How The Pursuit of Truth Led Me To Selling Viagra®

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Outline:

- This is a broad, *retrospective* talk about network security **Data**
- Specifically, 2 decades' worth of Internet measurement:
  - What the data tells us about the lay of the land
  - … what's changed
  - … and what in fact doesn't change ("invariants")
- A personal (ivory tower research) view:
  - From general network characterization ⇒ manual attacks ⇒ worms ⇒ bots ⇒ spam
  - Why all this leads to selling Viagra

First, some acknowledgments:

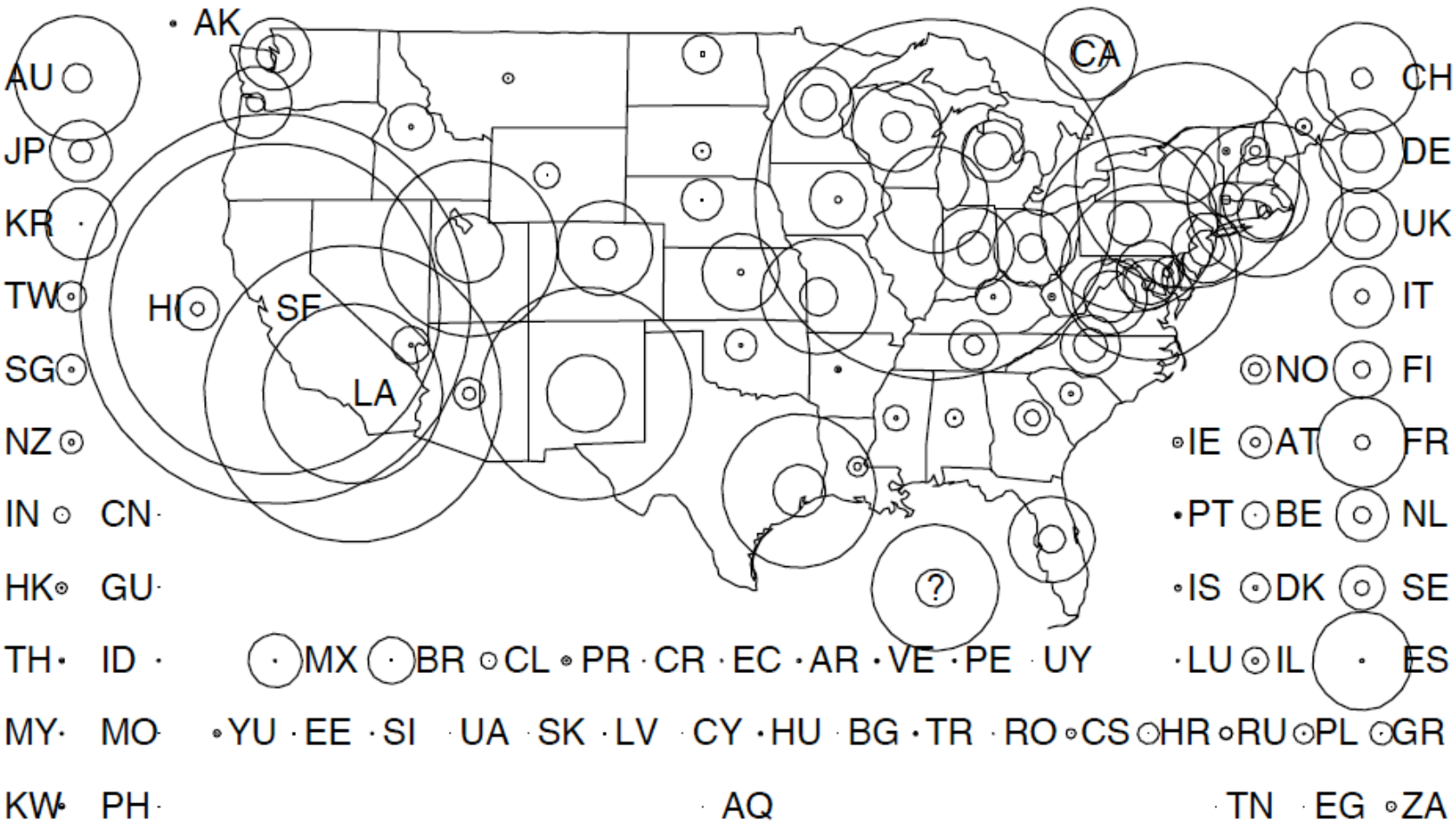
- ICSI: Mark Allman, Christian Kreibich, Robin Sommer, Nicholas Weaver
- LBL: Craig Leres, Jim Rothfuss, Dwayne Ramsey, Brian Tierney, et al
- UC San Diego: Stefan Savage, Chris Kanich, Kirill Levchenko, Brandon Enright, Geoff Voelker

Part I

Pursuit of Truth +
Phobia of Being Fooled =
Thirst for Data

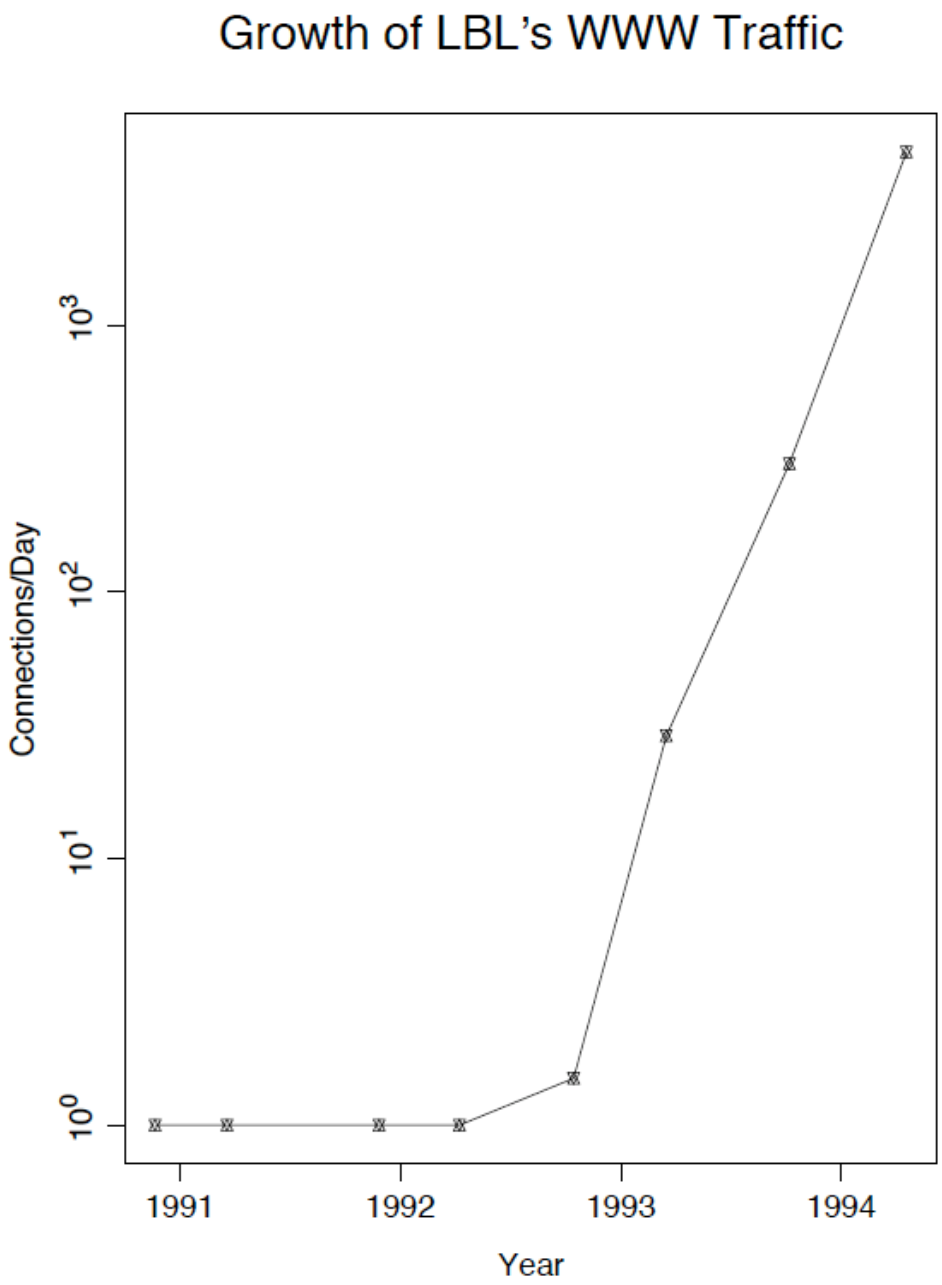
Three Invariants: Growth, Explosive Onset, & Diversity

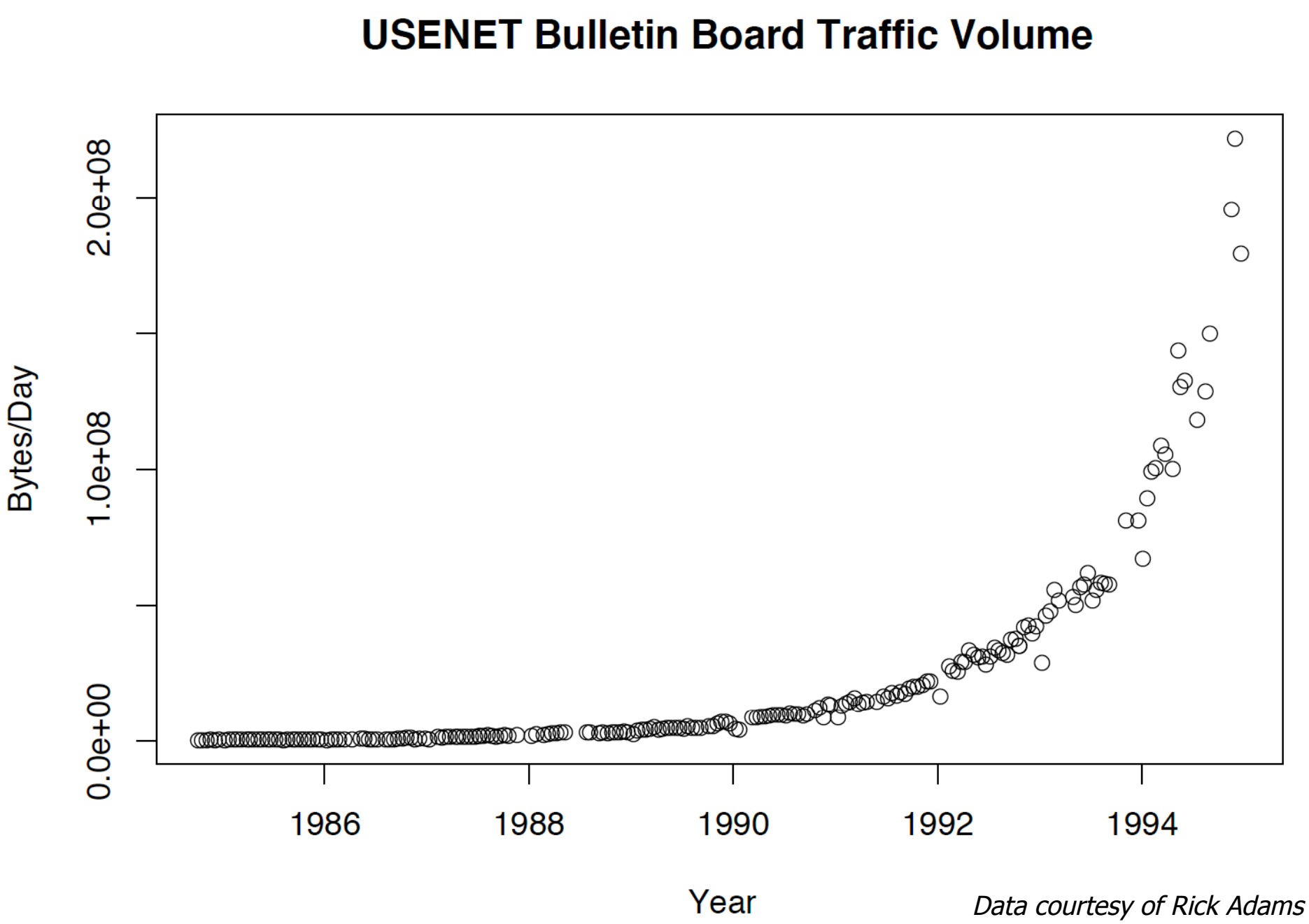
- Sep 1988: I apply to grad school
  - 56,000 Internet hosts (3.3 MB/day)
- Sep 1990: I enroll in grad "special topics" course on networking & start measuring traffic at LBL
  - 313,000 Internet hosts (9.5 MB/day)
- Oct 21 1991: I join Prof. Ferrari's *Tenet* group
  - 617,000 Internet hosts (17.5 MB/day)
- May 11, 1994: My paper *Growth Trends in Wide Area TCP Connections* accepted for publication
  - ≈ 3,000,000 Internet hosts (130 MB/day)

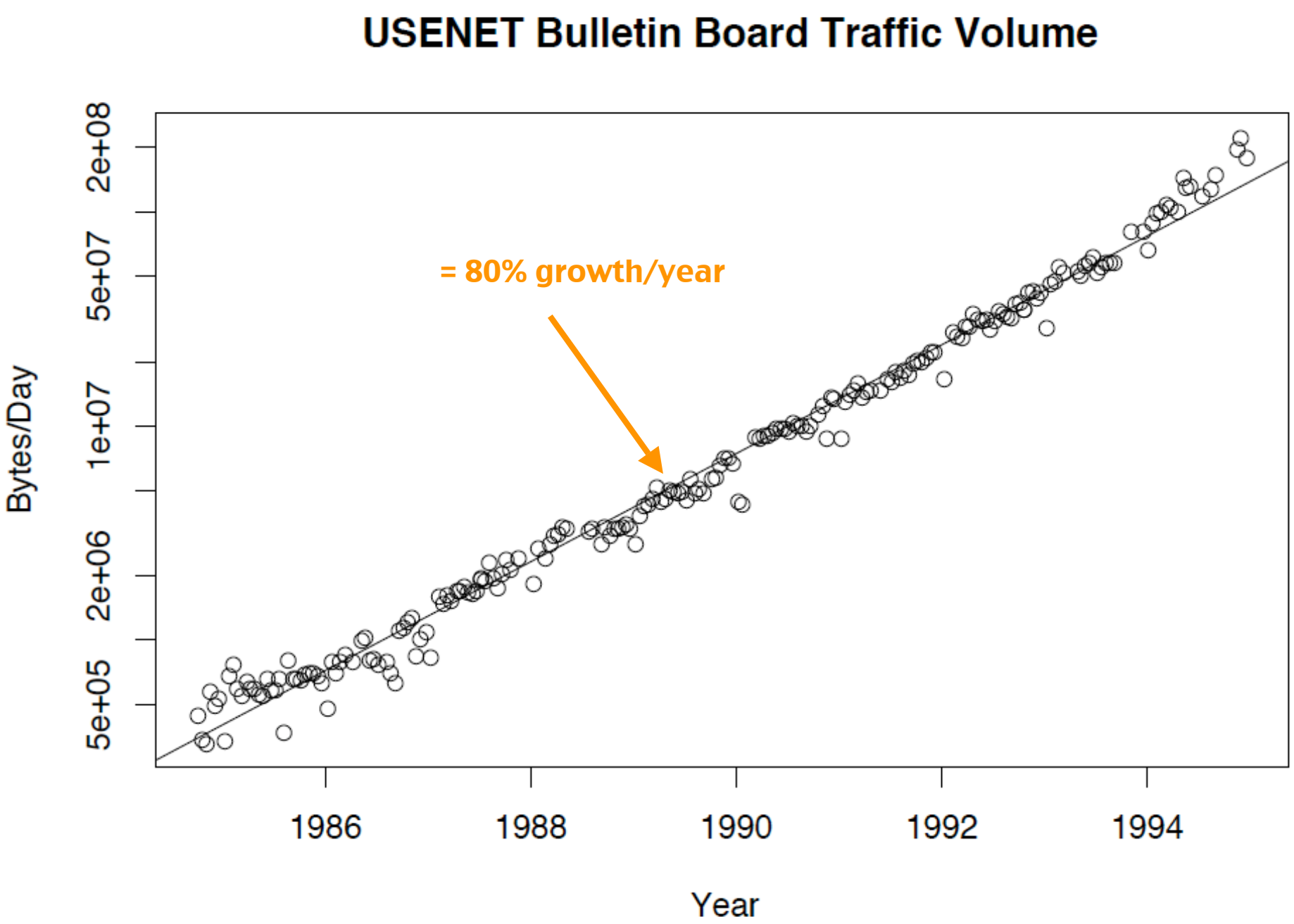


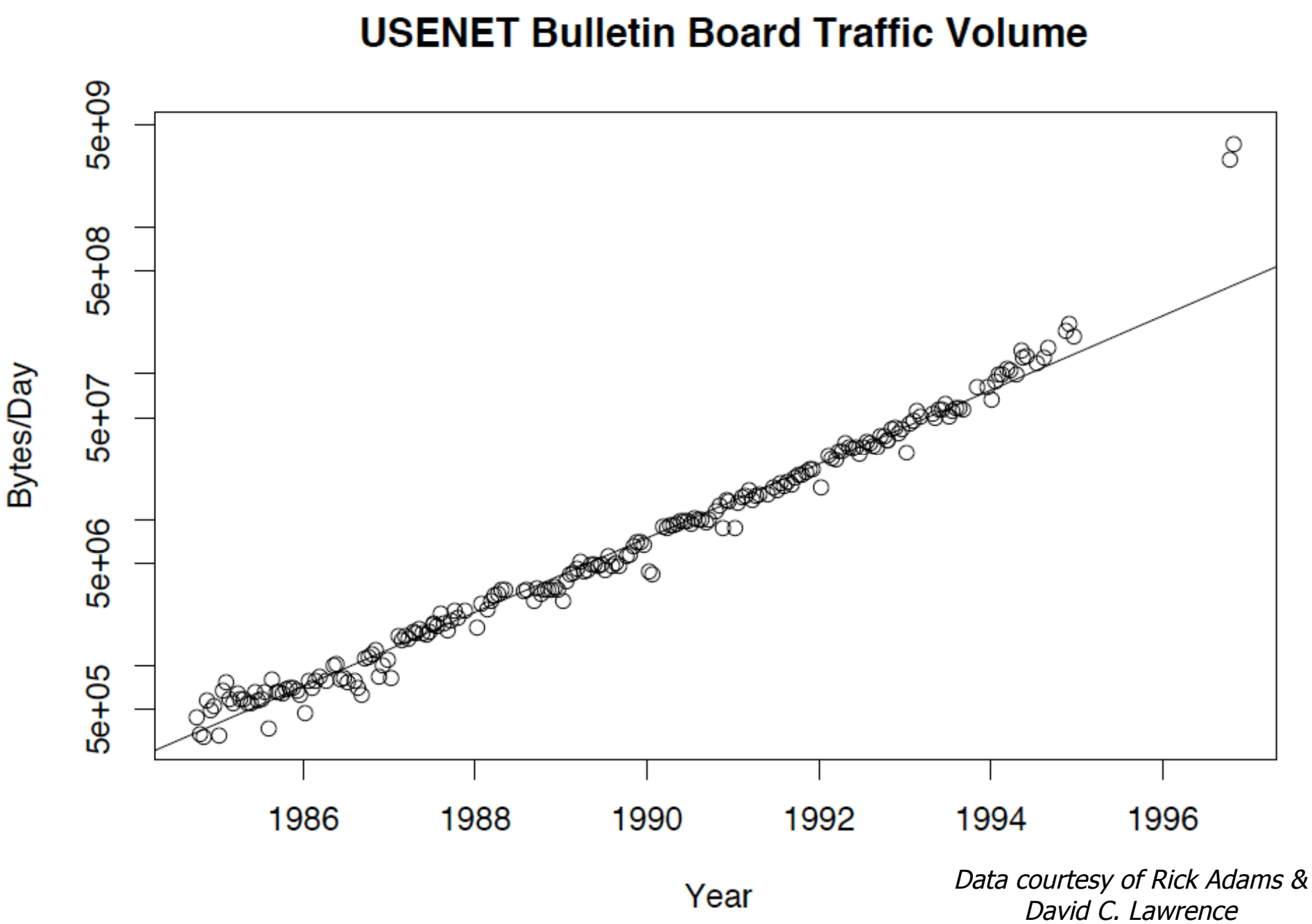
"Our data suggests a very recent explosion in commercial use of the Internet ..."

