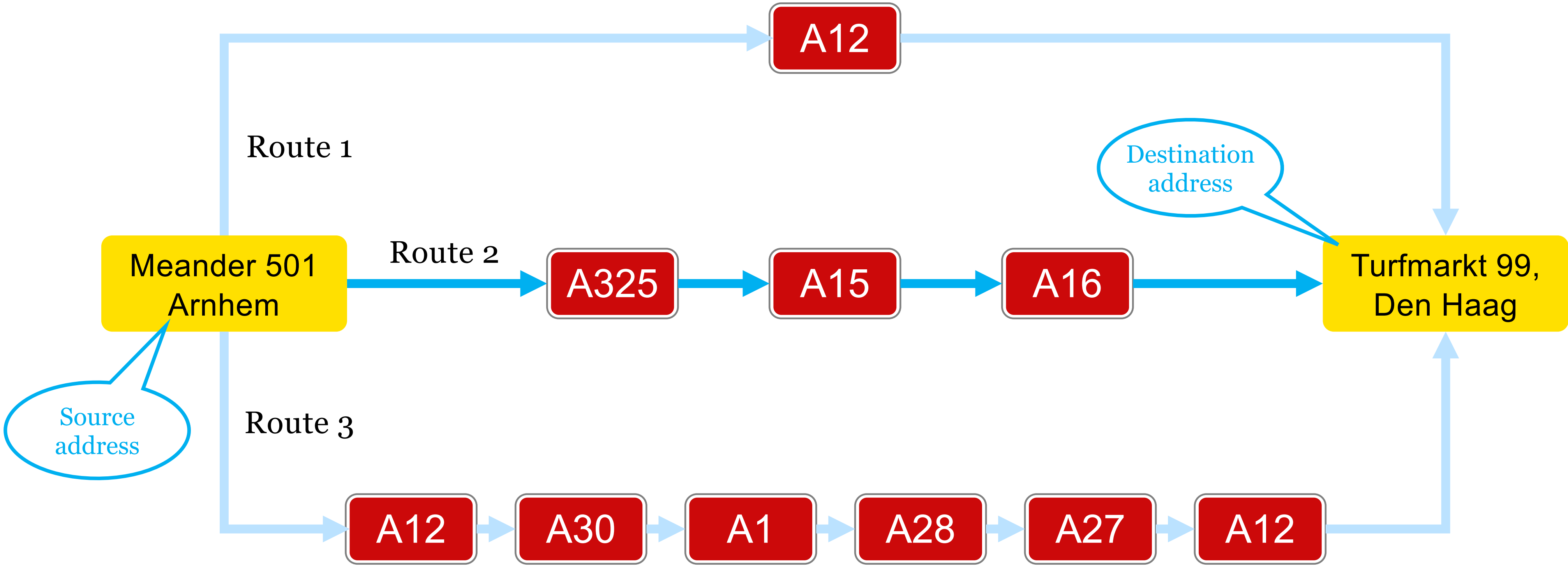
The Internet's routing system as a highway network



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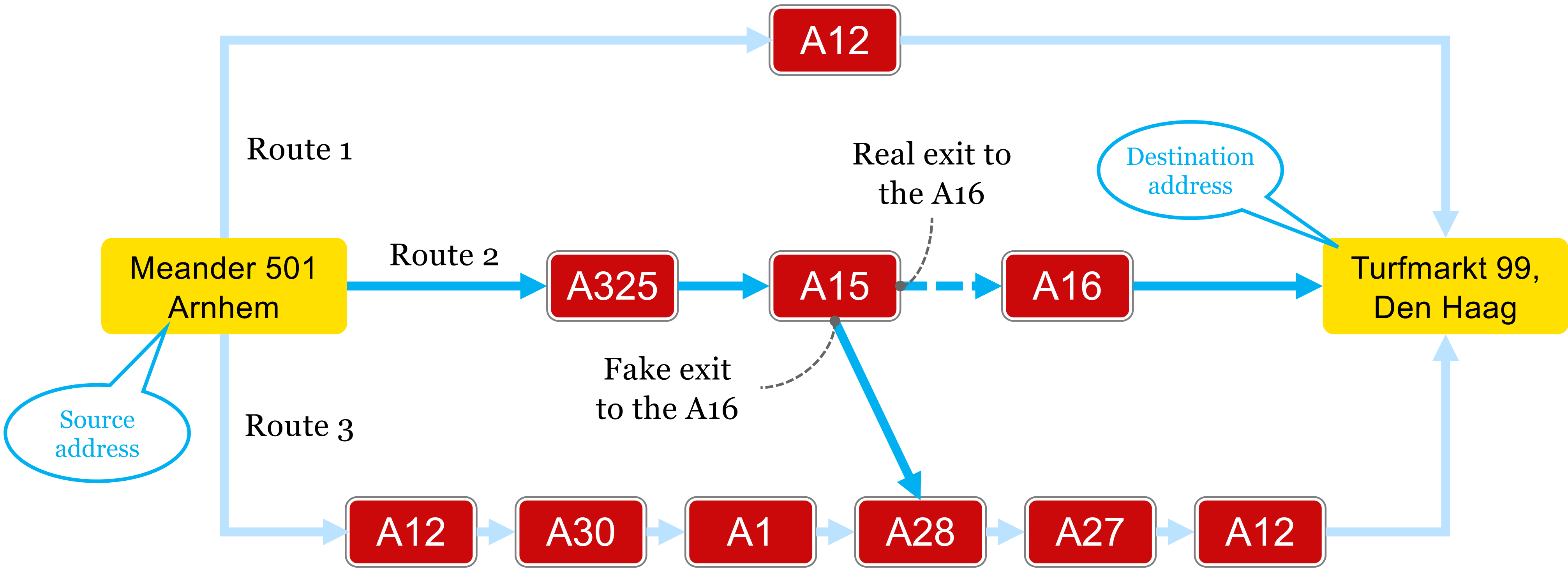
“Routing hijacks” in a highway network



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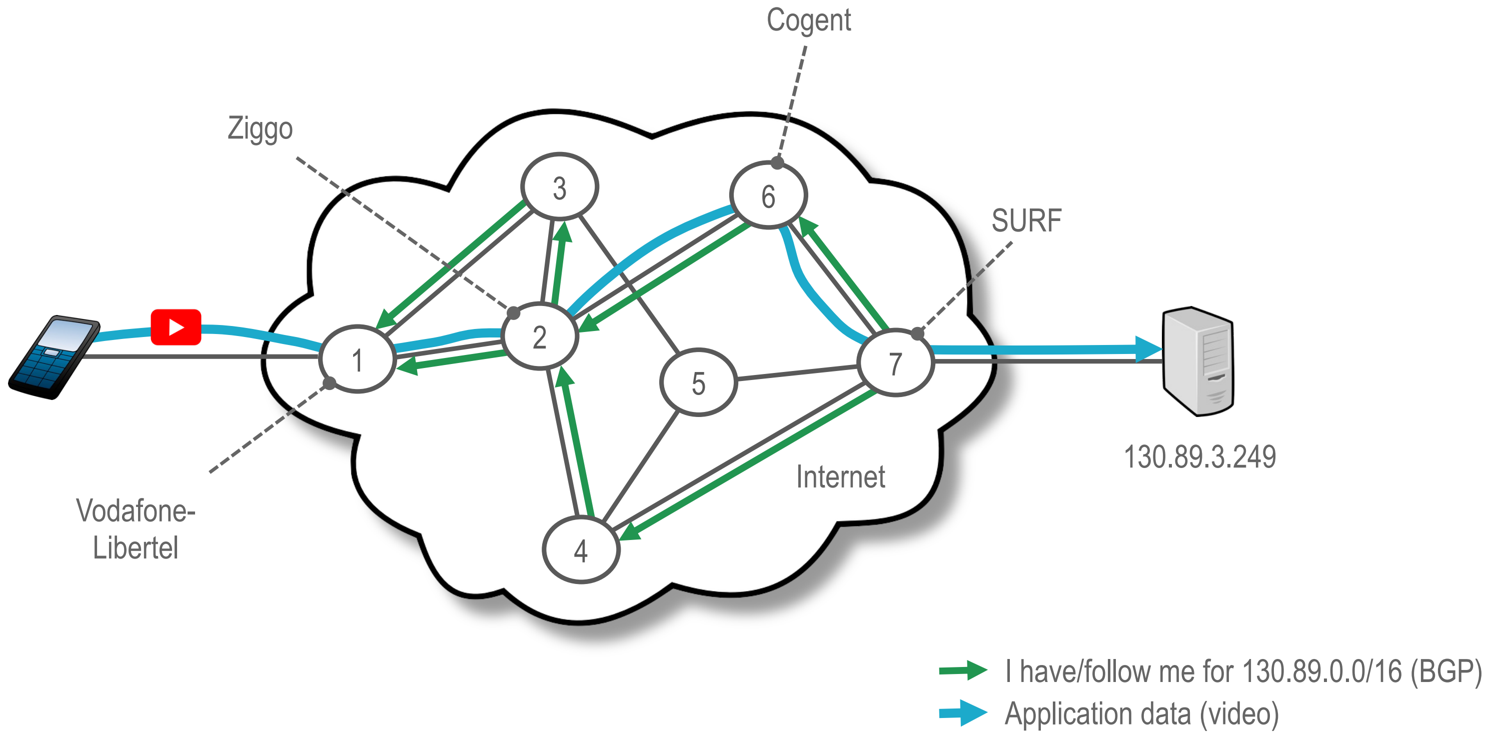
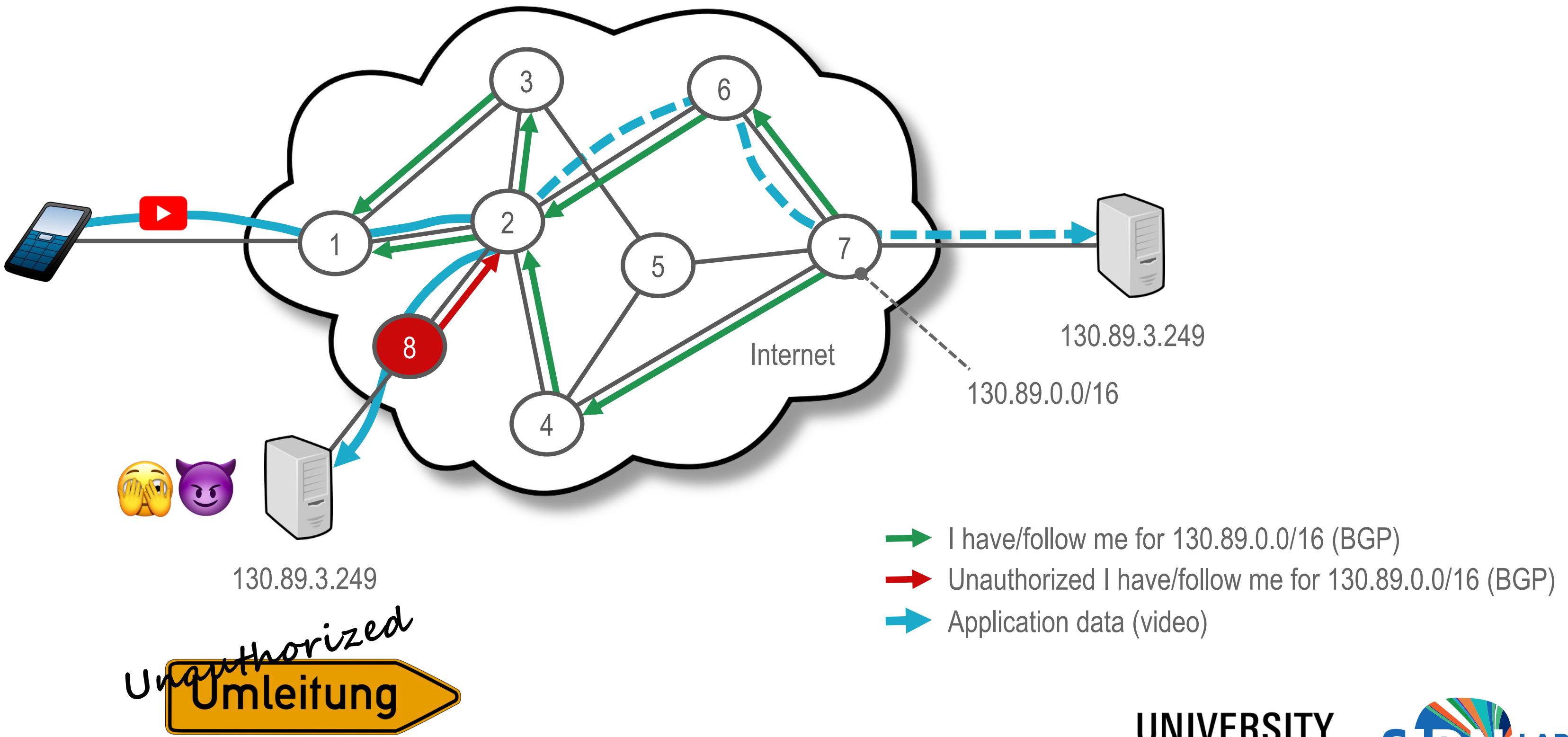
Toy example of Internet routing



