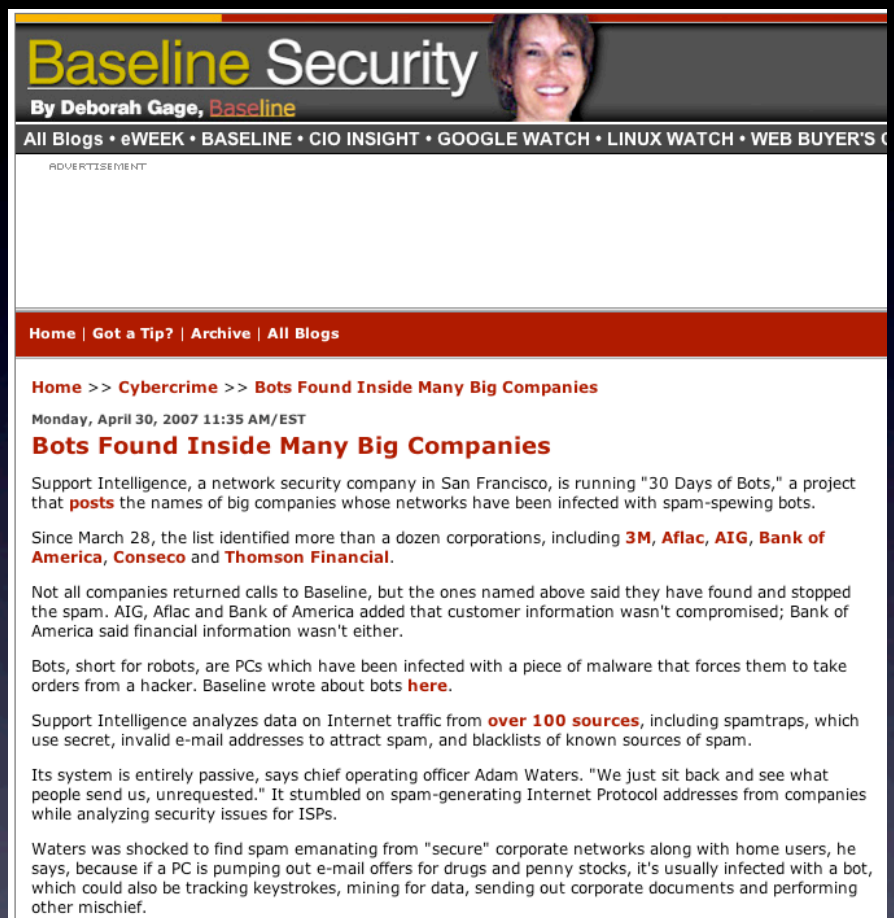
Studying Botnets Using *BotLab*

Arvind Krishnamurthy

Botnets: a Growing Threat



Baseline Security

By Deborah Gage, Baseline

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Monday, April 30, 2007 11:35 AM/EST

Bots Found Inside Many Big Companies

Support Intelligence, a network security company in San Francisco, is running "30 Days of Bots," a project that **posts** the names of big companies whose networks have been infected with spam-spewing bots.

Since March 28, the list identified more than a dozen corporations, including **3M**, **Aflac**, **AIG**, **Bank of America**, **Conseco** and **Thomson Financial**.

Not all companies returned calls to Baseline, but the ones named above said they have found and stopped the spam. AIG, Aflac and Bank of America added that customer information wasn't compromised; Bank of America said financial information wasn't either.

Bots, short for robots, are PCs which have been infected with a piece of malware that forces them to take orders from a hacker. Baseline wrote about bots **here**.

Support Intelligence analyzes data on Internet traffic from **over 100 sources**, including spamtraps, which use secret, invalid e-mail addresses to attract spam, and blacklists of known sources of spam.

Its system is entirely passive, says chief operating officer Adam Waters. "We just sit back and see what people send us, unrequested." It stumbled on spam-generating Internet Protocol addresses from companies while analyzing security issues for ISPs.

Waters was shocked to find spam emanating from "secure" corporate networks along with home users, he says, because if a PC is pumping out e-mail offers for drugs and penny stocks, it's usually infected with a bot, which could also be tracking keystrokes, mining for data, sending out corporate documents and performing other mischief.

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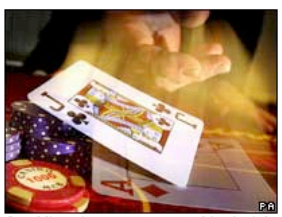
Firms hit rivals with web attacks

By Mark Ward
Technology Correspondent, BBC News website

Legitimate businesses are turning to cyber criminals to help them cripple rival websites, say security experts.



Gambling sites were targeted in denial of service attacks

The rise in industrial sabotage comes as some suggest cyber criminals are turning away from using web-based attack tools in extortion rackets.

Experts suspect this is because of the risks involved in mounting such an attack on a web shop or retailer.

Instead the tools, usually hijacked home computers, are being used to pump out junk e-mail.

Cash call

Often these hijacked PCs, known as bots, are used for "Distributed Denial of Service" (DDoS) attacks that attempt to knock a site or server offline by bombarding it with huge amounts of data.

Online gambling sites were among the first to be threatened with DDoS attacks if they did not hand over significant sums of cash.

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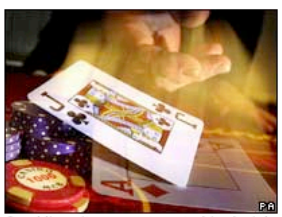

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Antispam firm says it was victim of attack

By Jaikumar Vijayan, Computerworld, 05/05/06

The CEO of an antispam firm whose service was knocked offline by a spammer earlier this week claimed his company was the victim of a sophisticated attack carried out, in part, with the help of someone at a top-tier ISP.

Eran Reshef, CEO of Blue Security, an Israeli antispam firm, said that his company was attacked by a major spammer named PharmaMaster who used a combination of methods to knock

Other stories on this topic

Hackers hijack Windows Update's downloader
5/11/2007

Nevis announces free LAN

Botnets: a Growing Threat

What do Bots do?

- Steal personal information, install keyloggers
- Participate in "distributed denial of service" attacks
- Send spam
- Infect other machines
- Perform click fraud
- ...

Botnets still a mystery...

- Increasing awareness, but there is a dearth of hard facts especially in real-time
  - Meager network-wide cumulative statistics
  - Sparse information regarding individual botnets
  - Most analysis is post-hoc

Inconsistent Information

Big Honkin' Botnet - 1.5 Million!