"... relatively new information-retrieval protocols such as Gopher and World-Wide Web exhibited explosive growth"

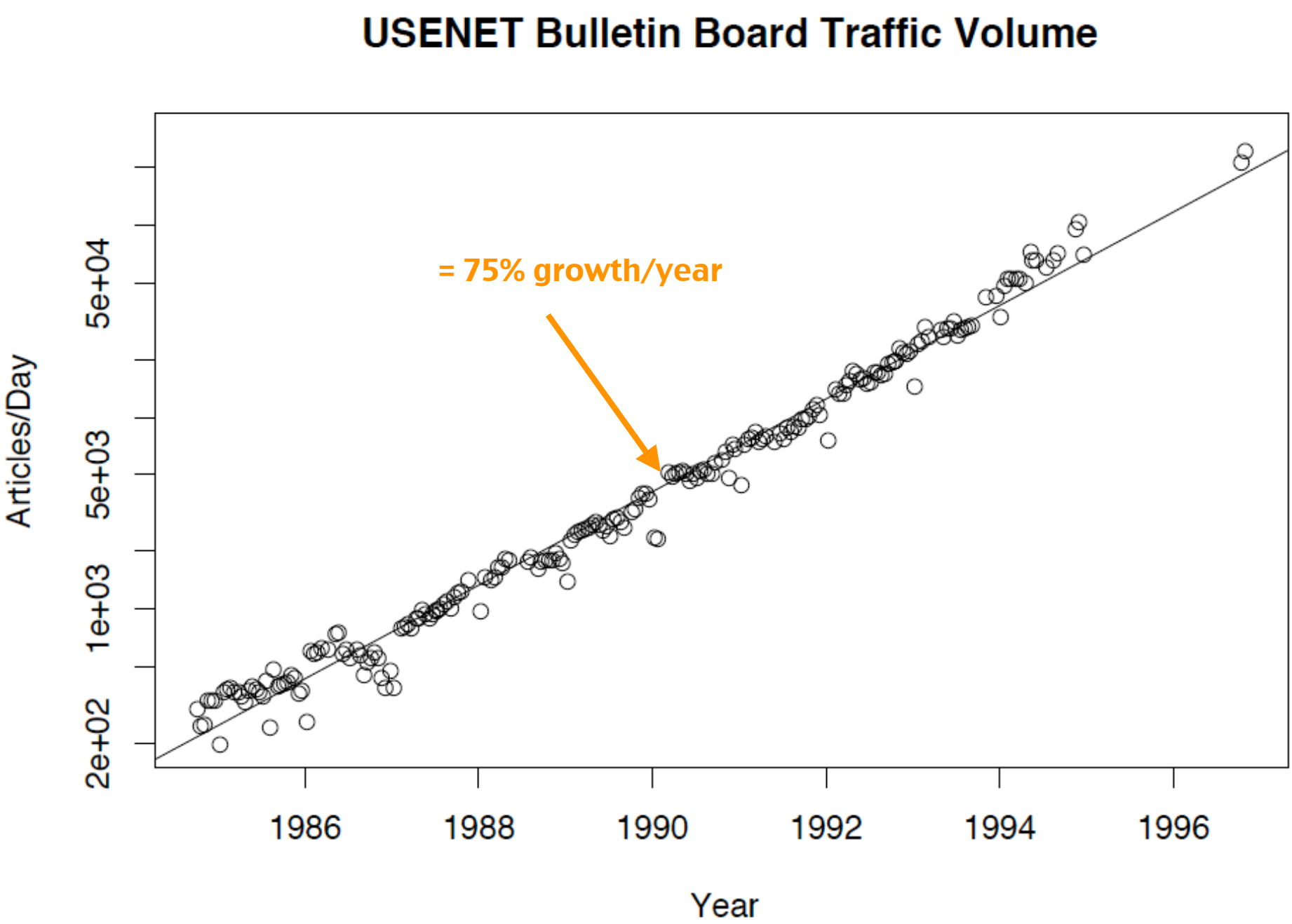

Growth of LBL's WWW Traffic
Connections/Day
10^0
10^1
10^2
10^3
1991
1992
1993
1994
Year

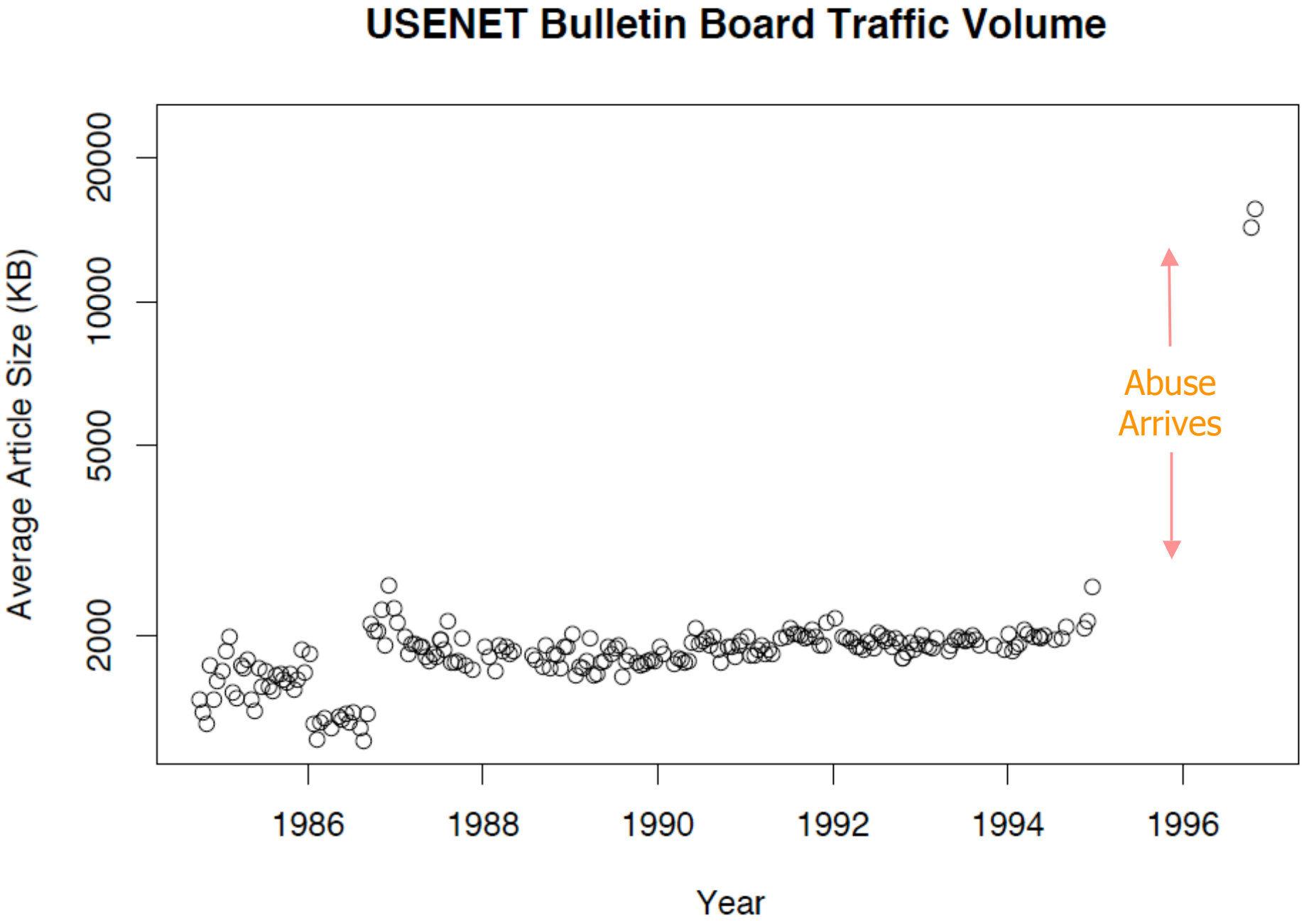

USENET Bulletin Board Traffic Volume
Bytes/Day
0.0e+00
1.0e+08
2.0e+08
1986
1988
1990
1992
1994
Year
Data courtesy of Rick Adams


USENET Bulletin Board Traffic Volume
= 80% growth/year
Bytes/Day
5e+05
2e+06
1e+07
5e+07
2e+08
1986
1988
1990
1992
1994
Year



Data courtesy of Rick Adams & David C. Lawrence


USENET Bulletin Board Traffic Volume
= 75% growth/year
Articles/Day
2e+02
1e+03
5e+03
5e+04
1986
1988
1990
1992
1994
1996
Year


USENET Bulletin Board Traffic Volume
Average Article Size (KB)
2000
5000
10000
20000
1986
1988
1990
1992
1994
1996
Year
Abuse
Arrives

Mid-1990s: Internet Abuse Starts Becoming a Concern

- Observation: operators increasingly ask whether my network data sheds light on security incidents
  - Hmmm, what about doing such measurement purposefully for security monitoring?
- Armed with equipment donation from DEC, the Bro *intrusion detection system* starts operating 24x7 in 1996
  - Inspects LBL border traffic in real-time
  - Who-talks-to-whom, what service, how much data
  - And, increasingly: what are the **semantics** of the conversations

Detecting Attackers, 1990s-style

- Inspect access to sensitive objects:
  - Hosts, usernames (“`lp`”, “`r00t`”), filenames (“`/etc/passwd`”), services (“`mountd`”, Windows file sharing)
- Look for specific forms of protocol abuse
  - E.g., FTP “`site exec`”, excessively long “`finger`” requests
- Check for telling behavior
  - Local host starts running an IRC chat server
  - Outbound requests to `www.uberhax0r.net`, `anticode.com`
  - Login sessions containing: “`unset HISTFILE`”; “`eggdrop`”; “`printf(“overflowing”`; “`smurf.c by TFreak`”; “`u_char sparc_shellcode[] =`”; “`Coded by James Seter`”
- Attackers exploit systems via interactive login sessions
  - Motivated by bragging rights / vandalism
  - Frequent community reuse of tools
  - Employment of “bots” for automating IRC management
- But what about “serious” attackers rather than weenies?

Real-World Security: *Threat Model*

- 1990s academic computer security research heavily influenced by cryptography's standard of mathematical assessment of security strength
  - Prove security properties …
  - … given a model of a powerful adversary
- In practice, goal is risk management, not bulletproof protection.
  - Much of the effort concerns "raising the bar" and *trading off resources*
- Threat model: what you are defending against
  - This can differ from what an academic might expect
  - Consider the Department of Energy …

Network Security Research Grounded in Operational Use

- Ties with LBL operational deployment have been **research gold**
  - *Transformative* compared to working in small, self-contained environment like a lab
- Along with *threat model* (policy) realities, **scale** completely alters the problem landscape:
  - Performance - current target: analyze >> 100K pps
    - Research on: clustering; FPGA front end; multicore architecture
  - Diversity - you see the darnedest (benign) behavior & “crud”
    - Greatly complicates **anomaly detection** & detecting **evasion**

1 day of “crud” seen at ICSI (155K times)

active-connection-reuse	DNS-label-len-gt-pkt	HTTP-chunked-multipart	possible-split-routing
bad-Ident-reply	DNS-label-too-long	HTTP-version-mismatch	SYN-after-close
bad-RPC	DNS-RR-length-mismatch	illegal-%-at-end-of-URI	SYN-after-reset
bad-SYN-ack	DNS-RR-unknown-type	inappropriate-FIN	SYN-inside-connection
bad-TCP-header-len	DNS-truncated-answer	IRC-invalid-line	SYN-seq-jump
base64-illegal-encoding	DNS-len-lt-hdr-len	line-terminated-with-single-CR	truncated-NTP
connection-originator-SYN-ack	DNS-truncated-RR-rdlength	malformed-SSH-identification	unescaped-%-in-URI
data-after-reset	double-%-in-URI	no-login-prompt	unescaped-special-URI-char
data-before-established	excess-RPC	NUL-in-line	unmatched-HTTP-reply
too-many-DNS-queries	FIN-advanced-last-seq	POP3-server-sending-client-commands	window-recision

