IBM Research

Postfix, past present and future

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Postfix in a nutshell

- Who runs Postfix:
  - Providers with 10+M mailboxes (Outblaze, UOL).
  - Desktops & servers (MacOS X, Ubuntu, NetBSD).
  - Appliances (Brightmail, Frontbridge, etc.).
- Who provides Postfix:
  - Yours truly, helped by small number of volunteers with input from a small core of active users.
  - Code contributions are accepted. Sometimes as is, usually after some editing.

Overview

- Publicity makes a big difference.
- Why (not) write another UNIX mail system.
- Postfix implementation.
- Extensibility as a proverbial life saver.
- Catching up on Sendmail.
- Lies, d*mned lies, and market share.
- Work in progress: postscreen.
- Conclusion.

- Publicity makes a difference

"[Releasing SATAN is] like distributing high-powered rocket launchers throughout the world, free of charge, available at your local library or school."

San Jose Mercury, 1995

SHARING SOFTWARE, IBM TO RELEASE MAIL PROGRAM BLUEPRINT

By JOHN MARKOFF

- - -

The program, **Secure Mailer**, serves as an electronic post office for server computers connected to the Internet. It was developed by **Wietse Venema**, an IBM researcher and computer security specialist.

- - -

Currently about 70 percent of all e-mail worldwide is handled by **Sendmail**, a program that has been developed over more. . .

New York Times Business Section, December 1998.

Publicity makes a difference

Postfix (Secure Mailer) project

- Primary goals: more secure, easier to configure, and better performance. All were easily met.
- Originally developed to illustrate “secure” programming with a realistic application.
- One year after the first release, several news articles began to mention Postfix as the project that triggered IBM’s adoption of open source.
  - Reportedly, this started when IBM’s top management saw the NY Times article.

Publicity makes a difference

How Postfix (Secure Mailer) helped IBM to embrace Open Source + Linux

Publicity makes a difference

Building up momentum

- June 1998 IBM joins the open source Apache project.
- Sept 1998 JIKES Java compiler open source release.
- Sept 1998 PKIX public key infrastructure software open source release under the name “Jonah”.
- Dec 1998 Secure Mailer open source release under the name “Postfix”. IBM’s CEO starts asking questions.
- 1999 IBM adopts Open Source and Linux strategies.

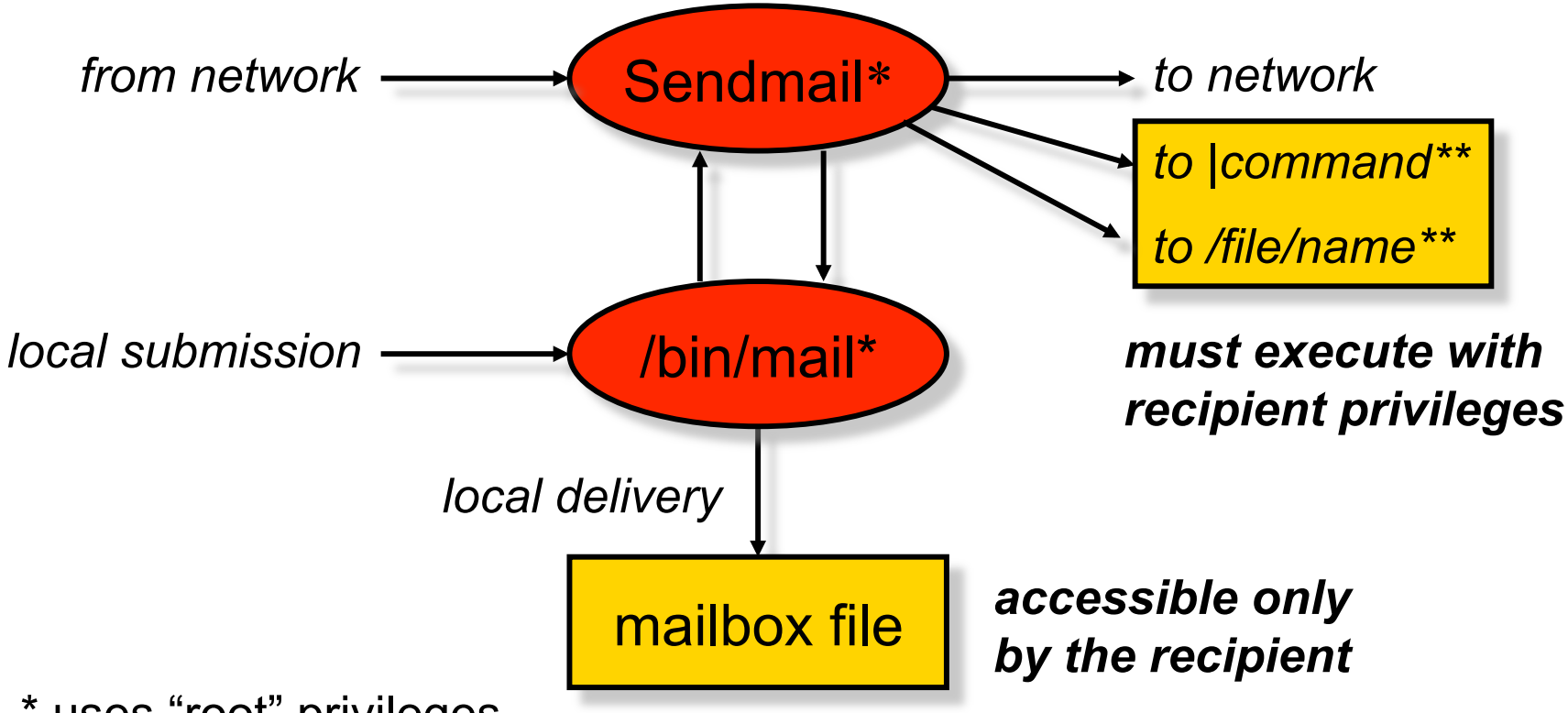
Publicity makes a difference

- Why (not) write yet another UNIX mail system

Idealism versus real-world compatibility.

Traditional (BSD) UNIX mail delivery architecture

(impersonation requires privileges; monolithic model hinders damage control)



* uses “root” privileges

** in per-user .forward files and in per-system aliases database

Plan for failure

CERT/CC UNIX email advisories (part 1 of 3)

Bulletin	Software	Vulnerability
CA-1988-01	Sendmail 5.58	run any command
CA-1990-01	SUN Sendmail	unknown
CA-1991-01	SUN /bin/mail	root shell
CA-1991-13	Ultrix /bin/mail	root shell
CA-1993-15	SUN Sendmail	write any file
CA-1993-16	Sendmail 8.6.3	run any command
CA-1994-12	Sendmail 8.6.7	root shell, r/w any file
CA-1995-02	/bin/mail	write any file

Plan for failure

CERT/CC UNIX email advisories (part 2 of 3)

Bulletin	Software	Vulnerability
CA-1995-05	Sendmail 8.6.9	any command, any file
CA-1995-08	Sendmail V5	any command, any file
CA-1995-11	SUN Sendmail	root shell
CA-1996-04	Sendmail 8.7.3	root shell
CA-1996-20	Sendmail 8.7.5	root shell, default uid
CA-1996-24	Sendmail 8.8.2	root shell
CA-1996-25	Sendmail 8.8.3	group id
CA-1997-05	Sendmail 8.8.4	root shell

Plan for failure

CERT/CC UNIX email advisories (part 3 of 3)

Bulletin	Software	Vulnerability
CA-2003-07	Sendmail 8.12.7	remote root privilege
CA-2003-12	Sendmail 8.12.8	remote root privilege
CA-2003-25	Sendmail 8.12.9	remote root privilege

Plan for failure

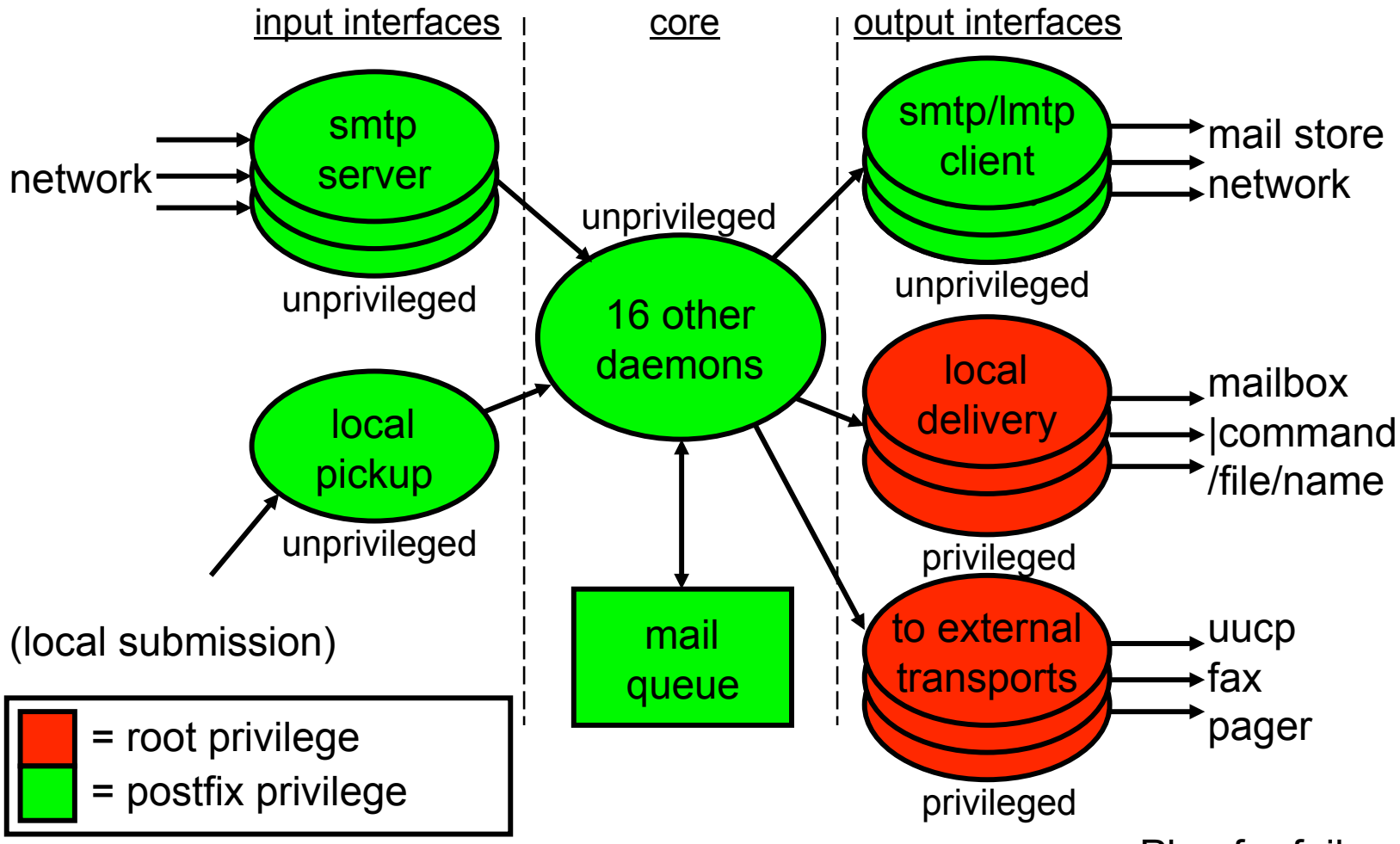
Monolithic and privileged: no damage control

- One mistake can be fatal:
  - A remote client can execute any command with “root” privilege, or can read/write any file they choose.
- No internal barriers:
  - Very convenient to implement (not really, see later).
  - Very convenient to break into (yes, really).