Published: 2005-10-20,
Last Updated: 2005-10-20 21:13:23 UTC
by Ed Skoudis (Version: 1)

0 comment(s) Digg submit

A diligent reader from the Netherlands requesting anonymity (lots of folks doing that today) pointed this article about a recent botnet bust in the Netherlands. The article is in Dutch, but our reader tra it thusly:

"The botnet in the spotlight by the Dutch National Criminal Investigation unit in the Netherlands, abo weeks ago was found to comprise approximately 1.5 million hacked computers (instead of 100k repo earlier) . This has been discovered by GovCert.nl, the Dutch Computer Emercency Response Team, dismantling the network of computers infected with a Trojan Horse. Of the total number of infected computers, it was estimated that only 30,000 were located in the Netherlands.

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Botnet scams are exploding

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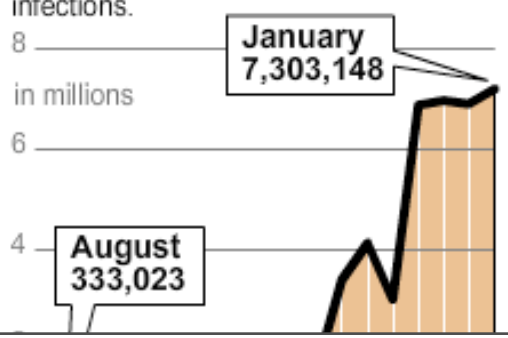
CYBERCRIME PAYS

The escalating number of botnets have helped feed a surge in various forms of online fraud.

Botnet deluge Virus rate
E-mail spam Phishing attacks

Botnet deluge

The average daily number of unique botnet communiqués to accept instructions from a controller, deliver spam, conduct phishing campaigns, click on ads to earn ad revenue, carry out denial-of-service attacks, steal data, scan for vulnerable computers, and spread infections.



By Byron Acohido and Jon Swartz, USA TODAY

Mixx it
Other ways to share:
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What's this?

SEATTLE — Two days after actor Heath Ledger died, e-mails began moving across the Internet purportedly carrying a link to a detailed police report divulging "the real reason" behind the actor's death. Ledger had been summarily drafted into the service of a botnet.

Bots are compromised computers controlled by profit-minded crooks. Those e-mails were spread by a network of thousands of bots, called a botnet. Anyone who clicked on the link got instantly absorbed into the fast-spreading Mega-D botnet, says security firm Marshal. Mega-D enriches its operators, mainly by distributing spam for male-enhancement pills.

BACKGROUND: Botnets can be used to blackmail targeted sites

Largely unnoticed by the [illegible] the Internet. On a typic[illegible] day, 40% of the 800 million computers connected to the Internet [illegible] spam, stealing sensitive data typed at banking and shopping websites, bombarding websites as part of extortionist denial-

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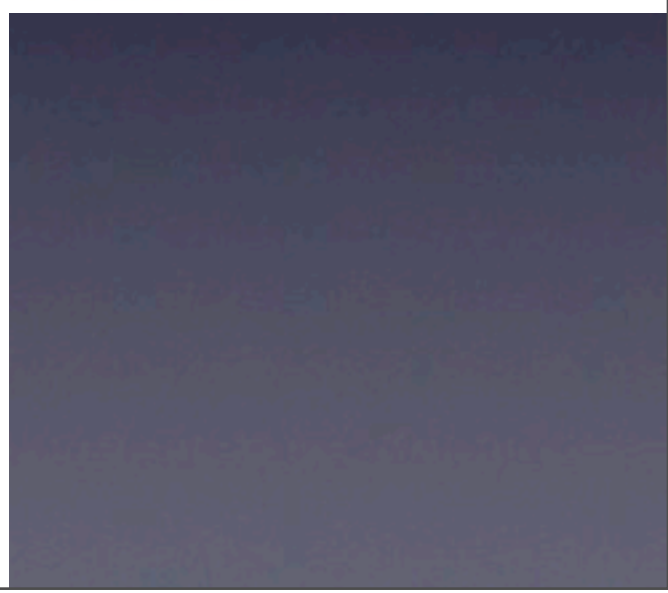

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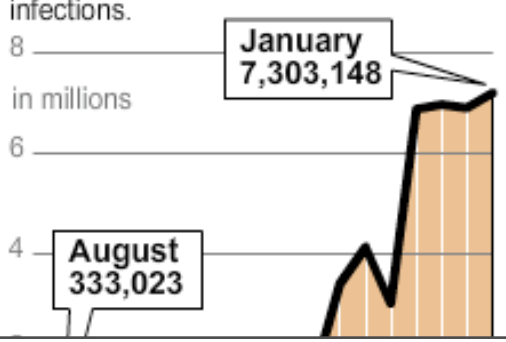

By Byron Ac
TODAY

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From the News Desk

Vint Cerf: one quarter of all computers part of a botnet

By Nate Anderson | Published: January 25, 2007 - 04:35PM CT

The World Economic Forum takes place this week in Davos, Switzerland, and leaders around the world gather to discuss issues like the Iraq war, global climate change, and globalization—along with the incredible prevalence of botnets.

The BBC's Tim Weber, who was in the audience of an Internet panel featuring Vint Cerf, Michael Dell, John Markoff of the *New York Times*, and Jon Zittrain of Oxford, came away most impressed by the botnet statistics. Cerf told his listeners that approximately 600 million computers are connected to the Internet, and that 150 million of them might be participants in a botnet—nearly all of them unwilling victims. Weber remarks that "in most cases the owners of these computers have not the slightest idea what their little beige friend in the study is up to."

If Cerf's estimate is accurate, that's one quarter of all machines connected to the Internet. So is the Internet doomed? Well, you're reading this, so no, not yet. But the botnet menace is no phantom, and it has been growing in strength for years. In September 2006, security research

Research Agenda

To build a *botnet monitoring platform* that can track the activities of the *most significant spamming botnets* currently operating in *real-time*

Botnet Lifecycle (Traditional View)

