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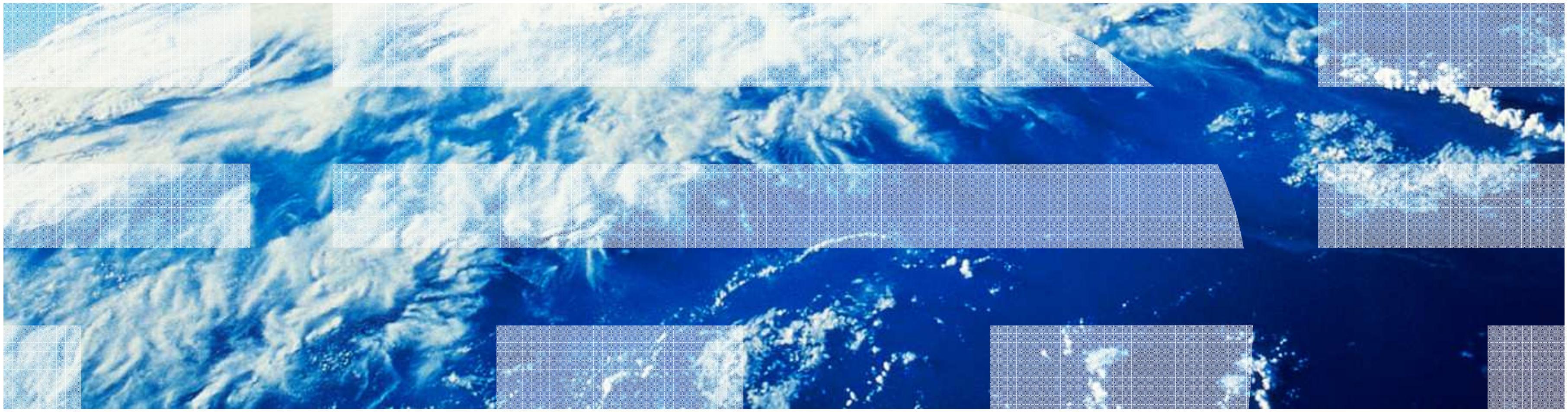
# Postfix, lessons learned and recent developments



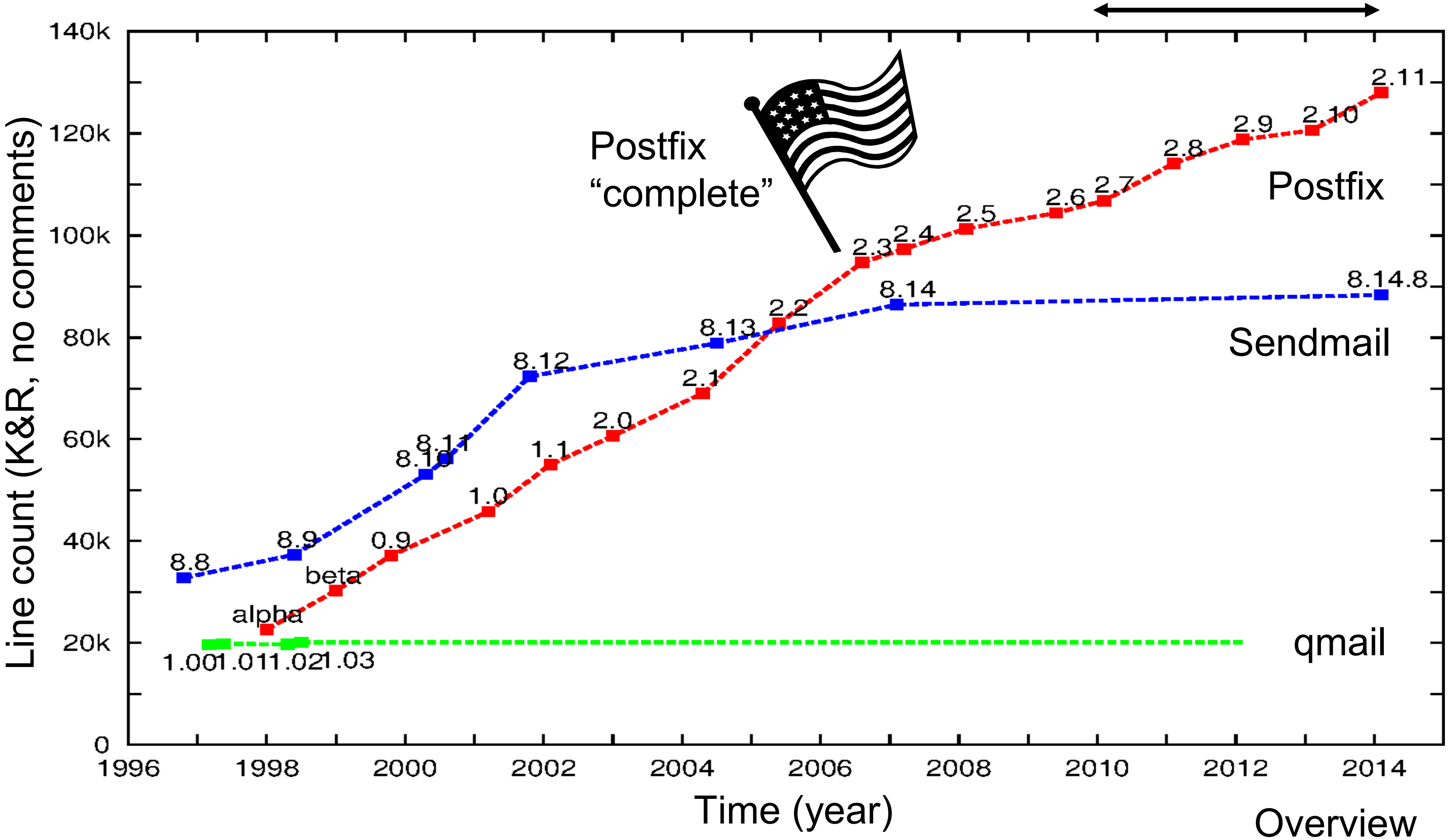
# Overview

- Overview.
- Motivation and architecture.
- Spam around the clock.
- Scalable defense (postscreen zombie blocker).
- New: miscellaneous improvements.
- New: security without global PKI (DANE).
- New: replacing Berkeley DB with LMDB.
- Conclusion.

