Towards Better Internet Citizenship: Reducing the Footprint of Internet-wide Scans by Topology Aware Prefix Selection

Johannes Klick, Stephan Lau
Matthias Wählisch, Volker Roth

{johannes.klick,stephan.lau,m.waehlisch,volker.roth}@fu-berlin.de

Freie Universität Berlin

Internet-Wide Service Discovery

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- Collection of

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Internet-Wide Service Discovery: Problems

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The censys.io project transmits more than 72.2 billion IP packets per week.

Common Scan Strategies for Service Discovery

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Announced addresses (BGP)

Addresses: $\sim$2.8 billion

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IP hitlists and samples

Addresses: 1-20 million

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Can we do better?

TASS: Topology Aware Scanning Strategy

Announced addresses (BGP)

Addresses: ∼2.8 billion

BGP prefix hitlists (TASS)

Addresses: 0-2.8 billion

IP hitlists and samples

Addresses: 1-20 million

Assumption for TASS

Hypothesis:

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- Hosts with dynamic IP addresses do not often change their announced BGP network prefix.

TASS in Action

Steps:

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Result: Reduce scan traffic by 35-90 % and miss only 1-10 % service responses.

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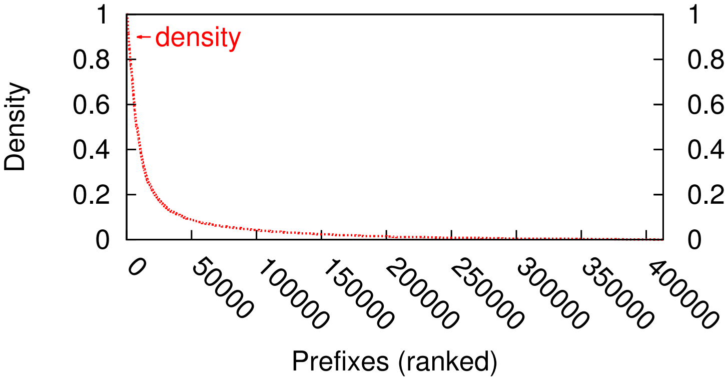
Get and Sort prefixes (HTTPS)



- Prefixes obtained by CAIDA Routeviews Prefix-to-AS database
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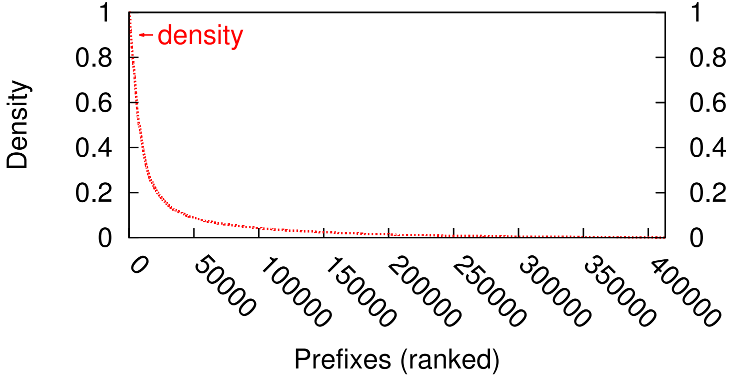

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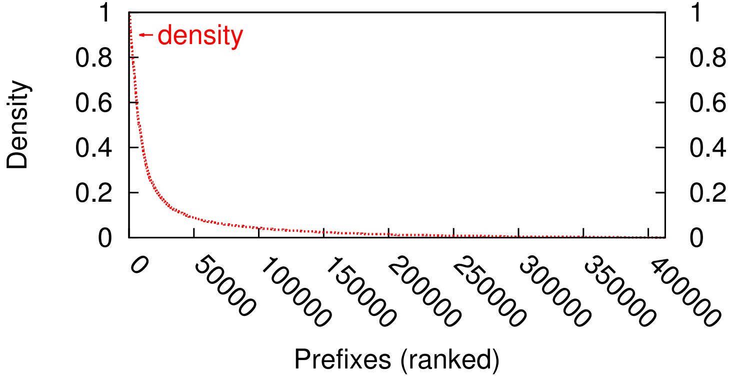

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- Prefixes sorted by their density