Infecting Machine

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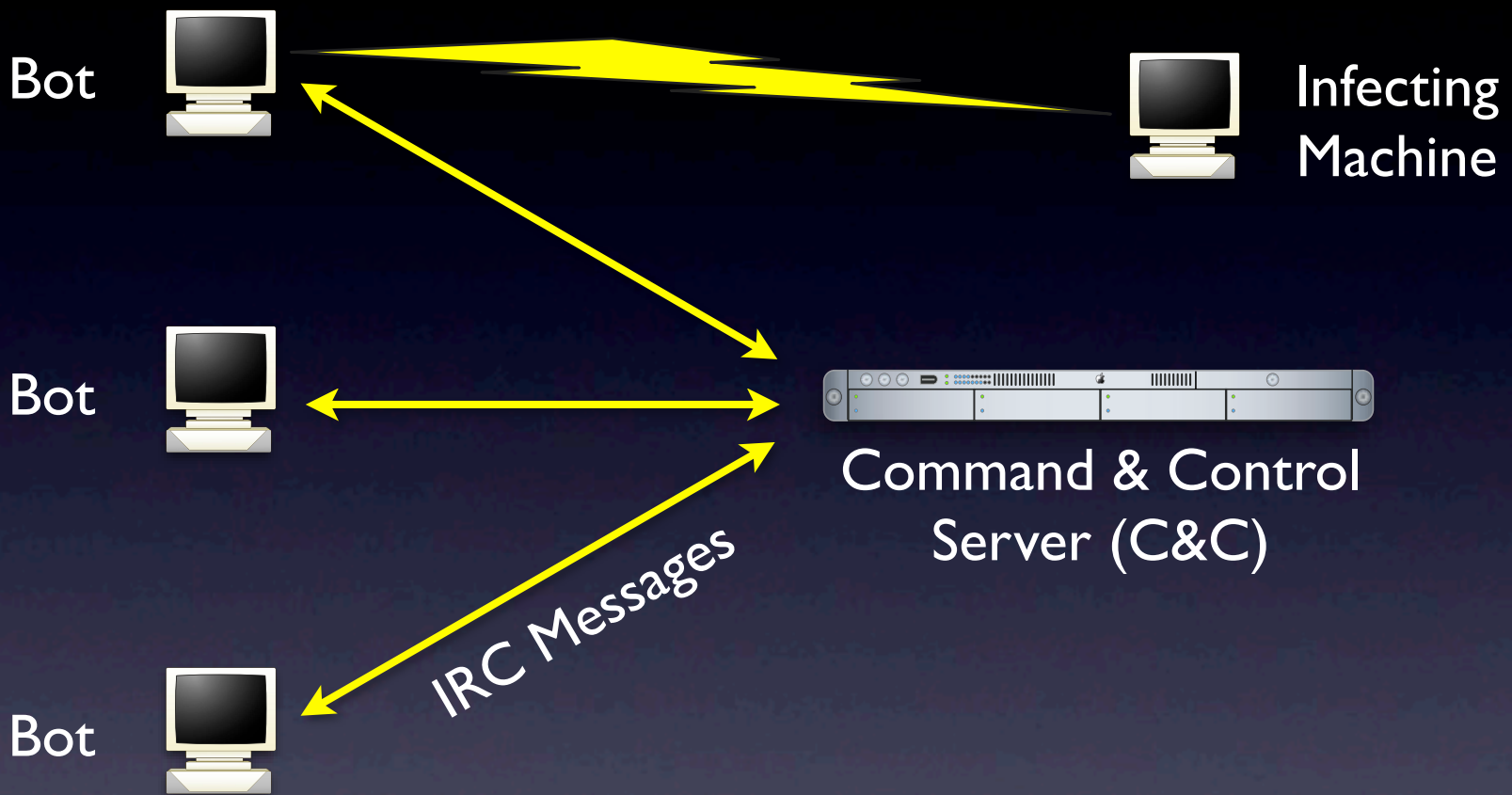
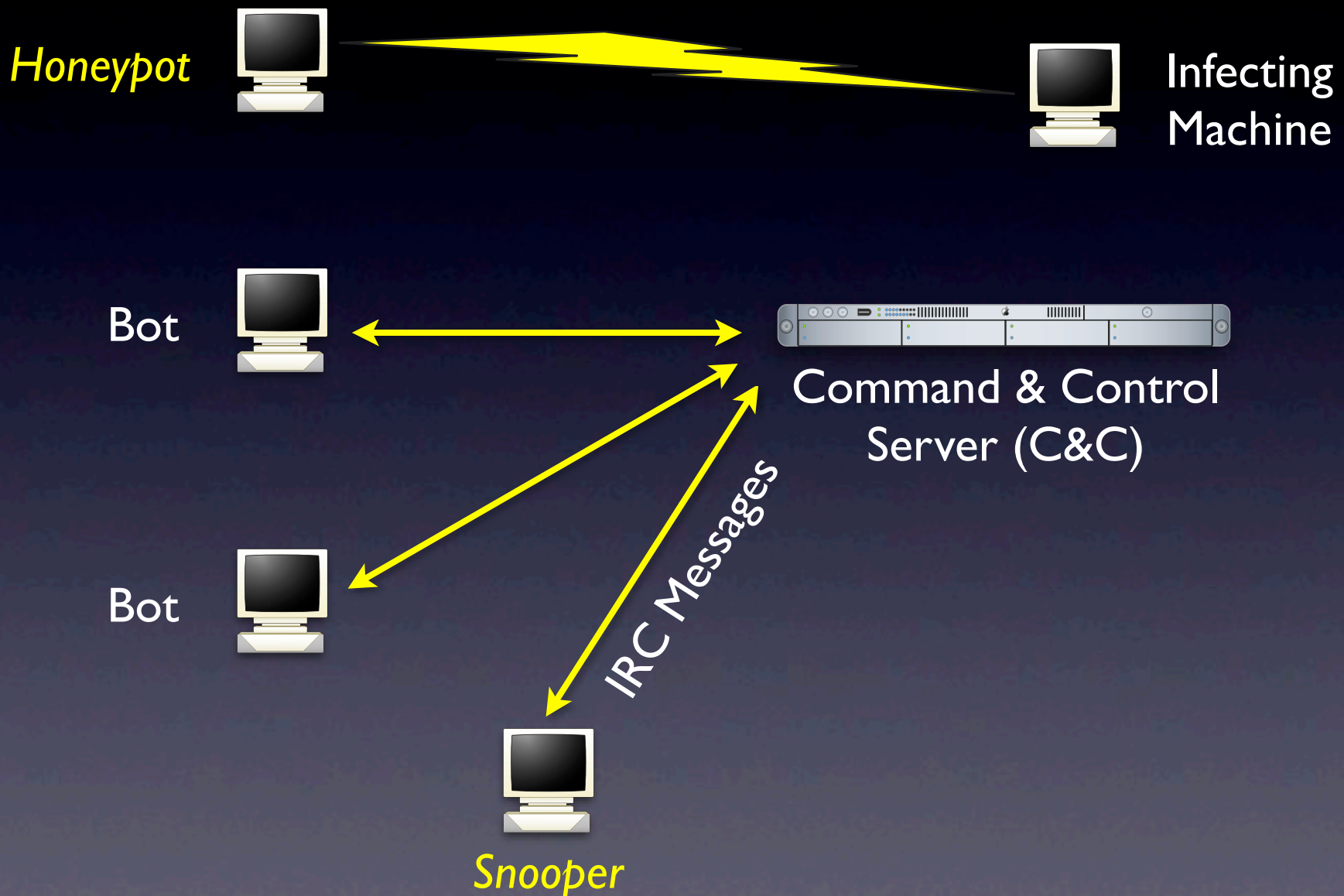
Infecting Machine