# Postfix timeline

## Larger is not necessarily better

Most of this presentation



Overview

- Postfix motivation and architecture

Why (not) write another UNIX mail system

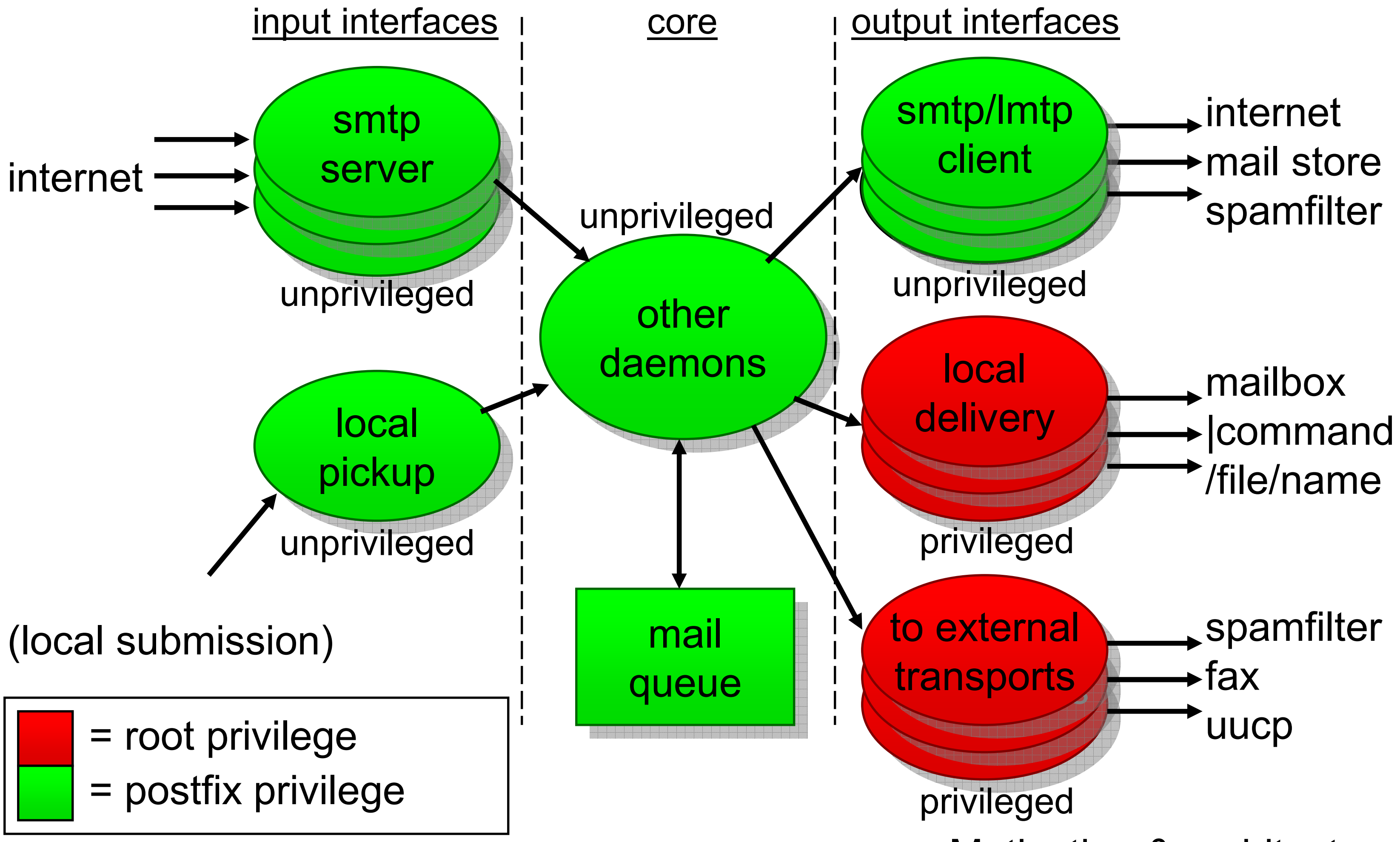
# CERT/CC advisories for Sendmail

## The initial threat model: mail server attacks

| Advisory | Version | Impact |
|---|---|---|
| CA-1988-01 | 5.58 | Unprivileged access |
| CA-1993-16 | 8.6.3 | Unprivileged access |
| CA-1994-12 | 8.6.7 | Full system privilege |
| CA-1995-05 | 8.6.9 | Full system privilege |
| CA-1995-13 | 8.7.0 | Full system privilege |
| CA-1996-04 | 8.7.3 | Full system privilege |
| CA-1996-20 | 8.7.5 | Full system privilege |
| CA-1996-24 | 8.8.2 | Full system privilege |
| CA-1996-25 | 8.8.3 | Group privileges |
| CA-1997-05 | 8.8.4 | Full system privilege |
| CA-2003-07 | 8.12.7 | Full system privilege |
| CA-2003-12 | 8.12.8 | Full system privilege |
| CA-2003-25 | 8.12.9 | Full system privilege |

# Postfix low-privilege architecture

## (omitted: non-daemon programs for submission and management)



input interfaces

core

output interfaces

internet

smtp server

unprivileged

local pickup

unprivileged

(local submission)