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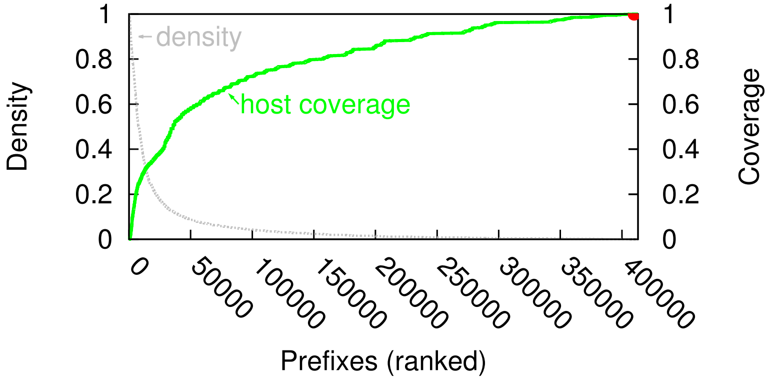

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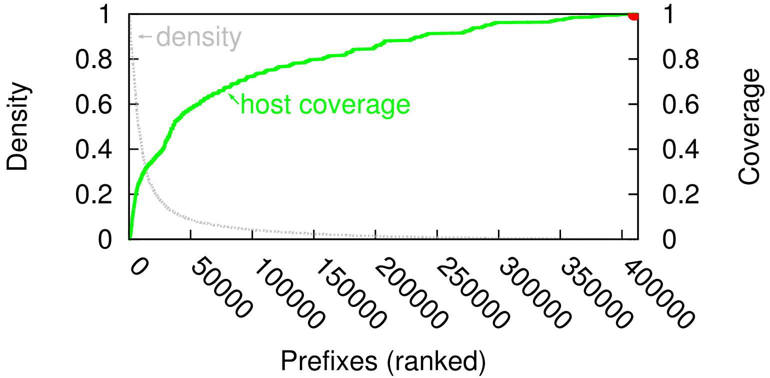

- **100 %** of the HTTPS host are distributed over ≈ 410,000 prefixes.

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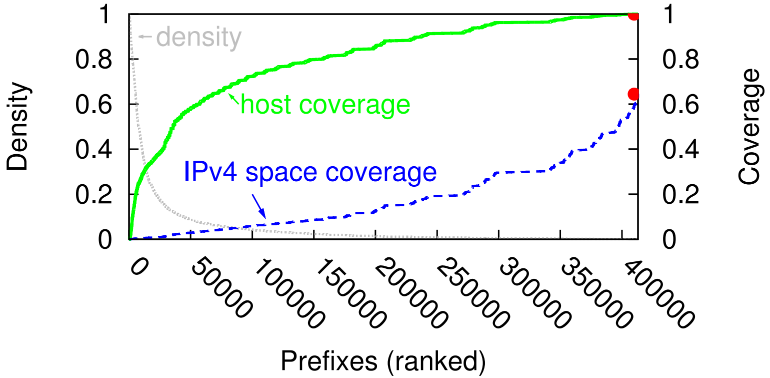

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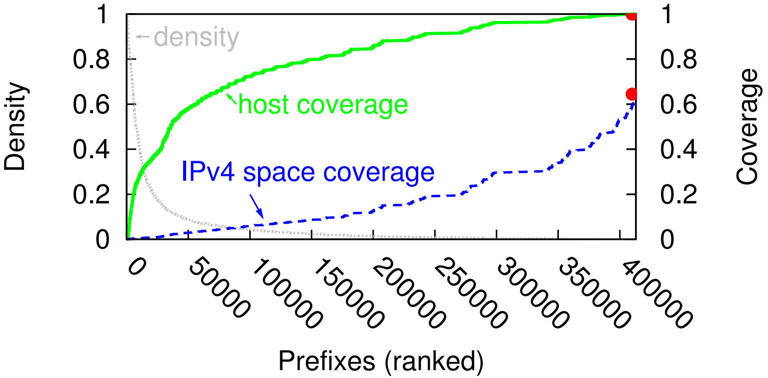