Botnet Lifecycle (Traditional View)



Tools for Monitoring



Botnet Operators' Response

- Use *social engineering* techniques for infection
  - Cleverly crafted emails/websites induce users to download malicious programs

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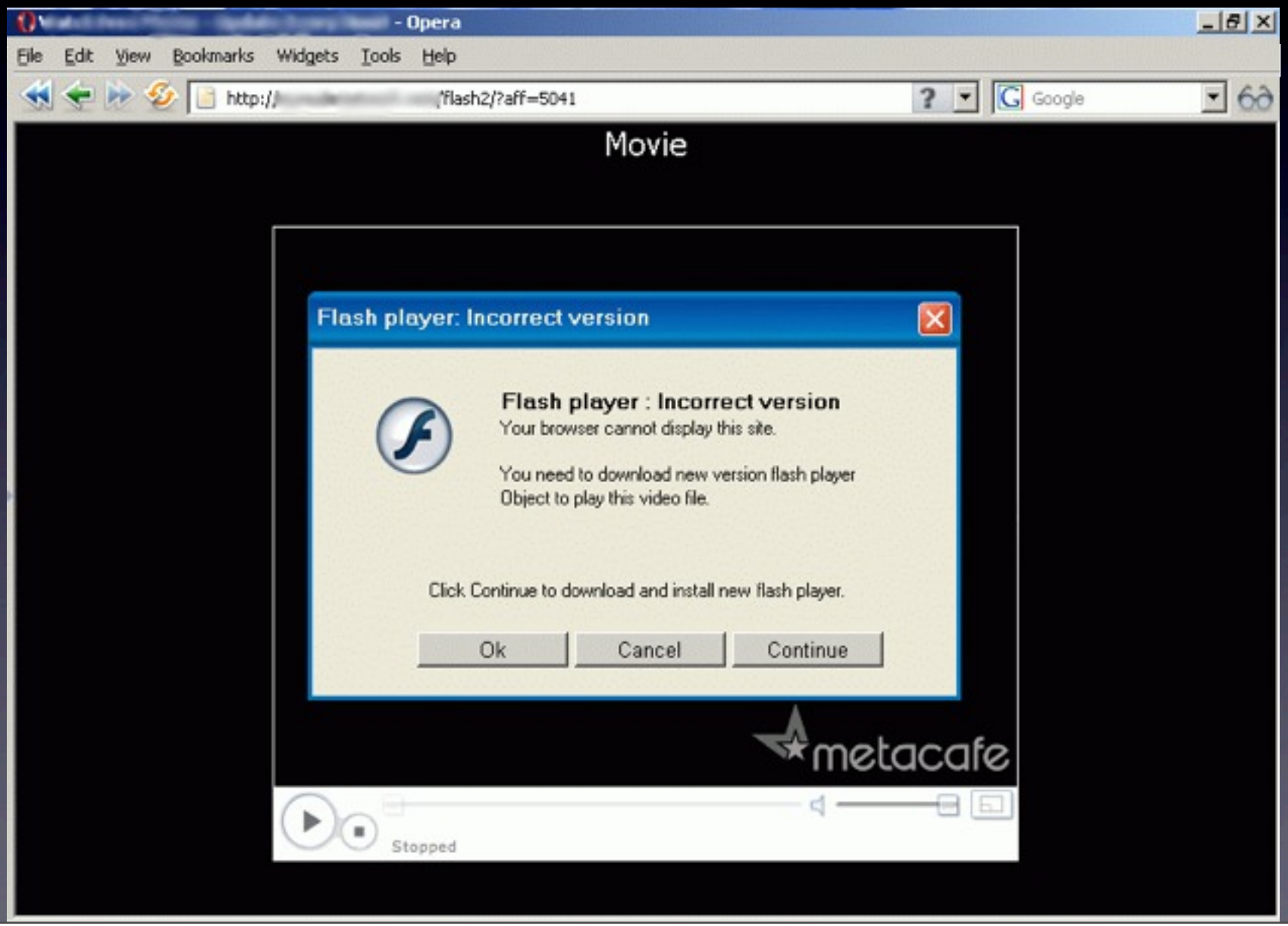


Botnet Operators' Response

- Use *social engineering* techniques for infection
  - Cleverly crafted emails/websites induce users to download malicious programs
- *Detect* virtualization
- Use *customized protocols* over HTTP
- Use *dynamic adaptation*
  - Malware binaries morph every few minutes
  - FastFlux DNS allows for fast redirection to new C&C
  - Change C&C protocols as well
- Serve malware/phishing from *compromised* websites

Finding vulnerable servers

- How are vulnerable servers found?
  - Brute force -- not very feasible
  - Use search to narrow scope
  - Lots of known bugs in php, asp, etc.
  - Underground sites post such vulnerabilities

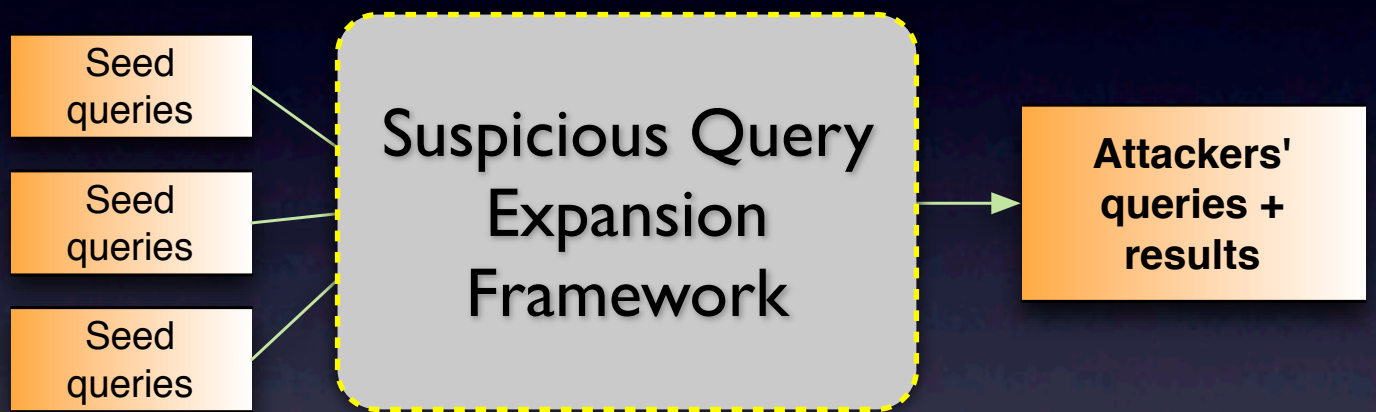
One such hacker site

A malicious query

```
=================================================
DatalifeEngine 8.2 Remote File Inclusion Vulnerability
=================================================
++++++++++++++++++++++ Exploit ++++++++++++++++++++++
=================================================
<<->> google dork : Powered By DataLife Engine
<<->> Exploit ::

 >>> www.site/path /engine/api/api.class.php?dle_config_api=[shell.txt?]
```