Plan for failure

Postfix distributed security architecture

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



Plan for failure

Major influences on Postfix architecture

- **TIS Firewall smap/smapd**
  - Low privilege, chroot jail, “air gap” between mail receiving and mail delivering processes.
- **qmail:** parallel deliveries, maildir file format.
- **Apache**: reuse processes multiple times.
- **Sendmail**
  - User interface; lookup table interface; some things to avoid.
- **Network routers**
  - Multiple interface types, but no queue-skipping fast path :-(

Plan for failure

- Postfix implementation

“I learned to program carefully for selfish reasons. I did not want to sleep on the floor next to my physics experiments”.

Wietse, date unknown

Optimization is the root of evil

- When a server is exposed to the Internet, the worst case will become the normal case, *and vice versa*.
  - Postfix is designed to deliver mail fast.
    - Not optimal when >90% of mail is spam ☹
  - Postfix assumes that SMTP clients move quickly.
    - Buggy Storm zombies clog up all SMTP server ports.
- Don't improve the common case at the cost of the worst case (Postfix content filter user interface).

Postfix implementation

How to implement SMTP without screwing up

- Multi-protocol: SMTP/DNS/TLS/LDAP/SQL/Milter.
- Broken implementations: clients, servers, proxies.
- Concurrent mailbox “database” access.
- Complex mail address syntax <@x,@y:a%b@c>.
- Queue management (thundering herd).
- SPAM and Virus control.
- Anti-spoofing: DKIM, SenderID, etc., etc.

Postfix implementation

Strategies: divide and conquer

Juggle fewer balls, basically

- Partitioned “least privilege” architecture.
- More-or-less safe extension mechanisms:
  - Use SMTP or “pipe-to-command” for content inspection; let other people provide applications that do the work.
  - Simple SMTP access policy protocol; let other people provide SPF, greylist etc. applications.
  - Adopt Sendmail Milter protocol; let other people provide DKIM, SenderID etc. applications.
- More-or-less safe C programming API (example).

Postfix implementation

Example: buffer overflow defense

- 80-Column punch cards become obsolete years ago.
  - Fixed buffers are either too small or too large.
- Dynamic buffers are not the whole solution.
  - IBM httpd (and qmail 1.03 on contemporary platforms):

    forever { send “XXXXXX....”; }
- Postfix: bounds on memory object counts and sizes.
  - Don’t run out of memory under increasing load.

Postfix implementation

- Adding anti-spam/virus support, part 1:
  Use standard protocols where you can.

"*Junk mail is war. RFCs do not apply.*"

Wietse on Postfix mailing list, 2001

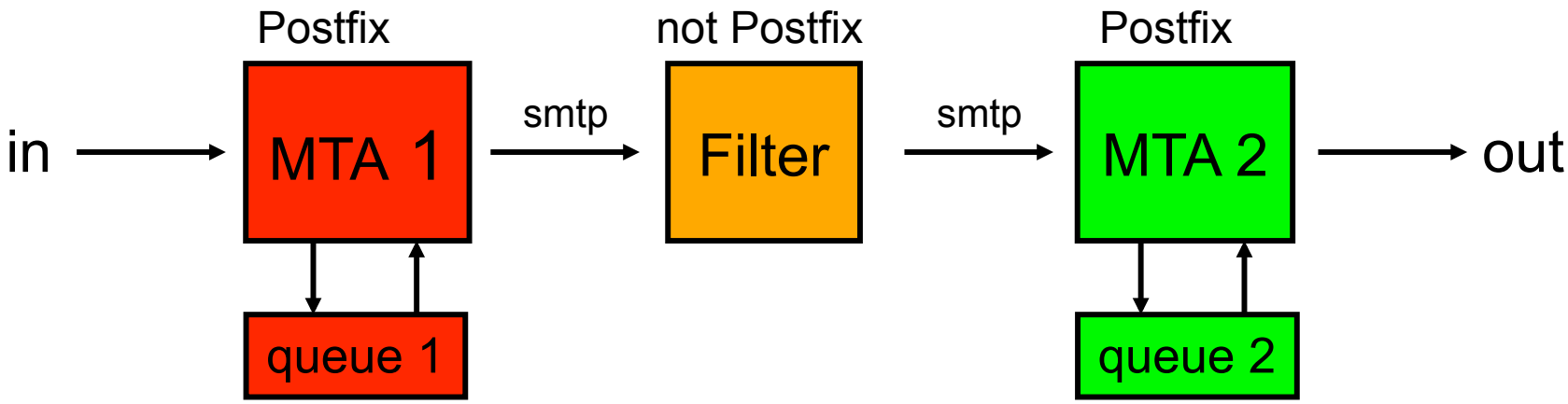
1999 - Melissa ravages the Internet

- You can run from Windows but you can't hide: Postfix becomes a vehicle for malware distribution.
  - *Short term*: block "known to be bad" strings in message.

    /^Subject:.*Important Message From/ REJECT
  - *Long-term*: *delegate* deep inspection to third-party code.
- Emergence of specialized protocols: CVP, Milter, etc.
  - We already use SMTP for email distribution world-wide.
    - Why can't we also use SMTP to plug in anti-spam/virus?

Invent sparingly

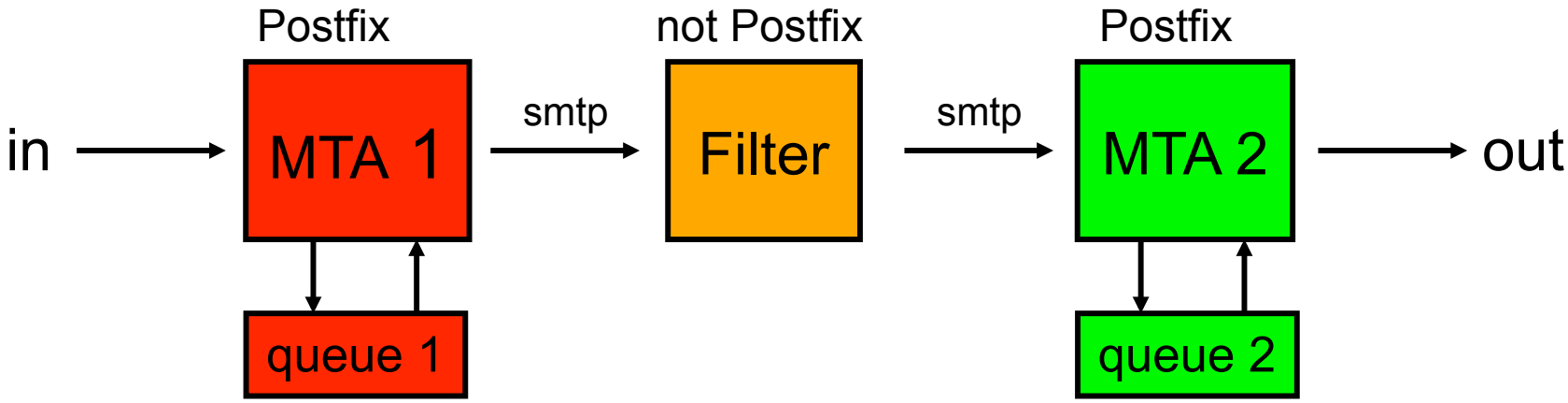
Postfix content filter via SMTP (after-queue)



- MTA = Mail Transport Agent.
- Red = dirty, green = clean.
- But it can't be that simple, right?
- Using two MTAs must be wasteful!