unprivileged

other daemons

mail queue

smtp/lmtp client

unprivileged

internet

mail store

spamfilter

local delivery

privileged

mailbox

|command

/file/name

to external transports

privileged

spamfilter

fax

uucp

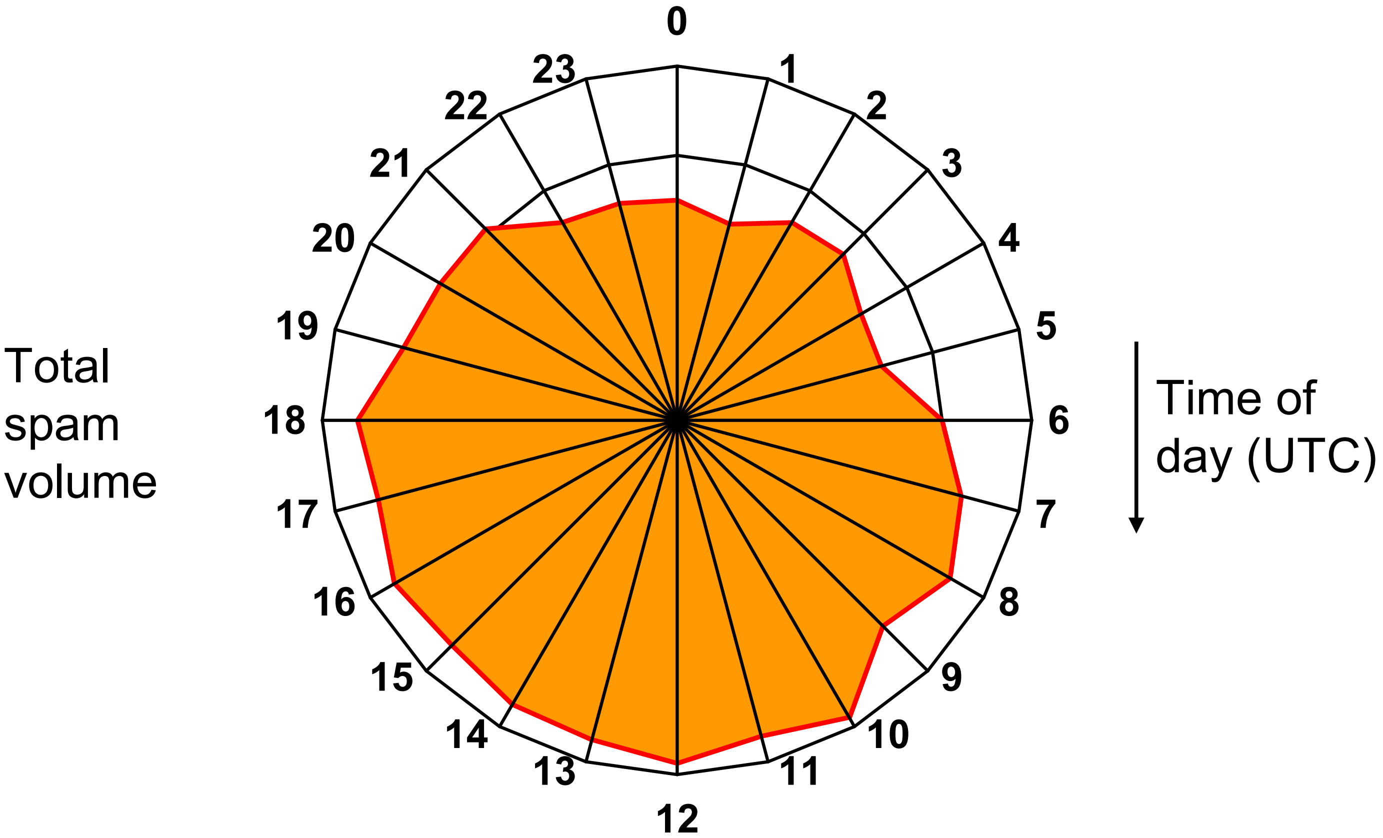
🟥 = root privilege

🟩 = postfix privilege

Motivation & architecture

- Spam around the clock

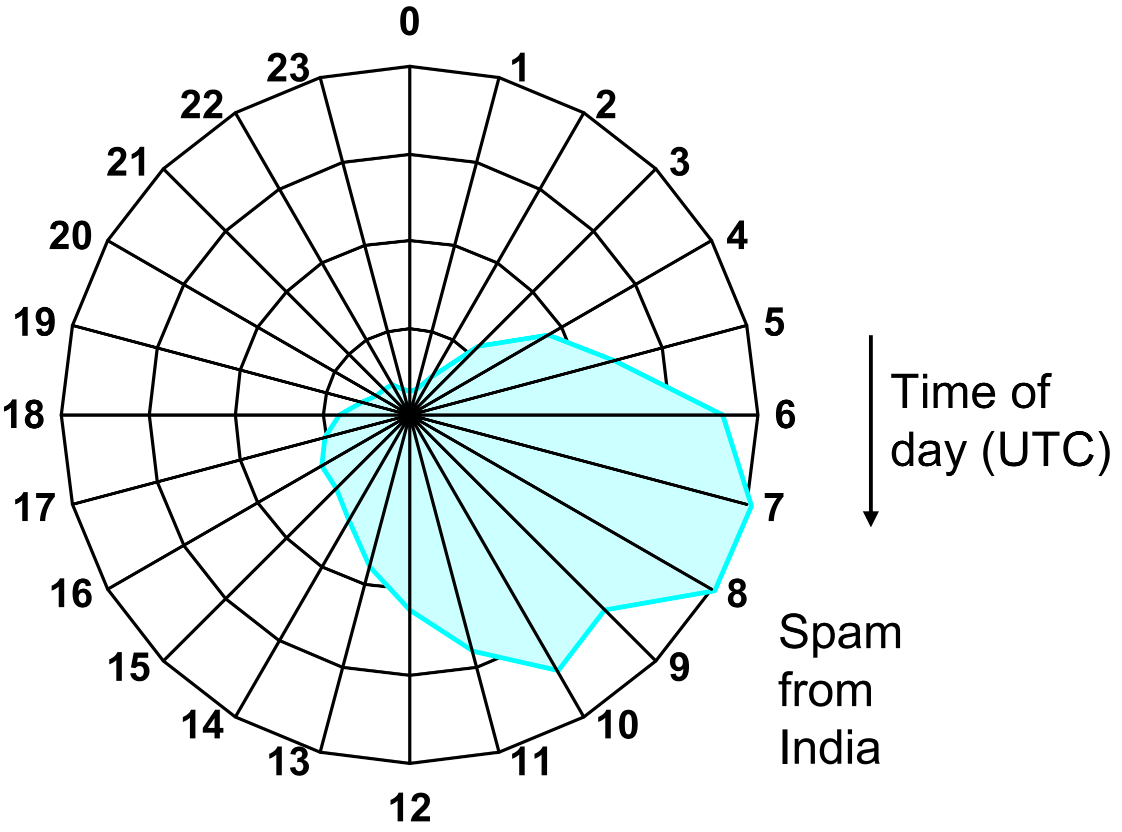
# SPAM is a 24-hour operation ...



- Spam connections to charite.de (Berlin, Germany) Oct 29 – Jan 23, 2014, from IP addresses blacklisted at zen.spamhaus.org.

Spam around the clock

# ... but many spambots are not

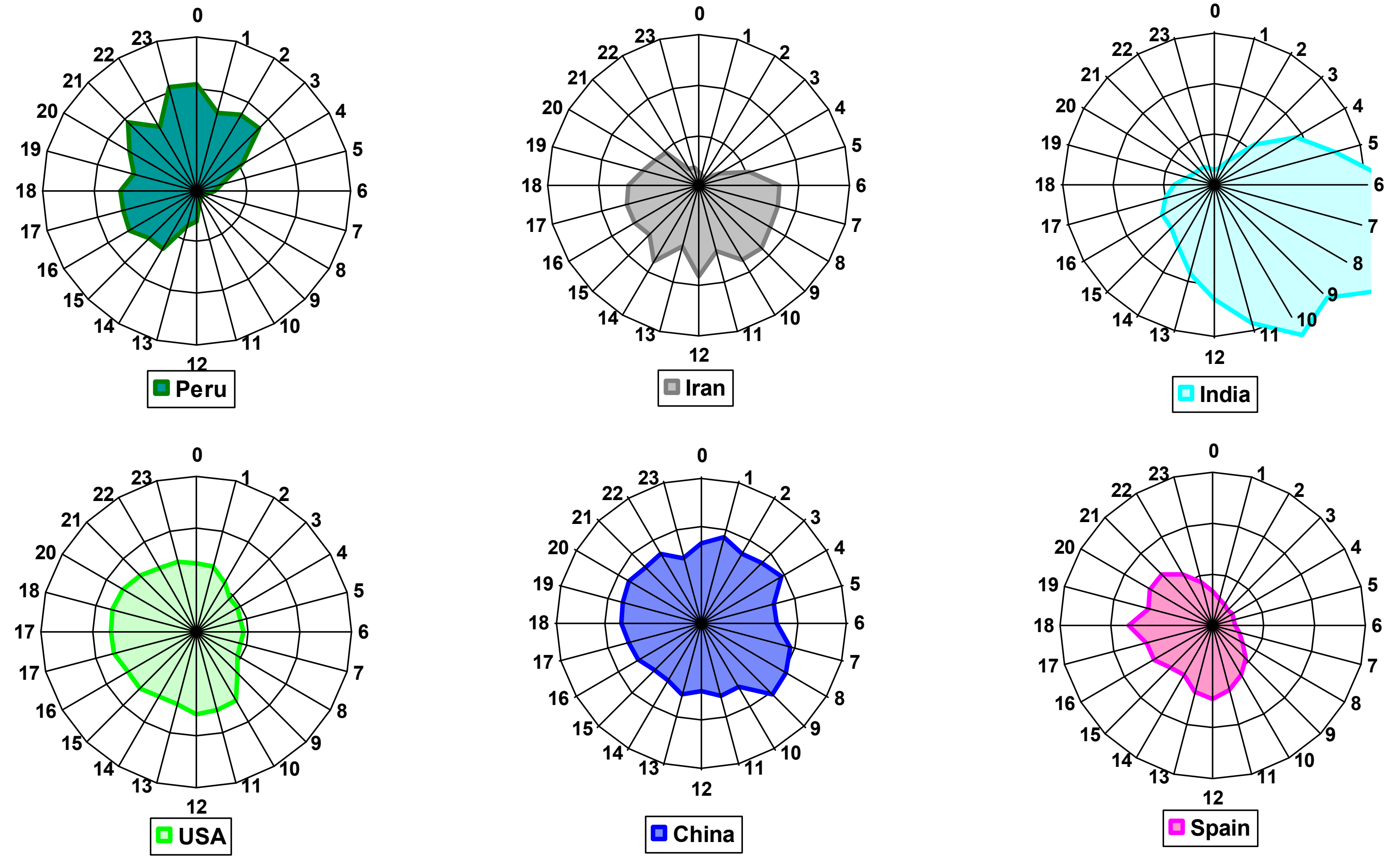


- Spam connections to charite.de (Berlin, Germany) Oct 29 – Jan 23, 2014, from IP addresses blacklisted at zen.spamhaus.org.