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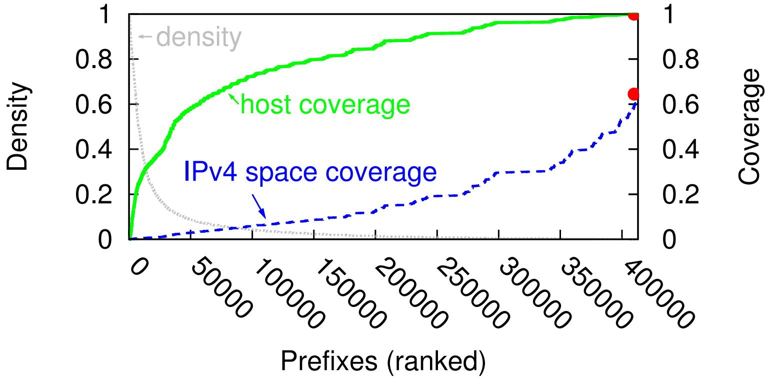

- Select all prefixes with density > 0
- Scanning **100 %** of the HTTPS host results in a IPv4 adress space coverage of **64,5 %.**

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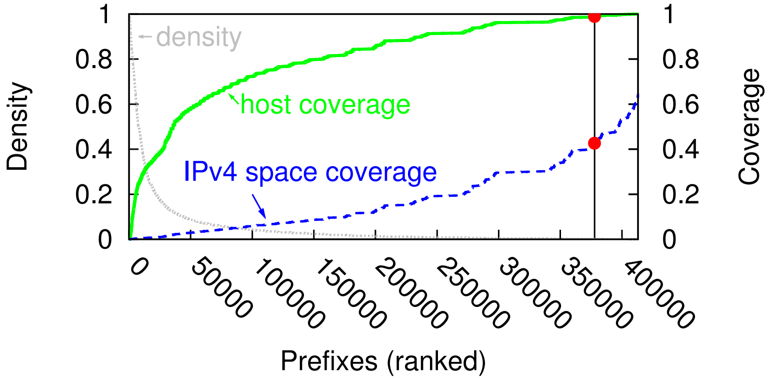

- Scanning **99%** of all HTTPS hosts results in a address space coverage of only **42,7%**
- Skipping some prefixes with the lowest density

Host Coverage vs. IPv4 Space Coverage

Adress Space Coverage	ϕ	FTP	HTTP	HTTPS	CWMP
	1	0.574	0.648	0.645	0.332
	0.99	0.371	0.440	0.427	0.113
	0.95	0.206	0.279	0.262	0.085
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- Host / address space coverage ratio depends on the prototocol.

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- We are able to scan **every second** host by scanning just **2%** of the announced IPv4 address space!
- This results in a scan traffic reduction of **98 %** compared to a IPv4 full scan.

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Steps:

1. Perfom a full IPv4 scan once
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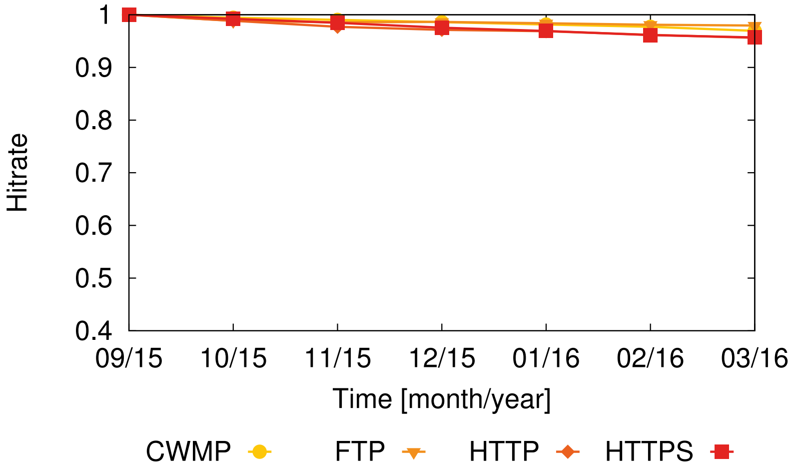
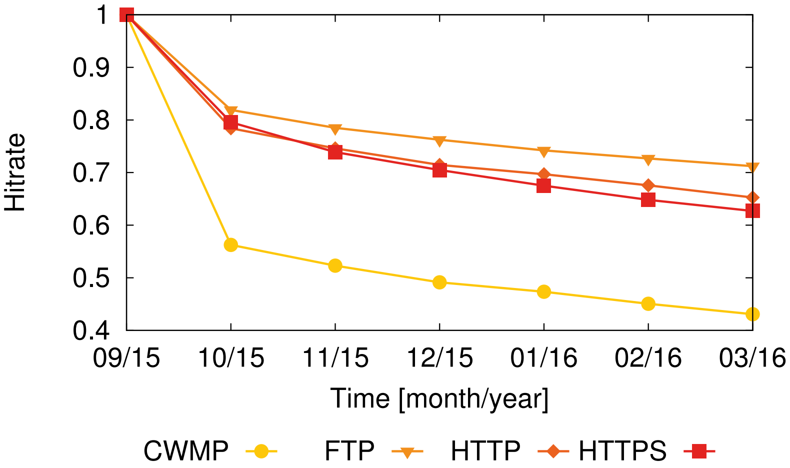
TASS compared to a IPv4 full scan ($\phi = 1$)