Invent sparingly

After-queue content filter support

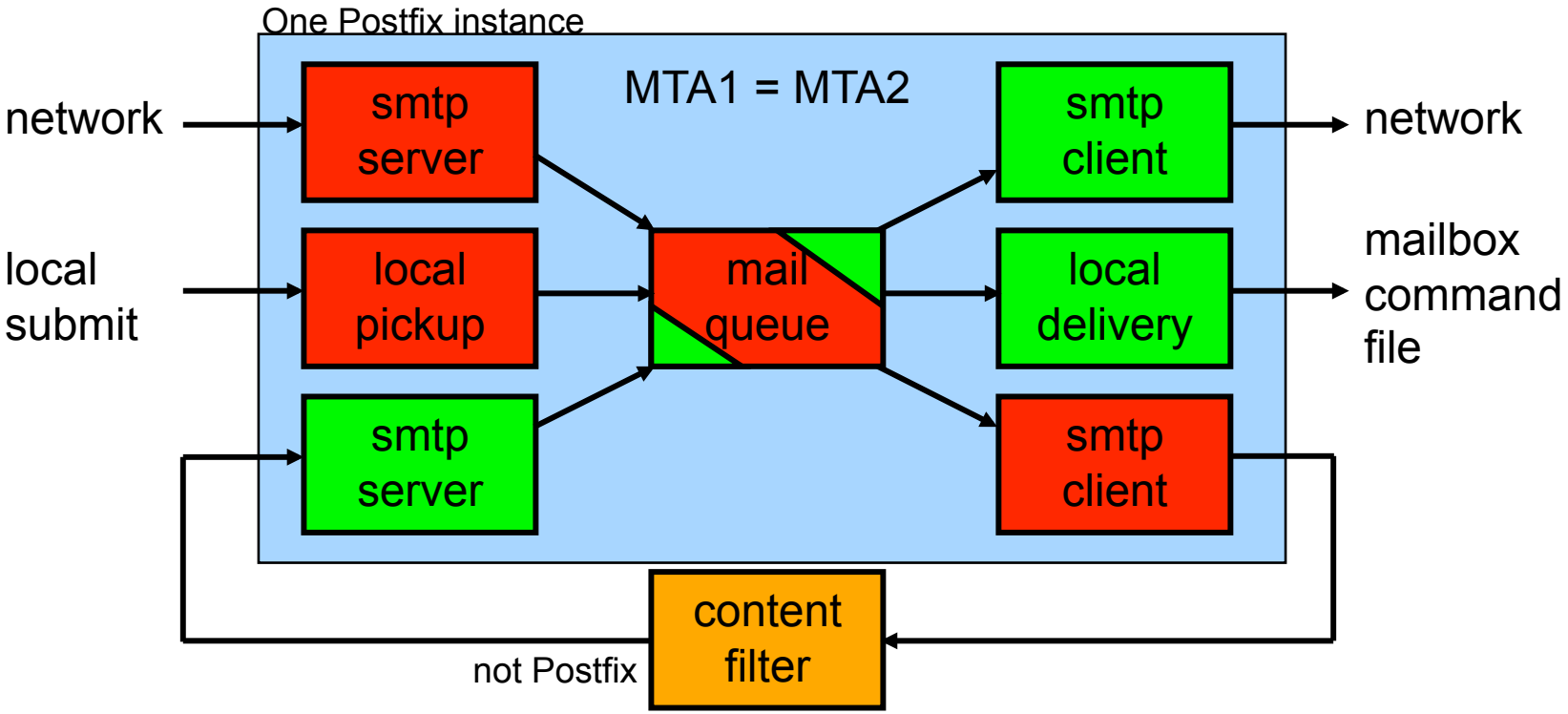


- Advantage of after-queue content filters:
  - Performance*:* 10 after-queue filter processes can handle the traffic from 100 before-queue SMTP sessions.
- Disadvantage: after-queue filter must *quarantine* or *discard* bad mail, instead of *reject* (don't become a backscatter source).
  - Problem: discarding mail is problematic e.g. in Europe.

Invent sparingly

Postfix content filter via SMTP (after-queue)

Two MTAs combined into one – optimization is the root of evil

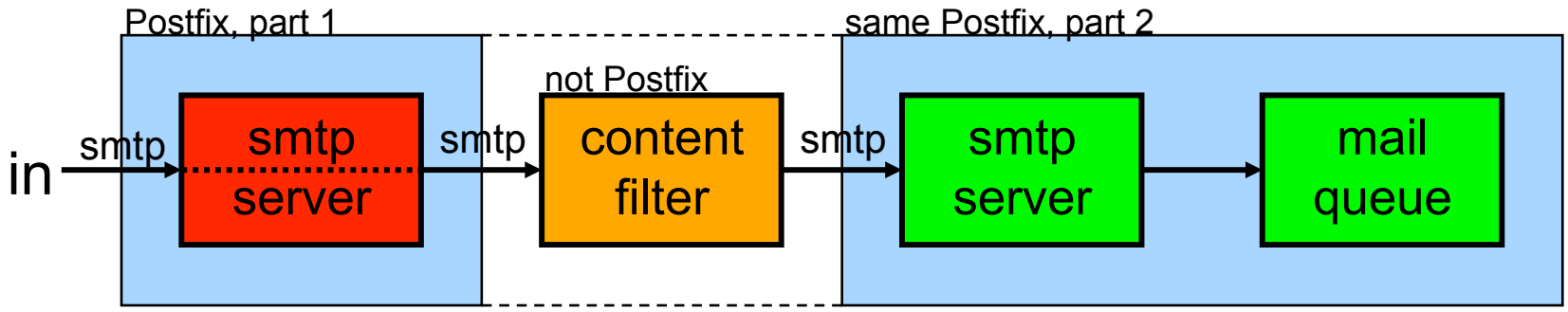


- Combining two MTAs into one increases complexity.
  - Two MTA behaviors, but only one set of configuration files.

Invent sparingly

Before-queue content inspection via SMTP

Responding to popular demand, despite performance limitation



- Before-queue spam/virus filtering is needed in Europe.
  - Reject bad mail before it is accepted into the mail queue.
    - Once you accept mail, you can't discard it.
- One content filter per SMTP client is expensive.
  - Reduce filter count by ~40% with "speed-match" trick.

Invent sparingly

- Adding anti-spam/virus support part 2: Embrace de-facto standards.

“It's not the spammers who destroy [email], it's well-meaning people who insist on broken anti-spam measures.”

Wietse on Postfix mailing list, 2003

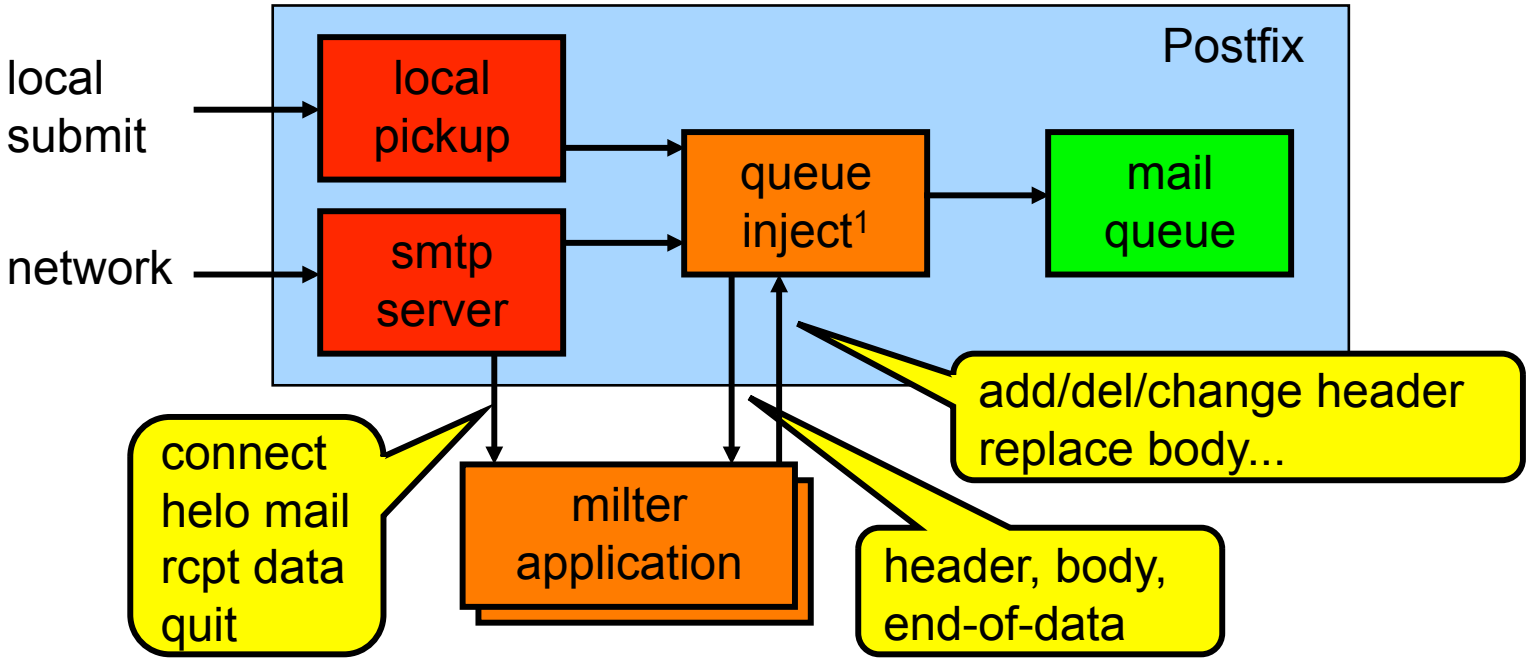
2005 - Proliferation of authentication technologies

- Alphabet soup: SPF, SenderID, DomainKeys, DKIM, BATV, SRS, ADSP, and the end is not in sight.
  - Building everything into Postfix is not practical.
    - Some distributions are two or more years behind on Postfix.
  - Using SMTP-based filters to sign or verify is overkill.

- *Solution*: adopt Sendmail Milter protocol and open up access to a large collection of available applications.

Plan for change

Retrofitting Milter support into a distributed MTA



- Red = dirty, green = clean.
- The effort was heroic, but the reward was sweet.

[1]With local submission, sends surrogate connect/helo/mail/etc events

Plan for change

Postfix author receives Sendmail innovation award

MOUNTAIN VIEW, Calif. October 25th, 2006 Today at its 25 Years of Internet Mail celebration event, taking place at the Computer History Museum in Mountain View, California, Sendmail, Inc., the leading global provider of trusted messaging, announced the recipients of its inaugural Innovation Awards.

. . .

Wietse Venema, author, for his contribution of extending Milter functionality to the Postfix MTA.

http://www.sendmail.com/pdfs/pressreleases/Sendmail%20Innovation%20Awards_10%2025%2006_FINAL.pdf

Plan for change

- Catching up on Sendmail

Why Postfix did not become a bloated mess.