Detecting Vulnerability Searches



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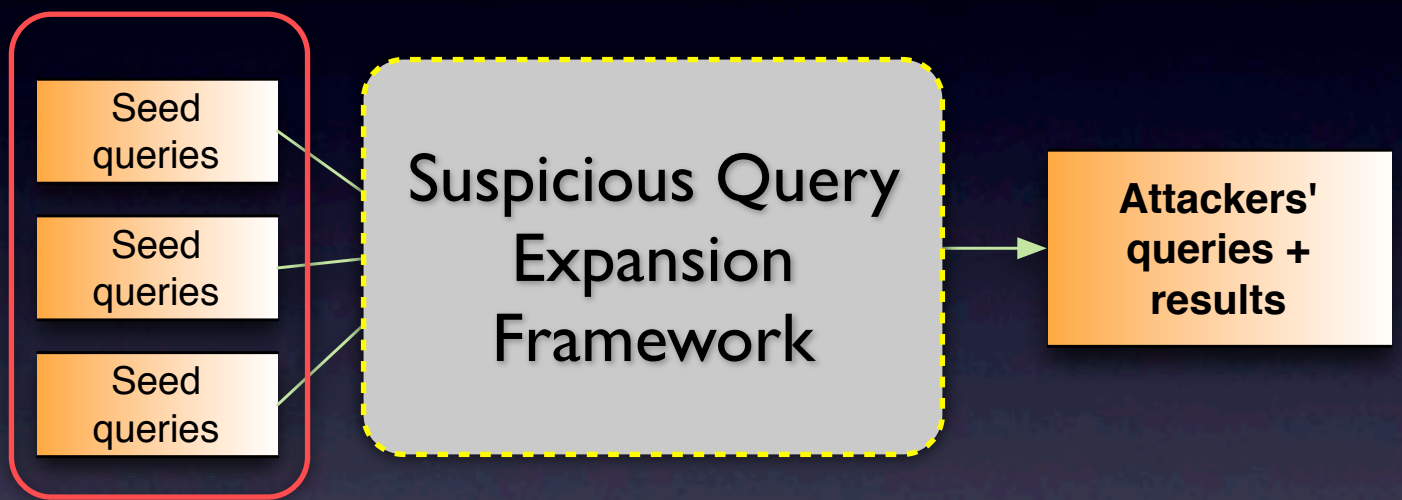

- 70 seed queries
- From `milw0rm`

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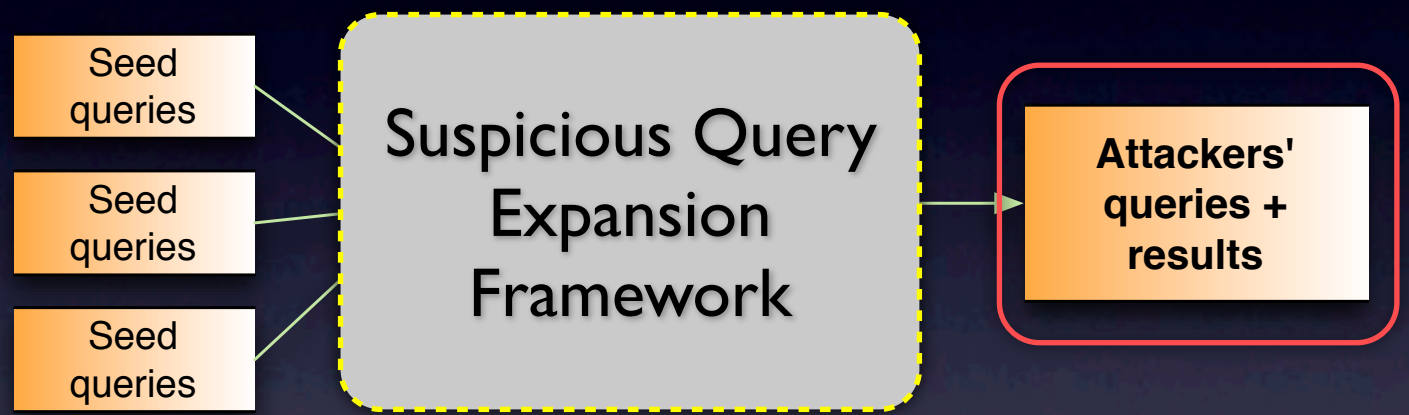

- 70 seed queries
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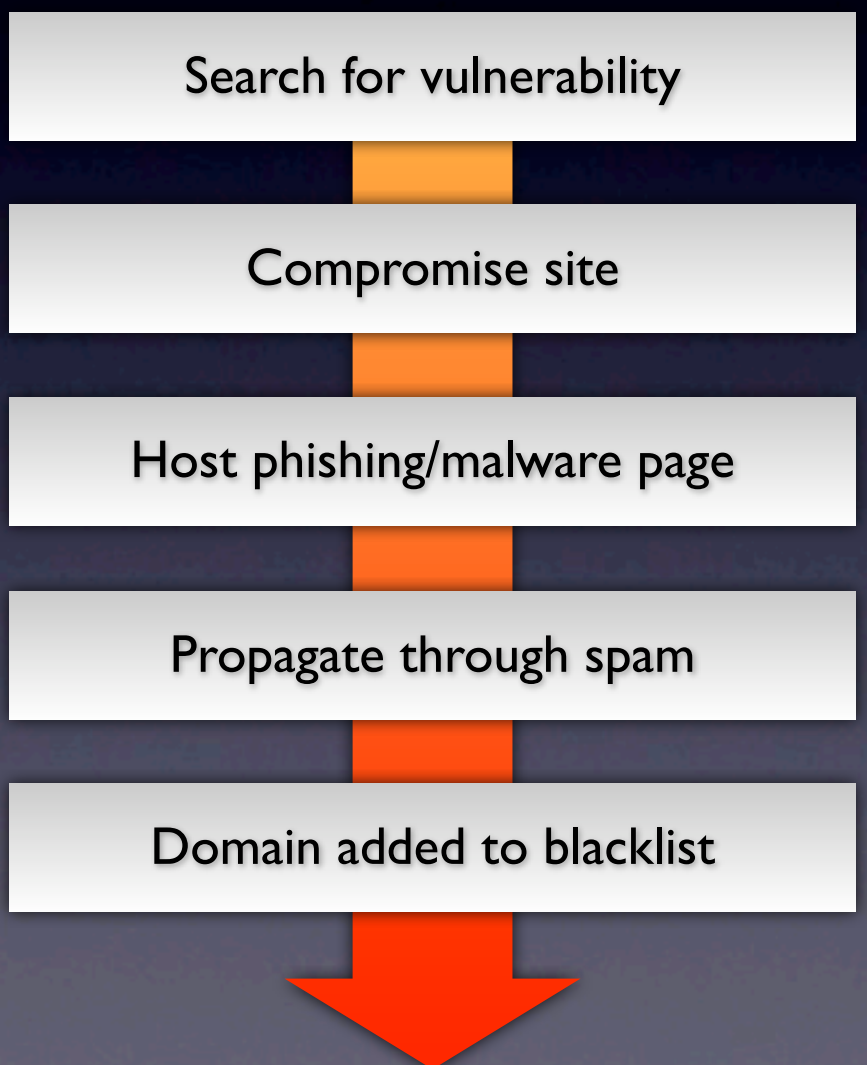
- 1.2M searches
- 16k unique queries
- 436 IPs