Spam around the clock

# Spam connections/hour at charite.de (time in UTC)

## From IP addresses blacklisted at zen.spamhaus.org, Oct 29 – Jan 23, 2014



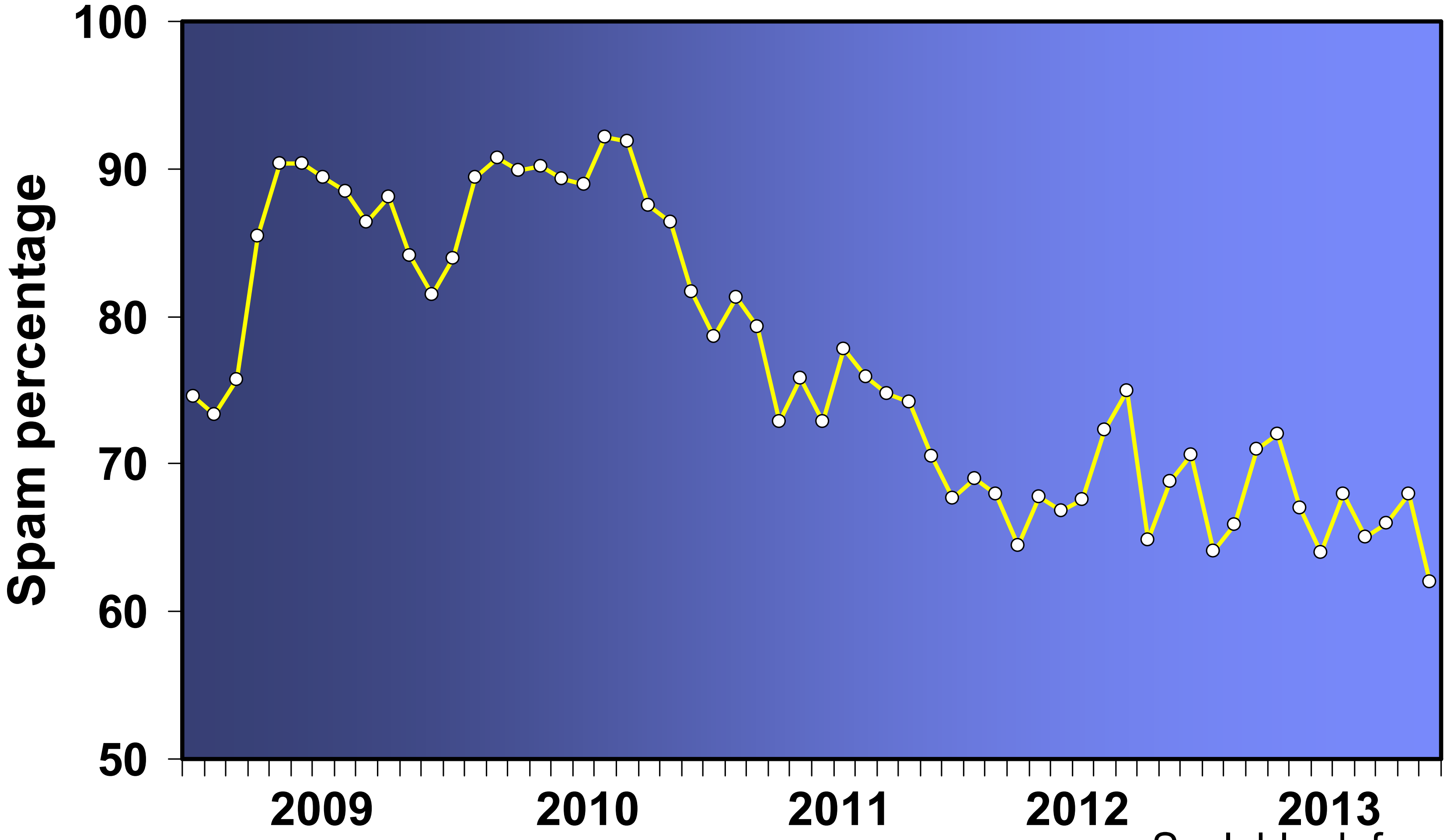
Spam around the clock

- Zombies suck the life out of the mail server

Adapting to changing threats

# Email spam percentage over time (Symantec)

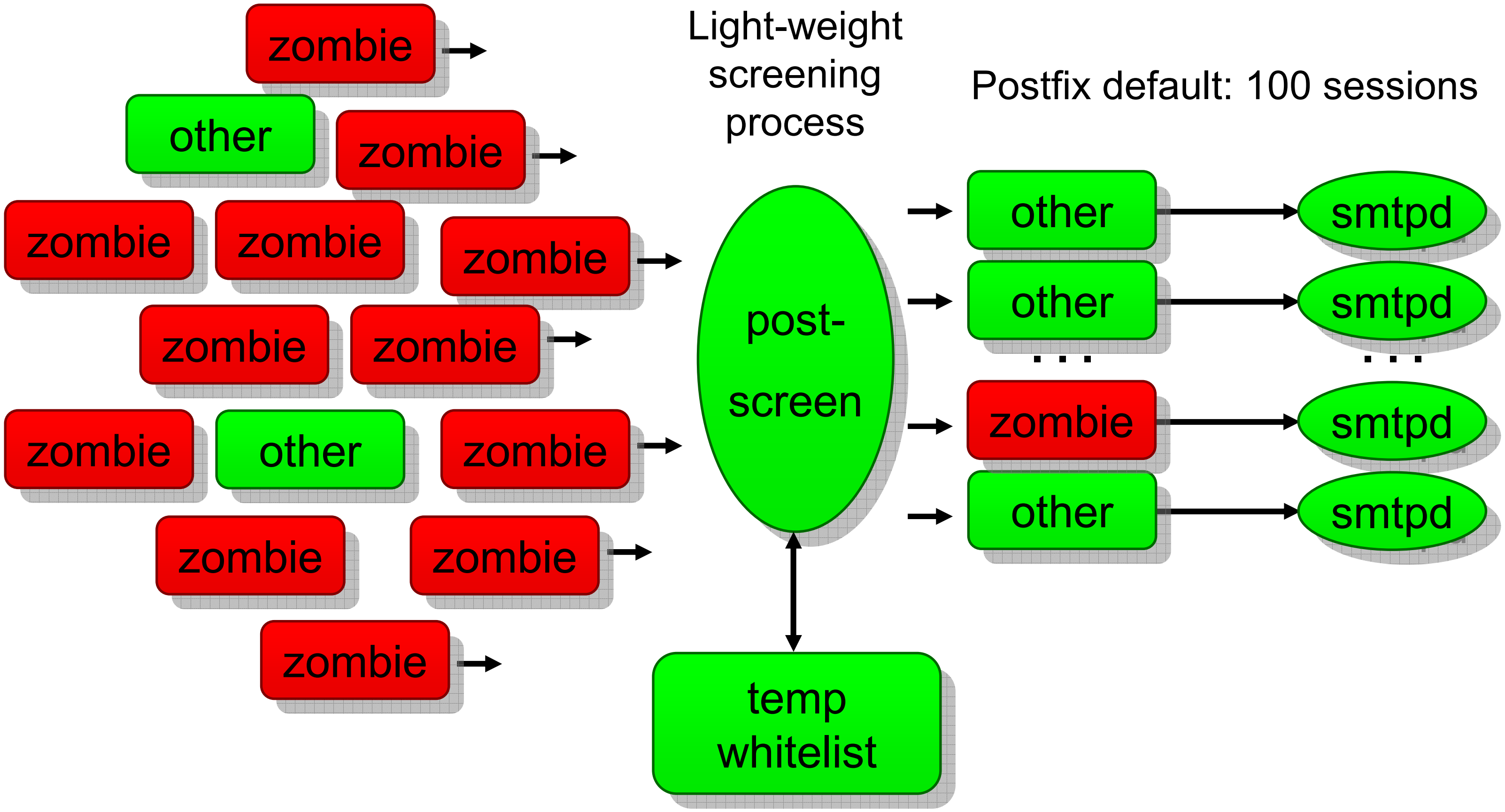
## August 2010: 92% Of email is spam, 95% of spam is from botnets