How Postfix has grown in size

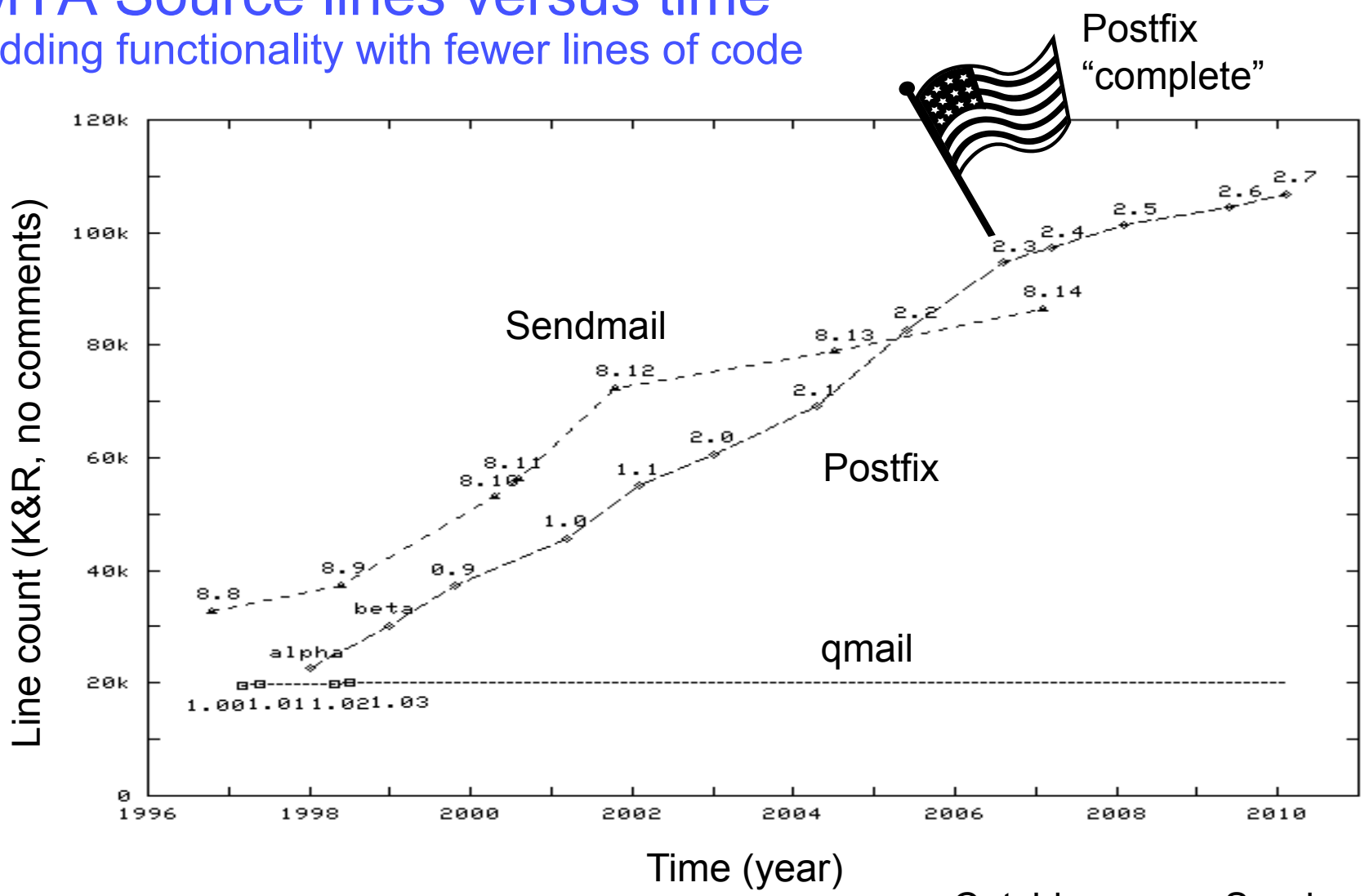
- Initial trigger: the Postfix source tar/zip file was *larger* than the Sendmail source tar/zip file.
  - Marcus Ranum asked if I had dragged in an XML parser.

- Analyze Sendmail, Postfix, and qmail source code:
  - Strip comments (*shrinking* Postfix by 45% :-).
  - Format according to “Kernighan and Ritchie” style (*expanding* qmail by 25% :-).
  - Delete repeating (mostly empty) lines.

Catching up on Sendmail

MTA Source lines versus time

Adding functionality with fewer lines of code



Catching up on Sendmail

Why Postfix did not become a bloated mess

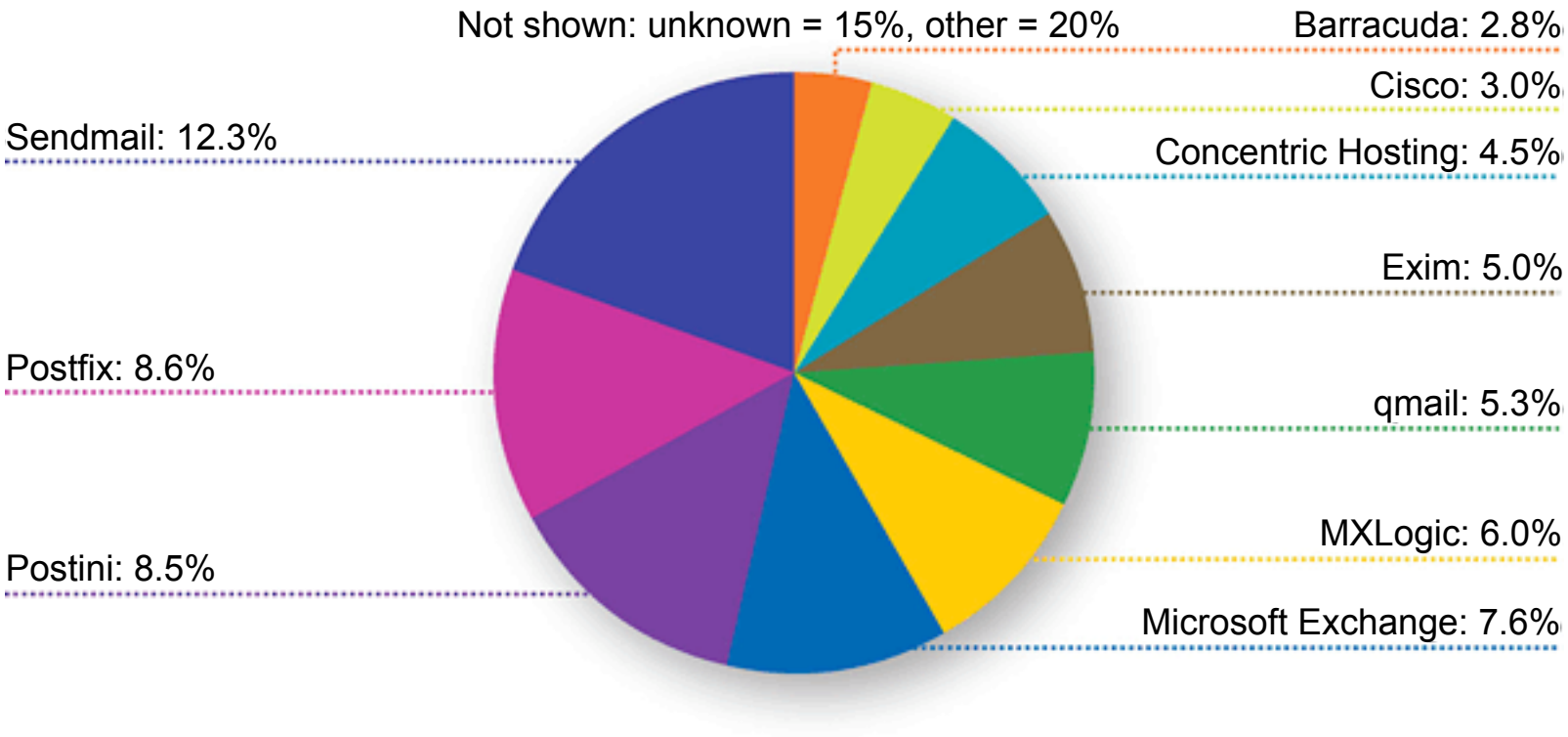
Benefits from a partitioned architecture

- Small programs are easier to maintain.
  - That is, after you build the communication infrastructure.
  - Minor features: easier to *modify* a small program.
  - Major features: easier to *add* a small program.
    - Present breakdown: 24 daemons, 13 commands.
  - Small is a relative term.
    - The SMTP server daemon now weighs in at almost 10k lines, half the size of the entire Postfix alpha release.

Catching up on Sendmail

- Market share (lies, d*mned lies, and ...)

Fingerprinting 400,000 company domains remotely



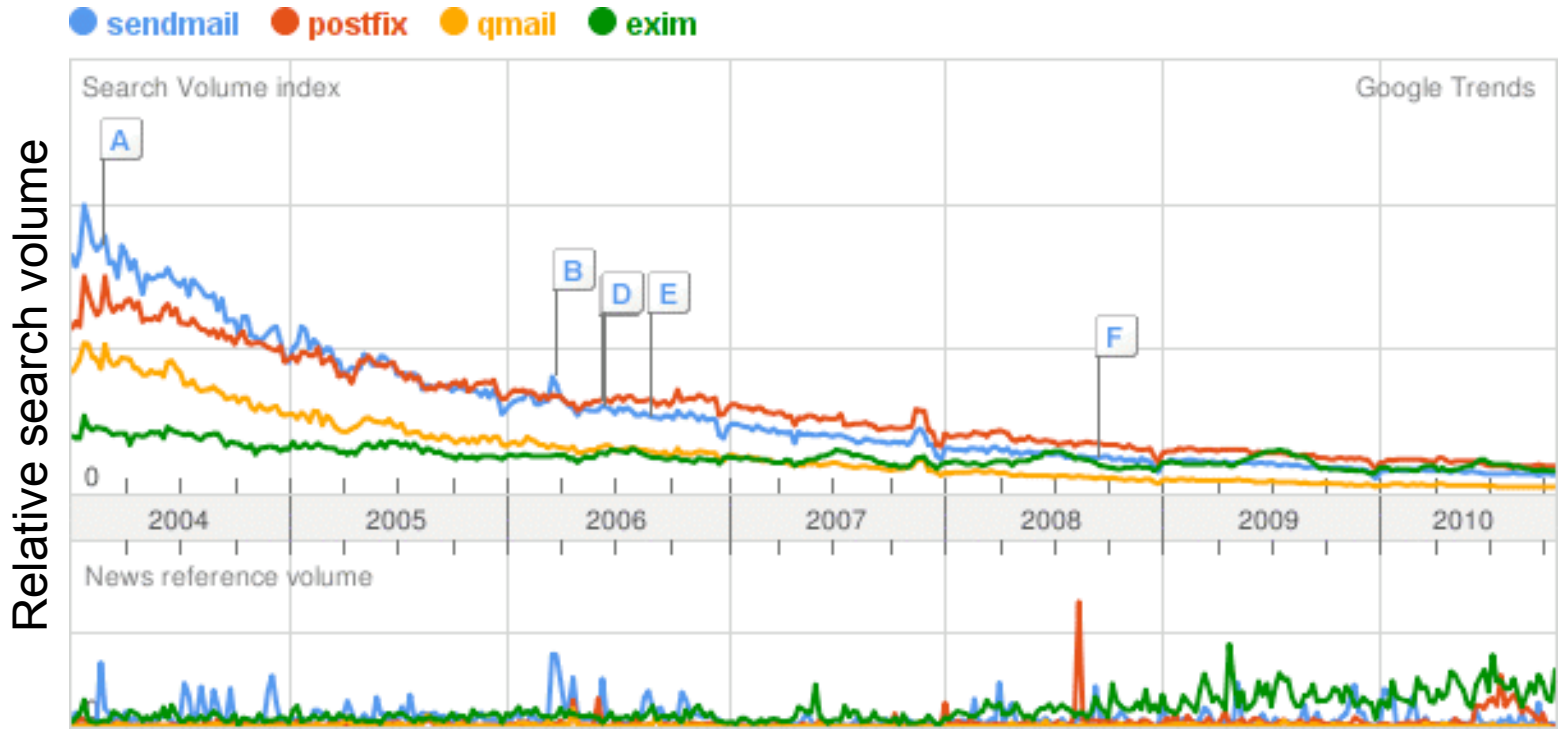
After: Ken Simpson and Stas Bekman, O'Reilly SysAdmin, January 2007.