- After six months, TASS finds only **4% less hosts** than a IPv4 full scan.

IP Hitlists compared to a IPv4 full scan



- After six months, IP hitlists finds **30-55% less hosts** than a IPv4 full scan.

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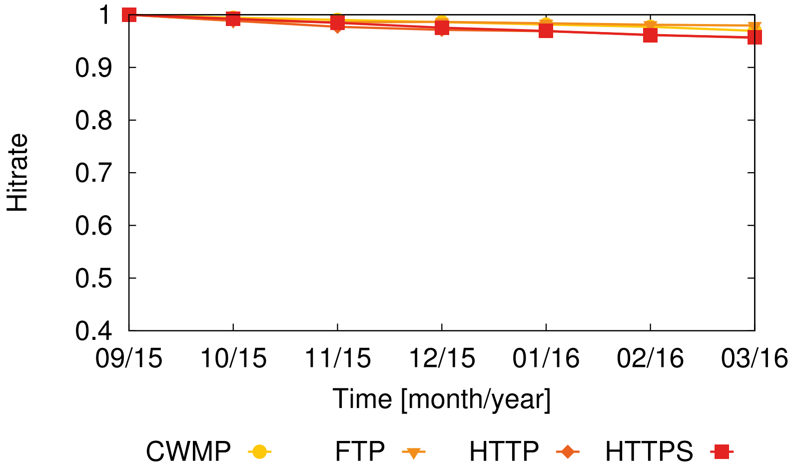

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Future Work

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- Analysis of longer time periods and more protocols

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- **50 %** of HTTP(S), FTP, CWMP hosts can be scanned by probing **2%** of the Internet.
- Scanning results of BGP prefix hitlists are quite stable over time for at least 6 months.
- Services with a high portion of dynamic IPs particularly benefit from TASS in comparison to IPv4 hitlists

The End


I DON'T ALWAYS EAT COOKIES.
BE A GOOD INTERNET CITIZEN.
SCAN LESS. DOESN'T HURT.

Questions?

More details:

"Towards Better Internet Citizenship: Reducing the Footprint of Internet-wide Scans by Topology Aware Prefix Selection"

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johannes.klick@fu-berlin.de

Stephan Lau
Freie Universität Berlin
stephan.lau@fu-berlin.de

Matthias Wählisch
Freie Universität Berlin
m.waehlisch@fu-berlin.de

Volker Roth
Freie Universität Berlin
volker.roth@fu-berlin.de

ABSTRACT

Internet service discovery is an emerging topic to study the deployment of protocols. Towards this end, our community periodically scans the entire advertised IPv4 address space. In this paper, we question this principle. Being good Internet citizens means that we should limit scan traffic to what is necessary. We conducted a study of scan data, which shows that several prefixes do not accommodate any host of interest and the network topology is fairly stable. We argue that this allows us to collect representative data by scanning less. In our paper, we explore the idea to scan all prefixes once and then identify prefixes of interest for future scanning.

Based on our analysis of the *censys.io* data set (4.1 TB data encompassing 28 full IPv4 scans within 6 months) we found that we can reduce scan traffic between 25-90% and miss only 1-10% of the hosts, depending on desired trade-offs and protocols.