BGP = Border Gateway Protocol

Routing hijacks: tricking traffic into taking a “detour”



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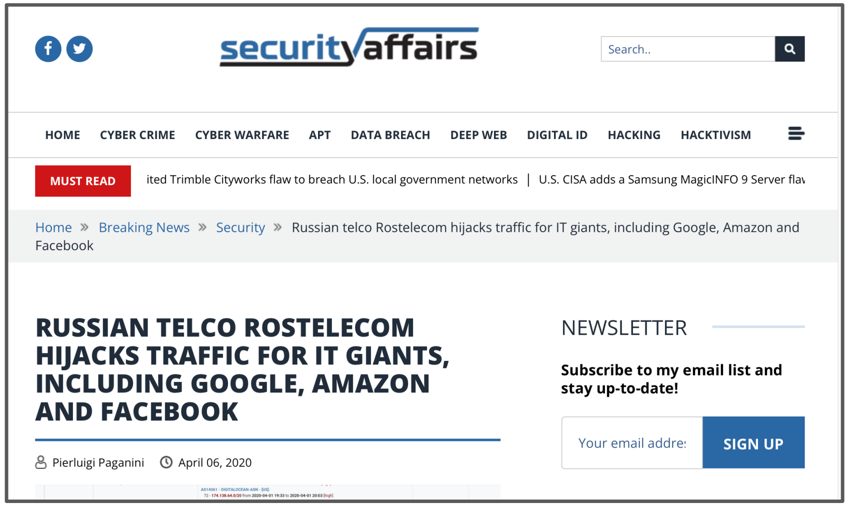
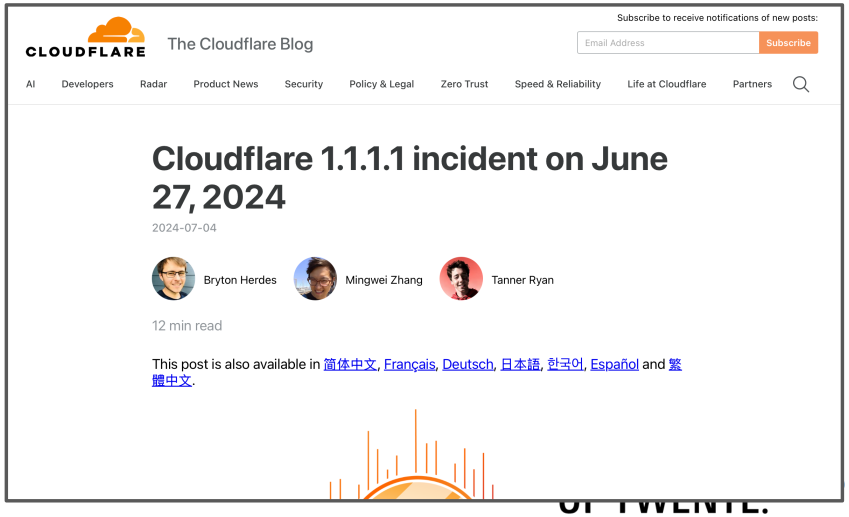
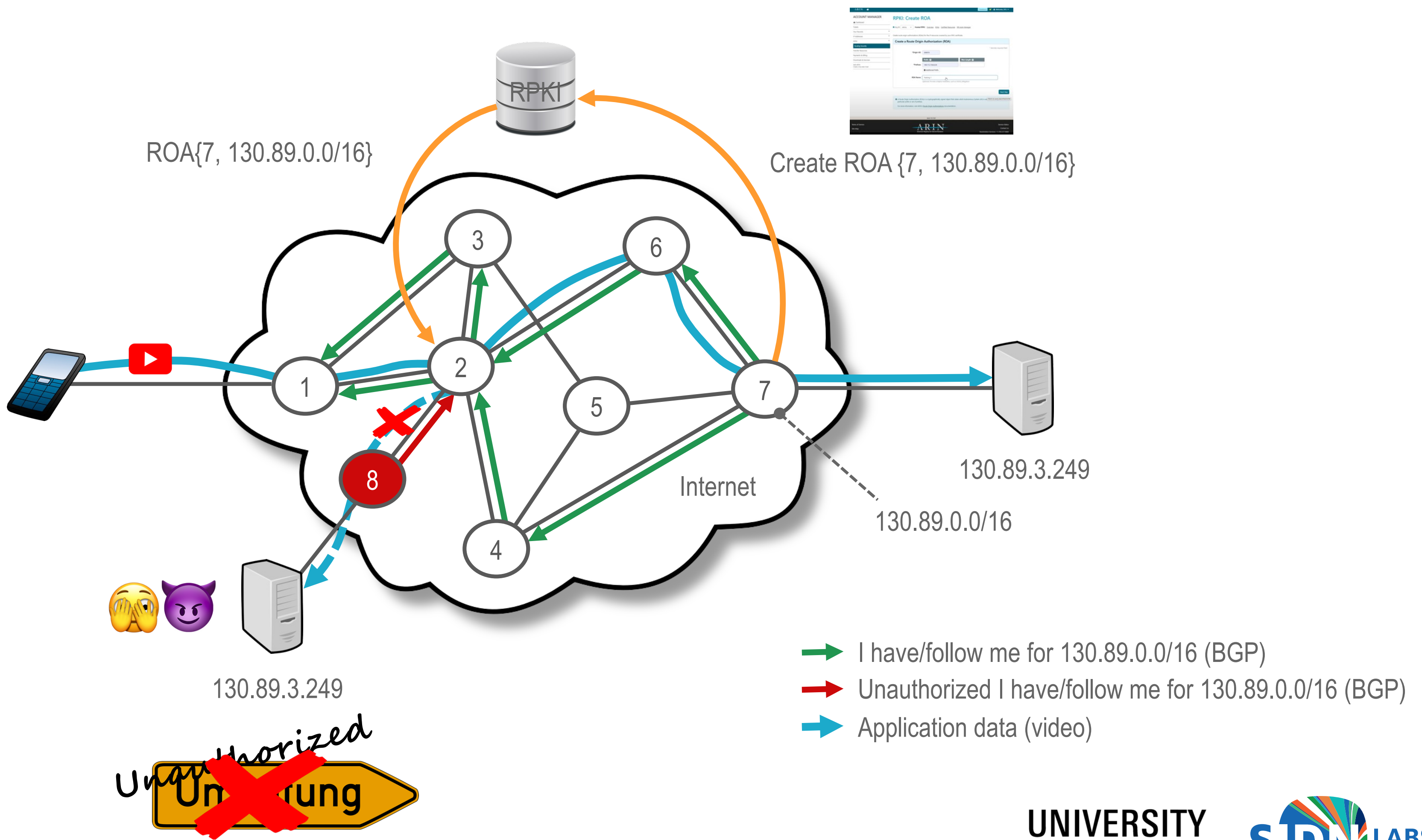
Routing hijacks “in the wild”





Solution: Resource Public Key Infrastructure (RPKI)