Scalable defense

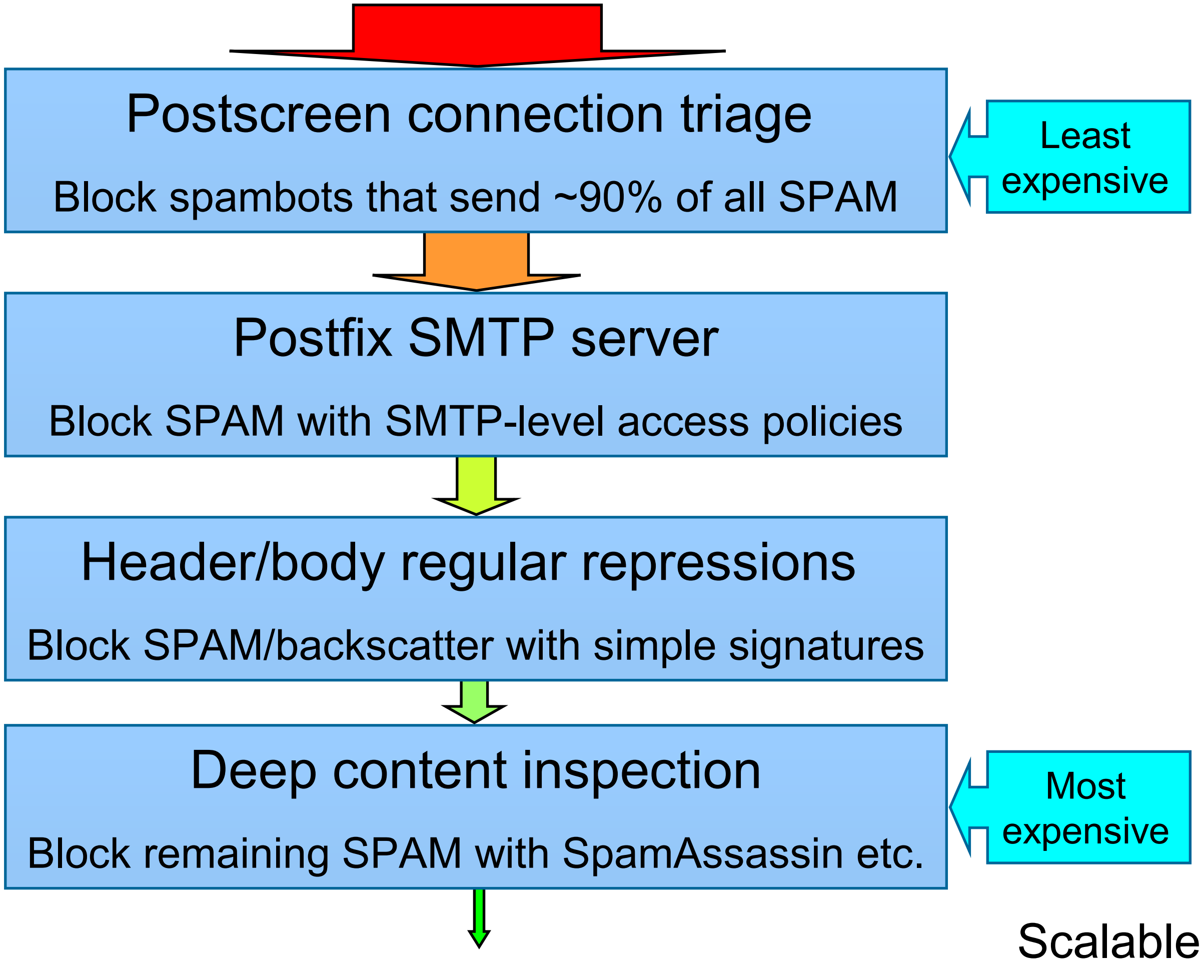
# postscreen zombie blocker

## Prior work: OpenBSD spamd, MailChannels TrafficControl, M.Tokarev



Scalable defense

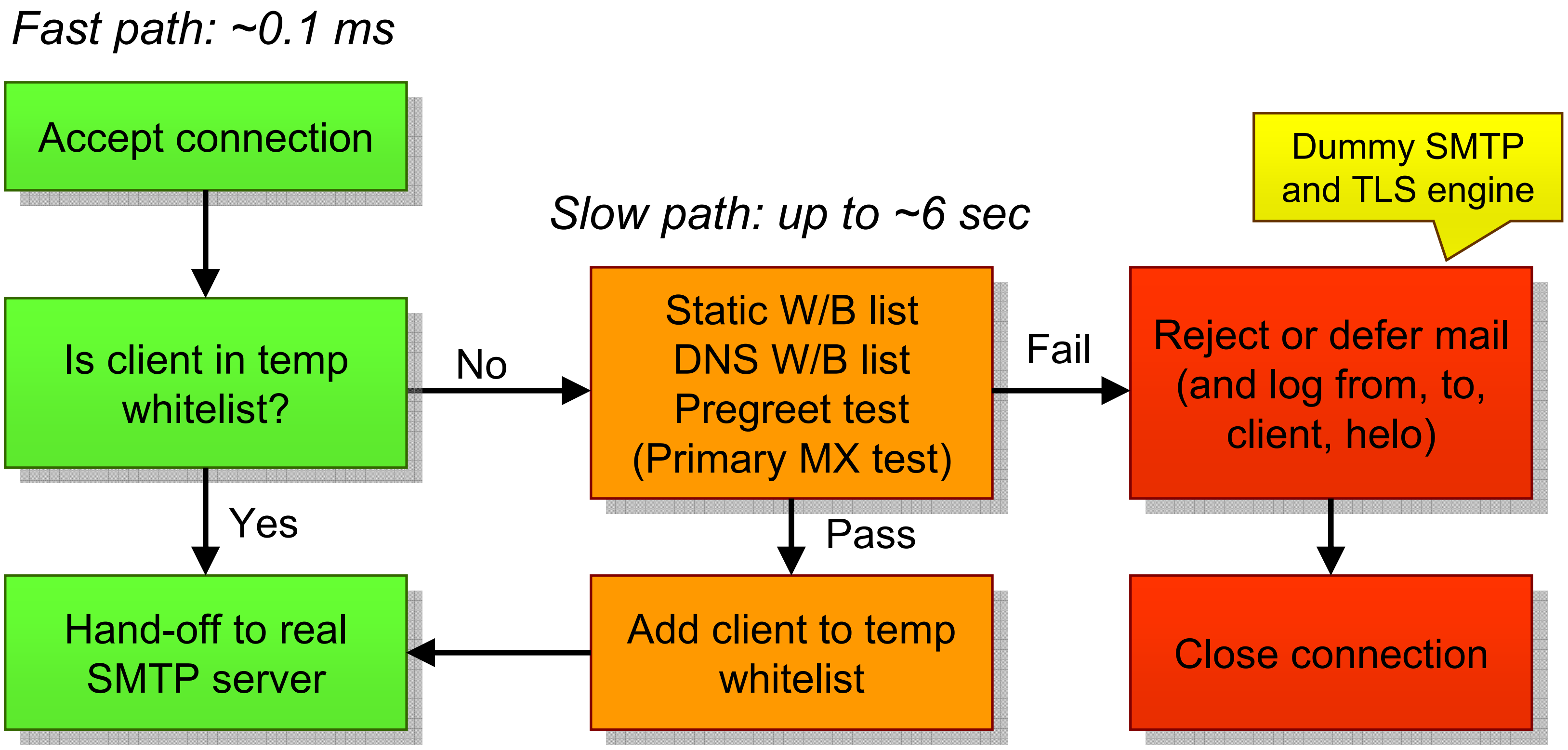
# postscreen – the first step in a four-layer defense


Postscreen connection triage
Block spambots that send ~90% of all SPAM
Least expensive
Postfix SMTP server
Block SPAM with SMTP-level access policies
Header/body regular repressions
Block SPAM/backscatter with simple signatures
Deep content inspection
Block remaining SPAM with SpamAssassin etc.
Most expensive