http://www.oreillynet.com/pub/a/sysadmin/2007/01/05/fingerprinting-mail-servers.html

Market share

Interesting result, but what does it mean?

Query = sendmail, postfix, qmail, exim



Market share

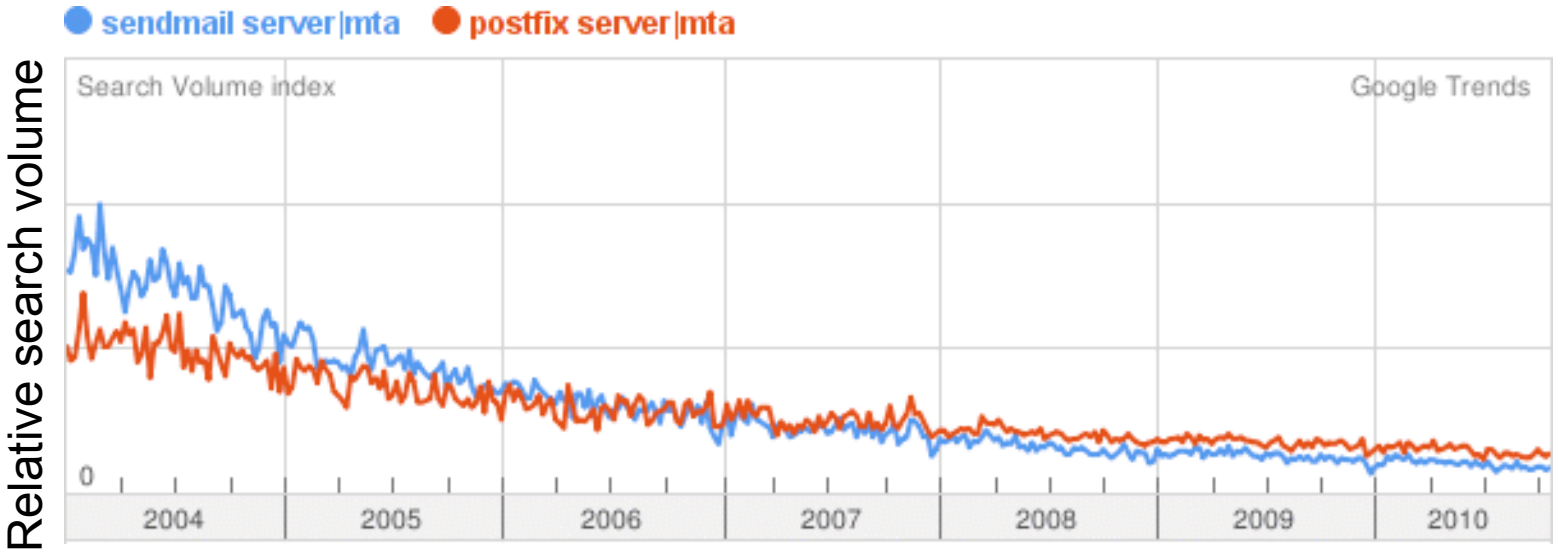
Introducing Google trends

- Website: trends.google.com (google.com/trends).
- Search for relative popularity of search terms.
  - Second-order Google.

Market share

Tweaking the query to avoid pollution

Query = sendmail server|mta, postfix server|mta



Market share

Google trends lessons

- The answer is only as good as the question you ask.
  - Beware of name collisions, common words, etc.
- Sobering lessons:
  - Only a minority of users is interested in mail servers.
  - Their proportion is steadily declining.

Market share

- Current developments

“Zombies suck the life out of the mail server.”

Wietse at mailserver conference, 2009

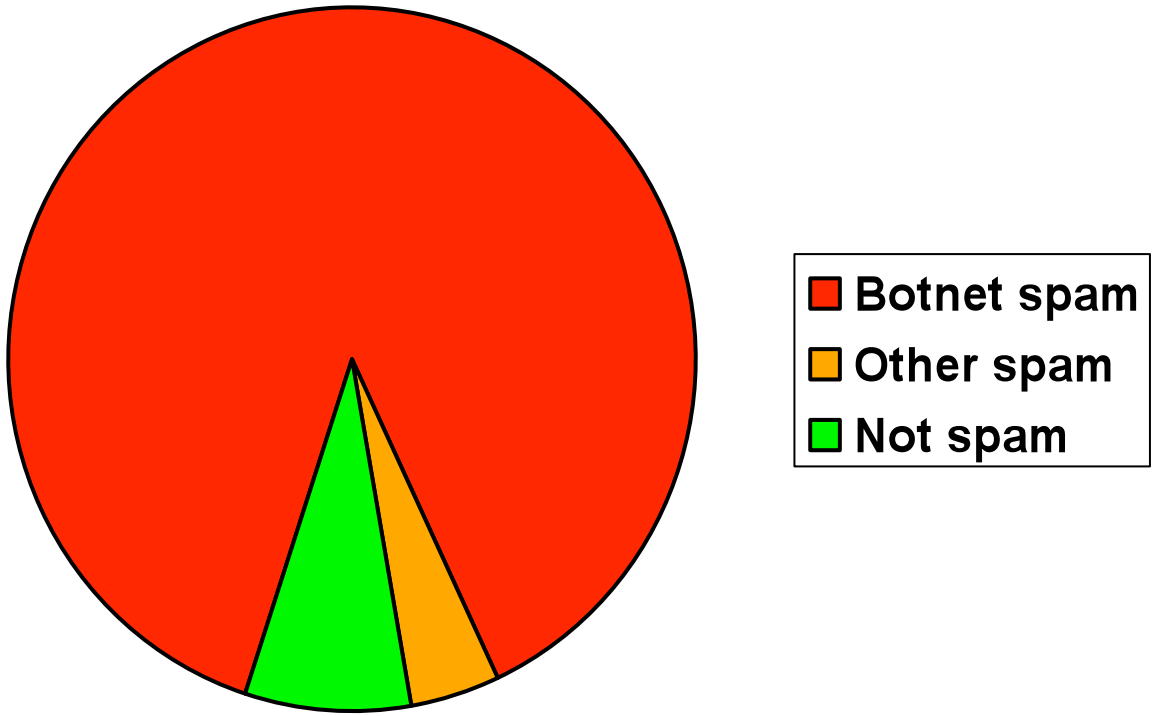
Changing threats

- 1999: You built a mail system that runs on UNIX, so you didn't have to worry about Windows viruses.
  - *Problem*: your UNIX-based mail system becomes a major distribution channel for Windows malware (Melissa).
    - *Solution*: outsource the job to external content filters.

Changing threats

- 2009: You built a mail system that has world-class email delivery performance.
  - *Problem*: your world-class performing mail system is now spending most of its resources *not delivering mail*.
    - *Solution*: work smarter.

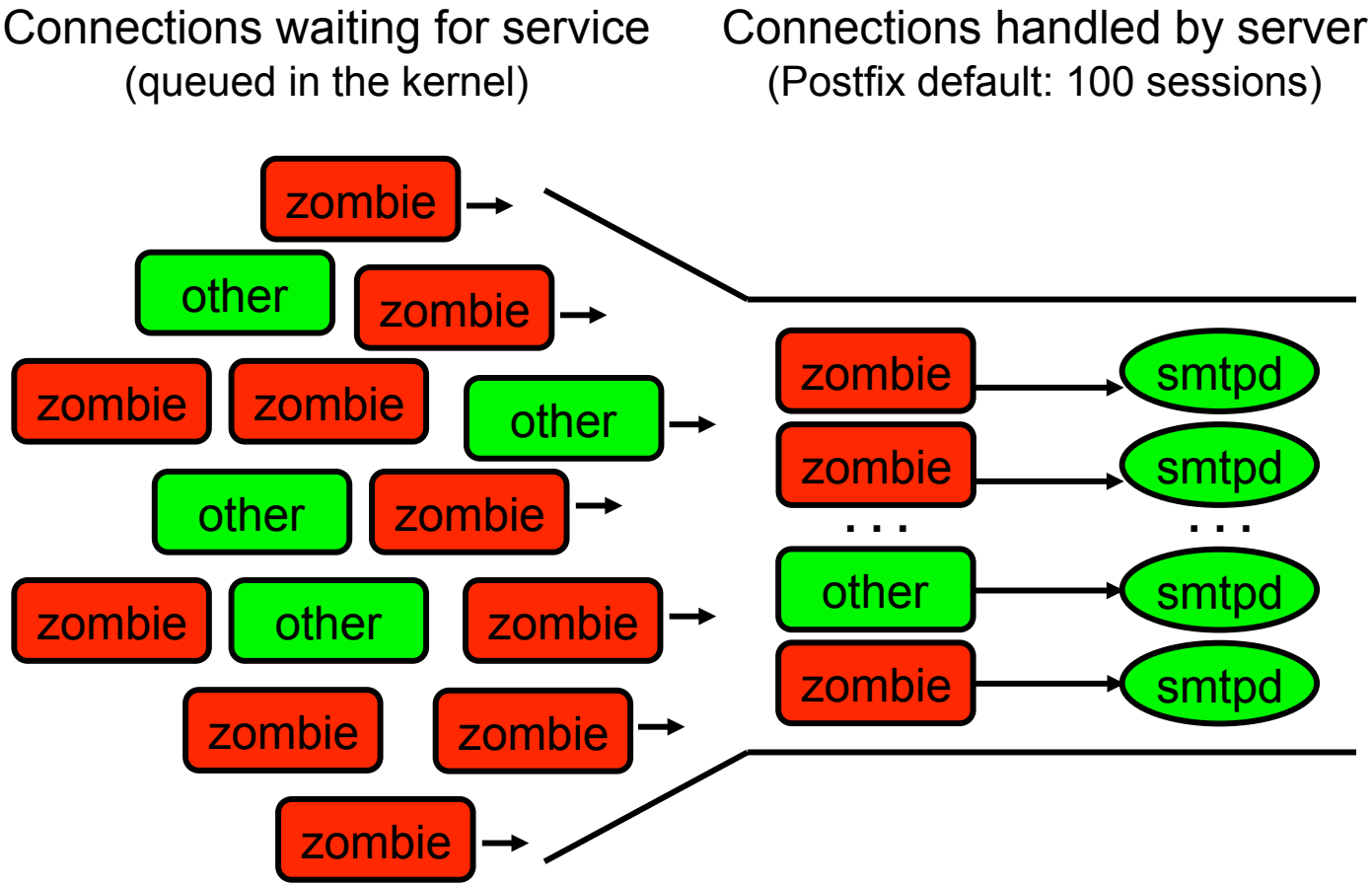
92% Mail is spam, 95% spam is from botnets