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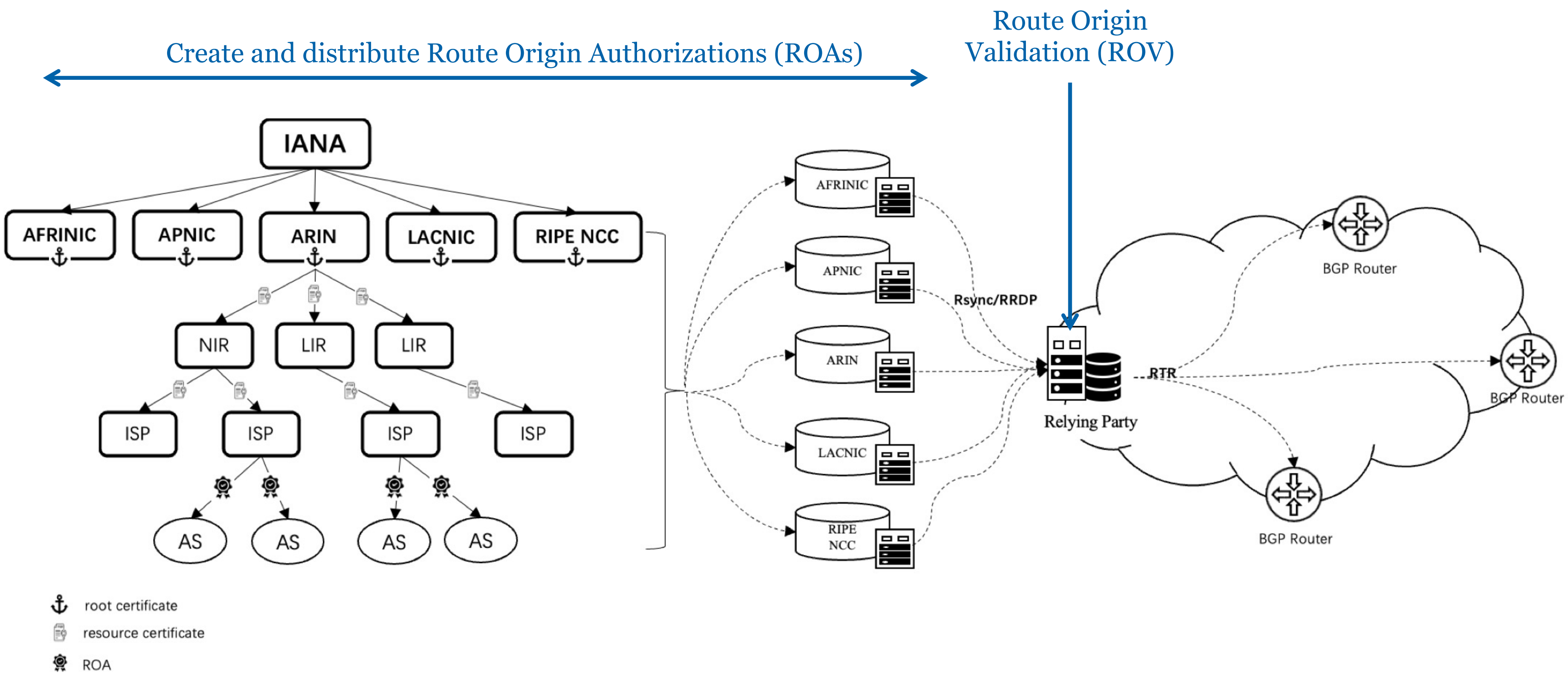
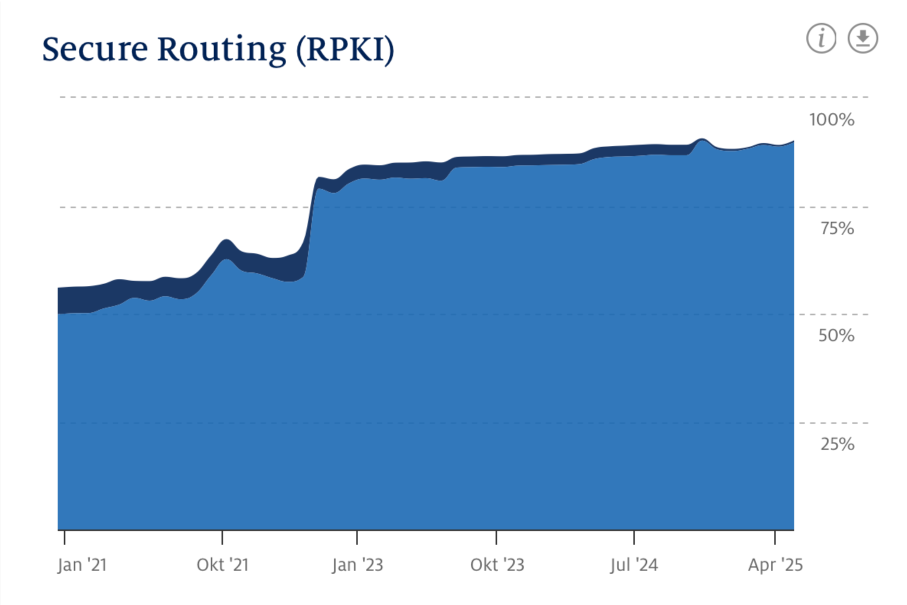
How does the RPKI work?



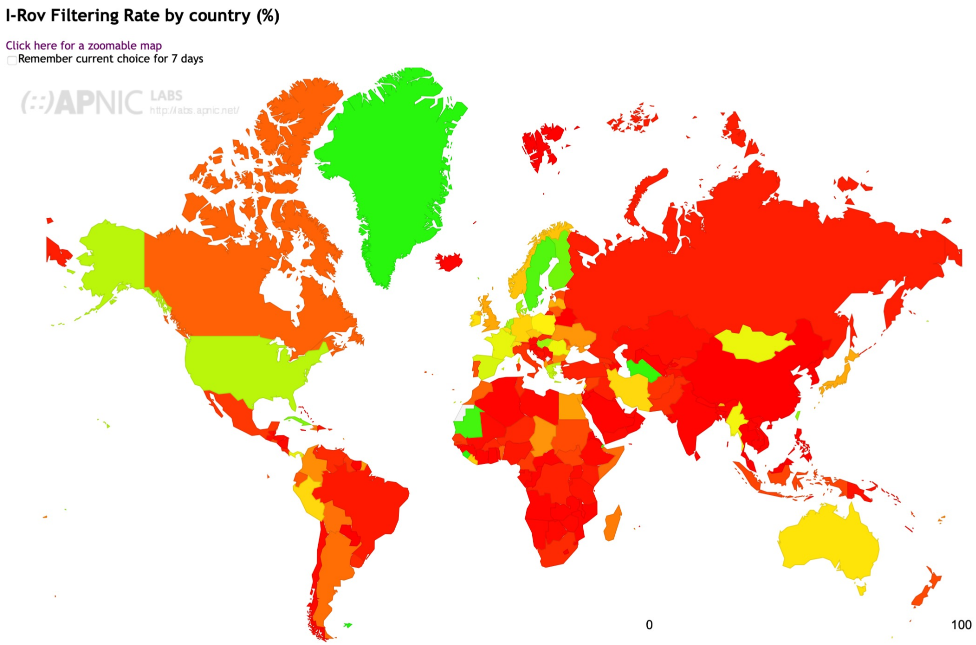
Source: https://2025.apricot.net/assets/files/APAC945/rpki-monitor-modelin_1740438360.pdf

RPKI deployment levels: ROAs and ROV

https://stats.sidnlabs.nl/nl/web.html#secure %20routing%20(rpki)



https://stats.labs.apnic.net/rpki



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Challenges ahead

- Incentivize adoption of ROA and ROV, such as for critical infrastructure
- Increase user demand through internet.nl, for example
- Further develop technologies such as BGPsec and ASPA as well as entirely new concepts such as "risk-based routing" and "zones of trust"


Threat #2: quantum computers
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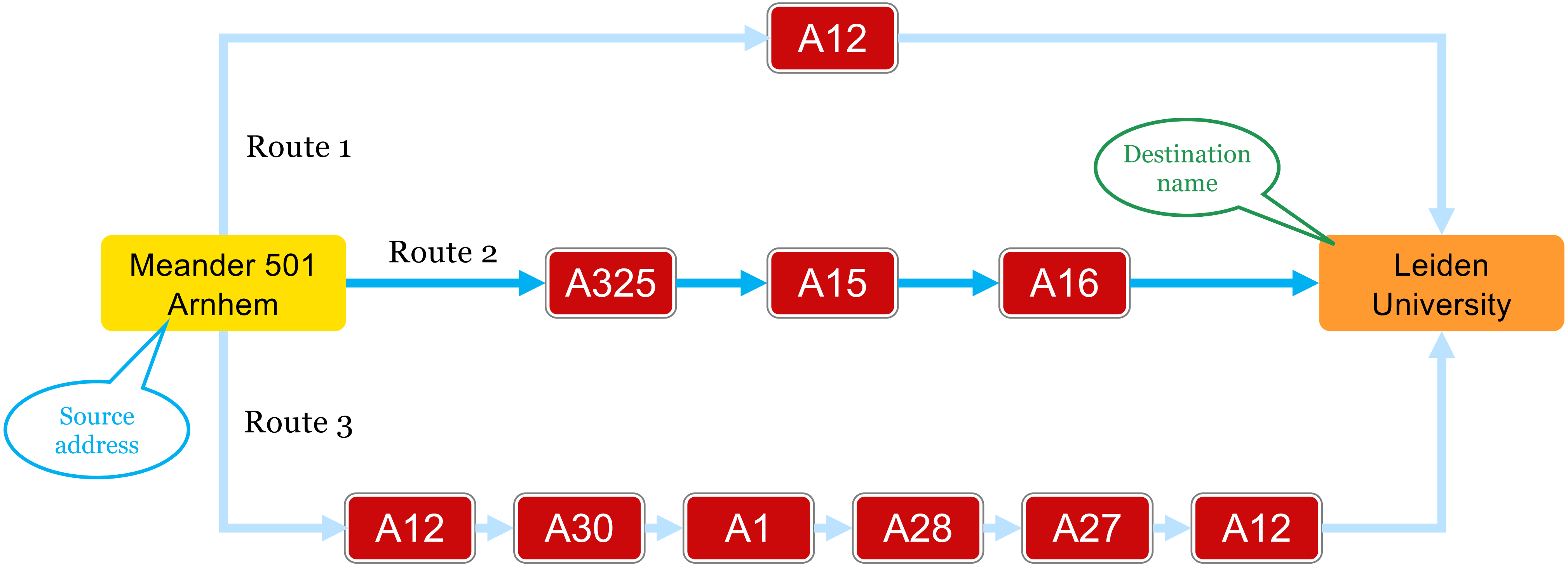
The Internet's naming system in a highway network