An attacker's view



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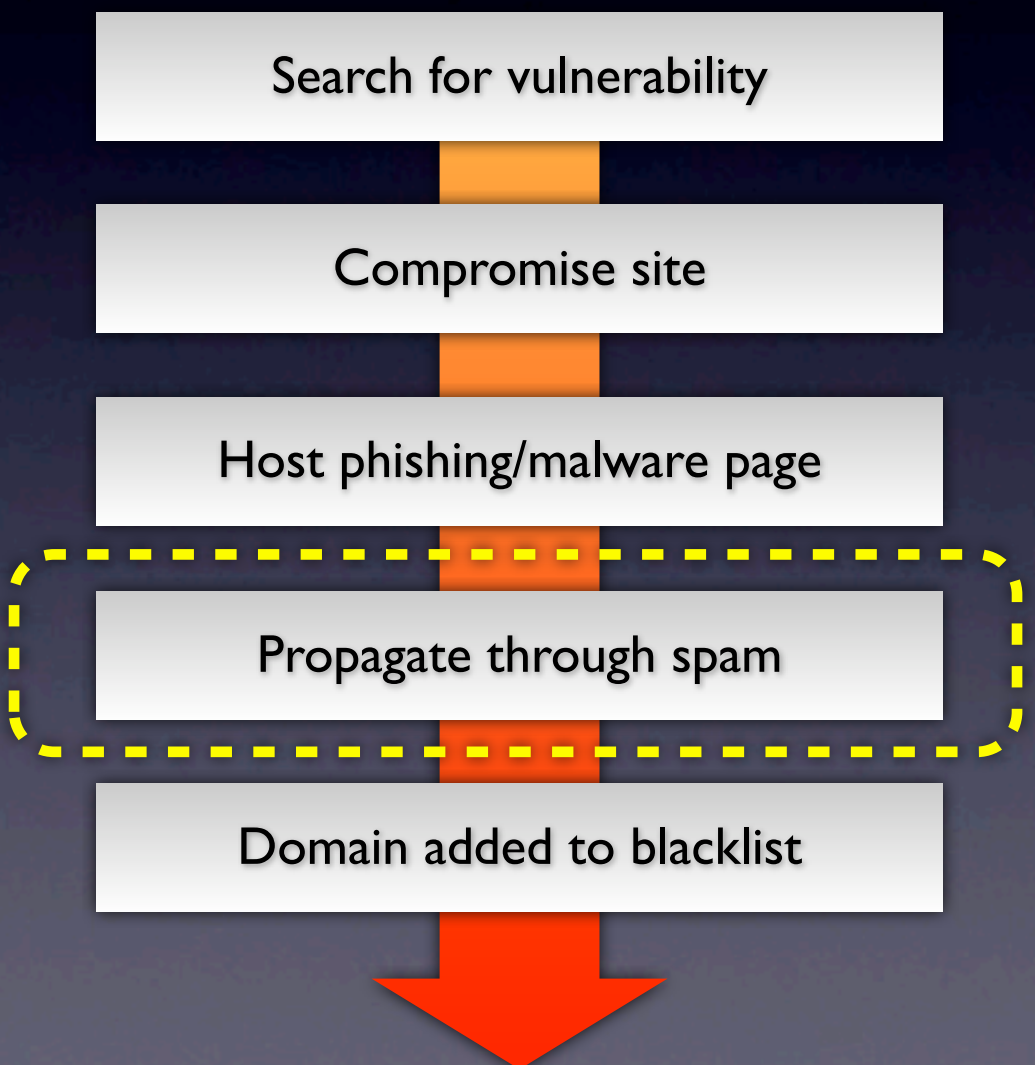
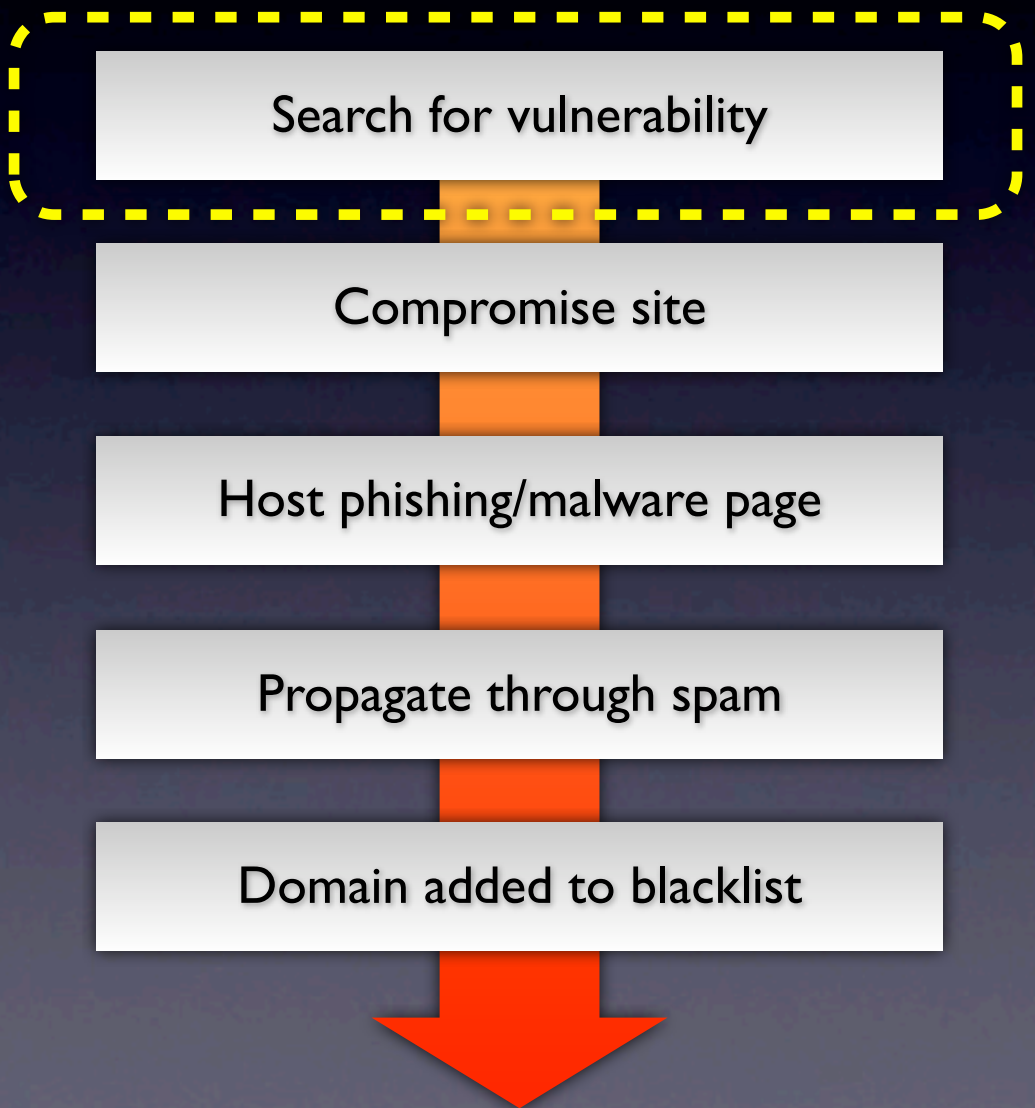