Source: MessageLabs Intelligence report, August 2010

Changing threats

Zombies keep mail server ports busy



Changing threats

Zombies suck the life out of the mail server

- Worst-case example: Storm botnet.

```
13:01:36 postfix/smtpd: connect from [x.x.x.x]
13:01:37 postfix/smtpd: reject: RCPT from [x.x.x.x]:
            550 5.7.1 blah blah blah
13:06:37 postfix/smtpd: timeout after RCPT from [x.x.x.x]
```

  - RFC 5321 recommends 5-minute server-side timeout.
    - Postfix implements SMTP according to the standard.
      - Result: all SMTP server ports kept busy by Storm zombies.

Changing threats

Mail server overload strategies

- Assumption: the zombie problem will get worse before things improve (if ever).
- Temporary overload:
  - Work faster: less time per SMTP client (load shedding).
- Persistent overload:
  - Work harder: handle more SMTP clients (forklift solution).
  - Work smarter: stop spambots up-stream (postscreen).

Temporary overload strategy

- Work faster: spend less time per SMTP client.
  - Reduce time limits, number of rejected commands, etc.
  - Will delay *some* legitimate email.
    - From sites with large network latency or packet loss.
    - From list managers with aggressive timeouts.
  - Better to receive *some* legitimate mail, than *no mail*.
    - OK as long as the overload condition is temporary.

Changing threats

Temporary overload implementation

- Postfix master(8) daemon detects “all SMTP ports busy” and updates SMTP daemon command lines[1]:

```
smtpd -o stress=yes
```

- Default parameter settings (Postfix 2.6 and later):

```
smtpd_timeout = ${stress?10}${stress:300}s
smtpd_hard_error_limit = ${stress?1}${stress:20}
```

[1]Feature is called “stress”, and implemented in 21 lines, because of author overload.

Changing threats

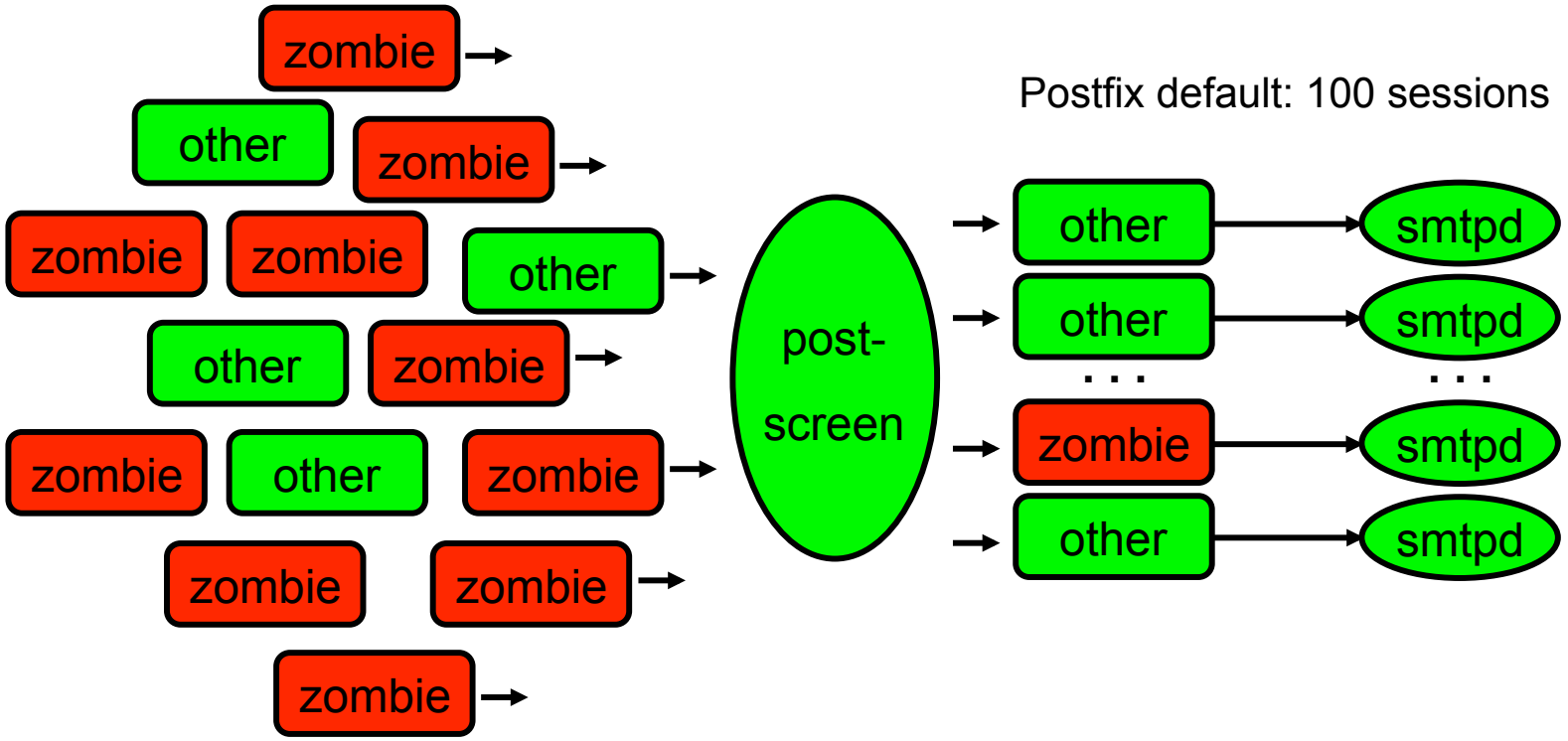
Persistent overload strategies

- Work harder: configure more mail server processes.
  - The brute-force, fork-lift approach for rich people.
  - OK if you can afford network, memory, disk, and CPU.
- Work smarter: keep the zombies away from the server.
  - Before-server connection filter.
  - More SMTP processes stay available for legitimate email.

Changing threats

Persistent overload - before-smtpd connection filter

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



Changing threats

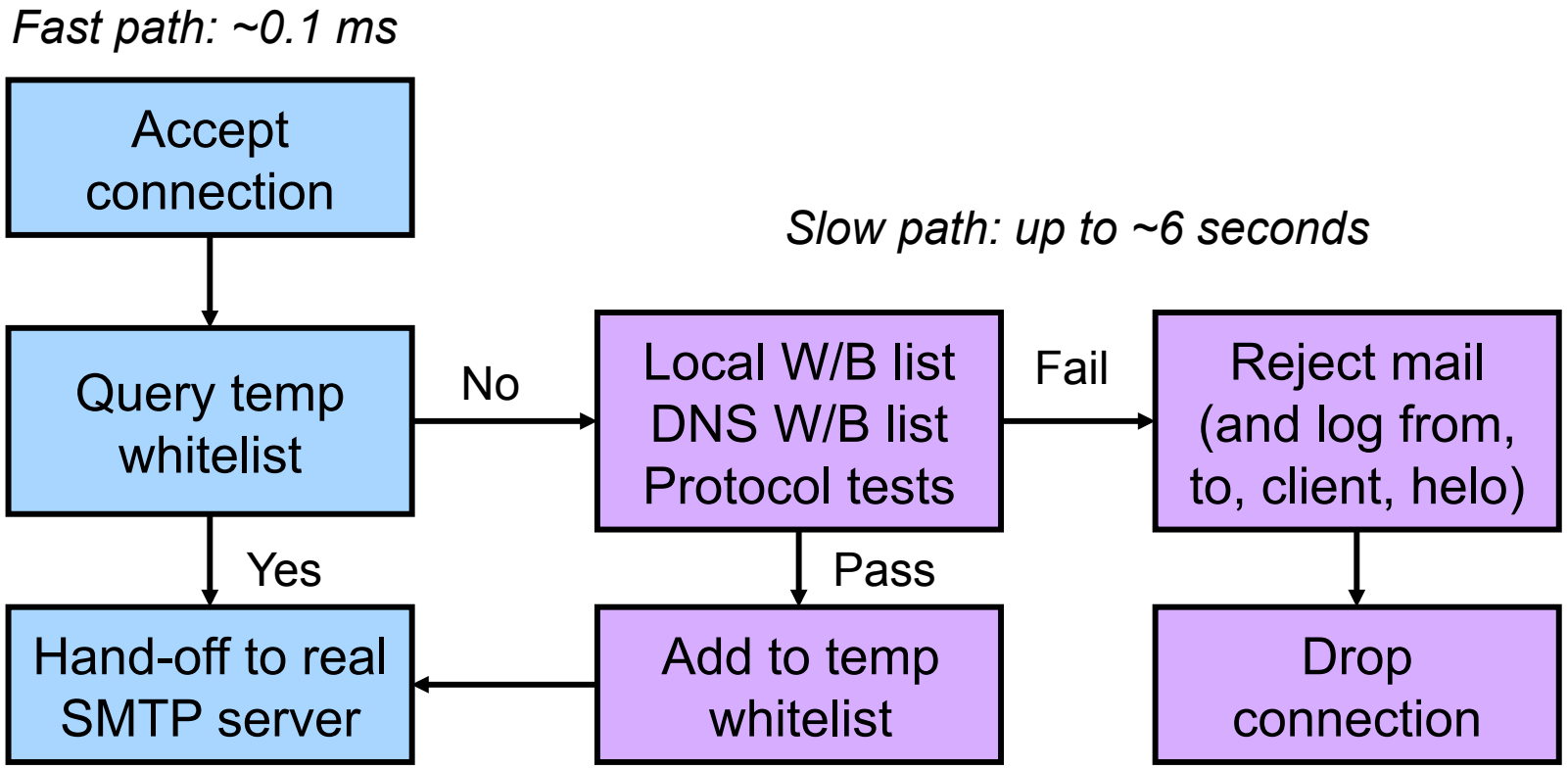
postscreen(8) challenges and opportunities