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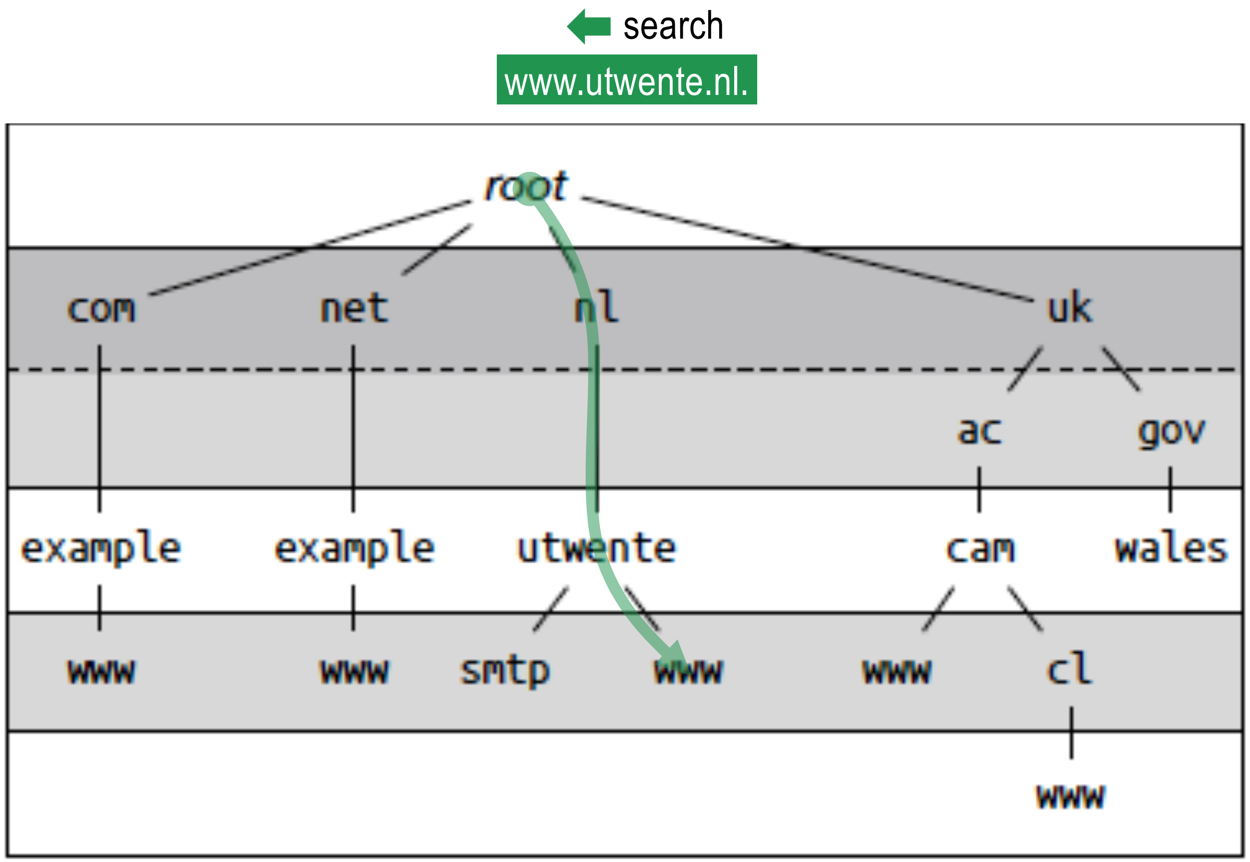
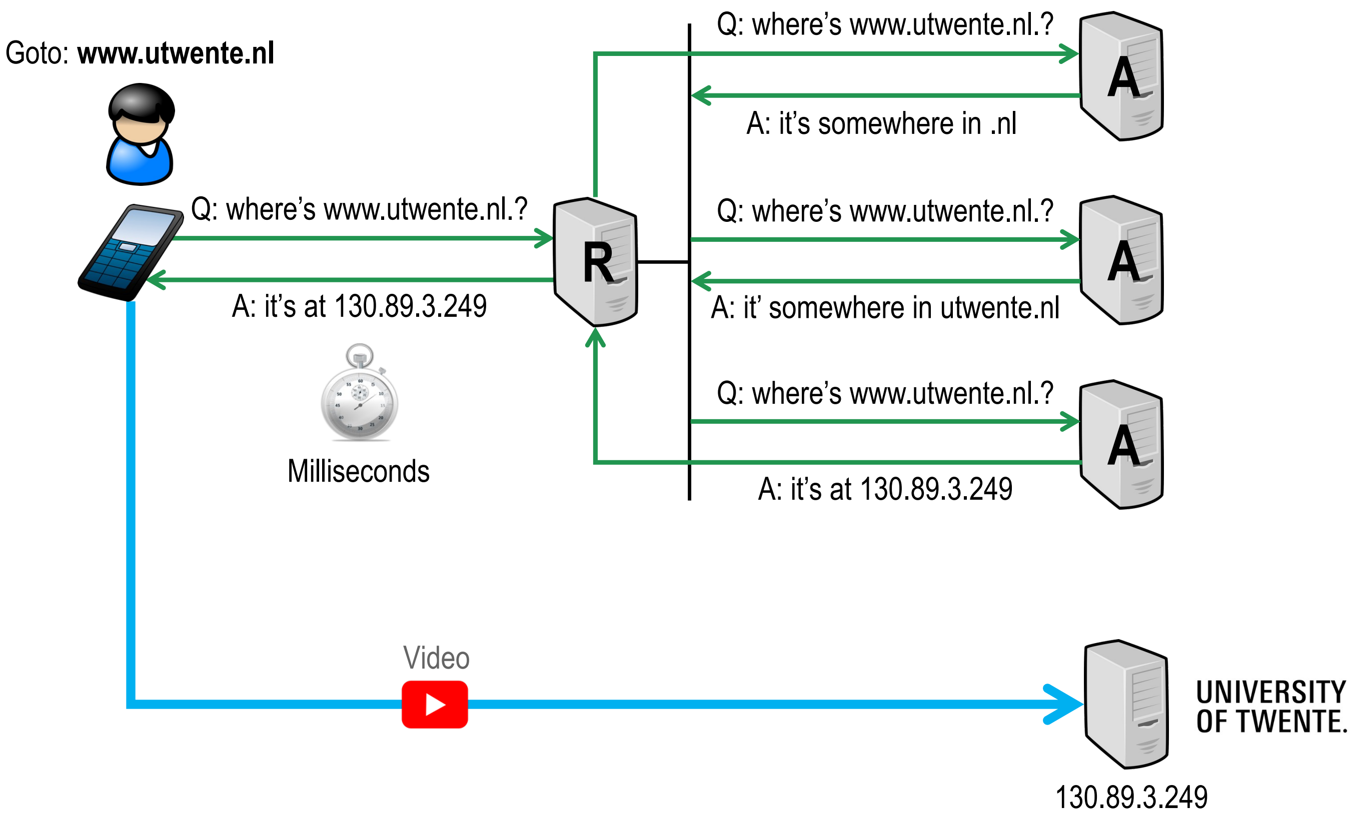
From names to numbers



DNS = Domain Name System

[Toorn22]

Underlying DNS interactions



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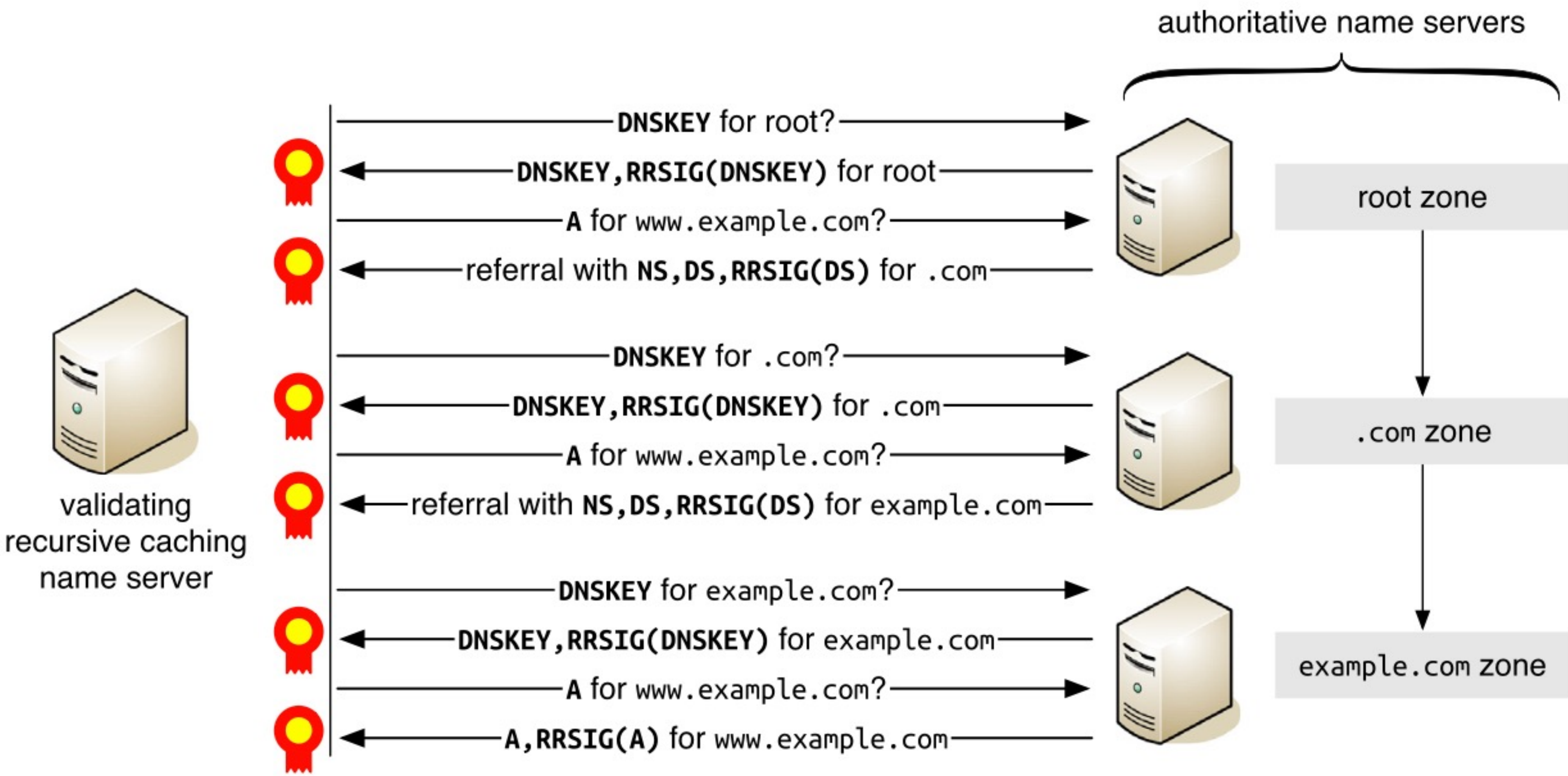
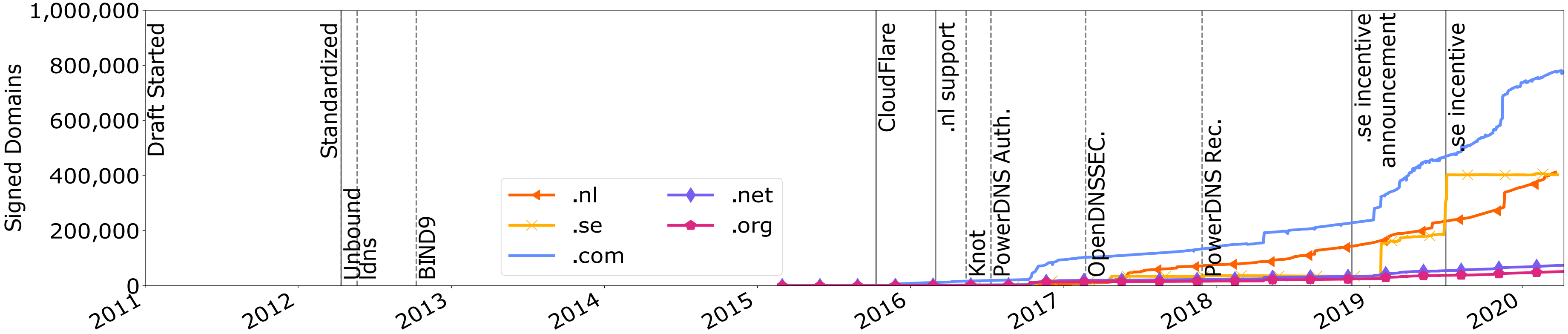
DNSSEC keys and signatures need PQC



O. van der Toorn, M. Müller, S. Dickinson, C. Hesselman, A. Sperotto & R. van Rijswijk-Deij, "Addressing the challenges of modern DNS: a comprehensive tutorial", Computer Science Review, June 2022

Why work on PQC in DNSSEC now?