Scalable defense

# postscreen workflow - tests before SMTP handshake

## One daemon screens multiple connections simultaneously


*Fast path: ~0.1 ms*
Accept connection
Is client in temp whitelist?
No
Yes
Hand-off to real SMTP server
*Slow path: up to ~6 sec*
Static W/B list
DNS W/B list
Pregreet test
(Primary MX test)
Pass
Add client to temp whitelist
Fail
Dummy SMTP and TLS engine
Reject or defer mail (and log from, to, client, helo)
Close connection

Scalable defense

# postscreen DNSBL/DNSWL support

## Parallel DNS lookups

- Weight factors (to whitelist, use *negative* numbers).

```
postscreen_dnsbl_sites = zen.spamhaus.org*2, bl.spamcop.net*1,
                   b.barracudacentral.org*1
postscreen_dnsbl_threshold = 2
```

- Reply filters.

```
postscreen_dnsbl_sites = zen.spamhaus.org=127.0.0.4 ...
postscreen_dnsbl_sites = zen.spamhaus.org=127.0.0.[1..11] ...
```

- Allow “good” clients to skip all other tests.

```
postscreen_dnsbl_sites = list.dnswl.org=127.0.[0..255].[1..3]*-2 …
postscreen_dnsbl_whitelist_threshold = -2
```

Scalable defense

# Making zombies bark - multi-line greeting trap

- Good clients wait for the full multi-line server greeting:

```
postscreen:  220–server.example.com ESMTP Postfix<CR><LF>
smtp server: 220  server.example.com ESMTP Postfix<CR><LF>
good client:  HELO client.example.org<CR><LF>
```

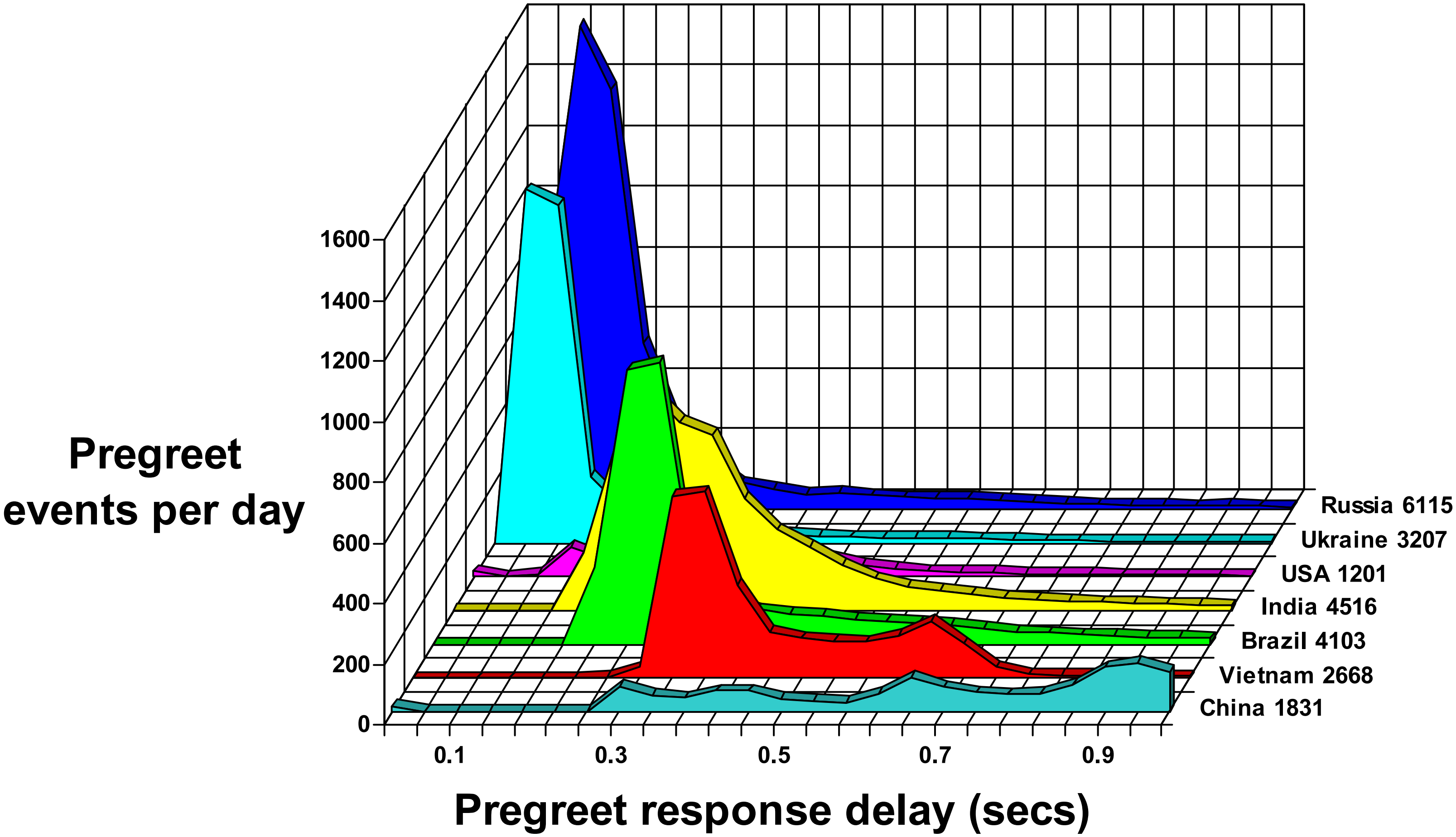
- Many spambots talk immediately after the first line of the multi-line server greeting:

```
postscreen:   220–server.example.com ESMTP Postfix<CR><LF>
postscreen:  (wait a few seconds)
spambot:      HELO i-am-a-bot<CR><LF>
```

Scalable defense

# Over 60% of bots pregreet (8% not on DNSBL)

## mail.charite.de, Berlin, Aug 26 – Sep 29, 2010



Scalable defense

- New developments: miscellaneous improvements

# Miscellaneous Postfix 2.11 improvements

- Documentation: “Perfect” Forward Secrecy.
- TLS-encrypted MySQL database connections.
- Both “user+suffix@example” and “user–suffix@example”.
- Managing master.cf files without text editor (just like main.cf).
  - Primary target: third-party management tools.
  - Basic idea: everything is a “name = value” pair:
    - **`postconf –F “*/*/chroot = n”`**
      - **Sets the “chroot” field to “n” for all master.cf entries.**
    - **`postconf –P “smtp/unix/smtp_bind_address = 192.0.2.1”`**
      - **Sets “-o smtp_bind_address=192.0.2.1” on “smtp unix ...” master.cf entry.**