Network Security Research Grounded in Operational Use

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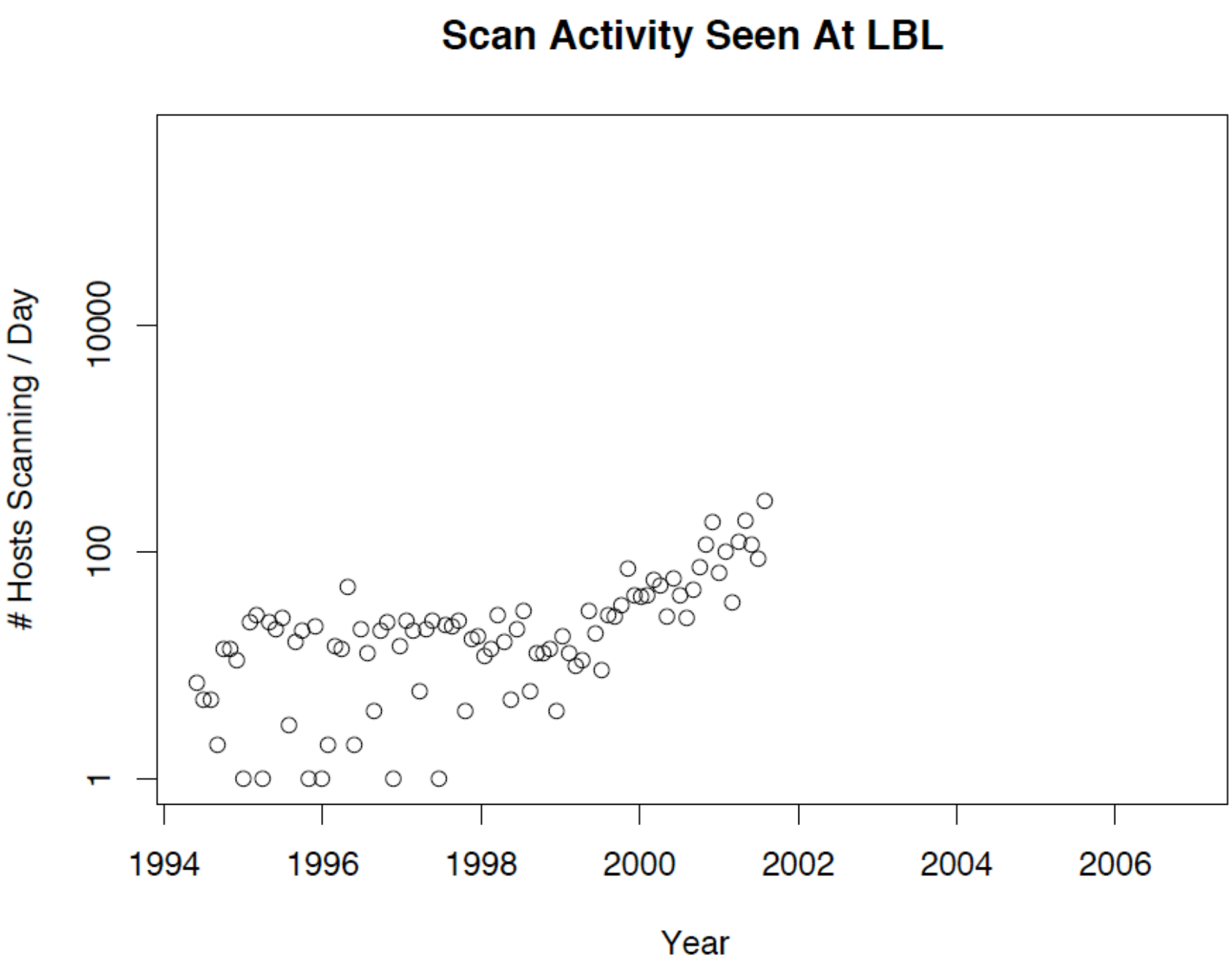
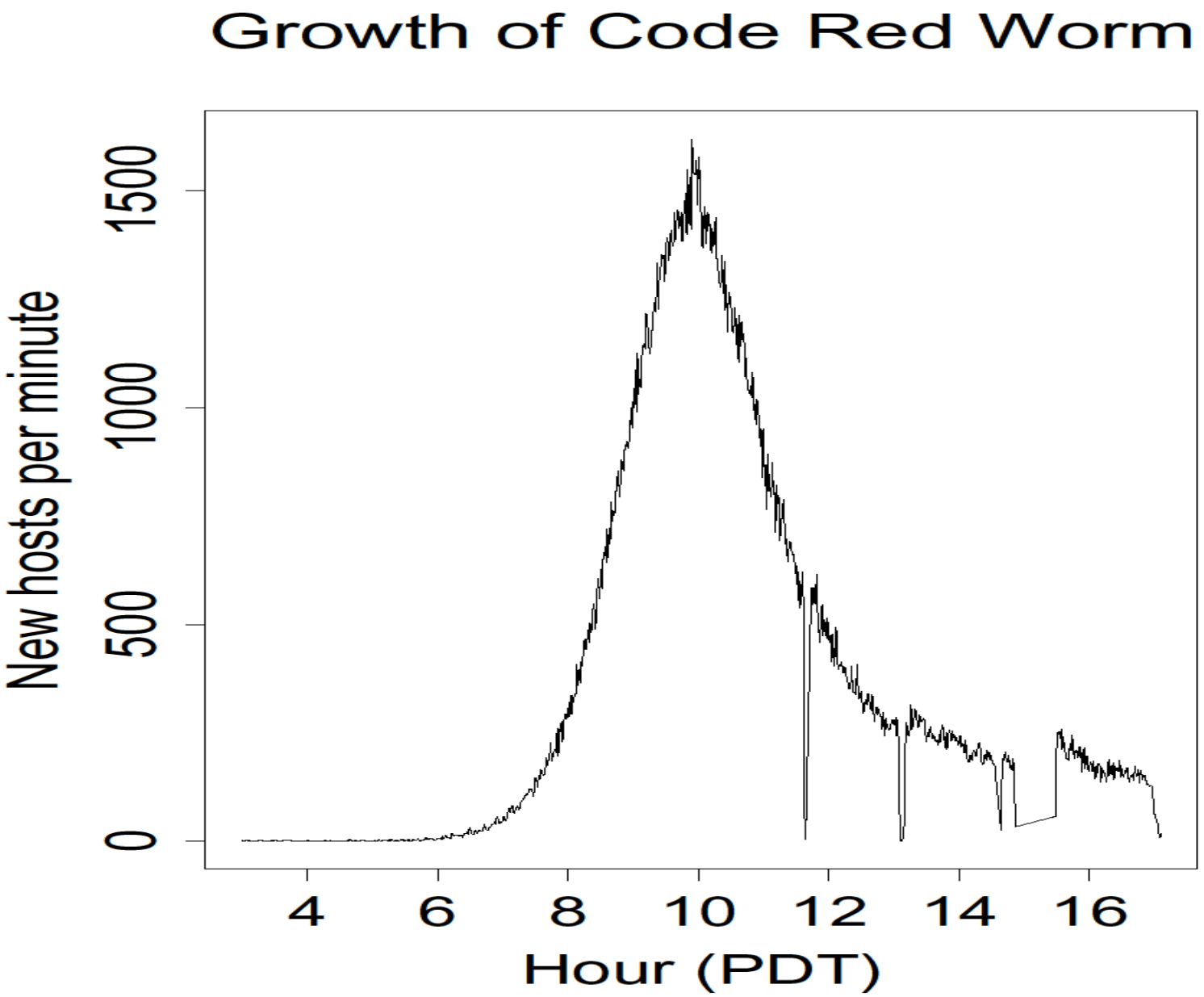
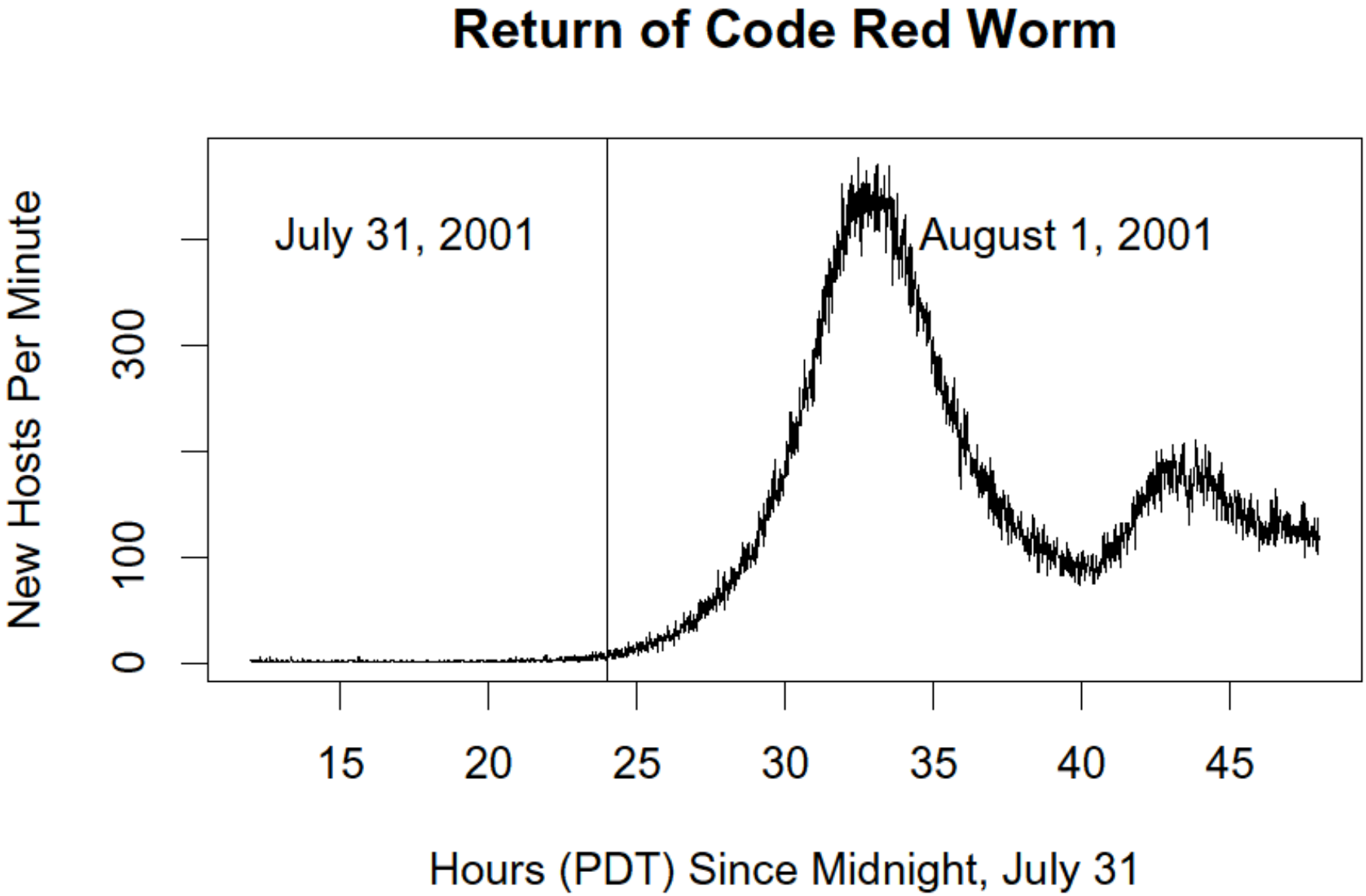
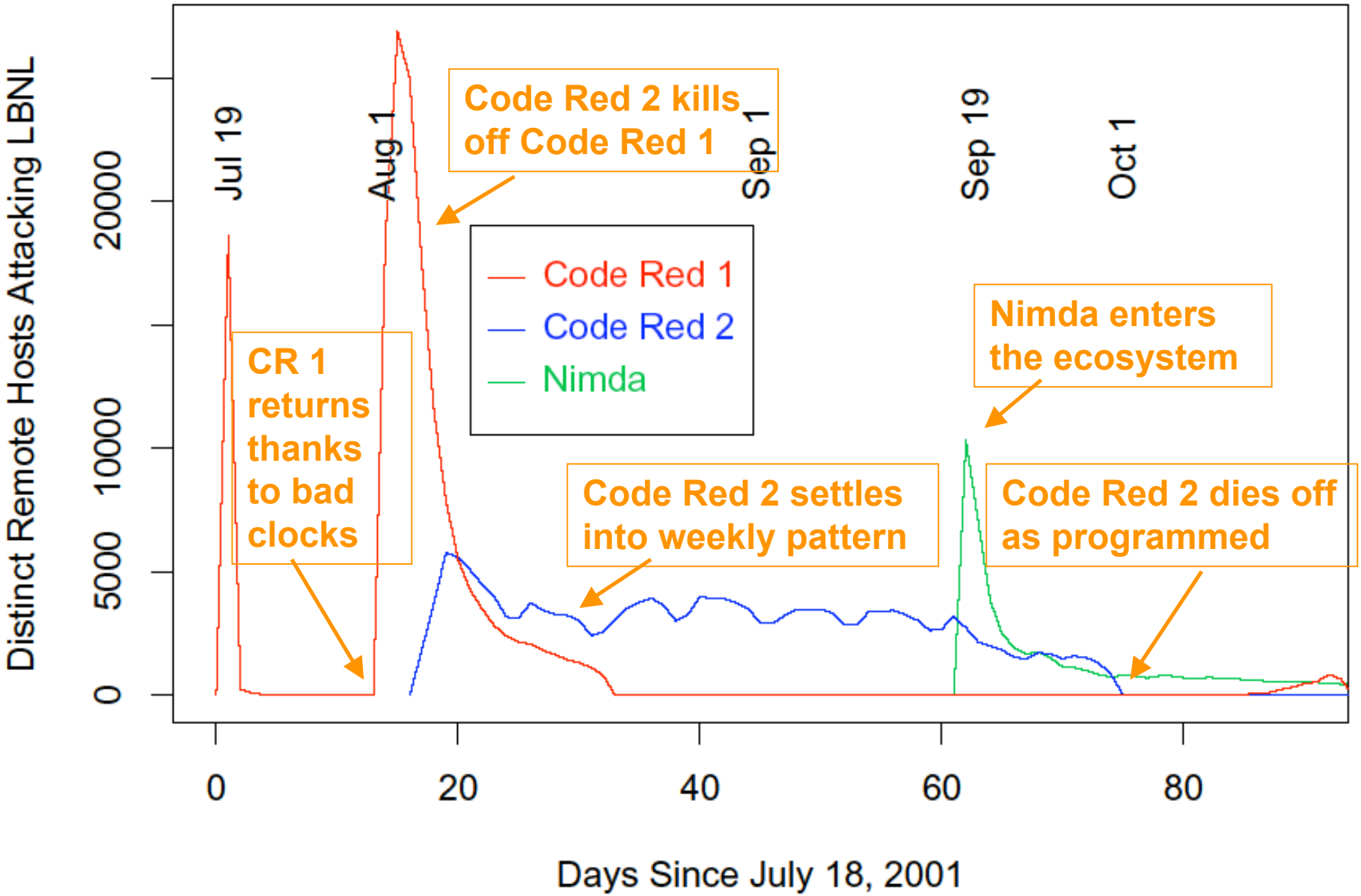
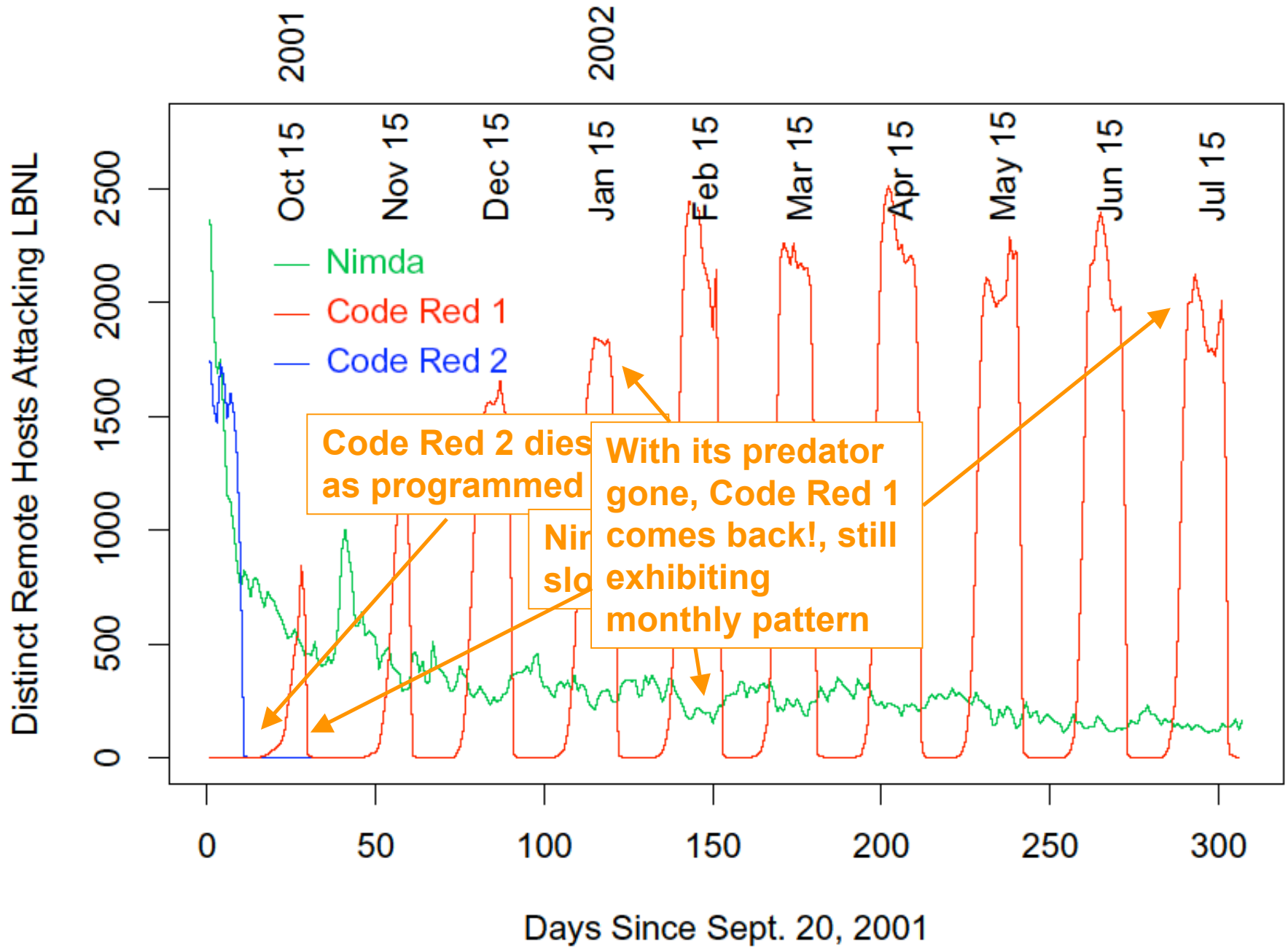
  - Diversity - you see the darnedest (benign) behavior & "crud"
    - Greatly complicates **anomaly detection** & detecting **evasion**
  - Base Rate Fallacy - detector w/ 10^{-6} error rate might not work!
- Another operational reality: intrusion **prevention**
  - Bro enabled to automatically block LBL traffic
    - (Very high standard for accuracy!)
  - #1 gain: dropping *scanners*

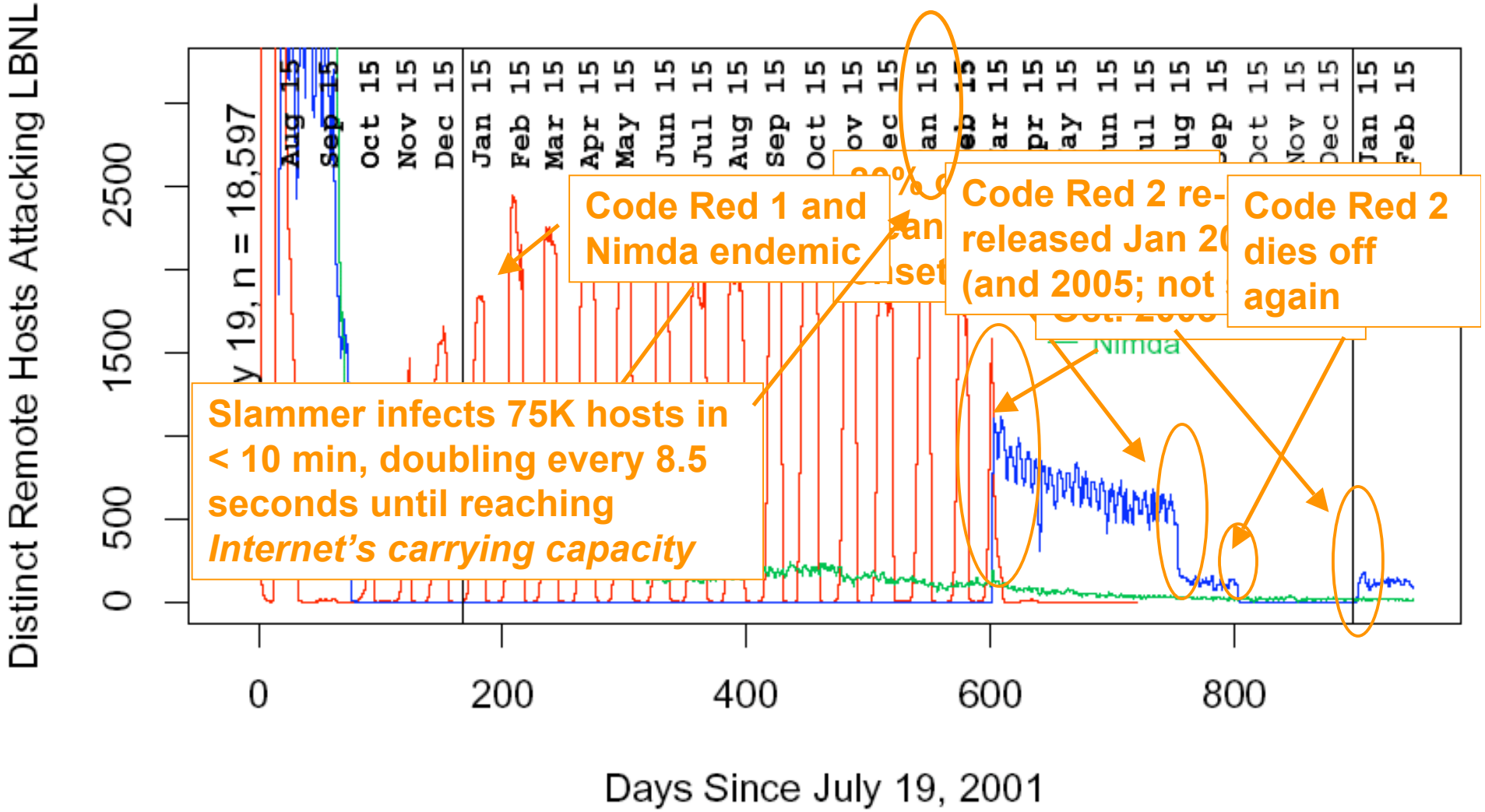

Scan Activity Seen At LBL
Hosts Scanning / Day
1
100
10000
1994
1996
1998
2000
2002
2004
2006
Year

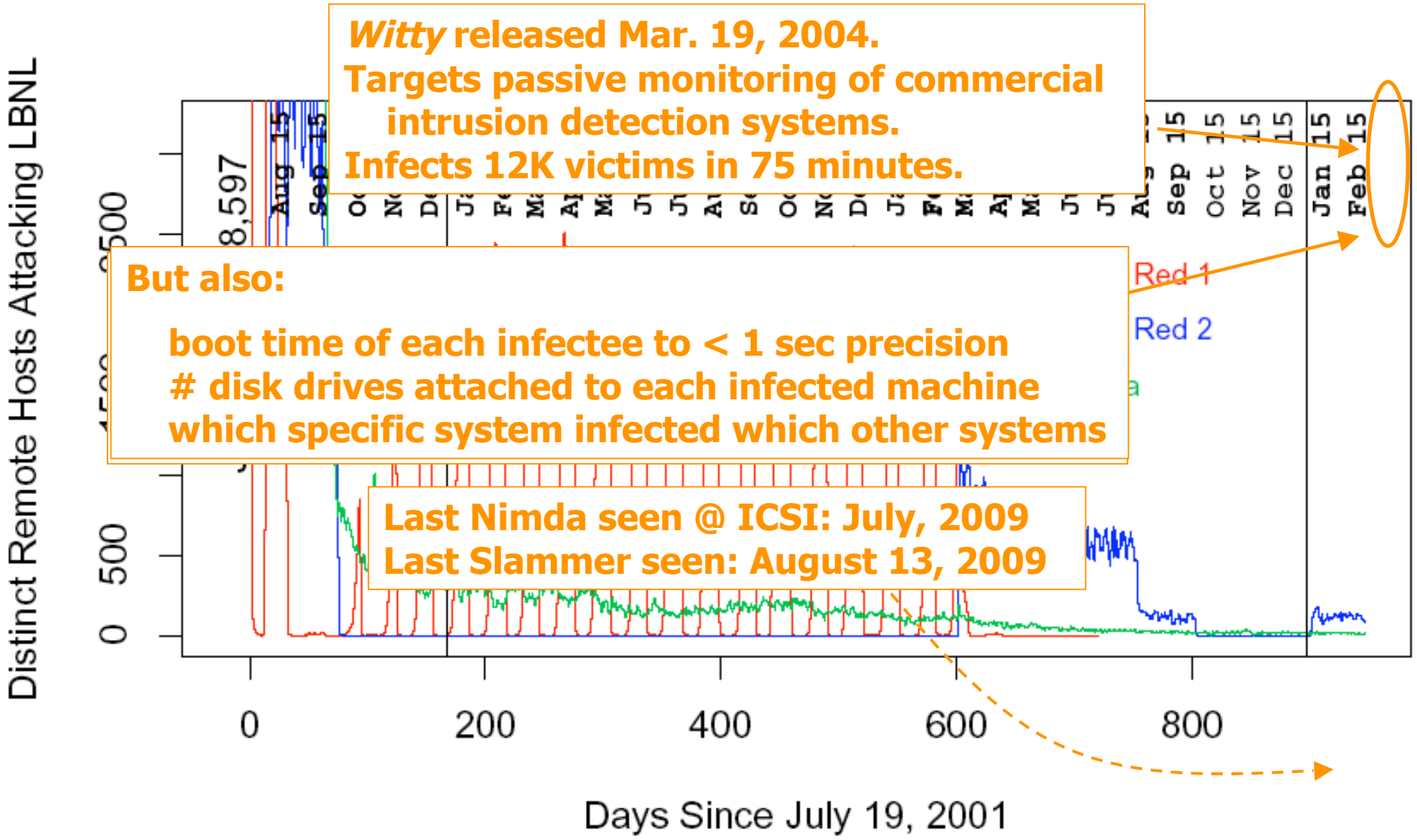

Growth of Code Red Worm
New hosts per minute
0
500
1000
1500
4
6
8
10
12
14
16
Hour (PDT)

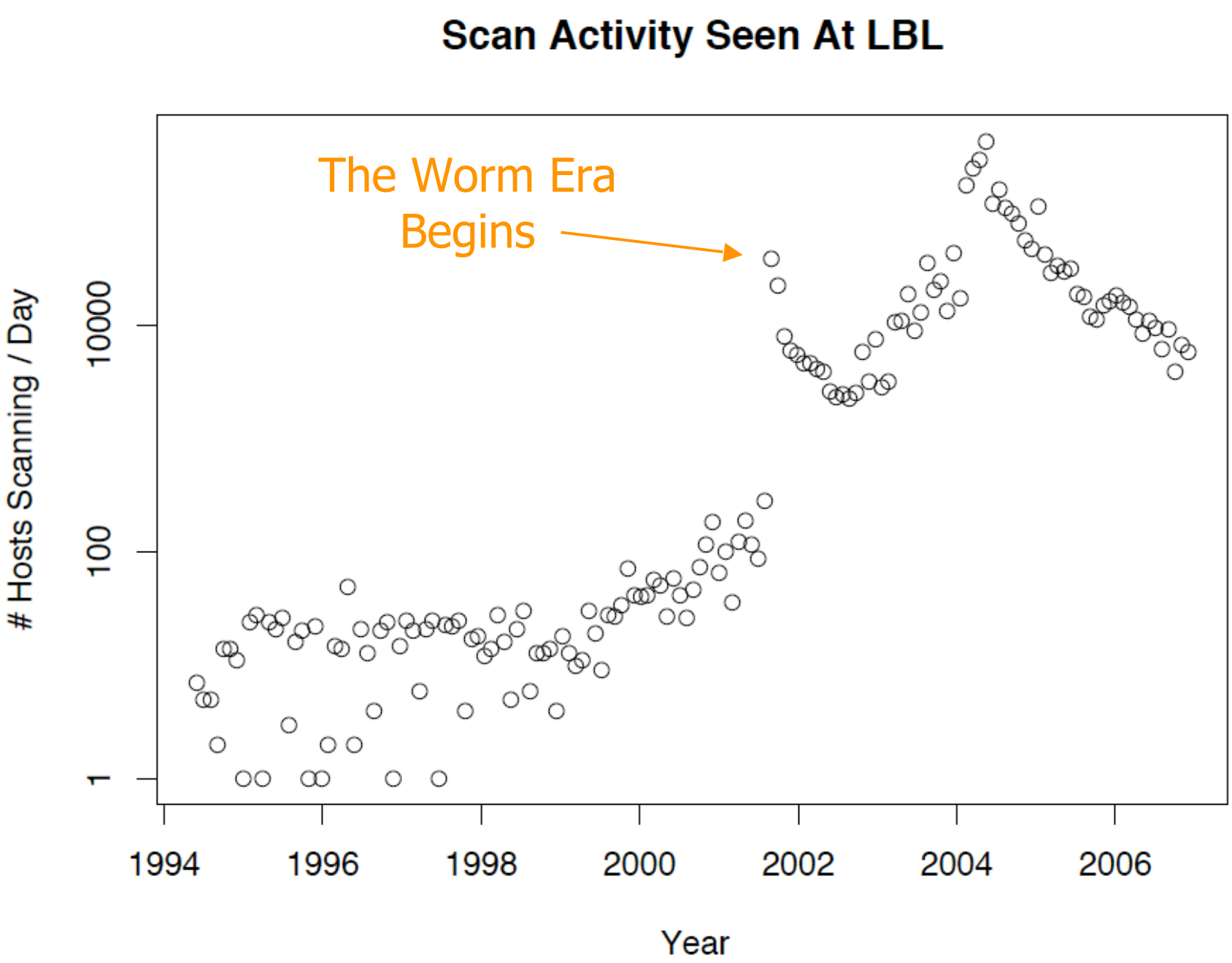

Return of Code Red Worm
July 31, 2001
August 1, 2001
New Hosts Per Minute
0
100
300
15
20
25
30
35
40
45
Hours (PDT) Since Midnight, July 31