1. INTRODUCTION

Fast Internet-wide scanning is growing in popularity among researchers. At the time of writing, researchers regularly scan the Internet for vulnerable SSL certificates [6,12], SSH public keys [10], and for the banners of plain text protocols such as SMTP, HTTP, FTP, and Telnet [5]. The majority of researchers scan at

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least 2.8 billion addresses advertised in the IPv4 address space [5–8, 10–12, 15, 16, 19]. Hitrates, the fraction of probed addresses from which a response is received, are very often under two percent [7]. This means that most scan traffic is overhead. Most of these scans are done periodically for trend analyses, which exacerbates the amount of unnecessary scan traffic. For example, the ongoing Internet-wide research project *censys.io* [5,7] probes the IANA allocated address space for 19 protocols on a continuous basis. This results in 72.2 billion generated IP-packets per week. which causes several hostile responses ranging from threatening legal actions to conducted denial-of-service attacks [7]. Whereas scanning the IPv4 address space is feasible this is not any more the case for IPv6. When IPv6 becomes more popular, we need scanning strategies that limit scans to parts of the address space that are in use.

Many measurement scenarios require only partial scans instead of exploring the full IP address space. However, we currently lack a systematic understanding of the deployment of Internet services with respect to IP address ranges.

In this paper, we want to start the discussion how we can reduce scan traffic systematically. We present the *Topology Aware Scanning Strategy (TASS)*, a new IP prefix based and topology aware scanning strategy for periodic scanning. *TASS* enables researchers to collect responses from 90-99% of the available hosts for six months by scanning only 10-75% of the announced IPv4 address space in each scan cycle (protocol dependent). *TASS* is seeded with the results of a full advertised IPv4 address scan for a given protocol and time period. The prefixes for all responses will be selected for periodic scans of the given protocol.

Periodic scanning of only selected prefixes reduces scan traffic significantly while hitting most of the hosts of interest. For instance, our analysis reveals that responsive prefixes obtained from a full FTP scan cover

johannes.klick@fu-berlin.de

Backup

Problem: Overlapping Prefixes

CAIDA Routeviews Prefix-to-AS database

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1. Prefixes are not complementary

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1. Prefixes are not complementary
2. Less specific prefixes (l-prefixes) contain more specific prefixes (m-prefixes)
3. A single IP address can have multiple prefixes

Problem: Overlapping Prefixes

Solution I:

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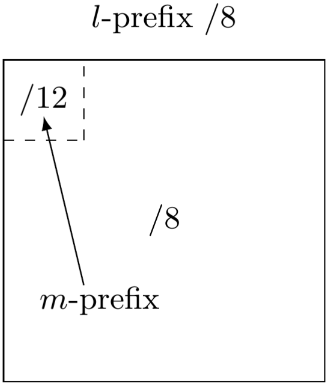
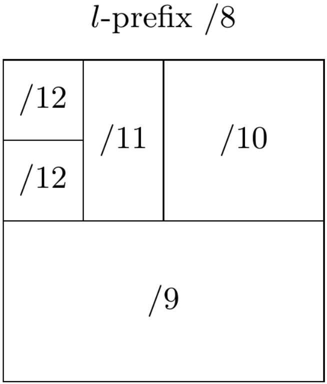
2. For more details: Have a look at the paper

Deriving Prefixes II



(a) Announced prefixes.



(b) Resulting m-prefixes.

- The less specific l-prefix /8 contains the more specific m-prefix /12.
- The l-prefix is then decomposed into the more specific one and the remaining smaller prefixes

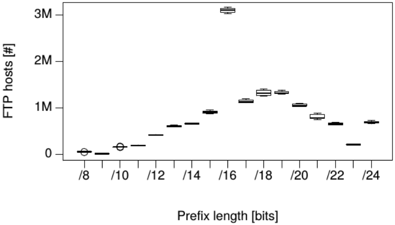
Nescessary Condition I:

- Service responses per prefix size should be stable over time

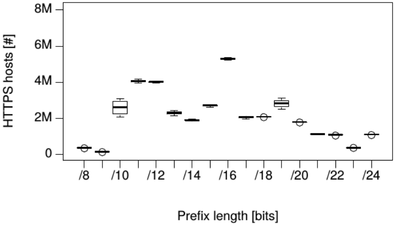
Analysis Results:

- Hosts prefix size distribution is protocol specific
- Service responses per prefix size are stable