Domains signed with ECDSA256 and resolvers able validating this algorithm

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M. Müller, "Making DNSSEC Future Proof", Ph.D. thesis, University of Twente, Sep 2021

Requirements for quantum-safe algoritms

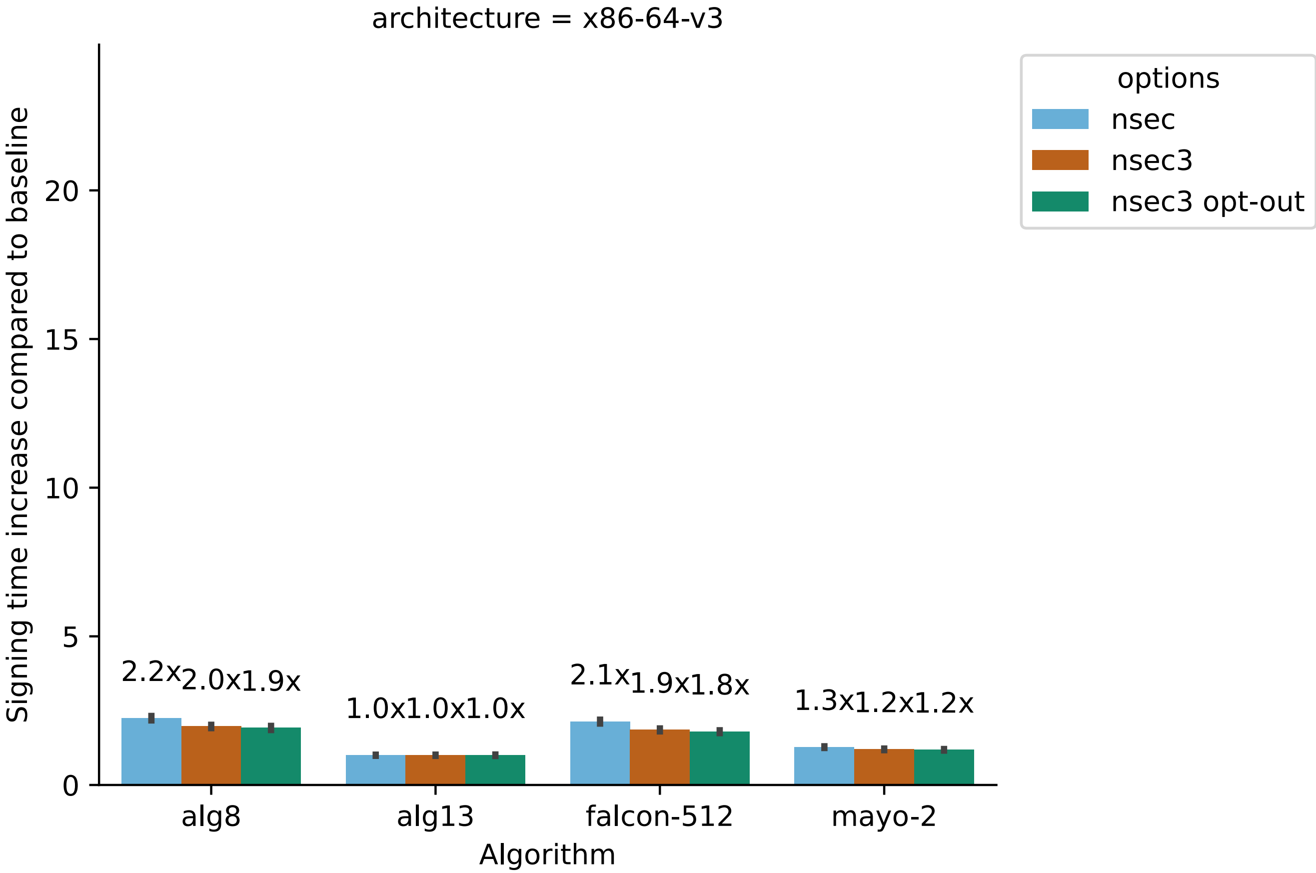
Prio	Requirement	Good	Accepted Conditionally
#1	Signature Size	≤ 1,232 bytes	—
#2	Validation Speed	≥ 1,000 sig/s	—
#3	Key Size	≤ 64 kilobytes	> 64 kilobytes
#4	Signing Speed	≥ 100 sig/s	—

M. Müller et al, "Retrofitting Post-Quantum Cryptography in Internet Protocols: A Case Study of DNSSEC", ACM SIGCOMM Computer Communication Review, vol. 50, no. 4, 2020.

PQC algorithm	ECC	MAYO	SQSign	Falcon
Signature size	😁😁	😁	😁😁	😡
Validation speed	😁	😁	😡	😁
Key size	😁😁	😡	😁😁	😁
Signing speed	😁	😁	😡	😁

Post-quantum signatures zoo: https://pqshield.github.io/nist-sigs-zoo

Signing performance looks good



C. Schutijser, R. Koning, E. Lastdrager, C. Hesselman, "Evaluating Post-Quantum Cryptography in DNSSEC Signing for Top-Level Domain Operators", Traffic Measurements and Analysis conference (TMA2025), June 2025

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Challenges ahead

- Standardization at NIST and in the IETF
- Assess operational impact of PQC algorithms on the DNS and its operators
- Create user awareness, such as through internet.nl
- Develop software, such as via NLnet Labs, NLnet, Sovereign Tech Fund


Internet security measurements
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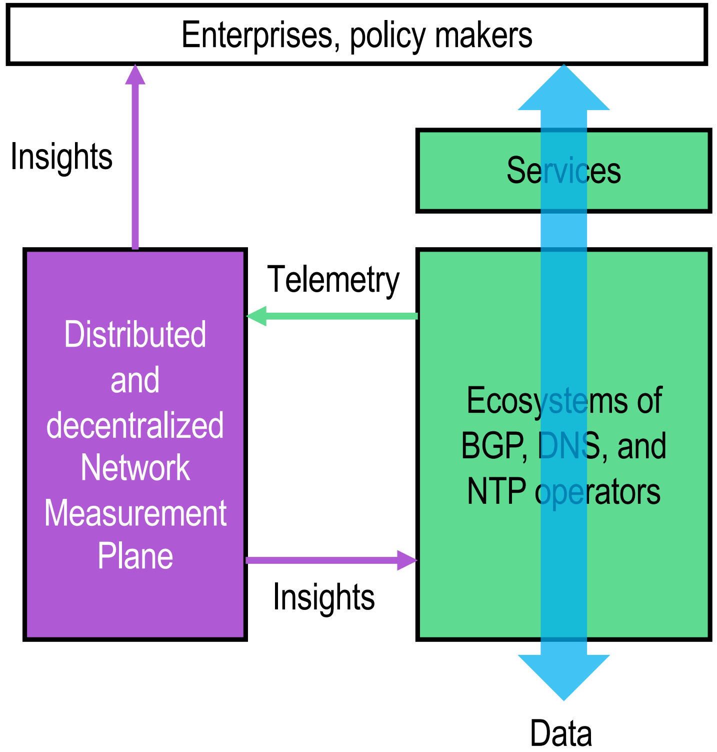
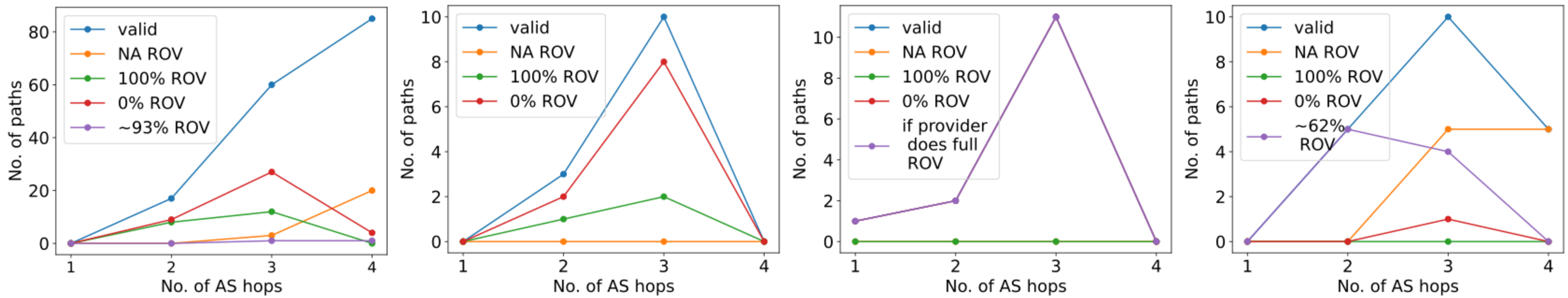
Vision: a measurement plane for Internet security

- Continually map the Internet's behavior and evolution: routing, DNS, time, certificates
- Input for (collaborative) incident response handling, infrastructure engineering, and policy making
- Ideally discover and share data across operators and researchers in an interoperable and federated way



Case study #1: security of network paths



(a) AS15625 (ING bank). **(b) AS56517 (Vitens).** **(c) AS40985 (Eneco energy).** **(d) AS15916 (ABN-Amro Bank).**

Figure 3: Number of paths for different numbers of AS hops between the four CIs and Microsoft mail service.

S. Krishna Khadka, S. Bayhan, R. Holz, and C. Hesselman, "Assessing the security of Internet paths: A case study of Dutch critical infrastructures", ACM/IRTF Applied Networking Research Workshop 2024 (ANRW'24), Vancouver, Canada, July 2024

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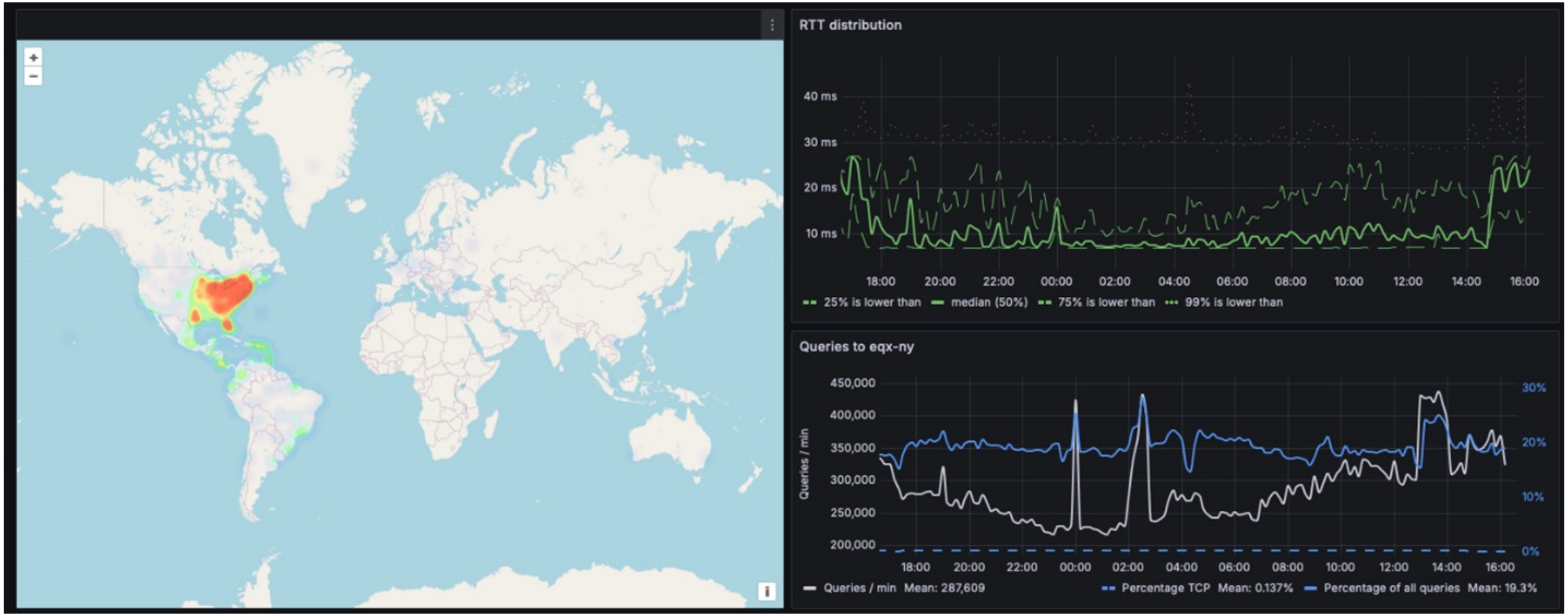
Case study #2: measuring DNS "catchments" for .nl