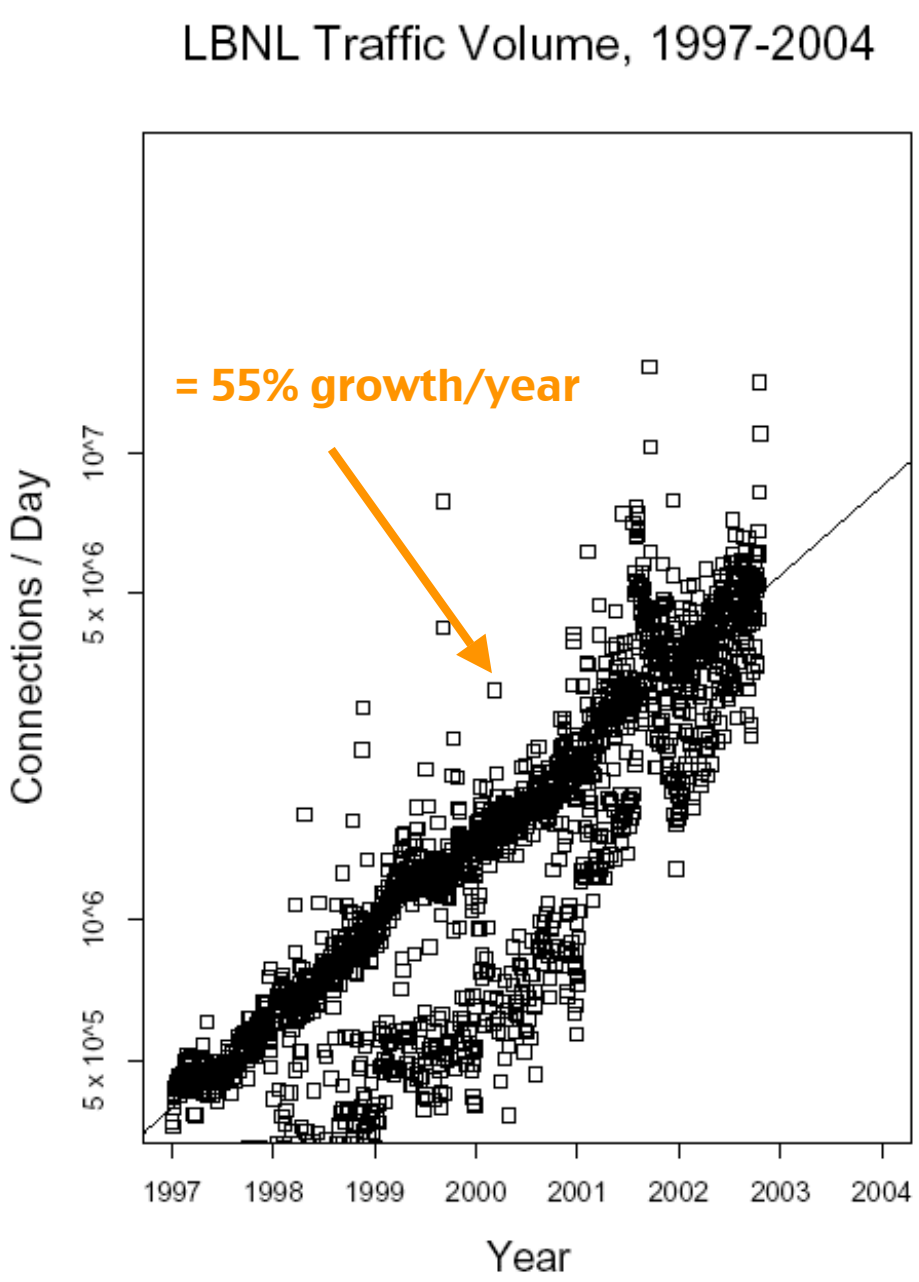

Distinct Remote Hosts Attacking LBNL
0
5000
10000
20000
Jul 19
Aug 1
Sep 1
Sep 19
Oct 1
Code Red 2 kills off Code Red 1
Code Red 1
Code Red 2
Nimda
CR 1 returns thanks to bad clocks
Nimda enters the ecosystem
Code Red 2 settles into weekly pattern
Code Red 2 dies off as programmed
0
20
40
60
80
Days Since July 18, 2001

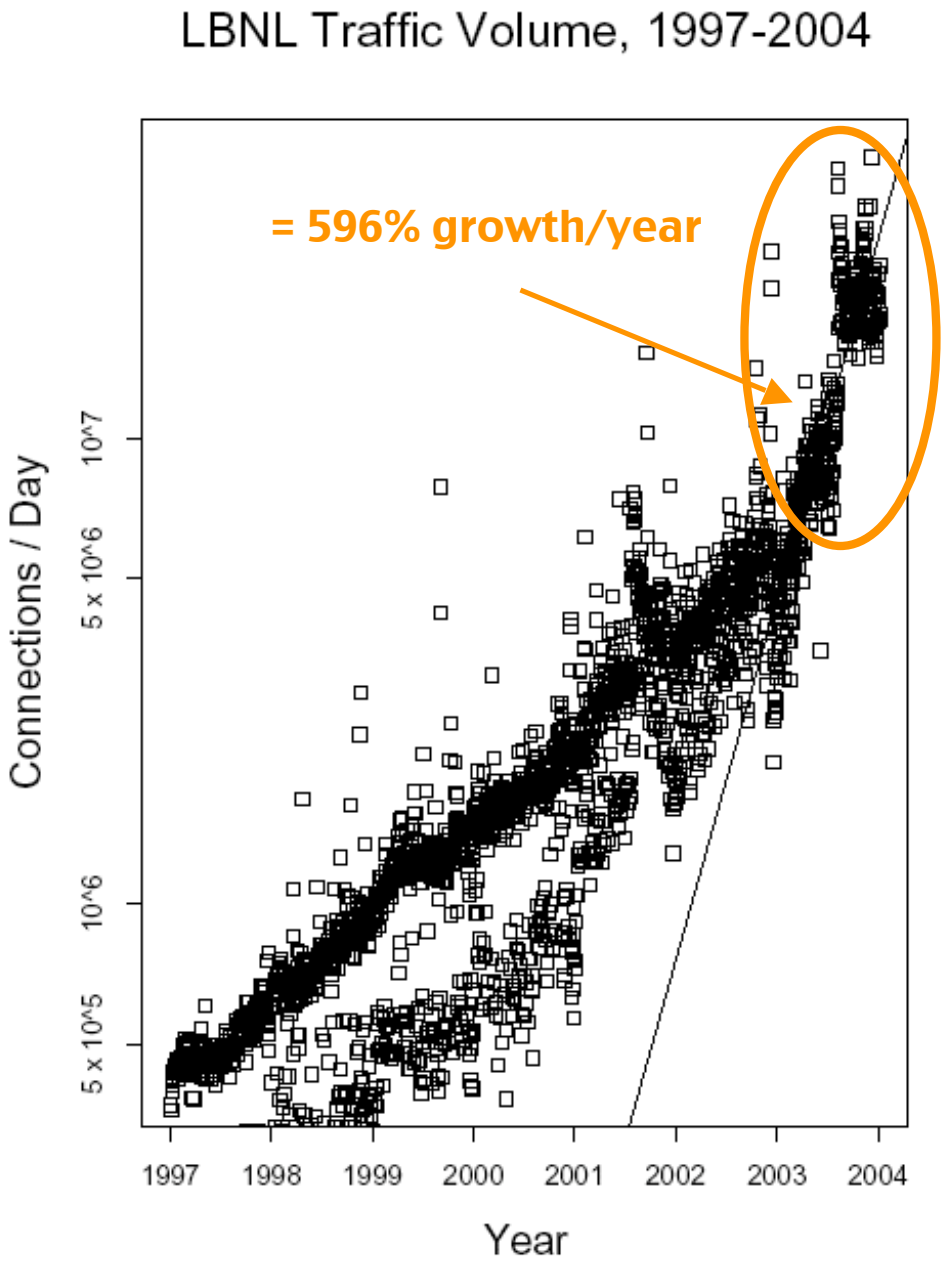

Distinct Remote Hosts Attacking LBNL
0
500
1000
1500
2000
2500
2001
2002
Oct 15
Nov 15
Dec 15
Jan 15
Feb 15
Mar 15
Apr 15
May 15
Jun 15
Jul 15
Nimda
Code Red 1
Code Red 2
Code Red 2 dies as programmed
With its predator gone, Code Red 1 comes back!, still exhibiting monthly pattern
0
50
100
150
200
250
300
Days Since Sept. 20, 2001


Distinct Remote Hosts Attacking LBNL
0
500
1500
2500
y 19, n = 18,597
Aug 15
Sep 15
Oct 15
Nov 15
Dec 15
Jan 15
Feb 15
Mar 15
Apr 15
May 15
Jun 15
Jul 15
Aug 15
Sep 15
Oct 15
Code Red 1 and Nimda endemic
Code Red 2 re-released Jan 20
(and 2005; not
Code Red 2 dies off again
Nimda
Slammer infects 75K hosts in < 10 min, doubling every 8.5 seconds until reaching *Internet's carrying capacity*
0
200
400
600
800
Days Since July 19, 2001

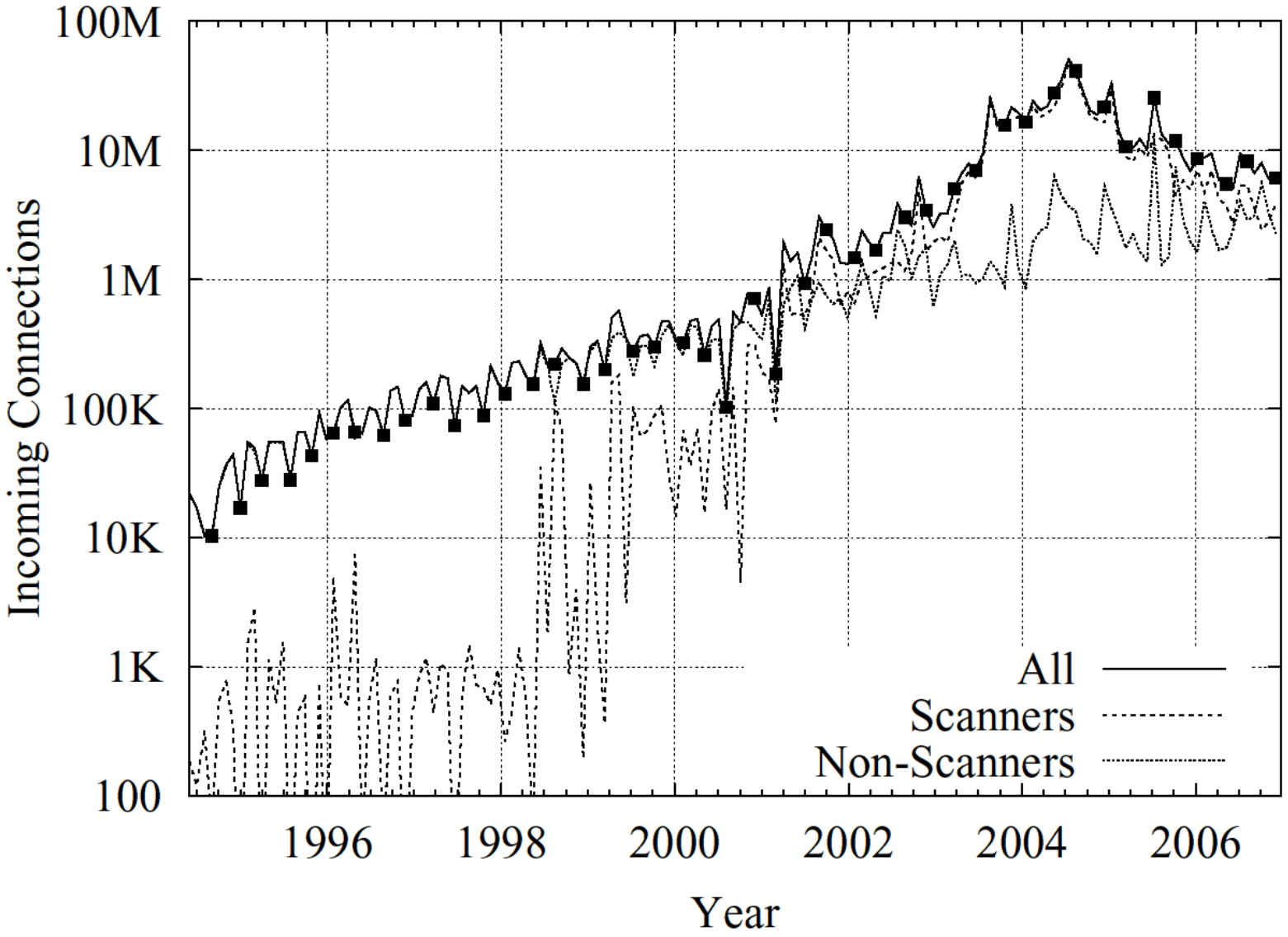

Witty released Mar. 19, 2004.
Targets passive monitoring of commercial intrusion detection systems.
Infects 12K victims in 75 minutes.
But also:
boot time of each infectee to < 1 sec precision
disk drives attached to each infected machine
which specific system infected which other systems
Last Nimda seen @ ICSI: July, 2009
Last Slammer seen: August 13, 2009
Distinct Remote Hosts Attacking LBNL
8,597
0
500
Red 1
Red 2
Aug 15
Sep 15
Oct 15
Nov 15
Dec 15
Jan 15
Feb 15
0
200
400
600
800
Days Since July 19, 2001


Scan Activity Seen At LBL
The Worm Era
Begins
Hosts Scanning / Day
1
100
10000
1994
1996
1998
2000
2002
2004
2006
Year

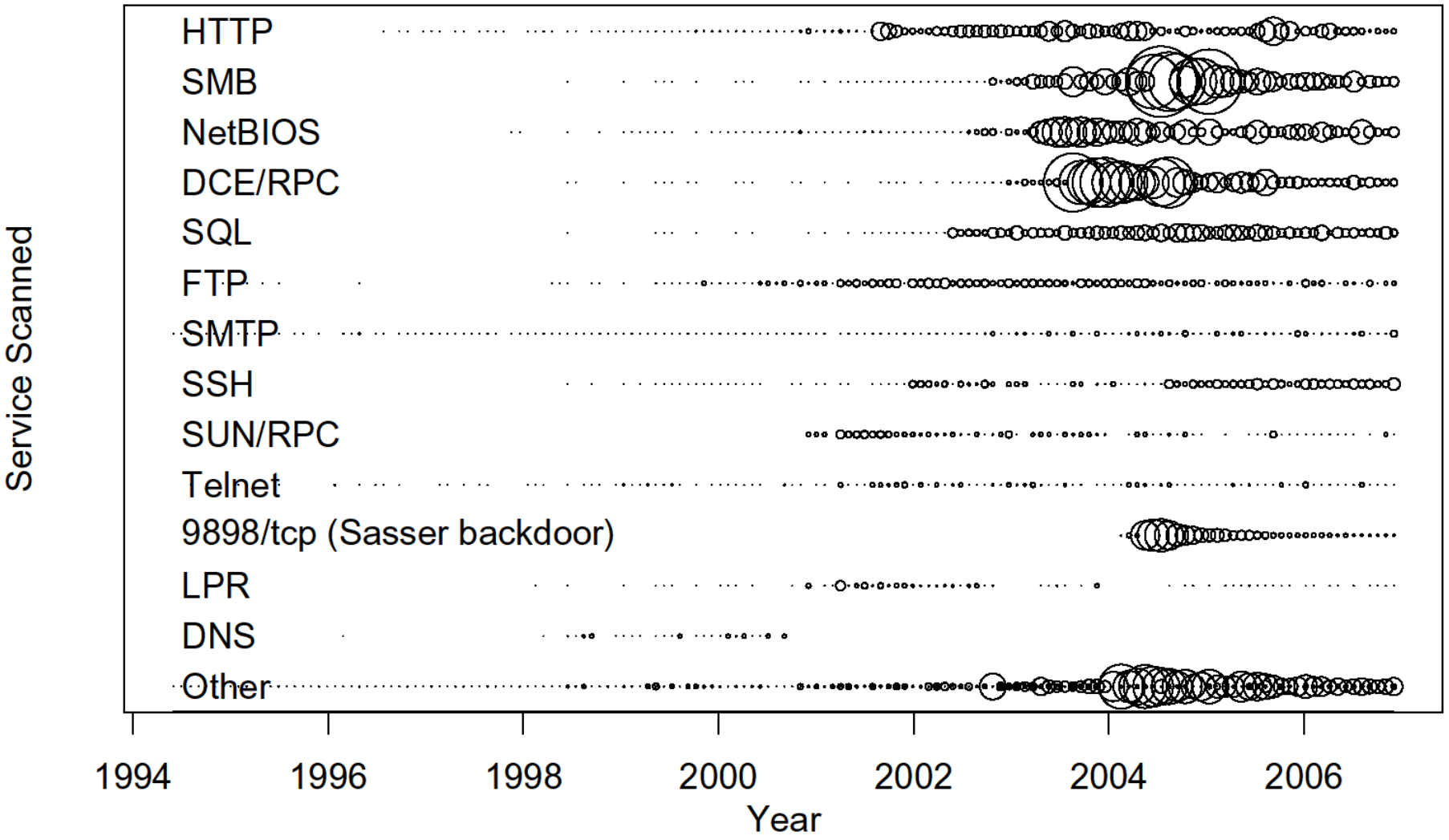

LBNL Traffic Volume, 1997-2004
= 55% growth/year
Connections / Day
5 x 10^5
10^6
5 x 10^6
10^7
1997
1998
1999
2000
2001
2002
2003
2004
Year