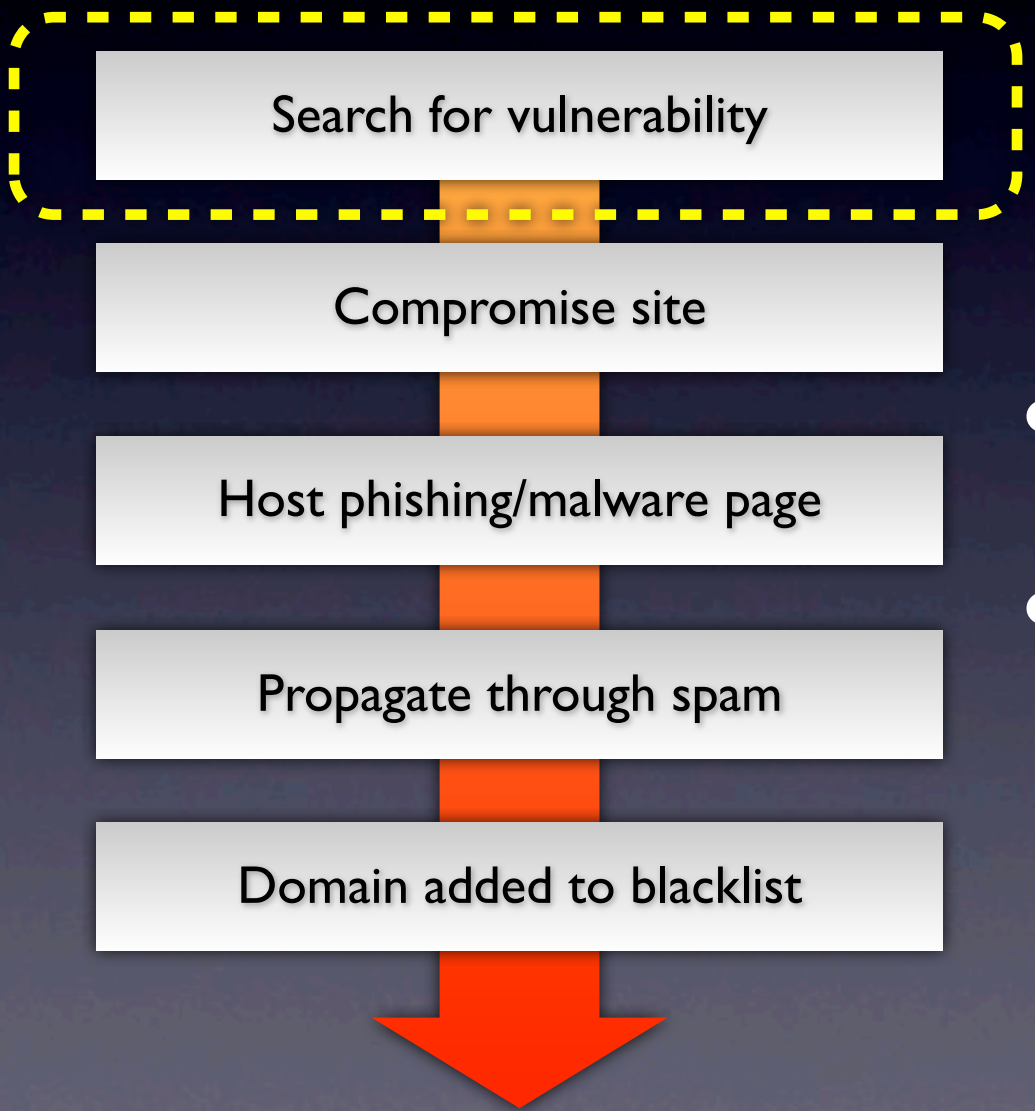
Detection

Defender's view



Possible detection

Defender's view



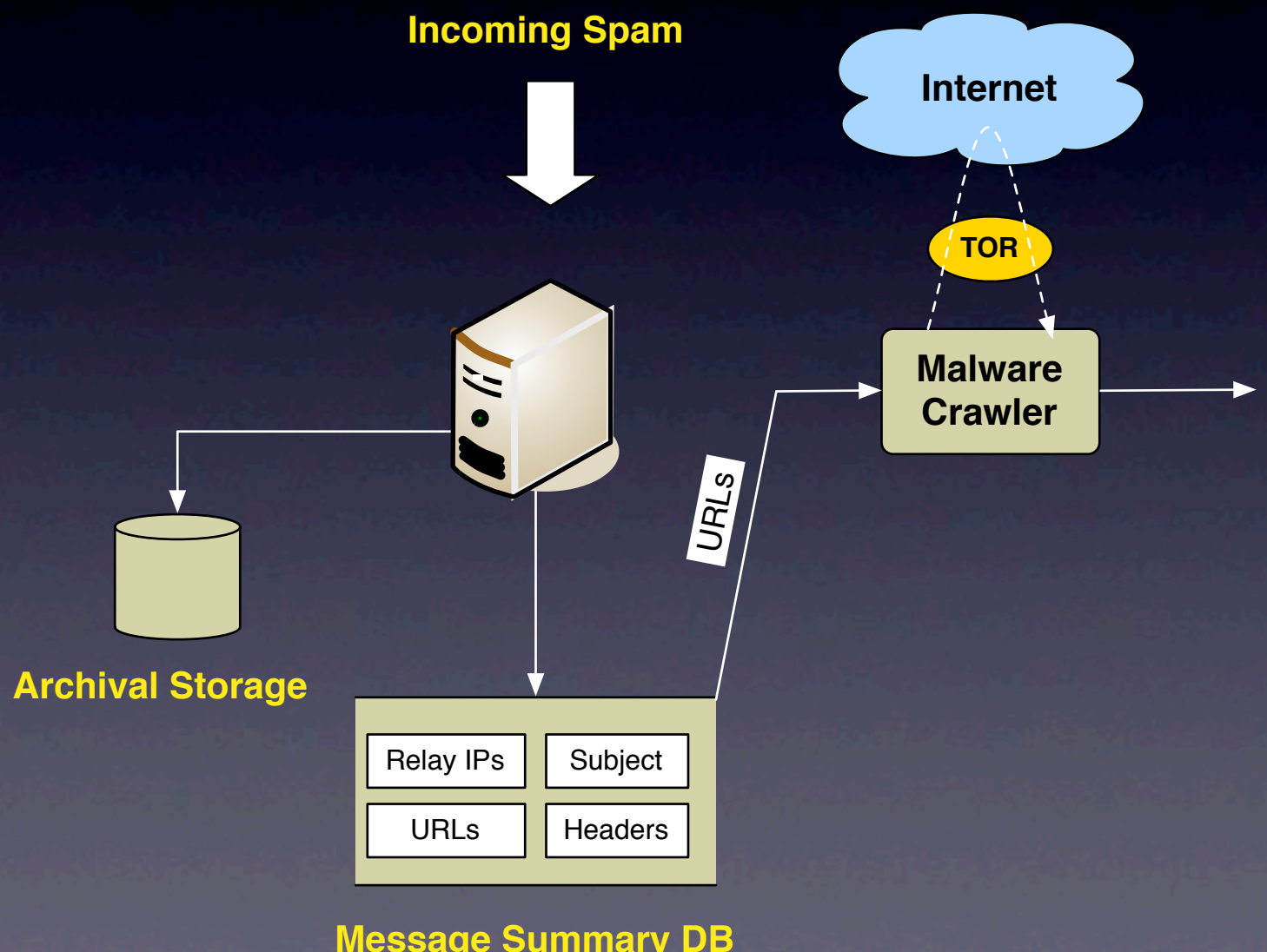
Possible detection

- Can proactively inform administrators
- Can predict which servers might be attacked

BotLab Design

- *Active* as opposed to passive collection of binaries