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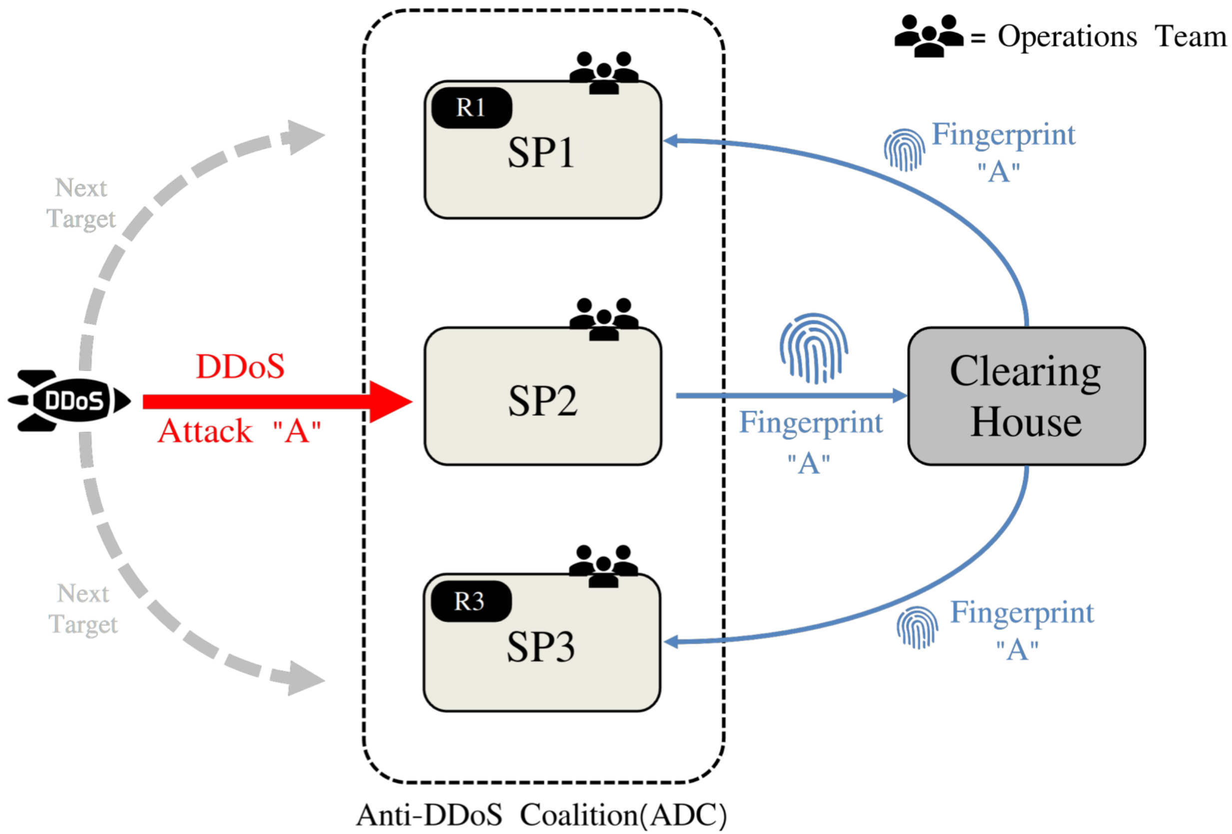
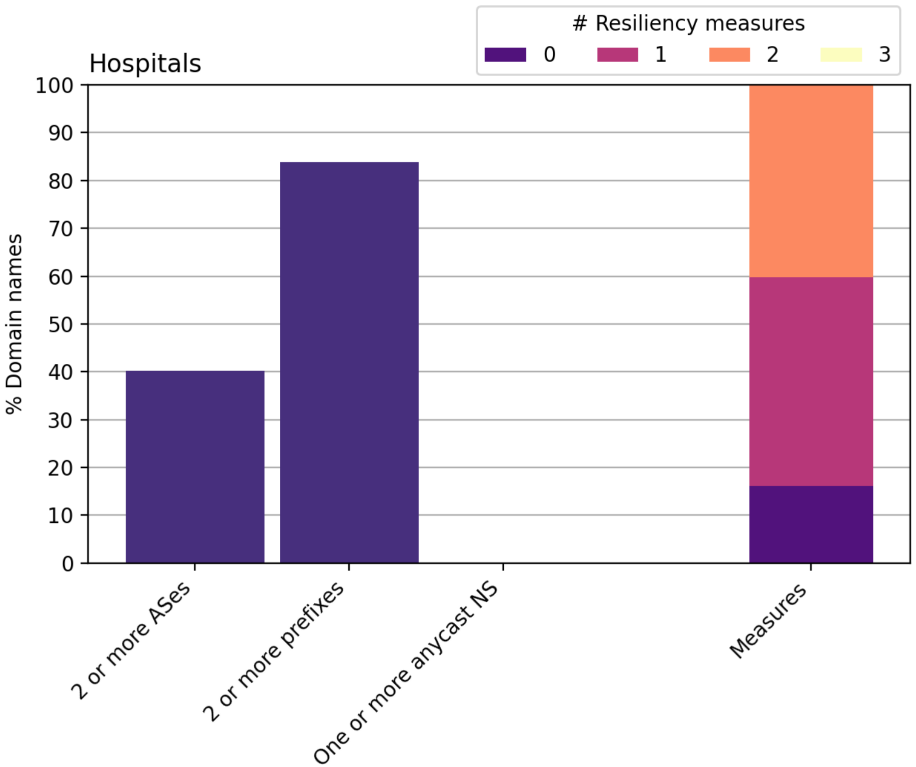
https://www.sidnlabs.nl/en/news-and-blogs/our-dns-infrastructure-in-focus

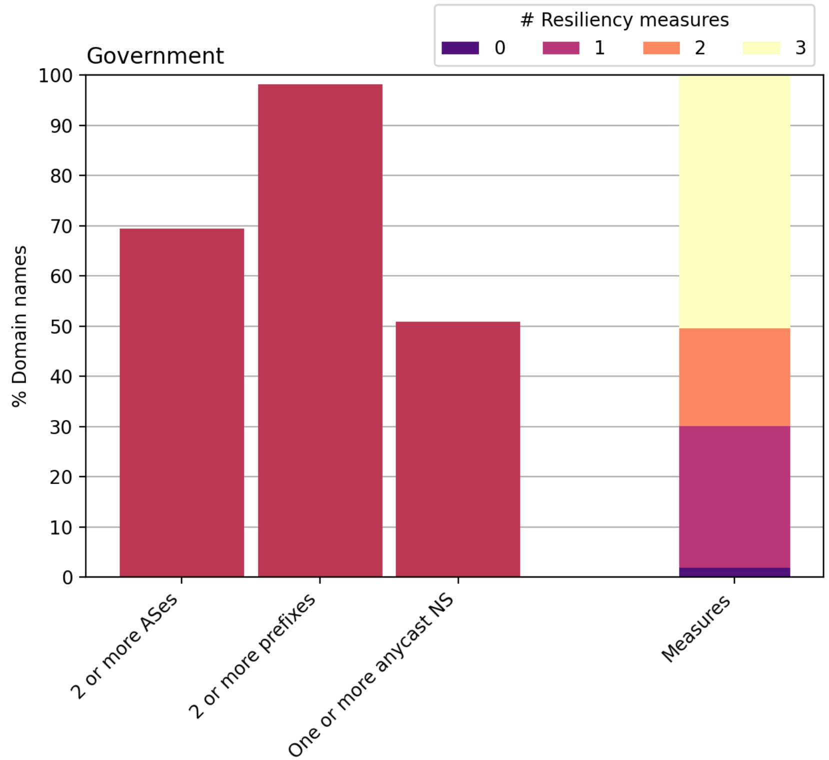
Case study #3: mitigate DDoS attacks collaboratively



R. Yazdani, T. van den Hout, R. Poortinga-van Wijnen, K. Lovink, and C. Hesselman, "Collaboratively Increasing the DDoS-Resilience of Digital Societies Through Anti-DDoS Coalitions", IEEE Communications Magazine, June 2024

Case study #4: DNS resilience in the Netherlands





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https://www.sidnlabs.nl/en/news-and-blogs/can-the-netherlands-digital-infrastructure-withstand-a-knock