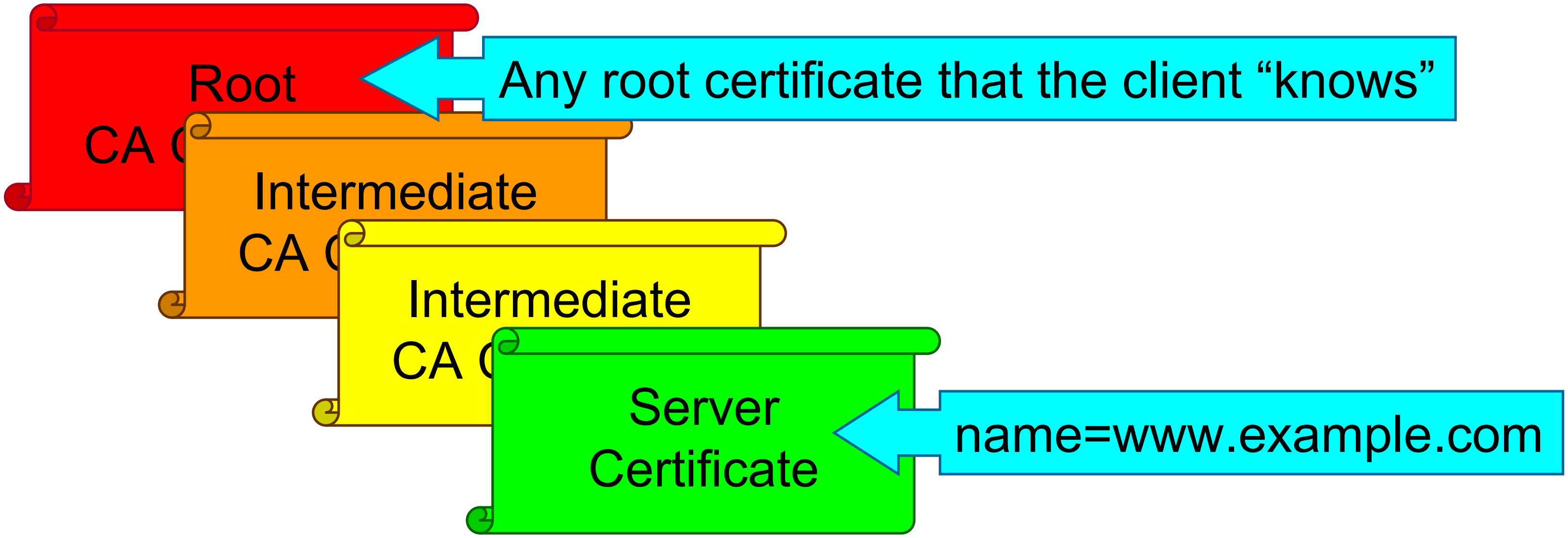
Miscellaneous

- New developments: security without global PKI

DNS-based authentication of named entities (DANE)

# Global PKI violates the principle of least privilege

- Hundreds of root CA certificates (Windows ~350, IOS ~200).
  - Owned by ~100 distinct organizations world-wide.
  - Hundreds (or more) registration authorities (RAs) world-wide.



# SMTP over TLS – no server certificate verification

## RFC 3207, published 2002

- Problem: RFC does not require certificate name verification.
  - Why not the recipient domain name (*example.com* below)?
    - One mail server may host many domains (RFC predates SNI).
  - Why not the mail server hostname (*lb-01.spam.filter* below)?
    - The mail server hostname is looked up with insecure DNS.

*Simplified connection setup procedure*

DNS query: example.com MX?
DNS reply: example.com MX lb-01.spam.filter

DNS query: lb-01.spam.filter A?
DNS reply: lb-01.spam.filter A 192.0.2.1

Negotiate TLS with host = 192.0.2.1, port = 25

# SMTP over TLS – downgrade vulnerability

- Problem: the client doesn’t know that it should use TLS.
  - <user@example.com>, not <smtps://user@example.com>.
  - Plaintext is the default, TLS is optional.

*No downgrade attack*

| | |
|---|---|
| S: | 220 server.example.com |
| C: | EHLO client.example.org |
| S: | 250-server.example.com<br>250 STARTTLS |
| C: | STARTTLS |
| S: | 220 Ready to start TLS |
| *No plaintext from here on* | |

*With man-in-the-middle downgrade attack*

| | |
|---|---|
| S: | 220 server.example.com |
| C: | EHLO client.example.org |
| S: | 250 server.example.com<br>(No STARTTLS announcement) |
| C: | MAIL FROM:<user@example.org> |
| S: | 250 Sender address accepted |
| *Plaintext throughout the entire session* | |

# RFC 6698 (DANE) to the rescue

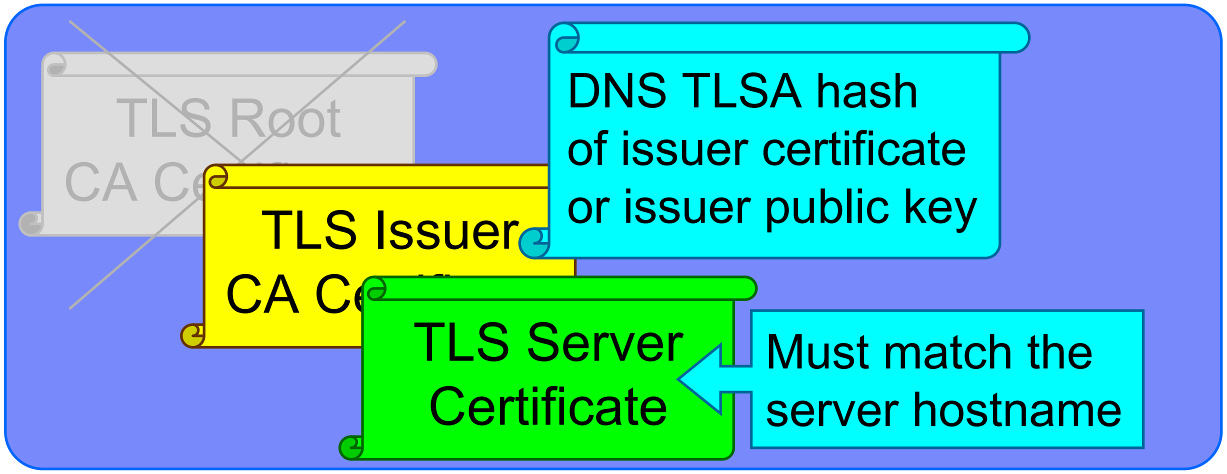
## DNS-Based Authentication of Named Entities

- Introduces TLSA[1] DNS records with:
  - Expected server (or issuer) certificate or public key.
  - Or better: their SHA-256 or SHA-512 hash.
- Requires secure DNS (DNSSec).
  - Unavoidable when using DNS for secure authentication.

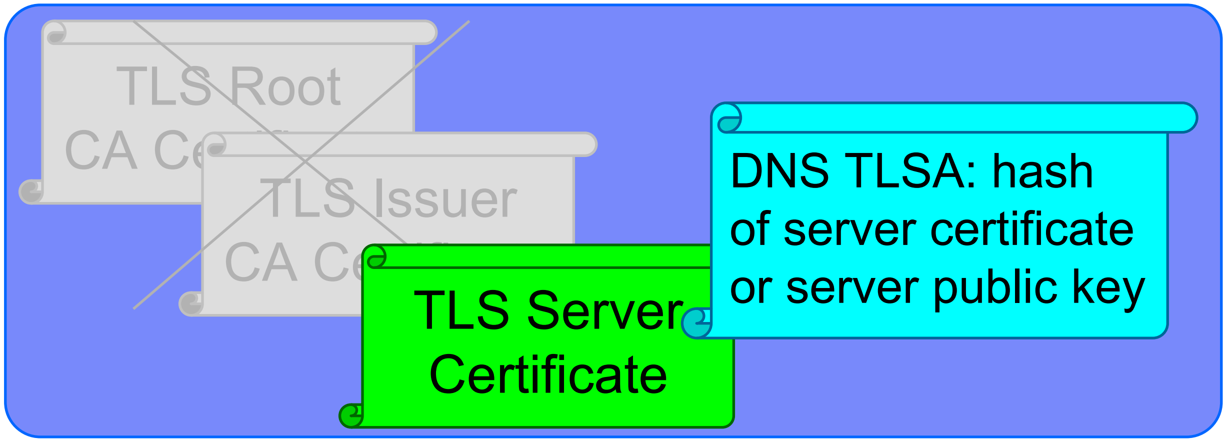
[1] RFC 6698: "TLSA does not stand for anything”.