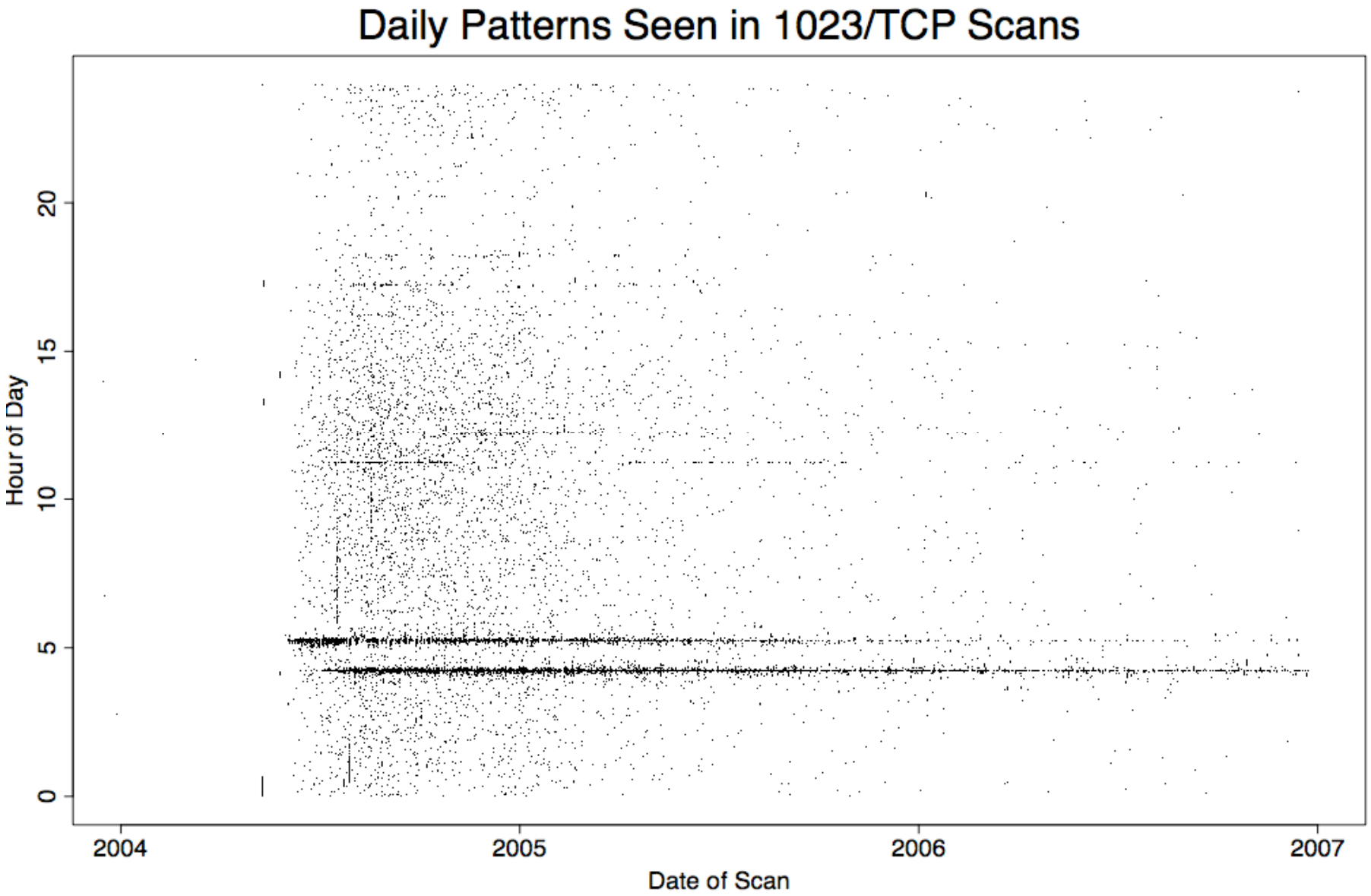

LBNL Traffic Volume, 1997-2004
= 596% growth/year
Connections / Day
5 x 10^5
10^6
5 x 10^6
10^7
1997
1998
1999
2000
2001
2002
2003
2004
Year

Scanning Activity Seen @ LBL

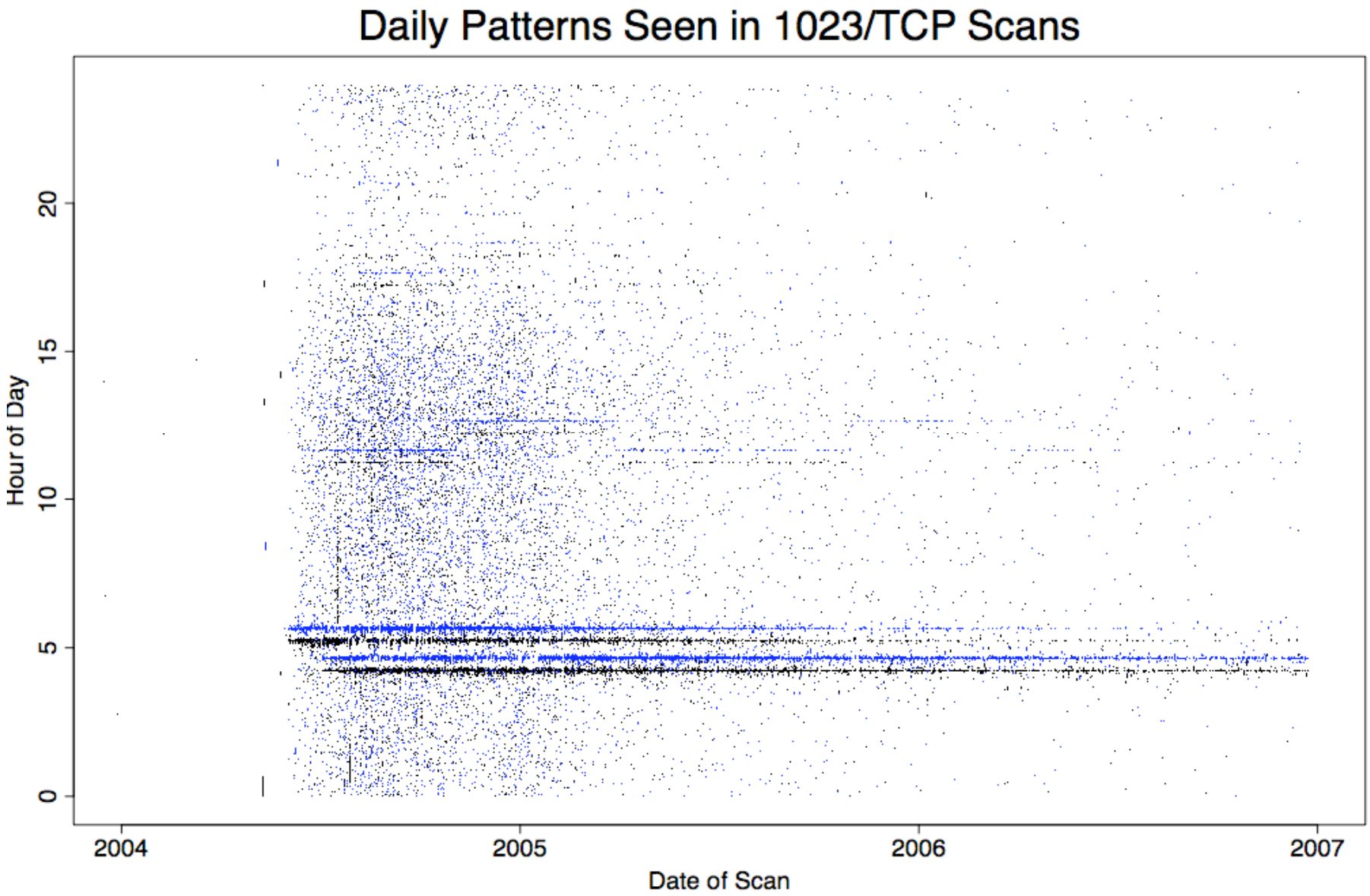


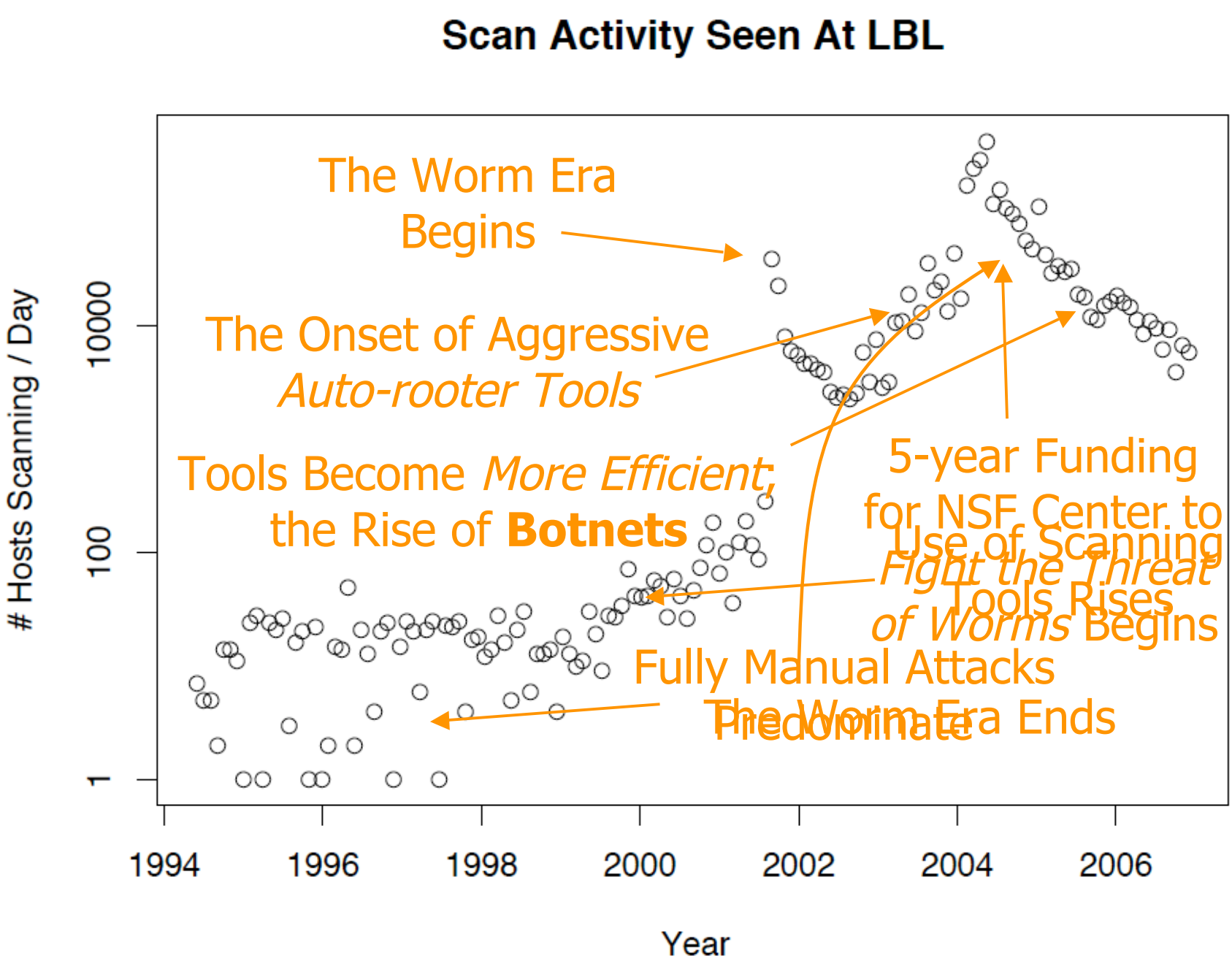
Services Scanned Over Time





/16 at LBL, sampled 1-in-1K


Daily Patterns Seen in 1023/TCP Scans
Hour of Day
0
5
10
15
20
2004
2005
2006
2007
Date of Scan
/16 at LBL, sampled 1-in-1K
2nd /16, sampled 1-in-1K

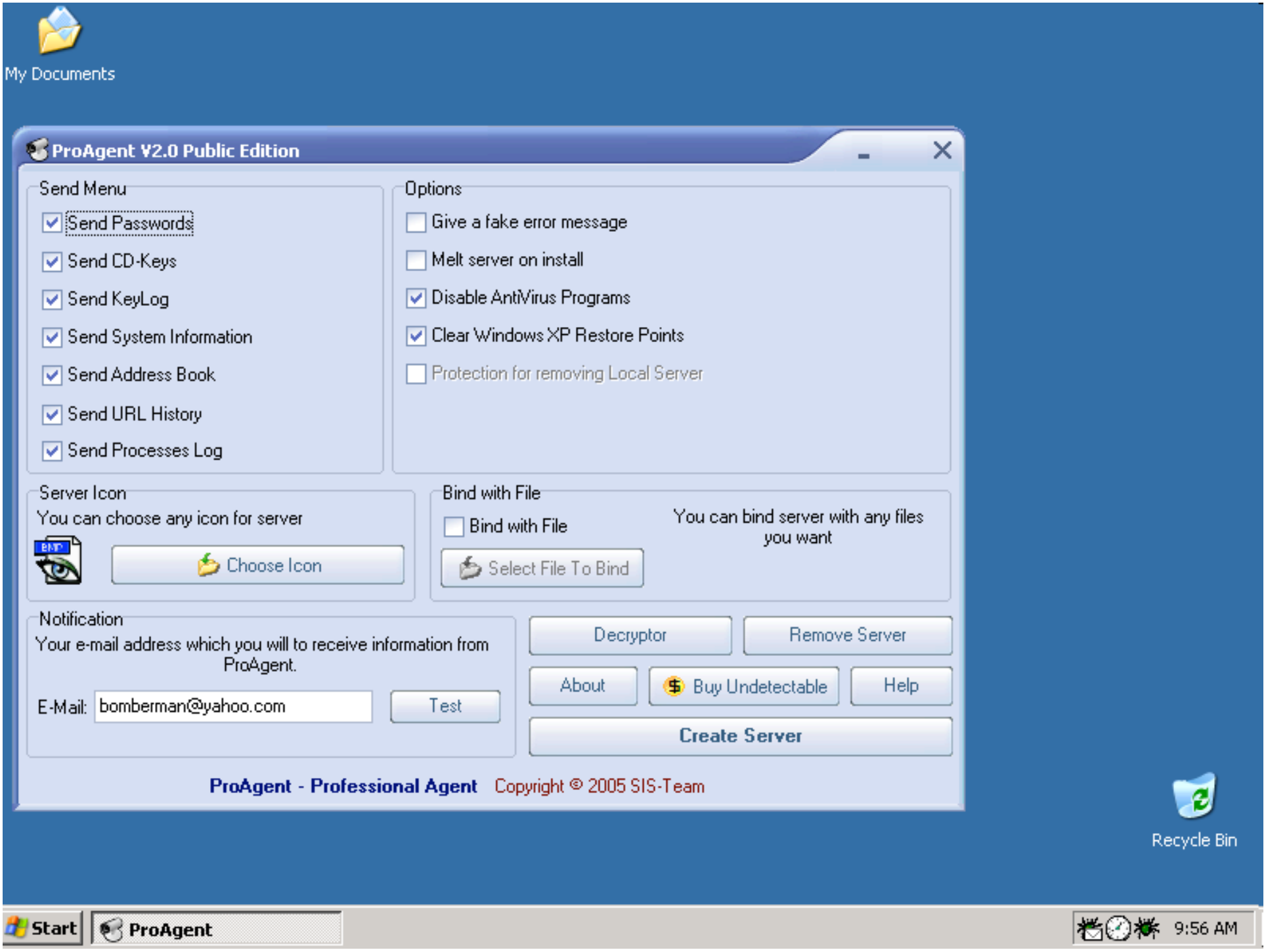

Scan Activity Seen At LBL
Hosts Scanning / Day
1
100
10000
1994
1996
1998
2000
2002
2004
2006
Year
The Worm Era Begins
The Onset of Aggressive *Auto-rooter Tools*
Tools Become *More Efficient*; the Rise of **Botnets**
5-year Funding for NSF Center to *Fight the Threat of Worms* Begins
Use of Scanning Tools Rises
Fully Manual Attacks Predominate
The Worm Era Ends

Part II

Selling Viagra®

Know Your Enemy

- A sophisticated underground economy has emerged to profit from Internet subversion


My Documents
ProAgent V2.0 Public Edition
Send Menu
Send Passwords
Send CD-Keys
Send KeyLog
Send System Information
Send Address Book
Send URL History
Send Processes Log
Options
Give a fake error message
Melt server on install
Disable AntiVirus Programs
Clear Windows XP Restore Points
Protection for removing Local Server
Server Icon
You can choose any icon for server
Choose Icon
Bind with File
Bind with File
You can bind server with any files you want
Select File To Bind
Notification
Your e-mail address which you will to receive information from ProAgent.
E-Mail: bomberman@yahoo.com
Test
Decryptor
Remove Server
About
Buy Undetectable
Help
Create Server
ProAgent - Professional Agent
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Recycle Bin
Start
ProAgent
9:56 AM

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Добрые юзеры аукцыона eBay предлагают вашему вниманию свои аккаунты.
Постоянным клиентам и тем, кто берет более 5 акков, различные бонусы и скидки.
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Вы сами выбираете акк (несколько акков) из списка. Говорите мне. Оплачиваете и получаете.
Все акки предварительно проверяются перед продажей, в случае, если что-то не работает - 100% замена.

Актив/не актив смотрите сами по юзер ид. По активности не сортирую, так как это для каждого субьективно.

Также в продаже бывают акки PayPal. Цены рыночные. Постоянно не продаю.

Оплата по WM.
Перед покупкой следует обязательно ознакомиться с FAQ.
По работе с товаром не консультирую.
Работа через гарант сервис приветствуется.

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seller/баер акк 10-25 фидов = 10$
seller/баер акк 25-50 фидов = 15$
seller/баер акк более 50 фидов = 25$


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About
Services
FAQ
Blog
Contacts
WabiSabiLabi
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Home page ▸ Current bids
Sign in
Username
Password
Sign in
New user? Sign up here
News
PRESS RELEASE 03/07/2007
Finally a Marketplace Site for Security Research
Current bids
MarketPlace history
4 items found, displaying all items. Page 1
Code
Time to live
Title
System
Offer type
Bid
ZD-00000007 9d 13h 26m Local Linux kernel memory leak Linux Bidding 600€ 1 bid(s)
ZD-00000005 9d 13h 26m Yahoo! Messenger 8.1 remote buffer overflow Windows XP Bidding 2,000€ 0 bid(s)
ZD-00000004 9d 13h 26m Squirrelmail GPG Plugin Command Execution Web application Bidding Buy now at 600€ 1,750€ 1 bid(s)
ZD-00000008 10d 13h 26m MKPortal SQL injection Web application Bidding Buy now at 500€ 800€ 0 bid(s)

allBots Inc.

Social Networking Bots

GOOD News!!! We have something more for you! Yes, we have just integrated **CAPTCHA Bypasser**** in all of our bots.

Winsock (Multi-threaded) Bots

Become an **Affiliate** and **Start Earning Now**

Click here for 30+ MySpace Bots

Accounts Creator

(You Just Need To Type In The CAPTCHAs To Create Accounts)

Social Networks			
MySpace Accounts Creator with Picture Uploader, Profile & Layout Manager	PayPal Buy Now	~~$180.95~~	$140.00
MySpace Accounts Creator with Picture Uploader, Profile & Layout Manager **(Winsock)**	PayPal Buy Now	~~$360.95~~	$320.00
YouTube Accounts Creator	PayPal Buy Now	~~$120.95~~	$95.00
Friendster Accounts Creator	PayPal Buy Now	~~$120.95~~	$95.00
Hi5 Accounts Creator	PayPal Buy Now	~~$120.95~~	$95.00
TagWorld Accounts Creator	PayPal		

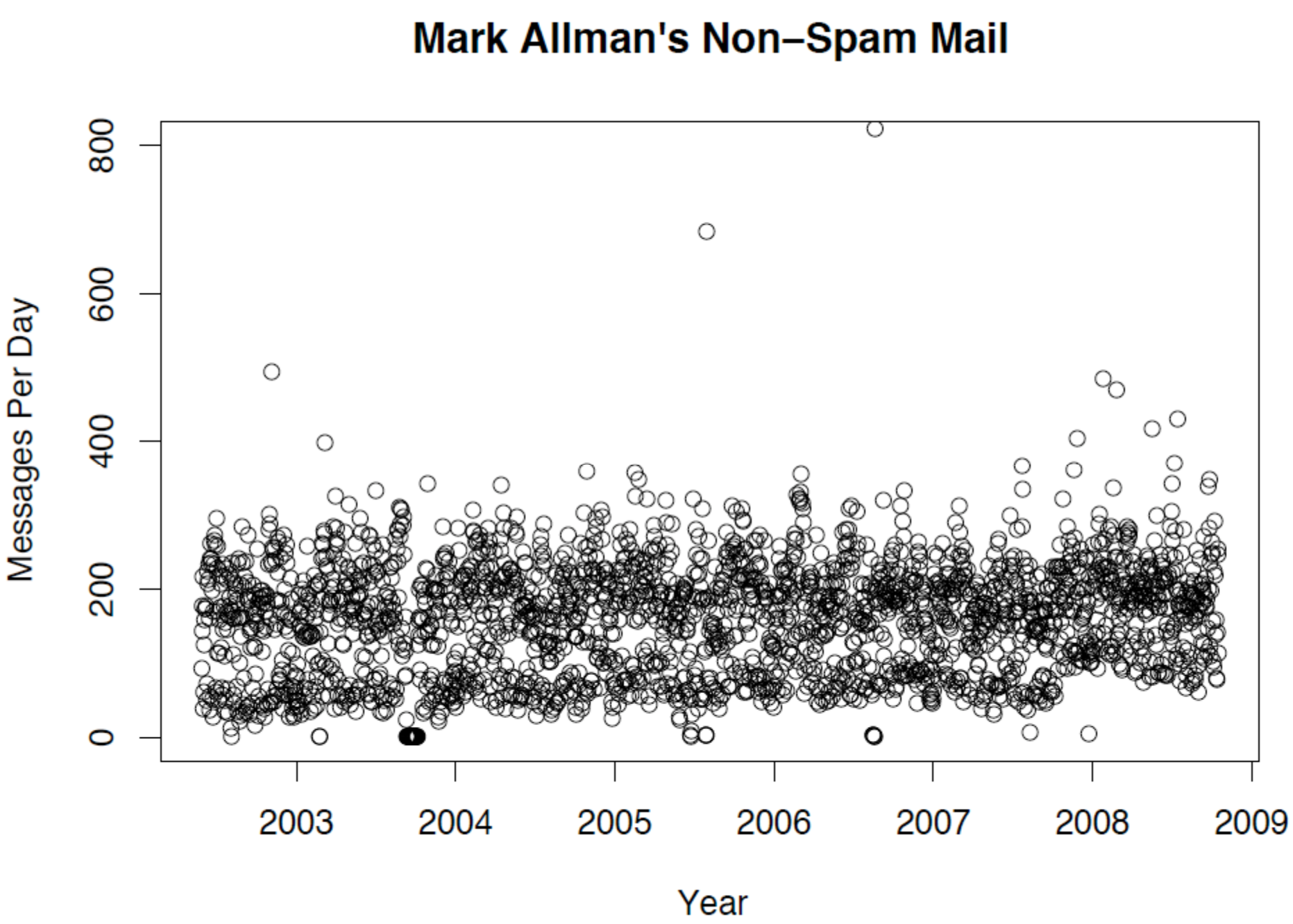
Friend Adders, Message Senders, Comment Posters & Others