- Zombies are blacklisted within a few hours[1].
  - Opportunity: reject clients that are in a hurry to send mail.
    - Clients that talk too fast: pregreet, command pipelining.
    - Other blatant protocol violations.
    - Fake “temporary” error when stranger connects (greylisting).
- Zombies avoid spamming the same site repeatedly.
  - Challenge: decide “it’s a zombie” for single connections.
    - Use DNS white- and blacklists as shared intelligence source.

[1]Chris Kanich et al., Spamalytics: An Empirical Analysis of Spam Marketing Conversion, CCS 2008.

postscreen(8) workflow

One daemon screens multiple connections simultaneously



Changing threats

Detecting spambots that speak to early (pregreet)

- Good SMTP clients wait for the SMTP server greeting:

SMTP server: **220 server.example.com ESMTP Postfix<CR><LF>**

SMTP client: **EHLO client.example.org<CR><LF>**

- Sendmail *greet_pause* approach: wait several seconds before sending the 220 greeting.
  - Very few clients greet too early.
  - More clients just give up after a few seconds.
  - Manual whitelisting.

Changing threats

Question for dog catchers

- Q: How do I quickly find out if a house has a dog?
- A: Ring the doorbell, and the dog barks immediately.

- postscreen(8) uses a similar trick with botnet zombies.

Changing threats

Making zombies bark - multi-line greeting trap

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

mail server: **220–server.example.com ESMTP Postfix<CR><LF>**

mail 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:

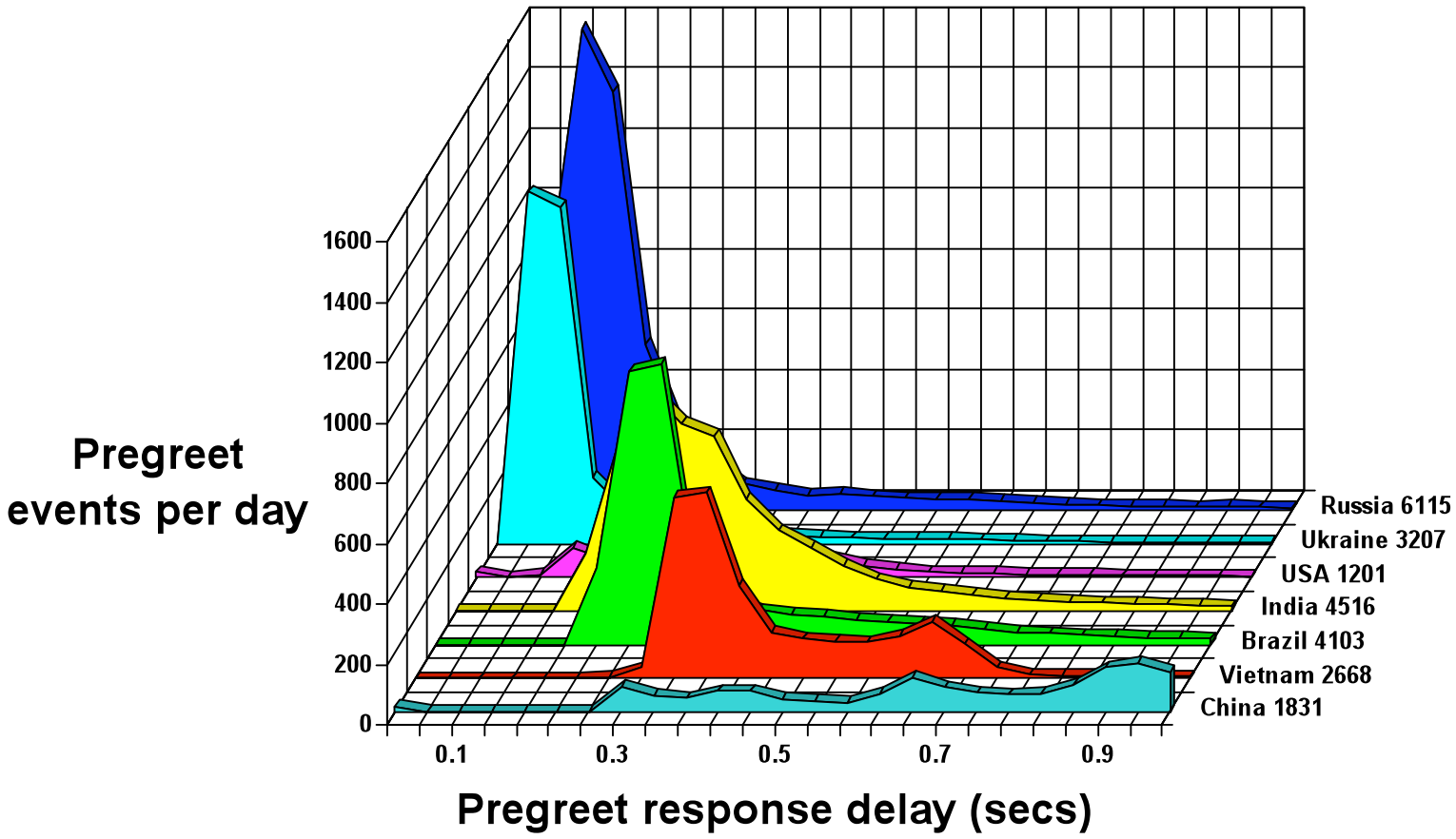
postscreen: **220–server.example.com ESMTP Postfix<CR><LF>**

spambot: **HELO i-am-a-bot<CR><LF>**

Changing threats

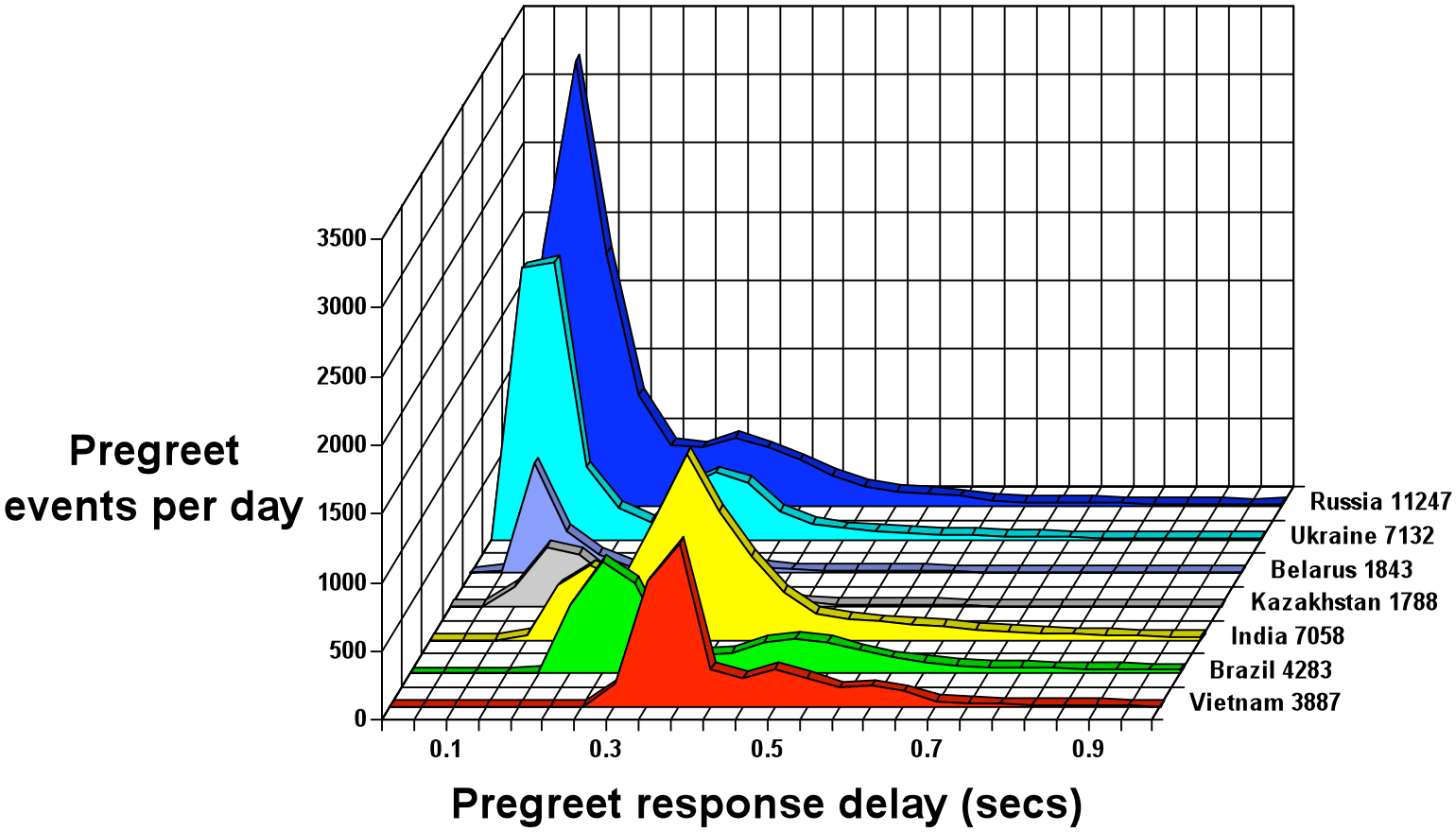
Over 60% of bots pregreet at mail.charite.de