# Two preferred (SMTP) DANE deployments

- Mini PKI



- No PKI



Security without global PKI

# Concrete example with debian.org

## Not showing the DNSSec signature records (RRSIG)

- Look up the debian.org mail server names:

Reply:
```
debian.org MX 0 mailly.debian.org
debian.org MX 0 muffat.debian.org
```

- Look up mailly A records:

Reply:
```
mailly.debian.org A 82.195.75.114
```

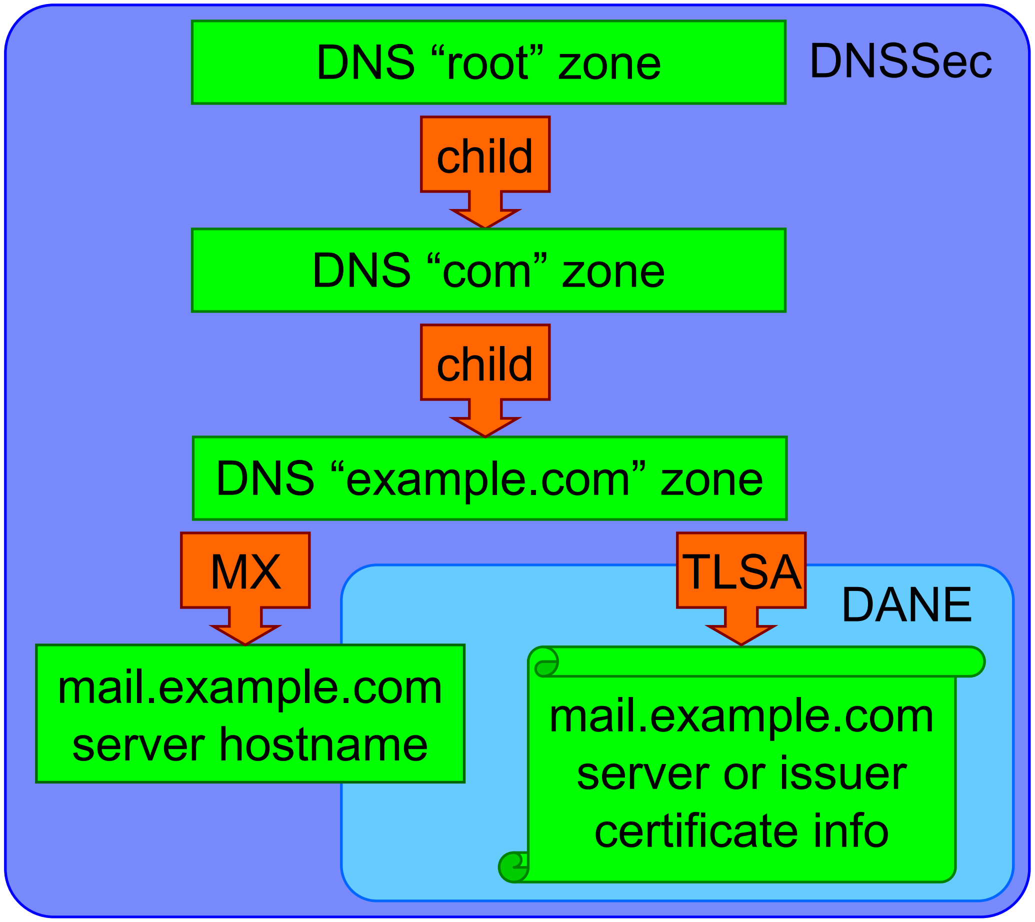
- Connect to 82.195.75.114 port 25.
- Look up mailly TLSA records:

Reply:
```
_25._tcp.mailly.debian.org TLSA 3 1 1 [SHA-256 of TLS server public key]
```

- Match TLSA record with SHA-256 of TLS server public key.

# Securing SMTP with DNSSec and DANE

- Minimized trust.
  - –Not: 100s of RAs.
  - –Secure copy of root zone public keys.
  - –DNS target zone plus its ancestors.
    - Maybe: issuer cert.
- No downgrade attack.
  - –Use TLS when DNS TLSA record exists.


DNS “root” zone
DNSSec
child
DNS “com” zone
child
DNS “example.com” zone
MX
TLSA
DANE
mail.example.com server hostname
mail.example.com server or issuer certificate info

Security without global PKI

# DANE support in Postfix 2.11 stable release

- Aug 2012: RFC 6698 is published.
- Q1  2013: Start of Postfix implementation (Viktor Dukhovni).
- Jan 2014: DANE support in Postfix stable release.
  - Requires DNSSec validating resolver (e.g., BIND or unbound).
- Please try DANE support, but be prepared for surprises.
  - A few DNS servers mis-handle TLSA queries.
    - Use “dane enabled” as default.
    - Use “dane disabled” SMTP TLS policy for problem sites.
    - See TLS_README (or the upcoming DANE_README).

- New developments: LMDB database support

Unintended consequences of adopting AGPL

# June 2013: Oracle updates Berkeley DB 6.0 license

## Popular open-source key-value store

- Berkeley DB v5: two licenses, copyleft and commercial.

> Copyleft: make all source code available if you *distribute work* that uses Berkeley DB.

- Berkeley DB v6: two licenses, AGPLv3[1] and commercial.

> AGPL: also make all source code available if you *provide network service* that uses Berkeley DB.

- Problem: cannot legally combine GPLv2 and AGPLv3 code without relicensing the GPLv2 code (GPLv3 would be OK).

[1] GNU Affero General Public License version 3.0. Pronunciation: /ˈaf.fe.roː/.

# LMDB - Lightning Memory-Mapped Database

## Author: Howard Chu

- Described by some as a Berkeley DB replacement.
- OpenLDAP Public License.
- Memory-mapped, max size limited by memory address range (typically ~31 bits on i386, ~47 bits on x86_64 or ~128 TB).
- Copy-on-write, zero-copy, MVCC, multi-reader, single-writer.
- Ported by its author to dozen+ other open source projects.
- Postfix integration took 5 iterations with changes to both Postfix and LMDB.

# Challenges integrating LMDB into Postfix

- Hard database size limit, specified when database is opened.
  - Postfix processes fail unexpectedly if size limit is set too low.
  - LMDB 0.9.8 allows Postfix to resize database on the fly.
- LMDB lockfile must be writable by readers. Hard limit on number of readers, specified when database is opened.
  - World-writable lock files, for example under /etc/postfix. ☠
  - Postfix process fail unexpectedly if reader limit is set too low.
  - LMDB 0.9.9 allows Postfix to use external (fcntl()-based) locks.

# Challenges integrating LMDB into Postfix

- Information leak: writing ~4kbyte chunks of uninitialized heap memory to the LMDB database file.
  - Contains traces from past activity in the same process, not necessarily meant to persisted or shared. ☠
  - LMDB 0.9.10 initializes malloc()ed memory by default.
- LMDB library functions rely on assert() extensively.
  - Write a message to stderr and abort the program immediately.
  - Postfix daemons fall out of the sky without logging any error.
  - LMDB 0.9.11 allows Postfix to log an error message.

# LMDB support in Postfix 2.11 stable release

- First persistent Postfix database that safely supports multiple writers such as postscreen.
- Not exactly a Berkeley DB drop-in replacement – requires additional Postfix code to recover from “hard limit” errors.
- Expect better safety than Berkeley DB, mainly due to COW.

# Postfix lessons learned

- Invent sparingly: don’t re-invent what works.
  - SMTP, Milter, maildir, Sendmail lookup tables.
- Build the stable protocols into Postfix.
  - SMTP, LMTP, TLS, SASL, IPv6, DSN, MIME, LDAP, SQL, CDB, memcache, LMDB, (DANE).
- Plan for change: provide safe plug-in interfaces for future proofing.
  - Anti-Spam, Anti-Virus, DKIM, SenderID, SPF, greylist.
- Optimize both worst cases and common cases.
  - On the Internet, worst cases will become common cases.
- Don’t let a C prototype become the final implementation.

Conclusion