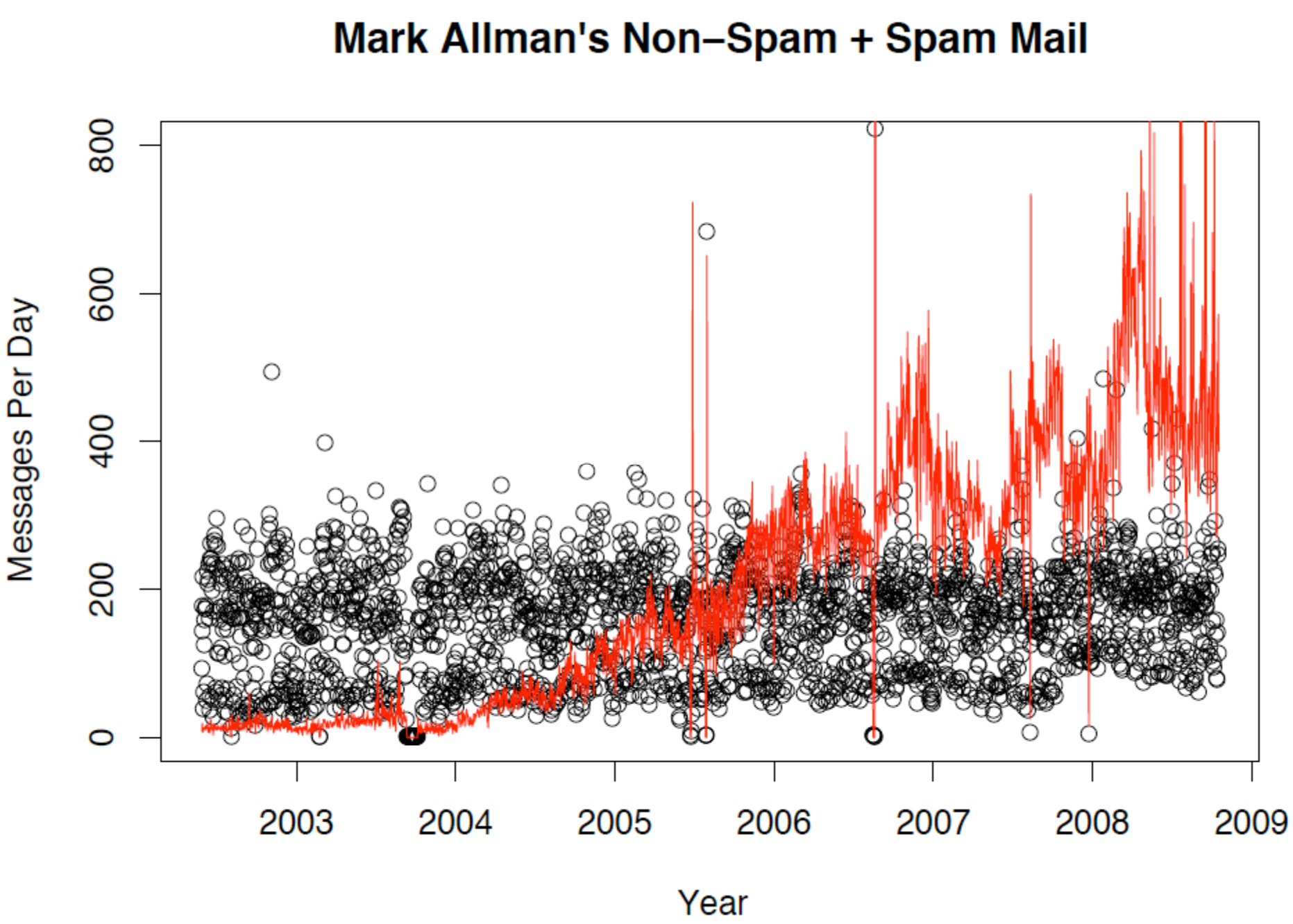
(All Bots Work In A Conventional Manner, They Gather Friend IDs/Names And Send Friend Requests, Messages, Comments Automatically)

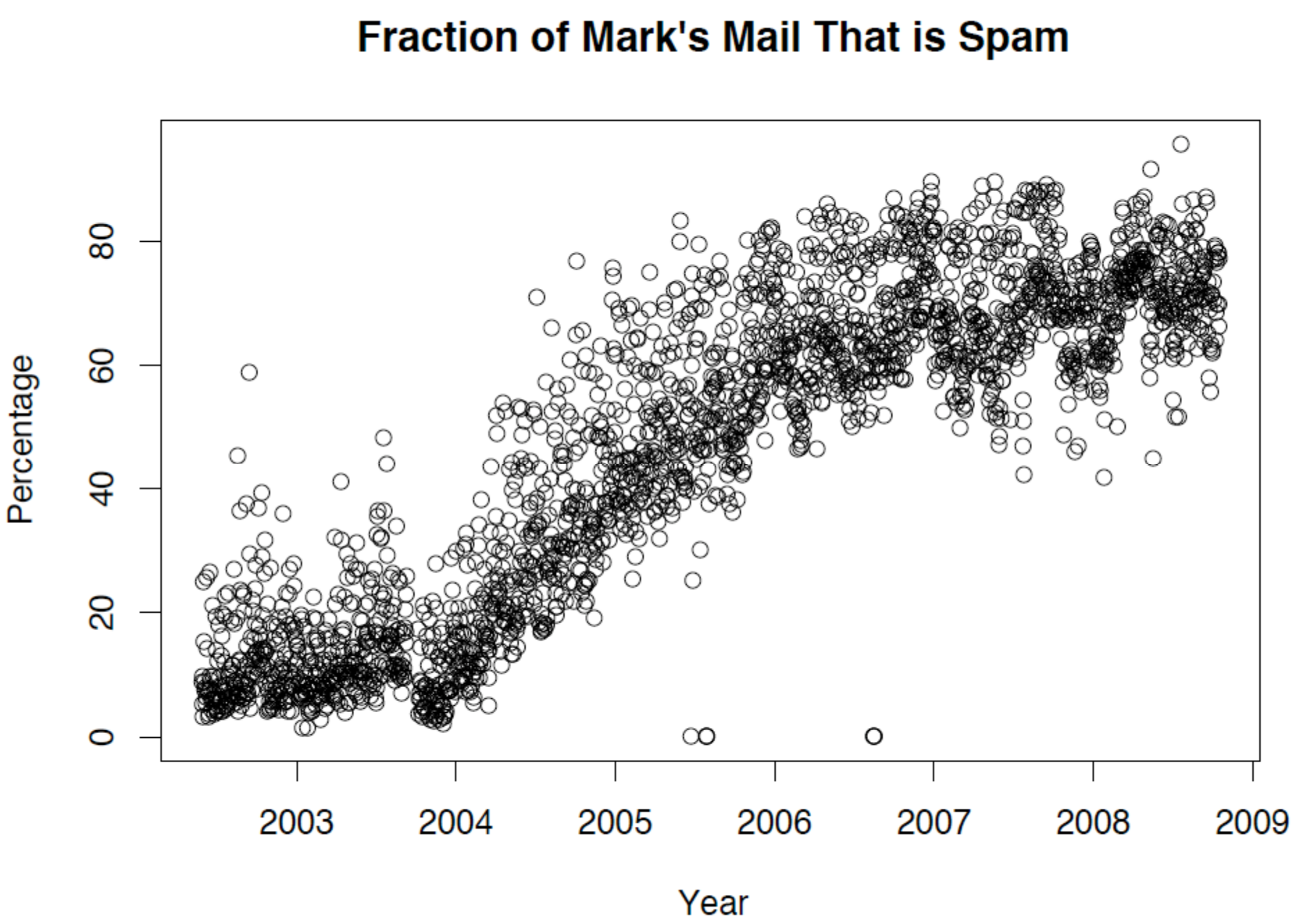
Chaining Feature Is Available On All Bots for All Networks Except Facebook

Know Your Enemy

- A sophisticated underground economy has emerged to profit from Internet subversion
- Empowered by virtually endless supply of bots
  - Internet systems under complete attacker control
- Dirt-cheap access to bots fuels *monetization* via relentless torrents of **spam**


Mark Allman's Non–Spam Mail
Messages Per Day
0
200
400
600
800
2003
2004
2005
2006
2007
2008
2009
Year


Mark Allman's Non–Spam + Spam Mail
Messages Per Day
0
200
400
600
800
2003
2004
2005
2006
2007
2008
2009
Year


Fraction of Mark's Mail That is Spam
Percentage
0
20
40
60
80
2003
2004
2005
2006
2007
2008
2009
Year

Know Your Enemy

- A sophisticated underground economy has emerged to profit from Internet subversion
- Empowered by virtually endless supply of "bots"
  - Internet systems under complete attacker control
- Dirt-cheap access to bots fuels *monetization* via relentless torrents of **spam**

- ***Just how profitable is all of this?***

Are Bots & Spam the New Black Gold?

Storm worm 'making millions a day'

Compromised machines sending out highly profitable spam, says IBM security strategist

Clive Akass, Personal Computer World 11 Feb 2008

The people behind the Storm worm are making millions of pounds a day by using it to generate revenue, according to IBM's principal web security strategist.

Joshua Corman, of **IBM Internet Security Systems**, said that in the past it had been assumed that web security attacks were essential ego driven.

How can we **measure** this? Seemingly only knowable by the spammers themselves.

- Spam finance elements:
  - Retail-cost-to-send vs. Profit-per-response
  - Key missing element: spams-needed-per-response, i.e., *conversion rate*

Welcome to **Storm**!

Would you like to be one of our newest bots?

Just read your postcard!

(Or even easier: just wait 5 seconds!)

September 6th, 2007

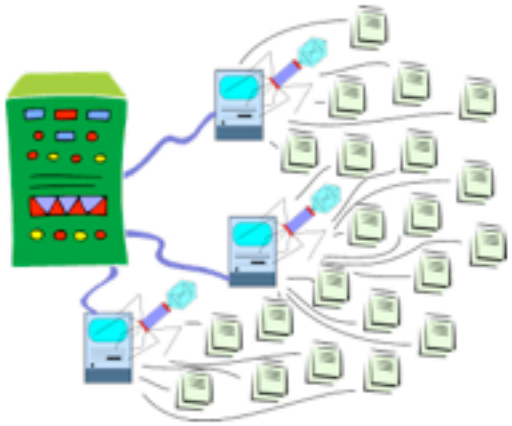
Storm Worm botnet could be world's most powerful supercomputer

Posted by Ryan Naraine @ 8:41 am

Categories: Botnets, Browsers, Data theft, Exploit code, Firefox.....

Tags: Operation, Supercomputer, Malware, Worm, Ryan Naraine

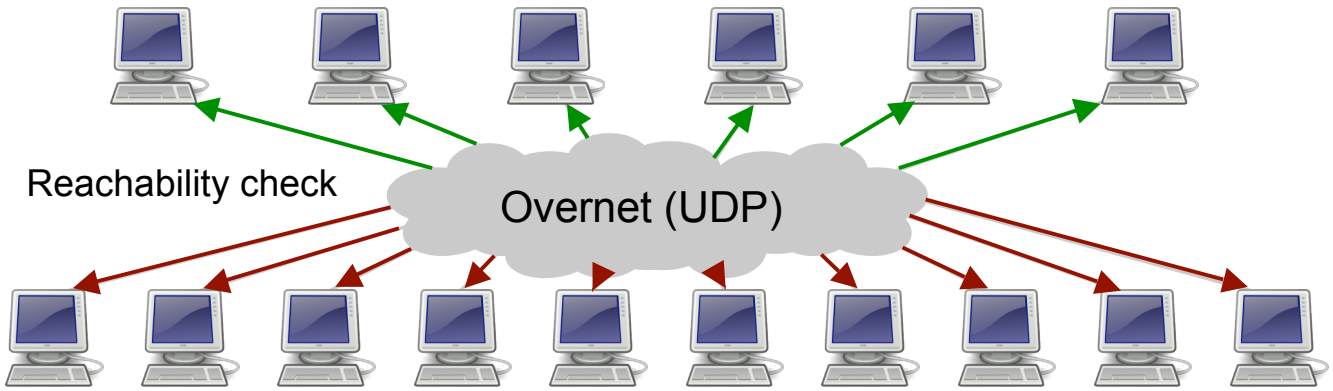
150 TalkBacks ADD YOUR OPINION | SHARE | PRINT | E-MAIL | +97 WORTHWHILE? 115 VOTES



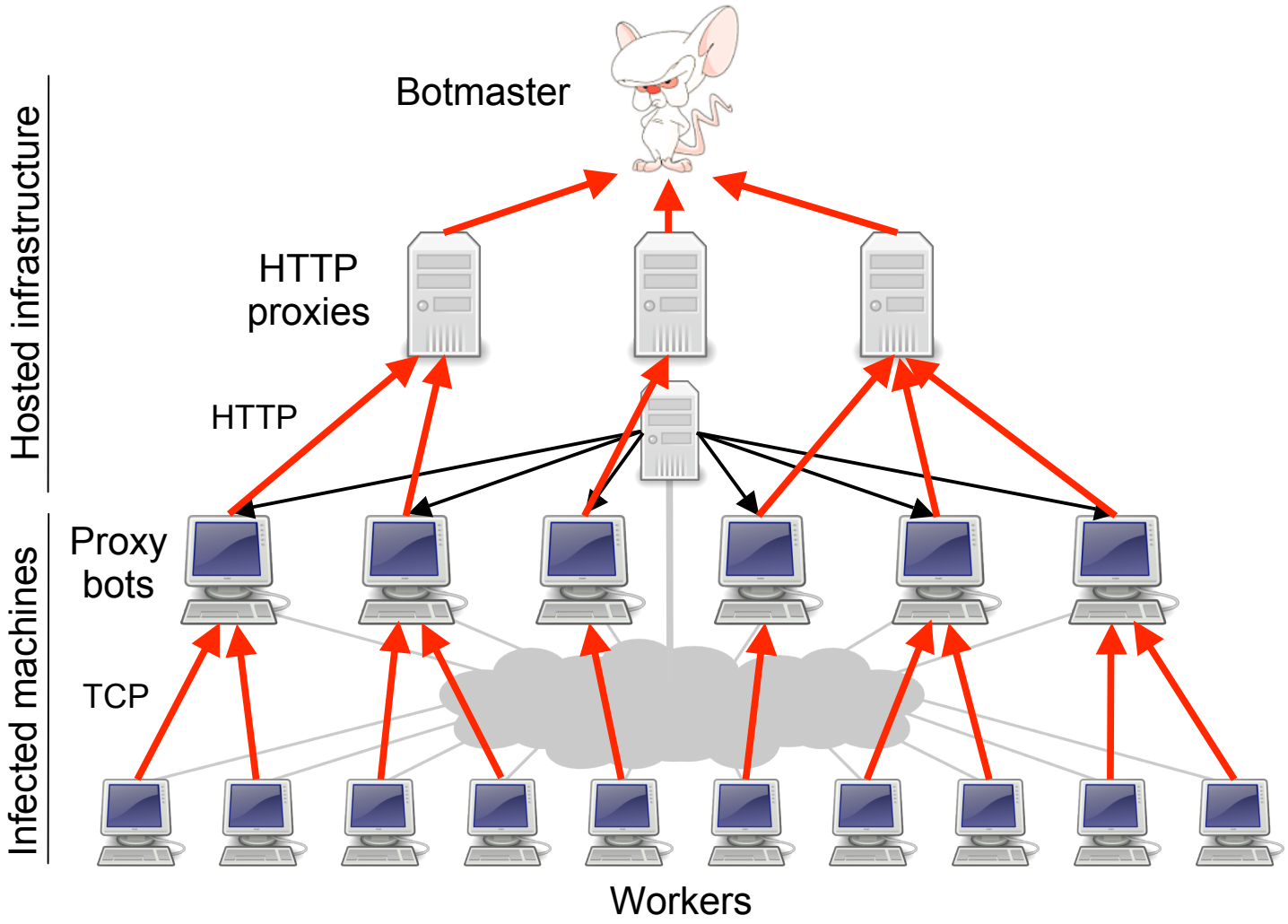
Nearly nine months after it was first discovered, the Storm Worm Trojan continues to surge, building what experts believe could be the world's most powerful supercomputer.