8% Not on DNS blacklists. Berlin, Aug 26 – Sep 29, 2010



Over 70% of bots pregreet at mail.python.org

1% Not on DNS blacklists. Amsterdam, Sep 16 – 29, 2010



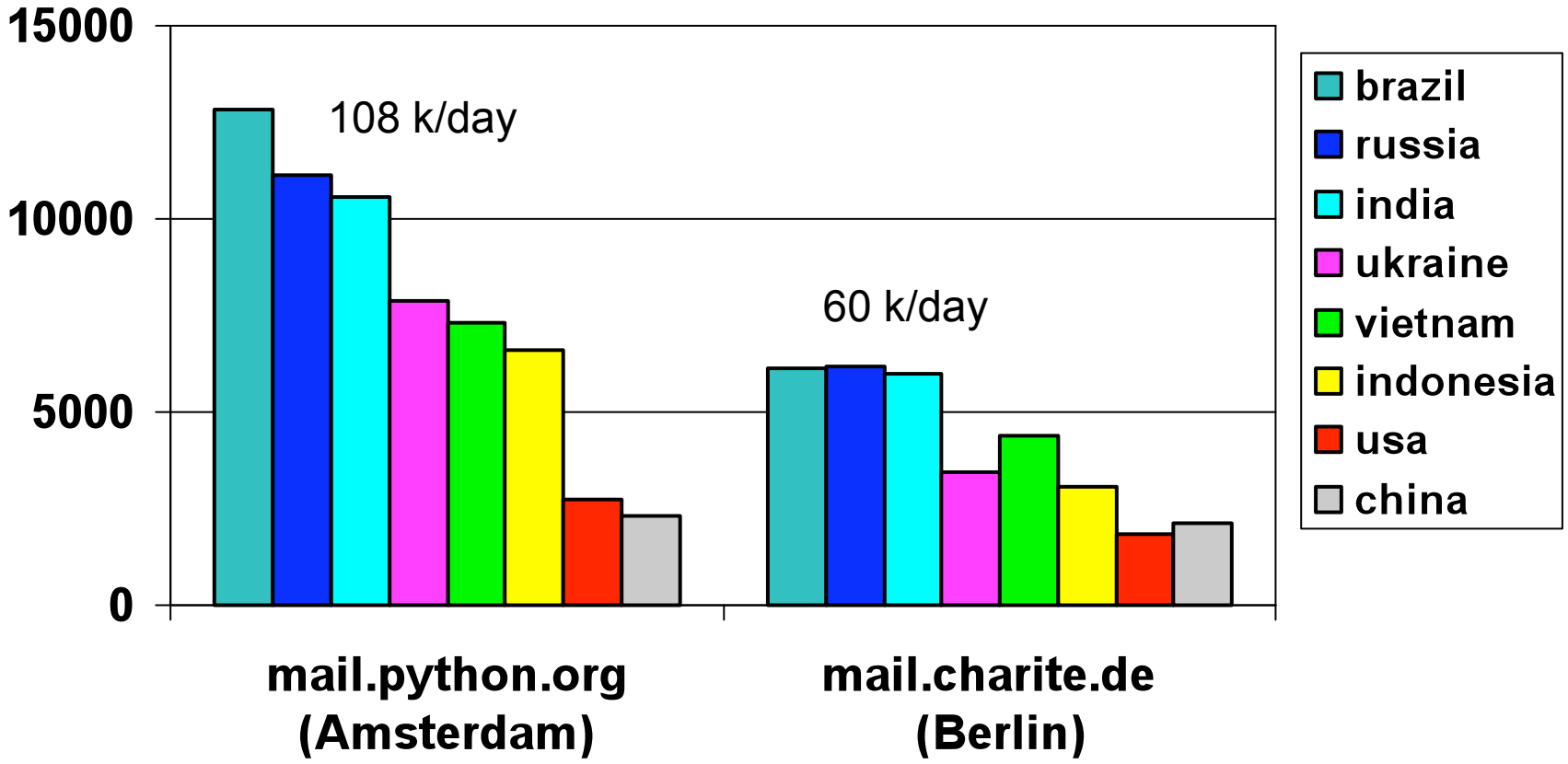
SPAM load varies by receiver and time of day

- SPAM load at different receivers:
  - A handful countries sends most of today's spam, but different receivers see different sender volumes.
- SPAM load at different times of day:
  - SPAM is a 24-hour operation, but spambots are not.
    - SPAM tends to be sent later in the day than HAM[1].

[1]S. Hao et al., Detecting Spammers with SNARE: Spatio-temporal Network-level Automatic Reputation Engine. Usenix Security 2009.

Spam connections/day at small European sites

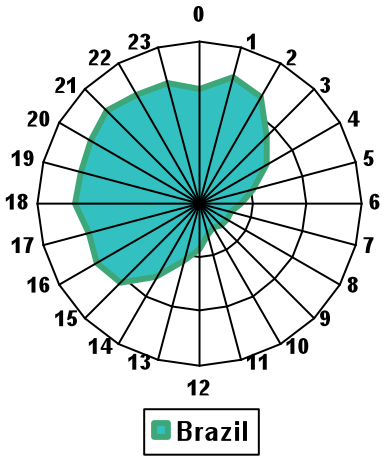
Spam according to zen.spamhaus.org, Sep 3 – 23, 2010

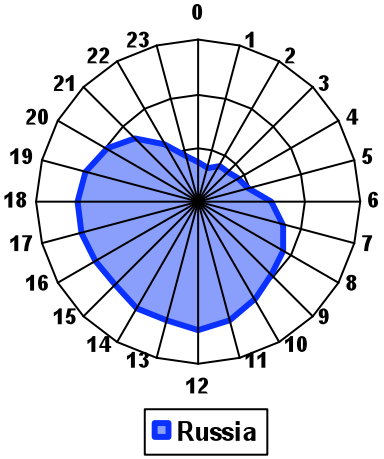


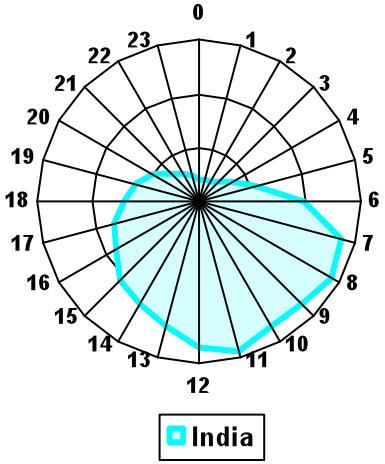
Changing threats

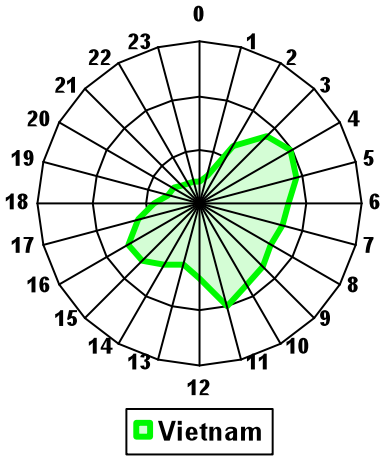
Spam connections/hour at mail.charite.de (UTC+2)

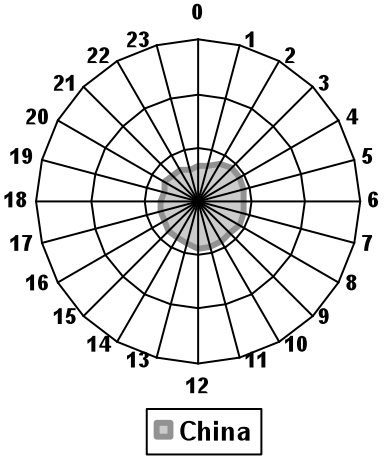
Spam according to zen.spamhaus.org, Aug 26 – Sep 29, 2010

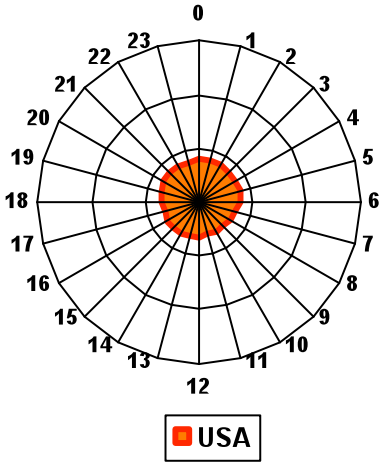












Changing threats

postscreen(8) results and status

- Parallel, weighted, DNS white/blacklist lookup.
- Static white/blacklist, dynamic “fast path” cache.
- Pilot results (small sites, up to 200k connections/day):
  - Pregreet (talking early): up to ~10% not on DNS blacklist.
  - Pipelining (multiple commands): ~1% of spambots.
- Other protocol tests to be added as botnets evolve.
- Start planning for extension interfaces.
- Expected release with Postfix 2.8, early 2011.

Changing threats

- Concluding remarks

Postfix lessons learned

- Good PR does make a difference. It's easy to under-estimate how swiftly a large company can move.
- Don't re-invent mechanisms that already work. E.g., SMTP, Milter, maildir, lookup tables. Invent sparingly.
- Build the stable protocols into Postfix: SMTP, LMTP, TLS, SASL, IPv6, DSN, MIME, LDAP, SQL.
- Use plug-ins for future proofing: Anti-Spam, Anti-Virus, DKIM, SenderID, SPF, greylist, etc. Plan for change.
- Optimize both the worst case and the common case. Worst cases become the normal case, and vice versa.
- Don't let a C prototype become your final implementation.

Conclusion

Conclusion

- Postfix has matured well. With a system implemented by small programs, many features can be added by *changing* a small program or *adding* a small program.
- Extensibility is a life saver[1]. It eliminates the pressure to implement everything within Postfix itself, and it gives the user more choice.
- The battle continues. For the near future, connection filtering helps to keep mail servers operable under increasing zombie loads.

[1]For both author and software.