Case study #5: evaluation of Internet sanctions

		Austria	Belgium	Bulgaria	Croatia	Cyprus	Czechia	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Lithuania	Netherlands	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	United Kingdom	Switzerland	Russian Federation	United States
	# ASes	8	6	7	3	2	10	10	1	10	10	37	4	5	6	14	2	12	7	5	4	4	6	13	28	18	42	55
	# Upstream resolvers	25	22	11	5	5	34	19	2	21	78	205	7	7	16	33	3	53	19	8	7	9	14	37	103	59	79	229
	# VPs	64	138	28	9	5	57	56	5	73	573	656	21	26	62	115	4	245	34	247	10	15	63	52	192	222	108	661
Orgs listed by the EC	www.rt.com	7	1	9	0	0	38	33	0	2	2	25	0	14	13	23	0	5	28	0	0	0	34	100	81	99	96	98
	de.rt.com	6	1	9	0	0	30	31	0	2	4	25	9	14	28	97	0	6	44	0		0	68	94	81	100	100	98
	deutsch.rt.com	13	48	0	0	0	23	24	0	4	1	24	0	12	27	100	0	62	35	97	0	19	67	100	81	99	96	100
	francais.rt.com	4	3	0	0	0	21	25	0	2	3	26	22	14	22	34	0	6	46	0	0	19	70	100	80	99	90	98
	fr.rt.com	8	46	12	0	0	31	30	0	2	2	93	0	11	14	100	0	64	33	96	0	22	67	100	83	98	97	99
	actualidad.rt.com	19	1	7	0	0	31	32	0	0	3	25	9	12	23	100	0	6	43	0	0	0	66	95	83	100	88	99
	actualidad-rt.com	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	100	100	100	97	99
	www.sputniknews.com	4	8	9	0	0	33	26	0	6	0	30	0	73	16	31	0	3	87	0	0	0	100	95	80	100	88	99
	sputniknewslv.com	90	5	9	100	0	29	29	0	2	60	57	100	47	23	30	100	49	100	100	0	22	100	100	100	100	97	99
	sputniknews.gr	100	1	0	75	0	35	8	0	0	60	63	11	46	25	26	100	50	100	100	0	0	100	100	100	98	96	99
	sputniknews.cn	100	1	8	80	0	27	8	0	2	58	56	100	41	25	31	100	45	100	100	19	0	95	100	100	100	97	100
	radiosputnik.ria.ru	5	34	7	100		42	80	0	2	99	99	87	100	100	100	0	100	6	100	0	100	95	100	100	100	97	100
	sputnikglobe.com	100	100	100	100	100	100	100	100	7	100	99	100	100	100	100	100	100	100	100	100	16	100	100	100	100	89	100
	www.rtr-planeta.com	6	55	100	60	100	100	100	100	2	95	100	100	100	41	100	100	47	12	0	100	100	100	100	100	100	97	99
	rtr-planeta.ru	17	100	100	100	100	100	77	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100
	vgtrk.ru	100	3	100	80	100	100	26	100	2	100	33	66	100	100	100	0	100	33	96	100	100	100	100	100	100	96	100
	www.vesti.ru	15	52	81	80	100	100	30	0	36	56	100	100	100	34	100	100	100	40	96	100	100	100	100	100	100	94	99
	www.tvc.ru	23	4	81	60	100	100	28	0	35	53	84	37	100	89	100	0	48	100	95	100	100	95	100	100	100	97	100
	ntv.ru	4	46	100	0	100	100	28	0	2	100	29	75	100	100	100	0	98	36	0	100	100	95	100	98	100	97	100
	smotrim.ru	100	58	100	19	100	100	30	0	2	57	31	50	100	18	100	0	100	33	0	100	100	95	100	100	100	97	99
	ren.tv	9	1	100	0	100	100	34	0	2	99	29	55	100	33	100	0	97	37	0	100	100	100	89	100	100	94	99
	1tv.ru	0	3	100	0	100	100	29	0	2	99	31	19	100	100	100	0	97	33	95	80	100	95	100	100	100	100	99
	ww.rtarabic.com	15	100	100	100	100	100	46	0	39	56	85	66	100	100	100	100	96	100	100	100	100	100	100	100	100	96	100
	sputnikarabic.ae	19	100	100	100	100	100	25	0	2	58	47	50	100	100	100	100	45	100	95	100	100	100	100	100	100	96	99
Mirror pages	esrt.online	17	100	100	100	100	94	100	100	100	99	99	100	92	100	100	100	100	100	100	100	100	100	100	100	100	94	99
	esrt.press	26	100	100	100		100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	rtde.site	14	100	100	100	100	100	76	100	100	99	28	75	100	100	100	100	100	100	96	100	100	100	100	100	99	100	100
	rtde.xyz	0	100	100	100	100	100	73	100	100	99	30	55	100	100	100	100	100	100	98	100	100	100	100	100	100	94	99
	rtde.team	0	100	100	100	100	100	73	100	100	100	32	50	100	100	100	100	100	100	98	100	100	100	100	100	100	96	99
	test.rtde.live	22	100	100	100	100	100	76	100	100	100	25	54	100	100	100	100	100	100	96	100	100	94	100	100	100	100	99
	rtde.live	18	98	100	100	100	100	76	100	100	99	98	92	100	100	100	100	100	100	100	100	100	95	100	100	93	97	100
	test.rtde.website	100	100	100	100	100	100	81	100	100	100	24	60	100	100	100	100	100	100	96	100	100	100	100	100	100	100	100
	rtde.tech	12	100	100	100	100	100	85	100	100	100	27	72	100	100	100	100	100	100	96	100	100	100	100	100	100	97	99
	rtde.world	35	100	100	100	100	100	78	100	100	99	29	63	100	100	100	100	100	100	94		100	100	100	100	100	100	99
	rtde.me	21	100	100	100	100	100	76	100	100	99	29	46	100	100	100	100	100	100	95	100	100	100	100	100	98	97	99
TV streaming svcs	a-russia.ru	100	100	100	60	100	94	86	0	100	100	30	50	100	100	100	0	100	100	95	100	100	100	100	99	100	100	98
	wwitv.com	100	100	100	100	100	100	43	100	88	100	28	28	100	100	100	0	100	100	94	100	100	100	100	100	100	100	100
	www.glaz.tv	100	100	100	60	100	100	81	0	97	100	43	60	100	100	100	0	100	100	96	100	100	100	83	99	100	100	100
	www.russisches-tv-fernsehen.de	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	100	100	100	96	99
	ontvtime.tv	100	53	100	60	100	100	31	0	88	100	31	71	100	25	100	0	100	100	95	100	100	100	100	100	99	100	100
	spbtv.online	100	100	100	100	100	100	100	0	100	100	32	50	100	100	100	0	100	100	97	100	100	100	100	100	100	97	100
	www.coolstreaming.us	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	92	99	100	97	99
	www.livehdtv.net	94	100	100	100	100	100	100	0	100	99	43	37	100	100	100	0	100	100	96	100	100	100	100	100	100	96	99
	snanews.de	15	1	9	100	25	50	28	100	2	59	31	28	15	26	83	100	86	100	94	0	30	100	100	100	100	96	100
Other	duma.gov.ru	100	100	100	100	100	100	81	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	99
	www.sber-bank.by	100	100	100	100	100	100	77	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	94	100
	www.sberbank.ru	100	100	100	100	100	100	85	100	100	100	100	81	100	100	100	100	100	100	100	100	100	96	100	100	100	100	100
	www.gazprombank.ru	100	100	100	100	100	100	78	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	99	99	97	99

J. Kristoff, M. Müller, A. Filastò, M. Resing, C. Kanich, and N. ten Oever, “Internet Sanctions on Russian Media: Actions and Effects”, Free and Open Communications on the Internet, February 2024

Challenges ahead

- Mindset change: securing the Internet is a joint responsibility
- Interoperability of network measurements and analyses
- Make measurements an integral part of the Internet architecture
- Data-driven design and evaluation of security-related policies


Future Internet security concepts
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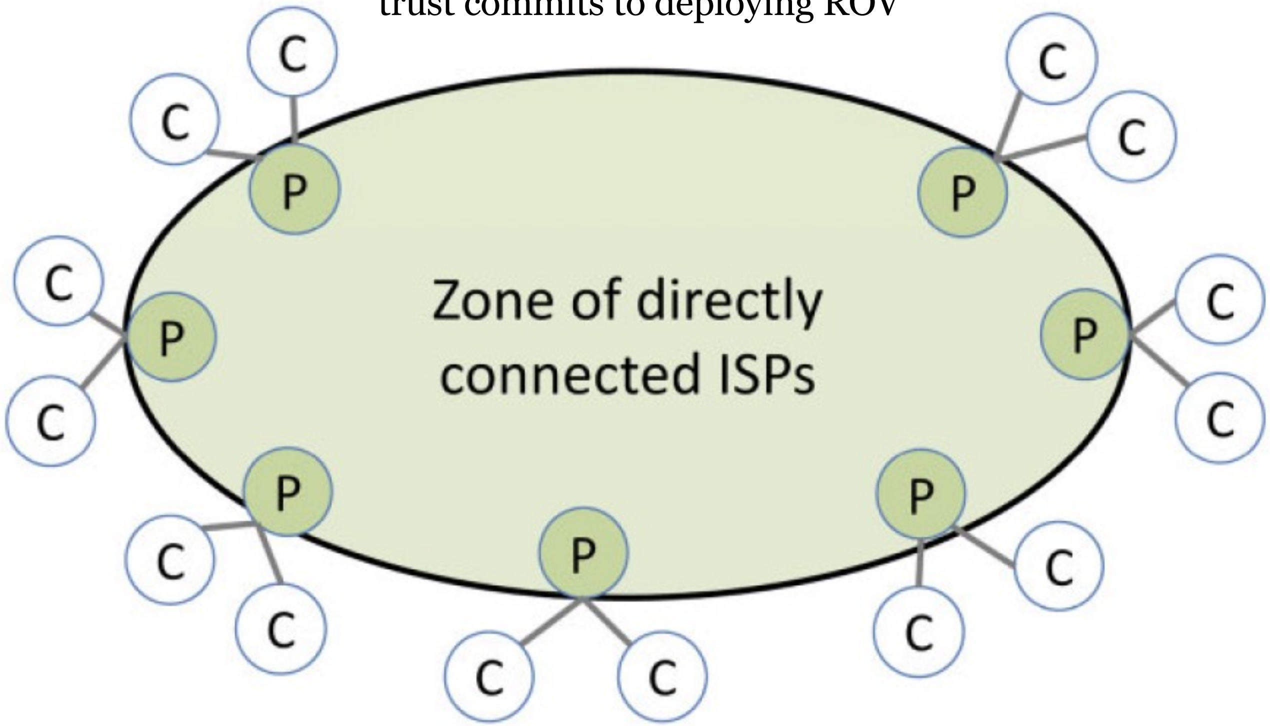
Concept #1: policy zones

- Groups of networks that agree on a "networking regime"
  - While staying fully connected to the rest of the Internet
  - Protect against routing hijacks, path hijacks, quantum computers
  - Deploy entirely new security-related features such path-aware networking

- Increased security levels at a "regional" level
  - New applications, such as remote train driving and intelligent transport systems
  - Verify that traffic is staying within certain jurisdictions
  - Might be more realistic than making BGP globally secure

Example #1: zones of trust

Example: everyone in the zone of trust commits to deploying ROV



D. Clark, C. Testart, M. Luckie, kc claffy, “A path forward: improving Internet routing security by enabling zones of trust”, Journal of Cybersecurity, Volume 10, Issue 1, December 2024, https://doi.org/10.1093/cybsec/tyae023