The Trojan, which uses a myriad of social engineering lures to trick Windows users into downloading malware, has successfully seeded a massive botnet — between one million and 10 million CPUs — producing computing power to rival the world's top 10 supercomputers

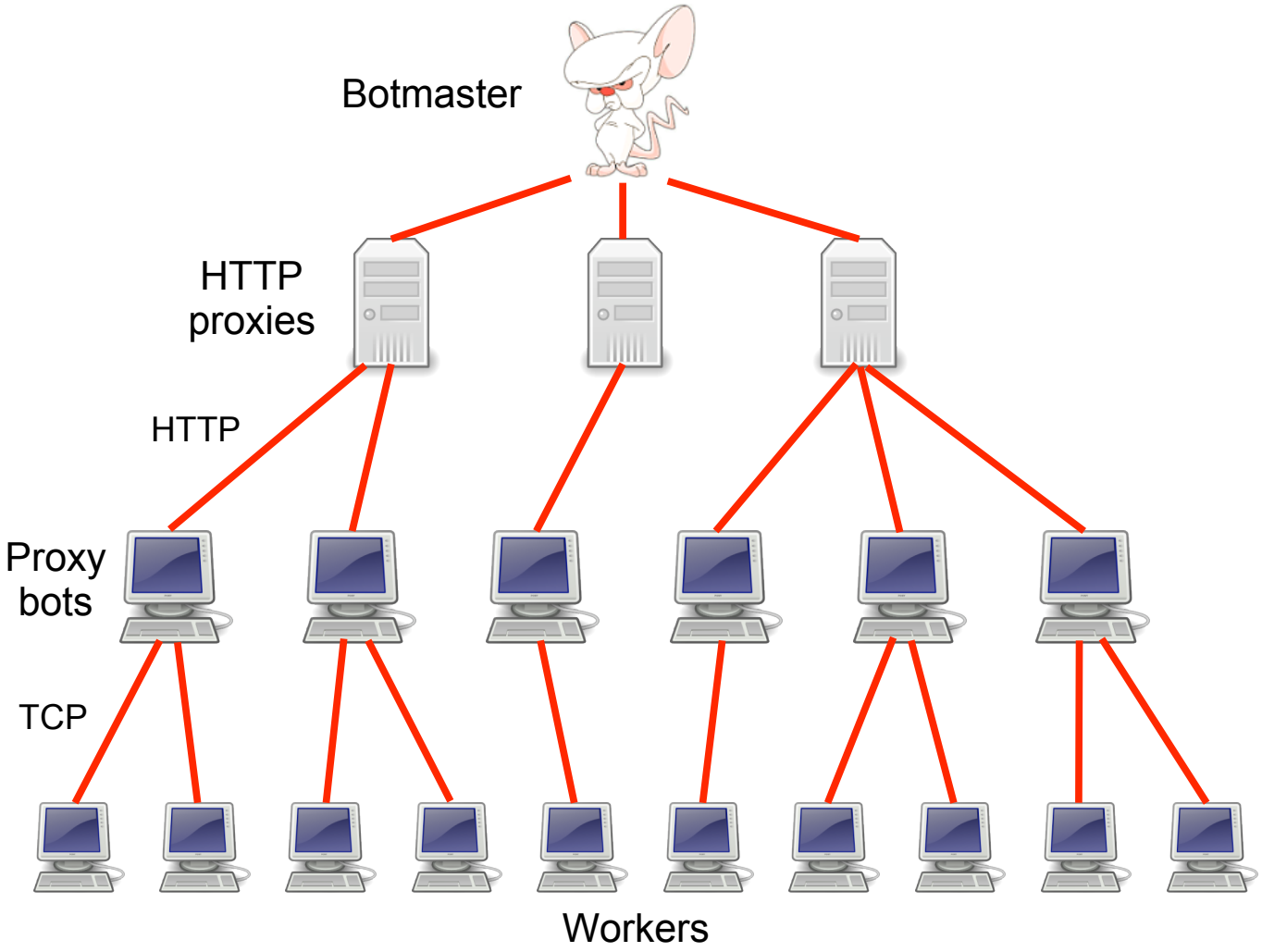
The Storm botnet



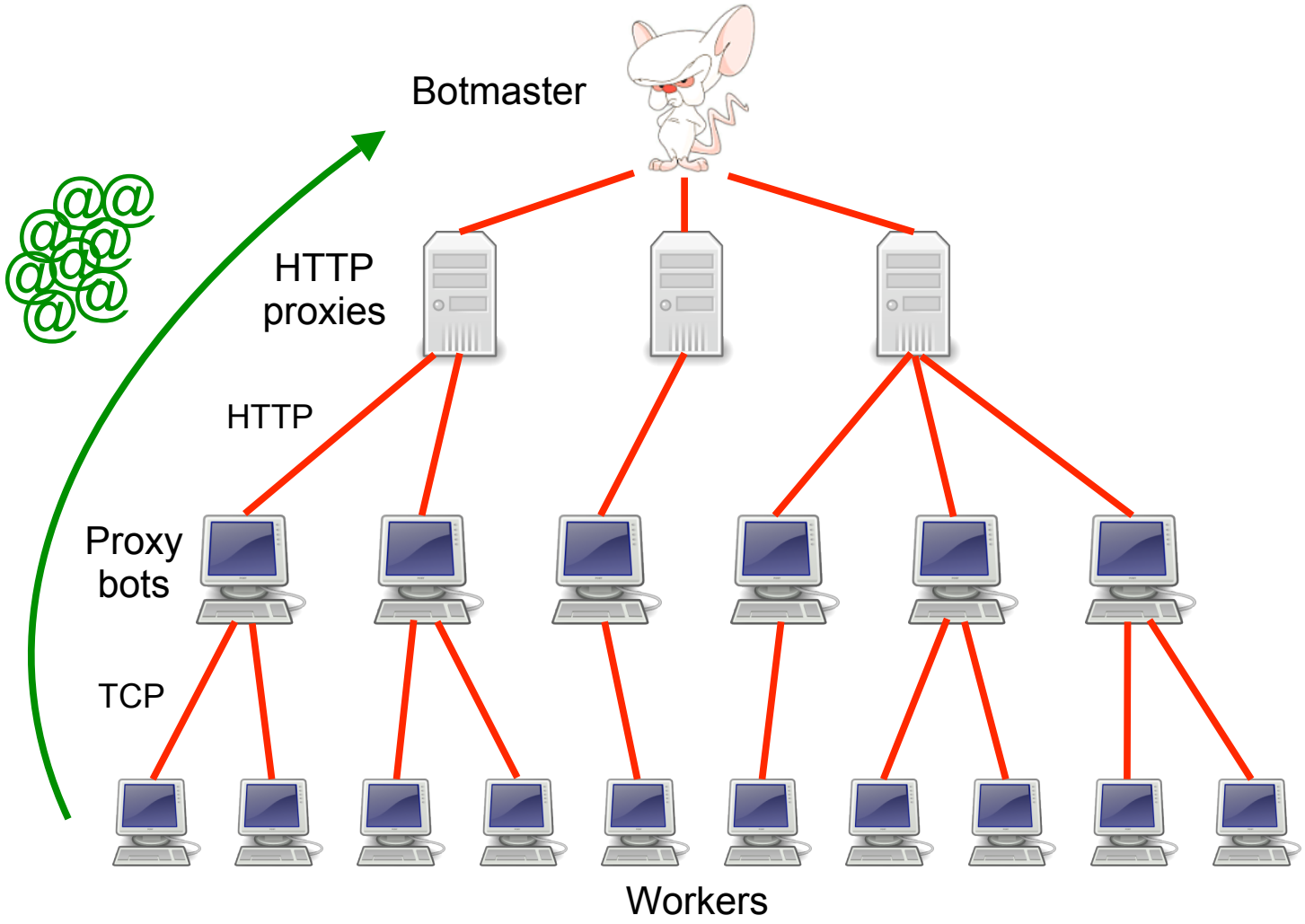
The Storm botnet



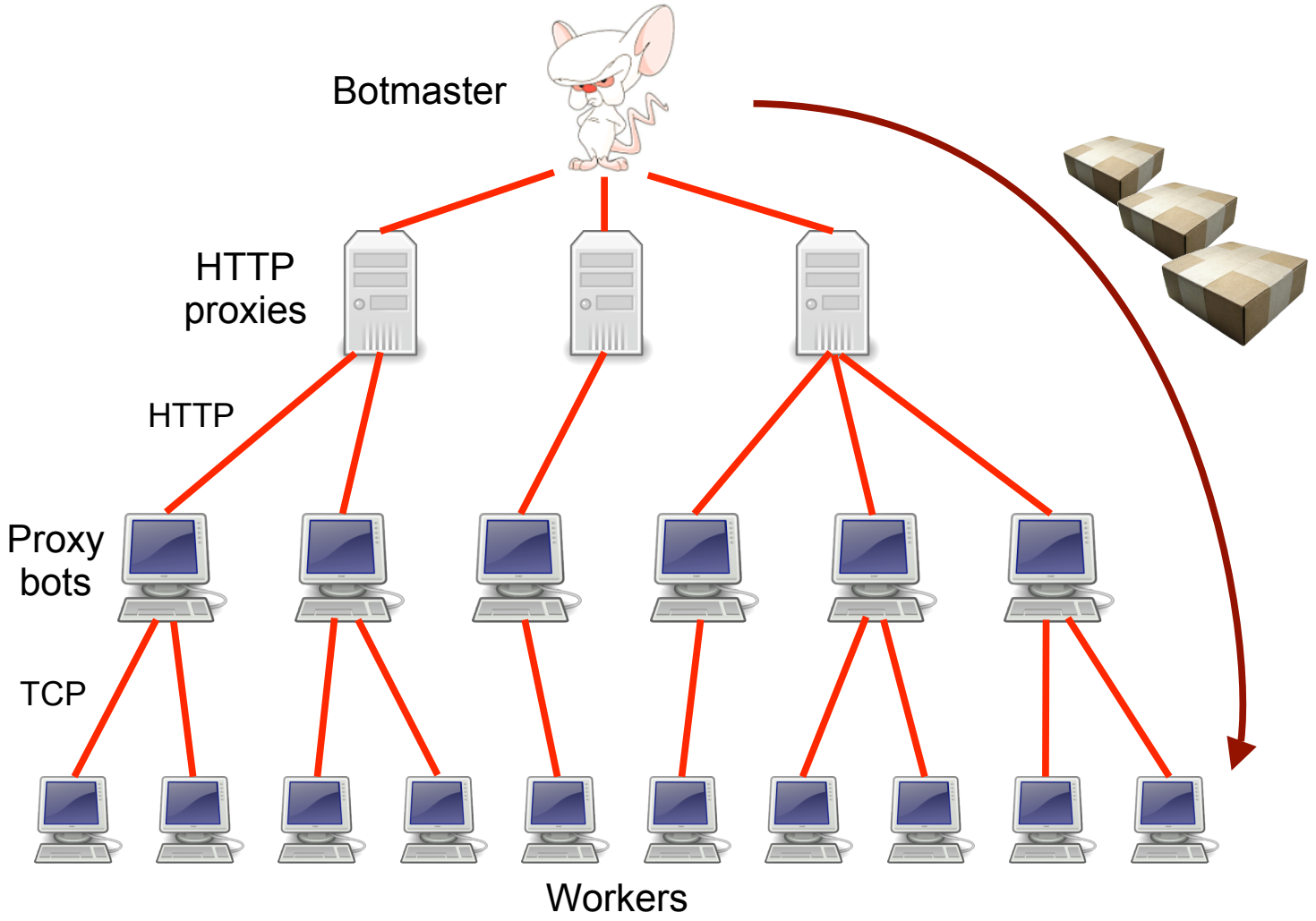
Spam campaign mechanics



Campaign mechanics: harvest



Campaign mechanics: spamming



MACRO	SEEN LIVE	FUNCTIONALITY
(0)	✓	Spam target email address.
(A)	✓	FQDN of sending bot, as reported to the bot as part of the preceding C&C exchange.
(B)		Creates content-boundary strings for multi-part messages.
(C*num*)	✓	Labels a field's resulting content, so it can be used elsewhere through (V); see below.
(D)	✓	Date and time, formatted per RFC 2822.
(E)		ROT-3–encodes the target email address.
(F*string*)	✓	Random value from the dictionary named *string*.[2]
(G*string*)	✓	Line-wrap *string* into 72 characters per line.
(H*string*)		Defines hidden text snippets with substitutions, for use in HTML- and plain-text parts.
(I)	✓	Random number between 1 and 255, used to generate fake IP addresses.
(J*string*)		Produces quoted-printable "=20" linewrapping.
(K)		IP address of SMTP client.
(M)	✓	6-character string compatible with Exim's message identifiers (keyed on time).
(N)		16-bit prefix of SMTP client's IP address.
(O*string*:*num*)	✓	Randomized message identifier element compatible with Microsoft SMTPSVC.
(Pnum_1[-num_2]:*string*)	✓	Random string of num_1 (up to num_2, if provided) characters taken from *string*.
(Q*string*)		Quoted-printable "=" linewrapping.
(Rnum_1-num_2)	✓	Random number between num_1 and num_2. Note, special-cased when used with (D).
(U*string*)		Randomized percent-encoding of *string*.
(V*num*)	✓	Inserts the value of the field identified by (C*num*).
(W)		Time and date as plain numbers, e.g. "20080225190434".
(X)		Previously selected member of the "names" dictionary.
(Y*num*)	✓	8-character alphanumeric string, compatible with Sendmail message identifiers.
(Z)	✓	Another Sendmail-compatible generator for message identifiers.

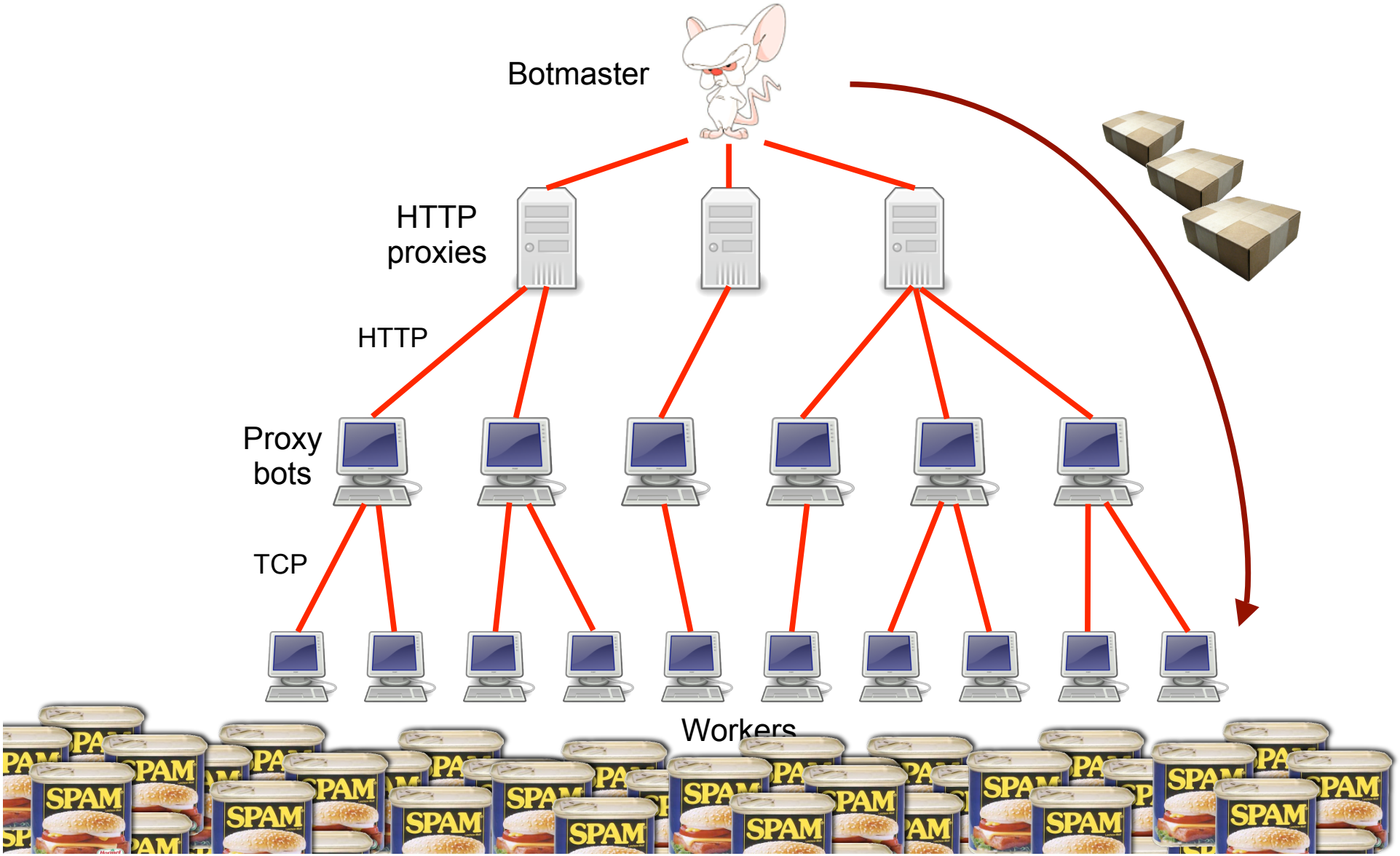
Table 2: Storm's spam-generation templating language.

```
Received: from %^C0%^P%^R2-6^%:qwertyuiopasdfghjklzxcvbnm^%.%^P%^R2-6^%:qwertyuiopasdfghjkl ▷
                                          zxcvbnm^%^% ([%^C6%^I^%.%^I^%.%^I^%.%^I^%^%]) by ▷
                                          %^A^% with Microsoft SMTPSVC(%^Fsvcver^%); %^D^%
Message-ID: <%^O%^V6^%:%^R3-50^%^%%^V0^%>
From: <%^Fnames^%@%^Fdomains^%>
To: <%^0^%>
Subject: JOB $1800/WEEK - CANADIANS WANTED!
Date: %^D-%^R30-600^%^%
```

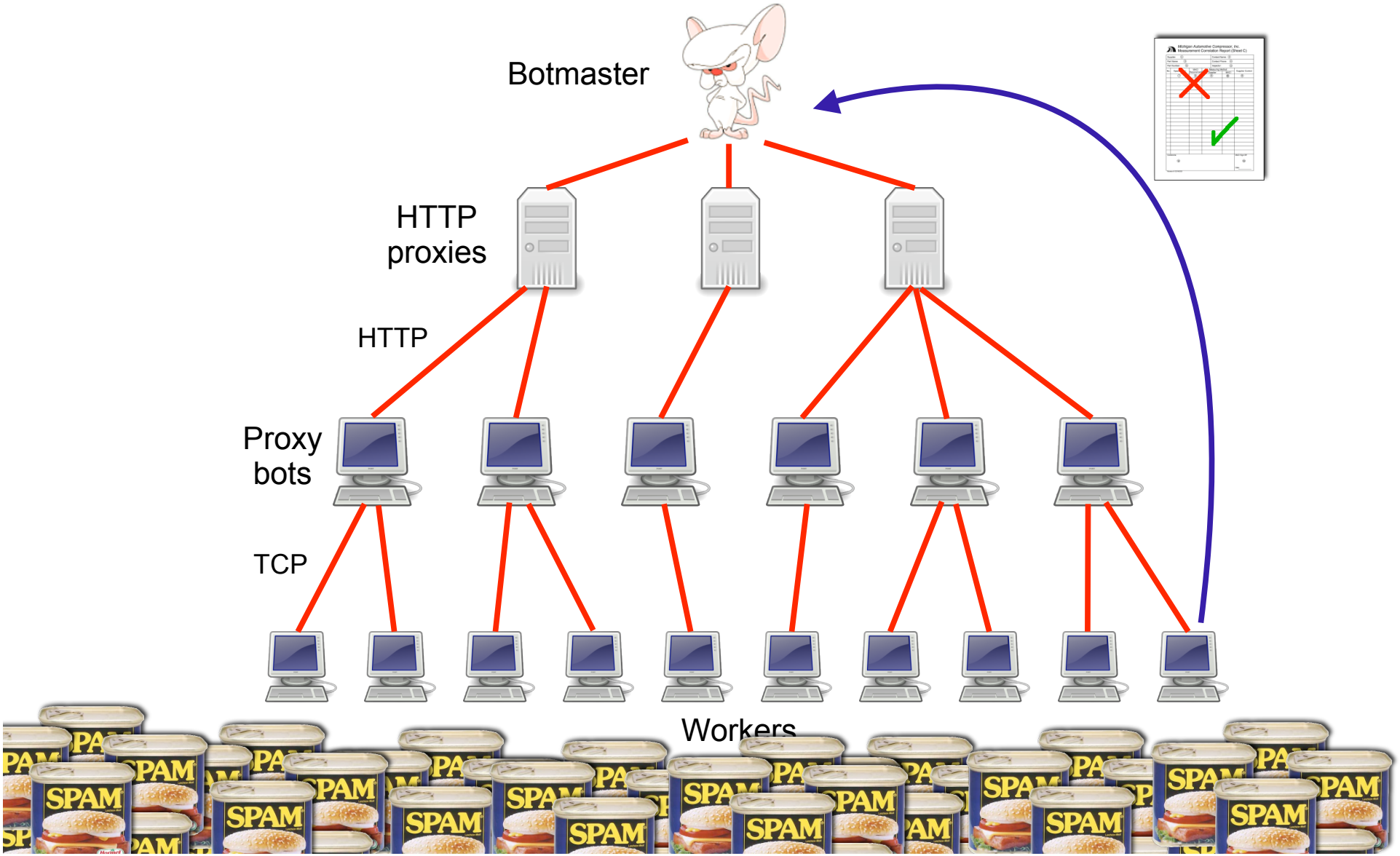
```
Received: from auz.xwzww ([132.233.197.74]) by dsl-189-188-79-63.prod-infinitum.com.mx with ▷
                          Microsoft SMTPSVC(5.0.2195.6713); Wed, 6 Feb 2008 16:33:44 -0800
Message-ID: <002e01c86921$18919350$4ac5e984@auz.xwzww>
From: <katiera@experimentalist.org>
To: <voelker@cs.ucsd.edu>
Subject: JOB $1800/WEEK - CANADIANS WANTED!
Date: Wed, 6 Feb 2008 16:33:44 -0800
```

Figure 2: Snippet of a spam template, showing the transformation of an email header from template (top) to resulting content (bottom). The ▷-symbol indicates line continuations. Bold text corresponds to the formatting macros and their evaluation.