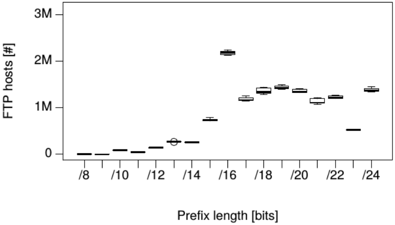
Host Stability per Prefix Length and Service



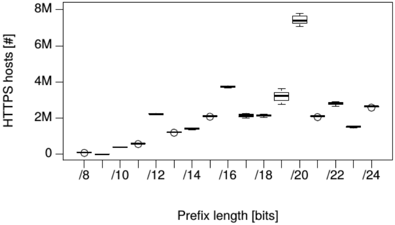
(a) FTP for less specific prefixes.



(b) HTTPS for less specific prefixes.



(c) FTP for more specific prefixes.



(d) HTTPS for more specific prefixes.

Host distribution over prefix lengths based on seven different measurements from 09/2015 to 03/2016. Datasource: censys.io.

TASS in Detail:

1. At time t_0, perform a full scan and output all responsive addresses. Let N be their number. Count the number of responsive addresses c_i in each responsive prefix i. The sum of all c_i is N.
2. Calculate the density $\rho_i = c_i/2^{32-\text{prefix length}}$ of all responsive prefixes and their relative host coverage $\phi_i = c_i/N$ of responsive addresses.
3. Sort the prefixes in the descending order of density. Relabel prefixes so that $i < j \Leftrightarrow \rho_i > \rho_j$.
4. Find the smallest k so that $\sum_{i=1}^{k} \phi_i > \phi$.
5. Scan prefixes $1, \ldots, k$ repeatedly until time $t_0 + \Delta_t$, then start over at step 1.

Results

Address Space Coverage		ϕ	FTP	HTTP	HTTPS	CWMP
	less	1	0.762	0.828	0.832	0.477
		0.99	0.470	0.548	0.542	0.142
		0.95	0.273	0.362	0.343	0.099
		0.7	0.031	0.064	0.065	0.043
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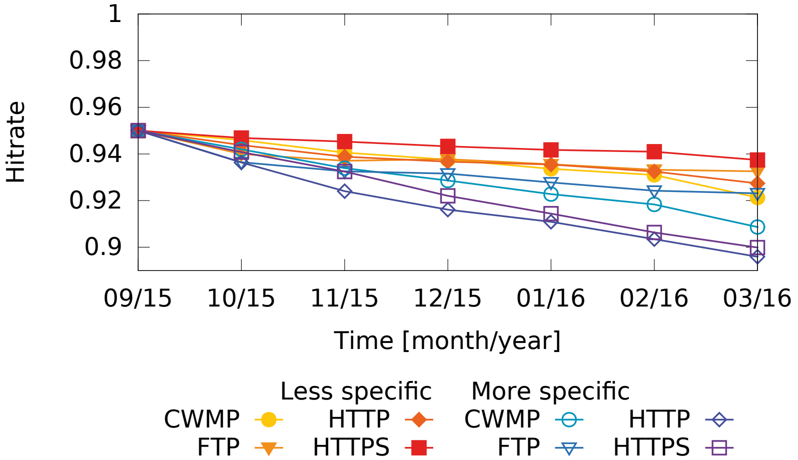
IPv4 address space coverage of the protocols using less and more specific prefixes.

Accuracy over Time: TASS (Host Coverage 95%)



Hitrate of a TASS scan compared to full IPv4 scans.

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		0.99	0.470	0.548	0.542	0.142
		0.95	0.273	0.362	0.343	0.099
		0.7	0.031	0.064	0.065	0.043
		0.5	0.008	0.021	0.024	0.024
	more	1	0.574	0.648	0.645	0.332
		0.99	0.371	0.440	0.427	0.113
		0.95	0.206	0.279	0.262	0.085
		0.7	0.023	0.048	0.052	0.037
		0.5	0.006	0.017	0.020	0.021

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- More-specific prefixes are up to 20 % more efficient than less-specific prefixes

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- Little tweaks on the host coverage have an important impact on the needed address space coverage

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- Special protocols can be very efficiently scanned with TASS
- 99 % of all the CWMP hosts can be scanned with a announced IPv4 space coverage of 11-14%

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- A **50 % host coverage** for one of the discussed protocols results in a scan **traffic reduction of 98 %** !