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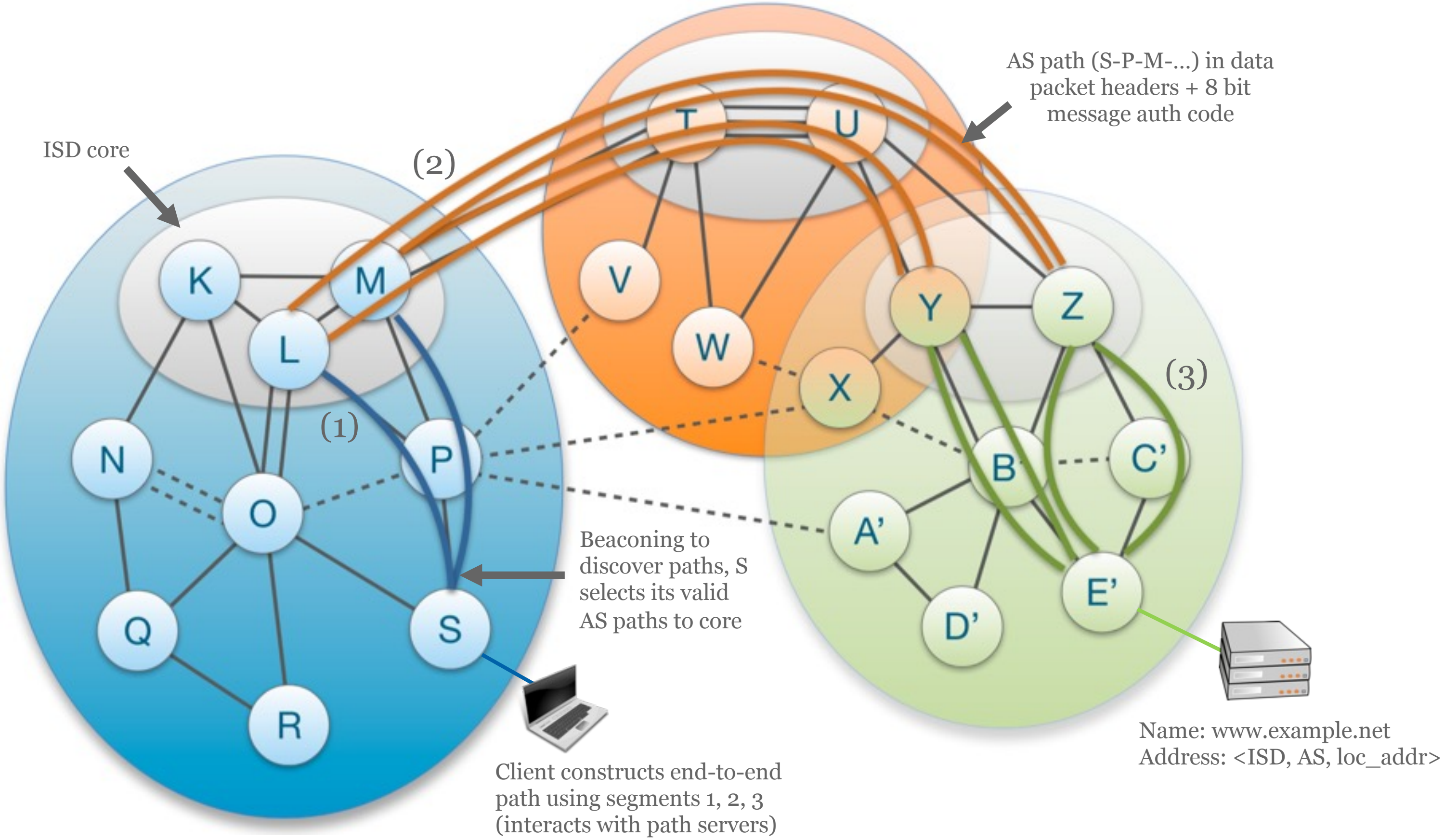
Example #2: isolation domains in SCION



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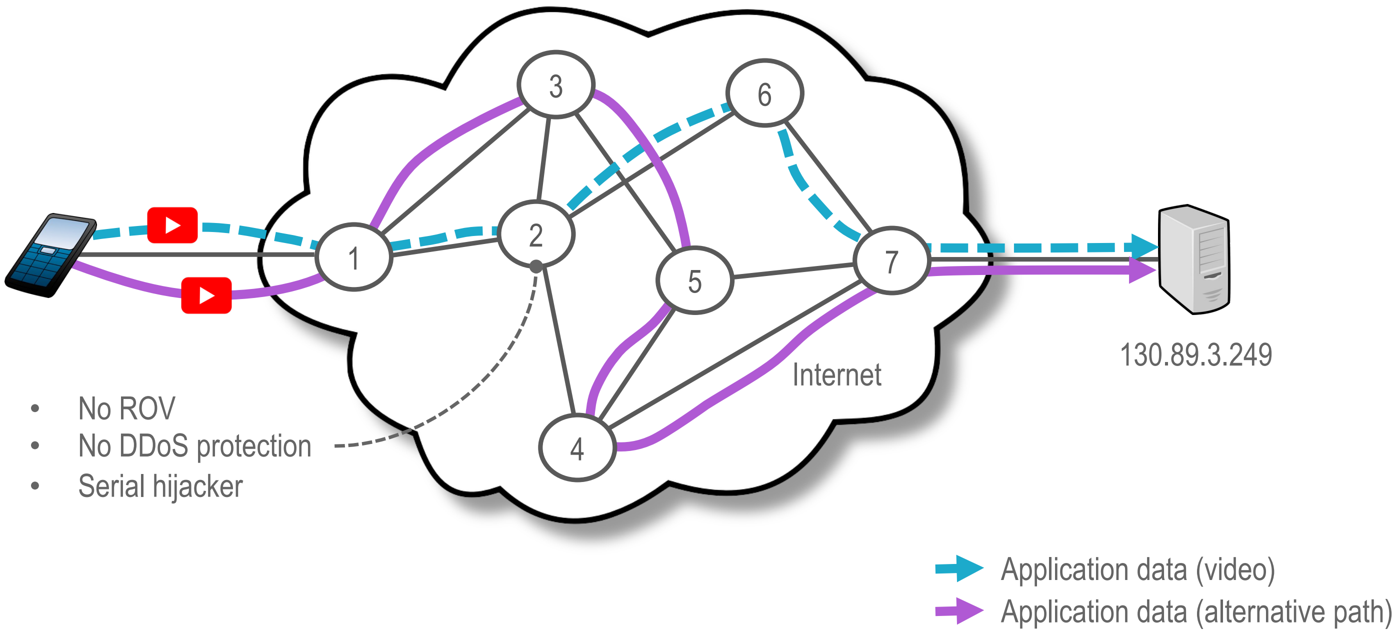
https://www.sidnlabs.nl/en/news-and-blogs/new-internet-infrastructures-an-introduction-to-scion

Concept #2: risk-based routing



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Challenges ahead

- Develop required measurement methodologies, such as
  - Demonstrate that the routers in a zone conform to the zone's rules
  - Create risk profiles of Autonomous Systems
- Experimentation and evaluation
  - Assess scalability, privacy, among others
  - Projects UPIN and CATRIN project and its demonstrator (under development)
- How could upper layers in the technology stack benefit? Example: Ecofed

Σ

Adding it all up

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Key takeaways

- The Internet is our newest civil infrastructure, but this time it's a global one
- Internet security is a joint responsibility (BGP, DNS)
- Internet measurements and analysis should be part of the Internet architecture
- Future applications might require new Internet security concepts
- Education, academic and applied research are essential to make all that happen

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Reinforce global Internet <u>and</u> European infrastructure

Global Internet

	KEY COUNTRIES	KEY FIRMS
Data and artificial intelligence	US, China	OpenAI, Microsoft, Google, Meta, Anthropic, XAI, Amazon, Baidu, Tencent, Alibaba, DeepSeek
Software	US, China, Germany	Microsoft, Apple, Alphabet, Meta, Amazon, Salesforce, SAP, ByteDance, Tencent
Cloud	US, China	Amazon, Microsoft, Alphabet, Alibaba
Internet of things & devices	US, China, Korea, Germany	Amazon, Google, Apple, Samsung, Huawei, Bosch, Siemens, Xiaomi
Networks	US, China, Europe, Japan	Huawei, Nokia, Ericsson, ZTE, SpaceX, NEC
Chips	Taiwan, Korea, US, Netherlands	TSMC, Samsung, Intel, NVIDIA, AMD, ASML
Raw materials, energy, and water	US, China, Russia	Chinese government (through SOEs e.g., China Rare Earth Group), ExxonMobil, Gazprom

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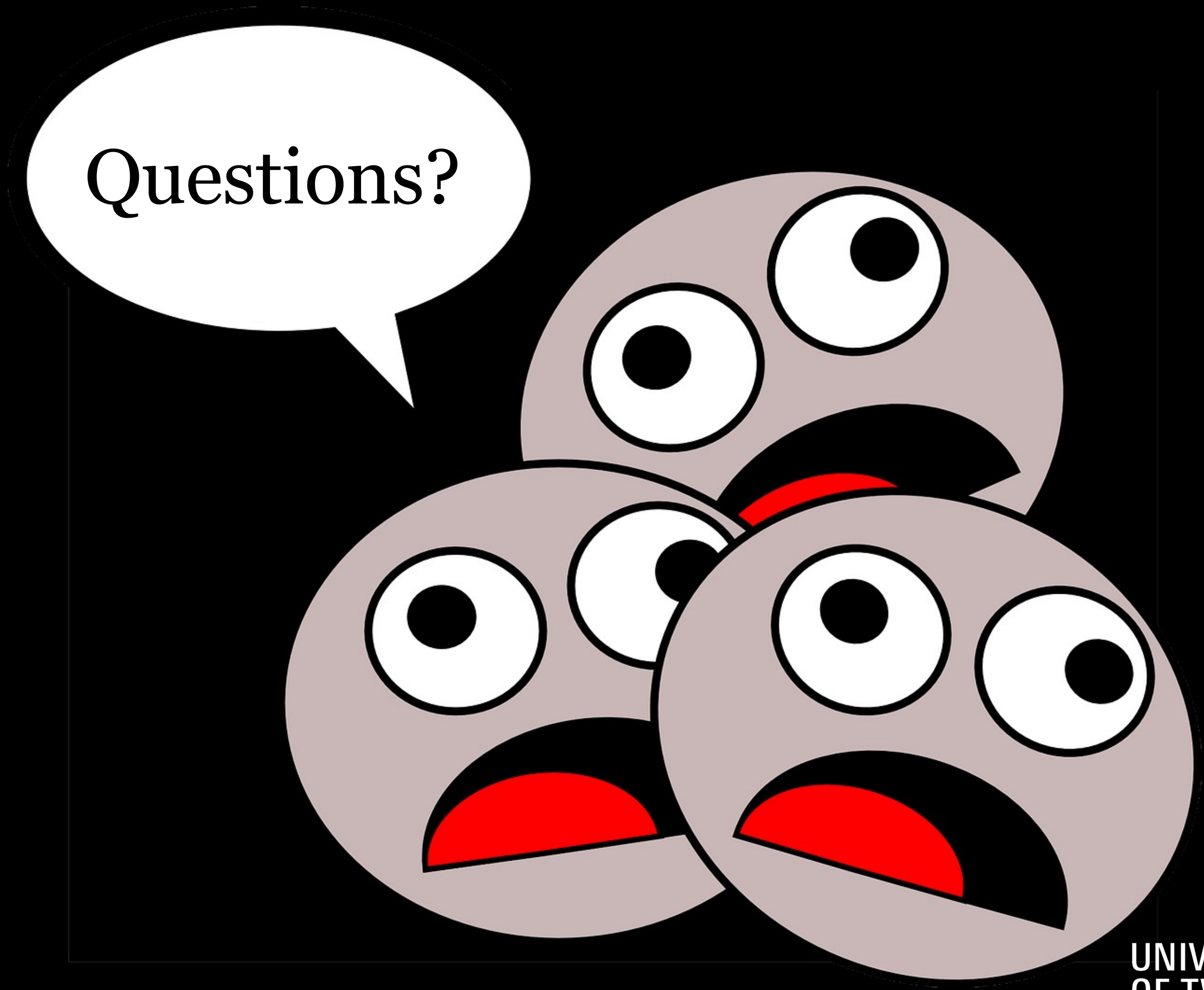

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To what extent will you be able to impress your friends with your knowledge on Internet security and where it might be going?

🙂 😐 ☹️

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