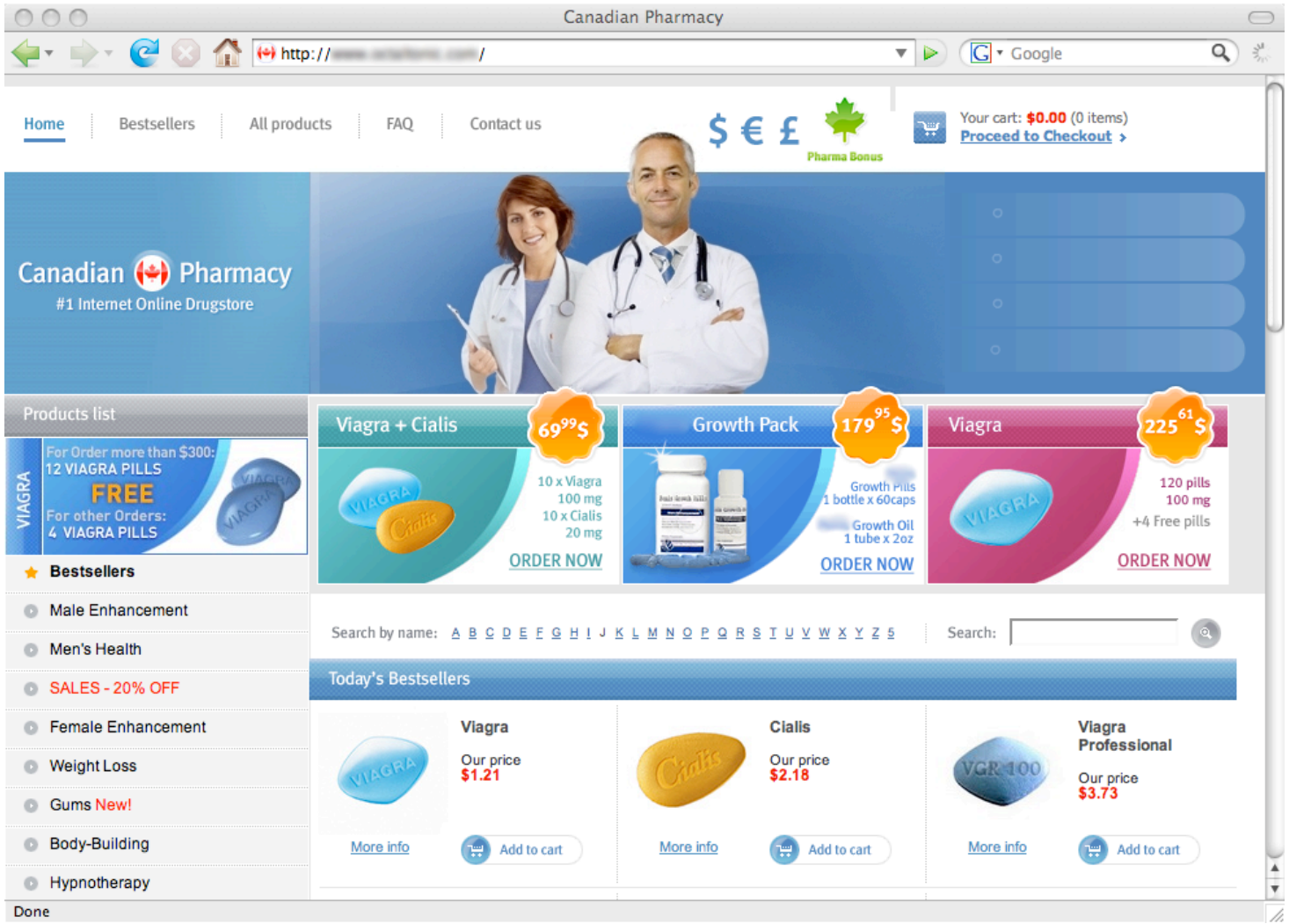
Campaign mechanics: spamming



Campaign mechanics: reporting



Welcome to **Storm**! What can we sell you?



Anatomy of a modern Pharma spam campaign

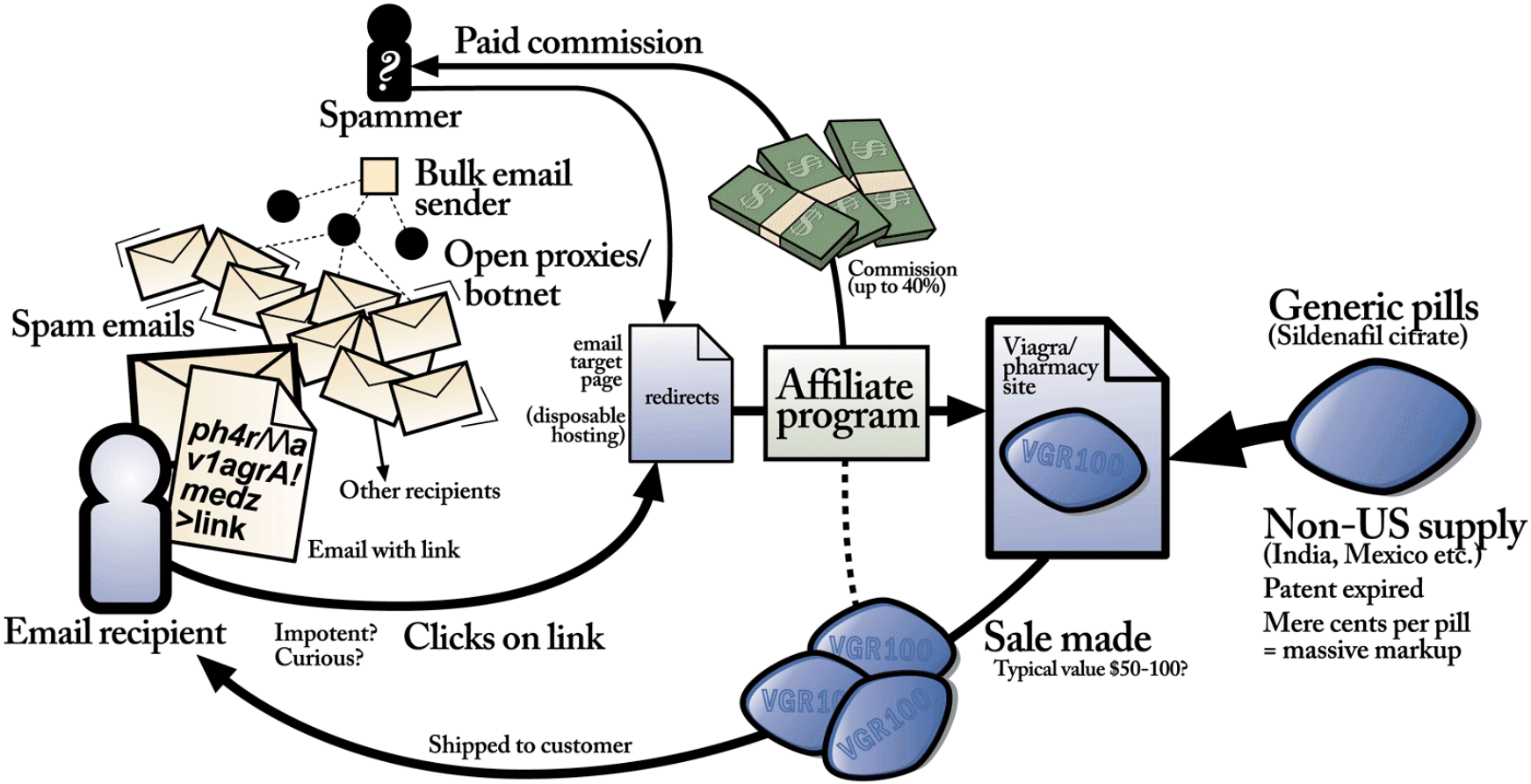
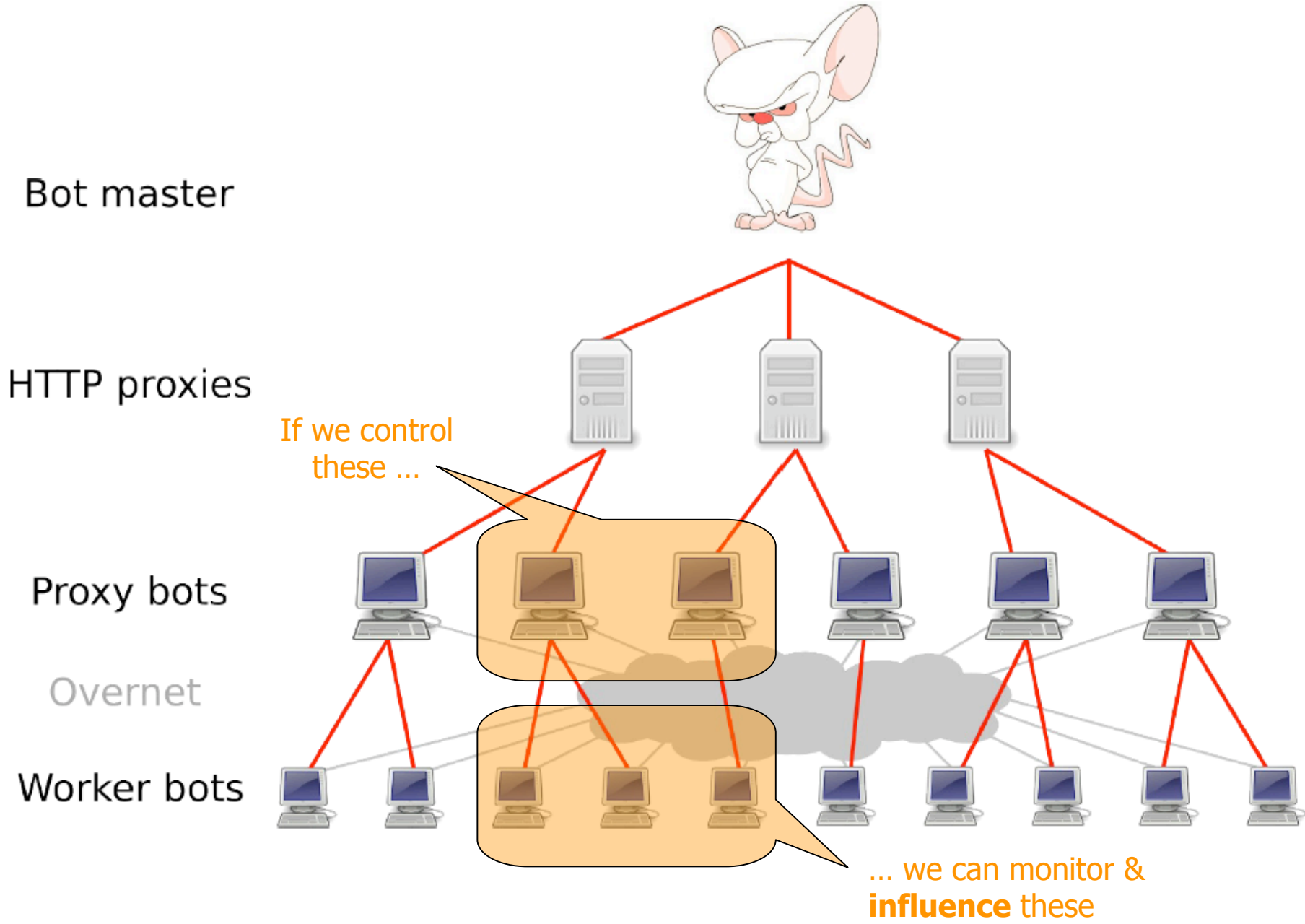
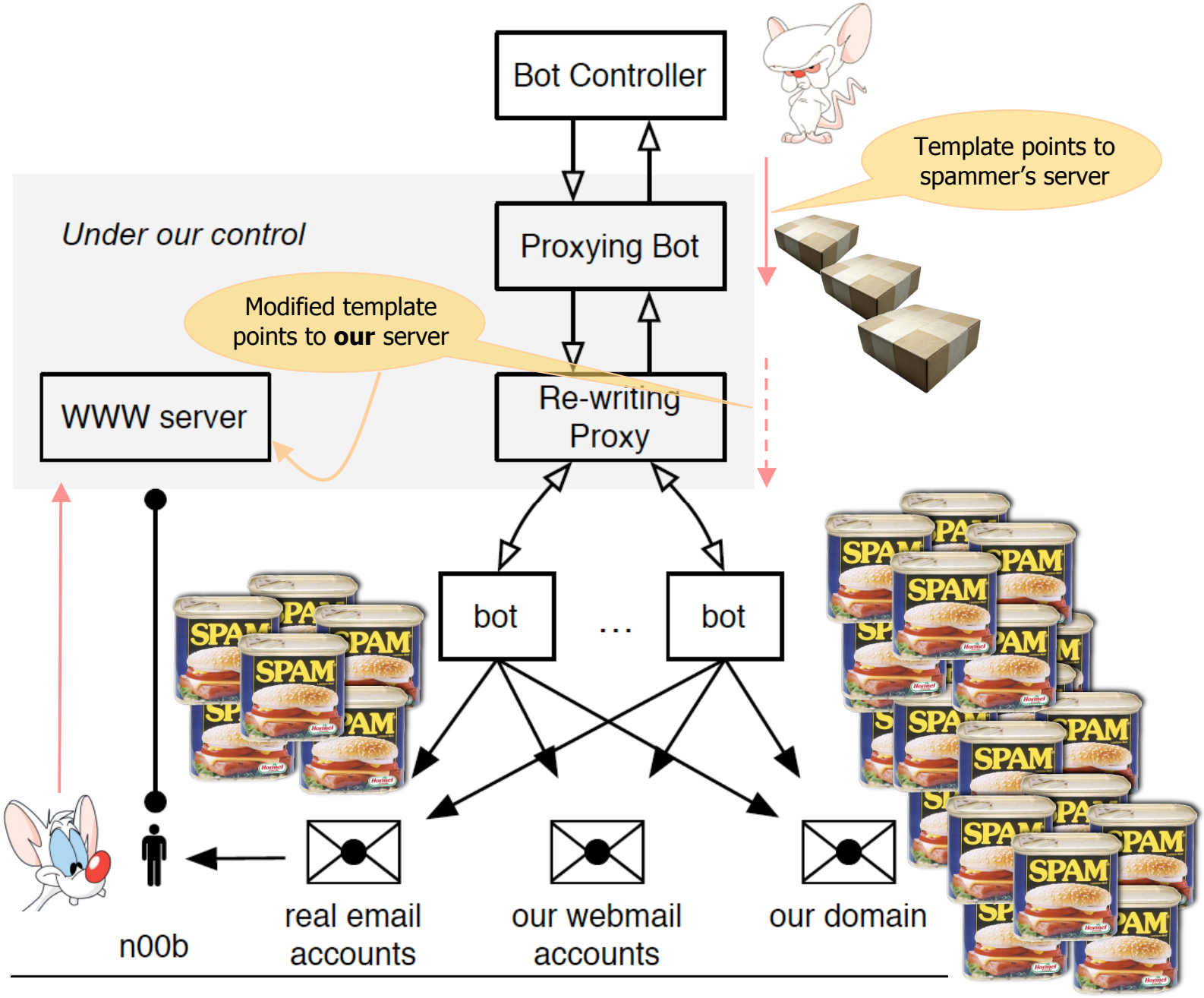


Diagram by Stuart Brown
modernlifeisrubbish.co.uk

These folks seem trustworthy …

… how about these?


Bot master
HTTP proxies
If we control these …
Proxy bots
Overnet
Worker bots
… we can monitor & **influence** these

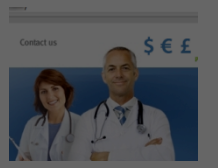

Bot Controller
Under our control
Proxying Bot
Template points to spammer's server
Modified template points to **our** server
WWW server
Re-writing Proxy
bot
…
bot
SPAM
n00b
real email accounts
our webmail accounts
our domain

Spam conversion experiment

- Experimented with Storm March 21 – April 15, 2008
- Instrumented roughly 1.5% of Storm's total output

	Pharmacy Campaign	**E-card Campaigns**	
		Postcard	April Fool
Worker bots	31,348	17,639	3,678
Emails	347,590,389	83,665,479	38,651,124
Duration	19 days	7 days	3 days

Spa



load will start in 5 seconds.
oad does not start, click here

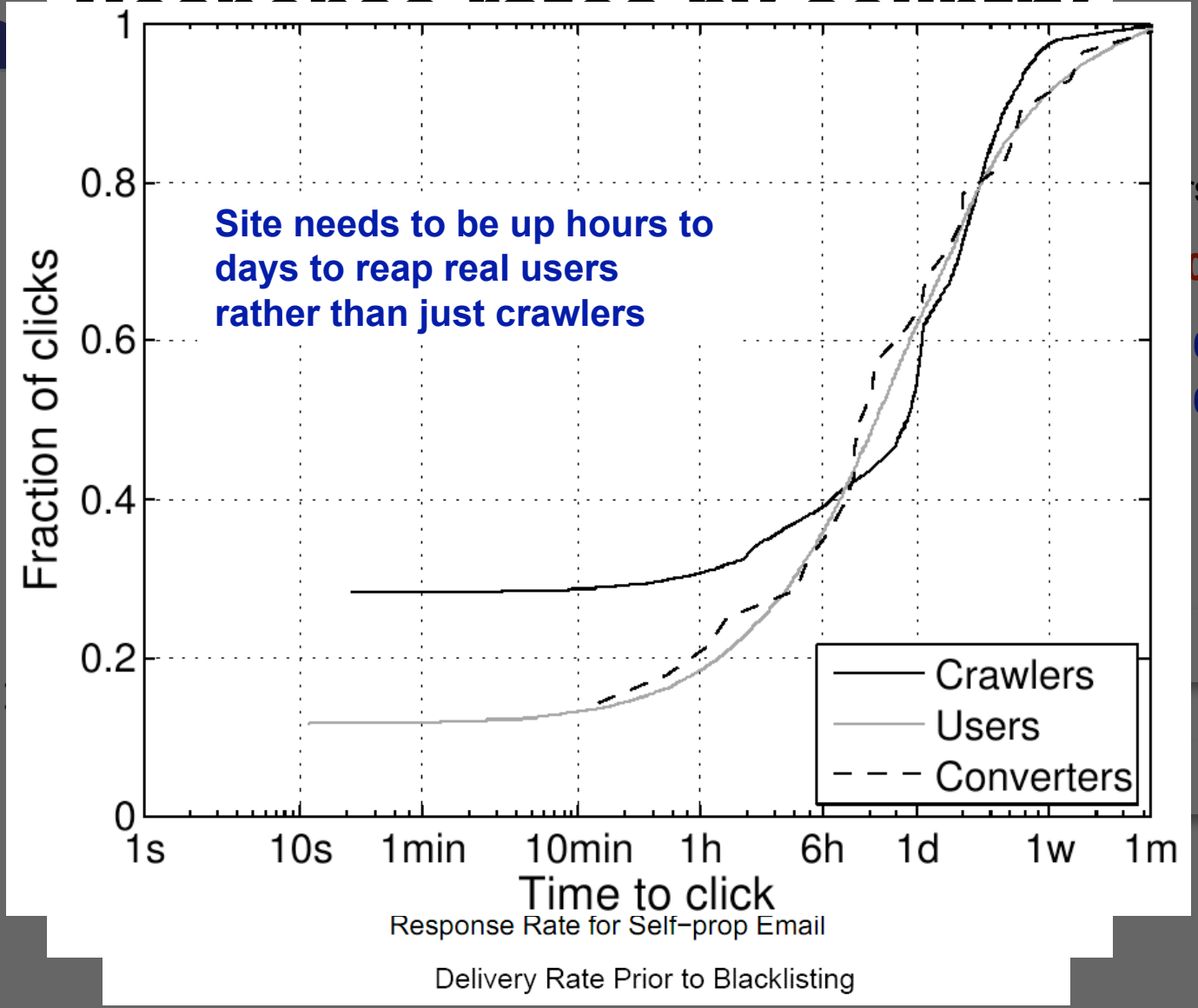
targeted

sions

0008%)

037%)

056%)



Response Rate for Self-prop Email

Delivery Rate Prior to Blacklisting

Corresponding Revenue

- 28 purchases in 26 days, average “sale” ~$100
  - Total: $2,731.88, $140/day
- **But**: we interposed on only ~1.5% of workers:
  - $9,500/day (8,500 new bots per day)
  - $3.5M/year
    - Though if selling Viagra via *Glavmed affiliation*, cut is **40%**
- Storm: service provider or integrated operation?
  - Retail price of spam ~$80 per million
    - Pharmacy spam would have cost 10x the profit!
  - Strongly suggests Storm operates as an integrated operation rather than a reseller

Reflections on the Journey

- Network security research has seen enormous change over the last 15 years, from:
  - Not a field …
  - … to fending off ardent amateurs
  - … to global worm epidemics
  - … to botnets employed for spam campaigns that fuel an emergent underground economy
- The first of these was pretty tenable (and fun!)
- The second was daunting but the field made some surprising advances
  - Though cyberwarfare remains a major latent threat
- The third is even more daunting …
  - … deeply worrisome because it's fueled by criminals out to make money - **hastening the pace of adversary innovation**

Reflections on the Process

- *Measuring* is easy
- Measuring in a *meaningful* and *sound* way is hard …
  - A lot of un-fun grunt work dealing with messiness & error
- But: only convincingly way to unearth Truth
- And sometimes you get surprised:
  - Pervasive diversity & exponential growth
  - Unanticipated threats & non-threats
  - Strikingly rapid changes in the landscape
- Security as a field is all about trading off resources vs. perceived risks
  - ⇒ Deep fundamental need for well-grounded empirical data
- In today's threat environment, biggest defense payoffs can come from understanding (= measuring) and then undermining attacker profit …
  - … rather than securing systems pointwise.