- *Attribution:* run actual binaries and monitor behavior without causing harm
- *Scalably* identify duplicate binaries
- *Correlate* incoming spam with outgoing spam

1. Malware Collection



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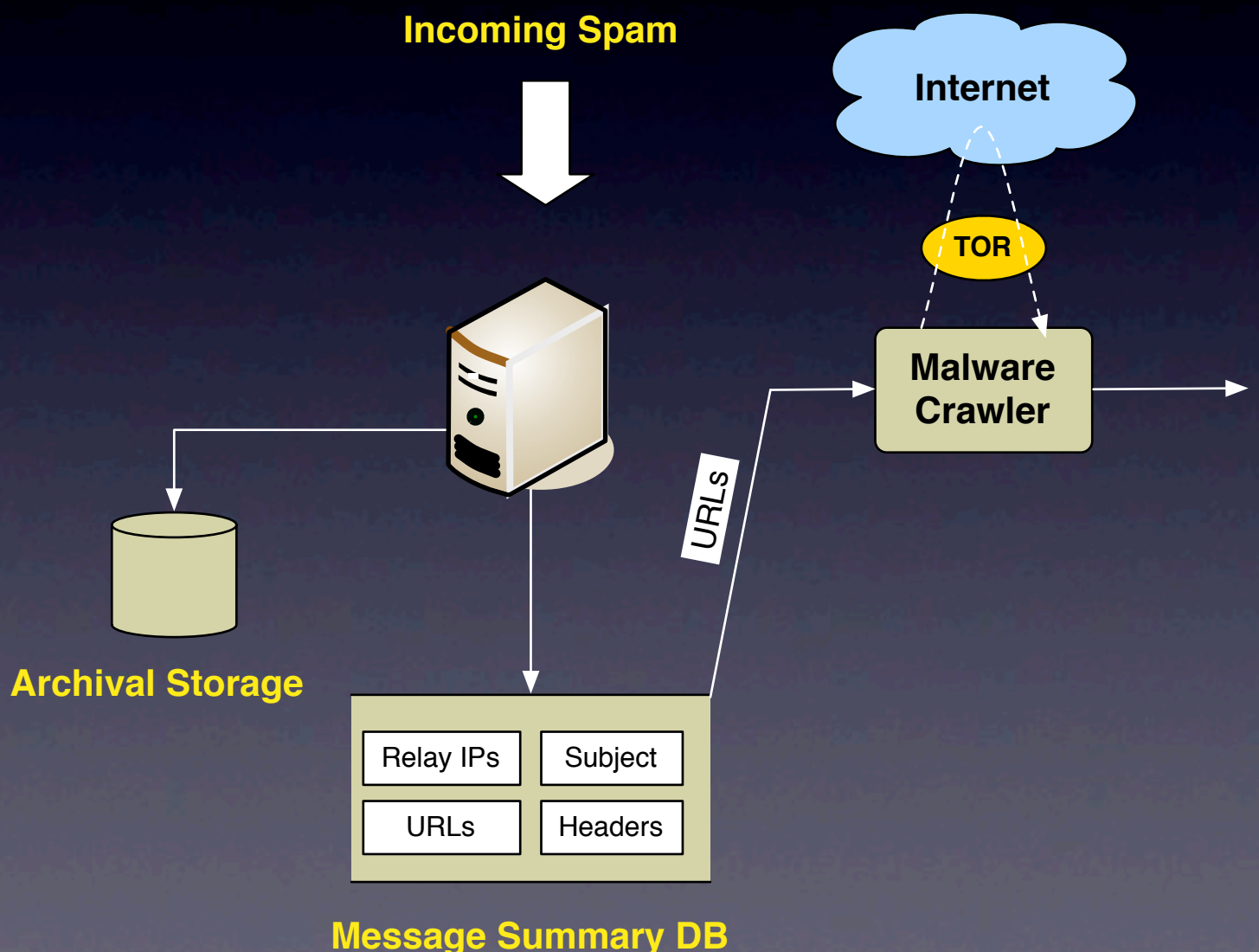
- Augment honeypots with active crawling of spam URLs



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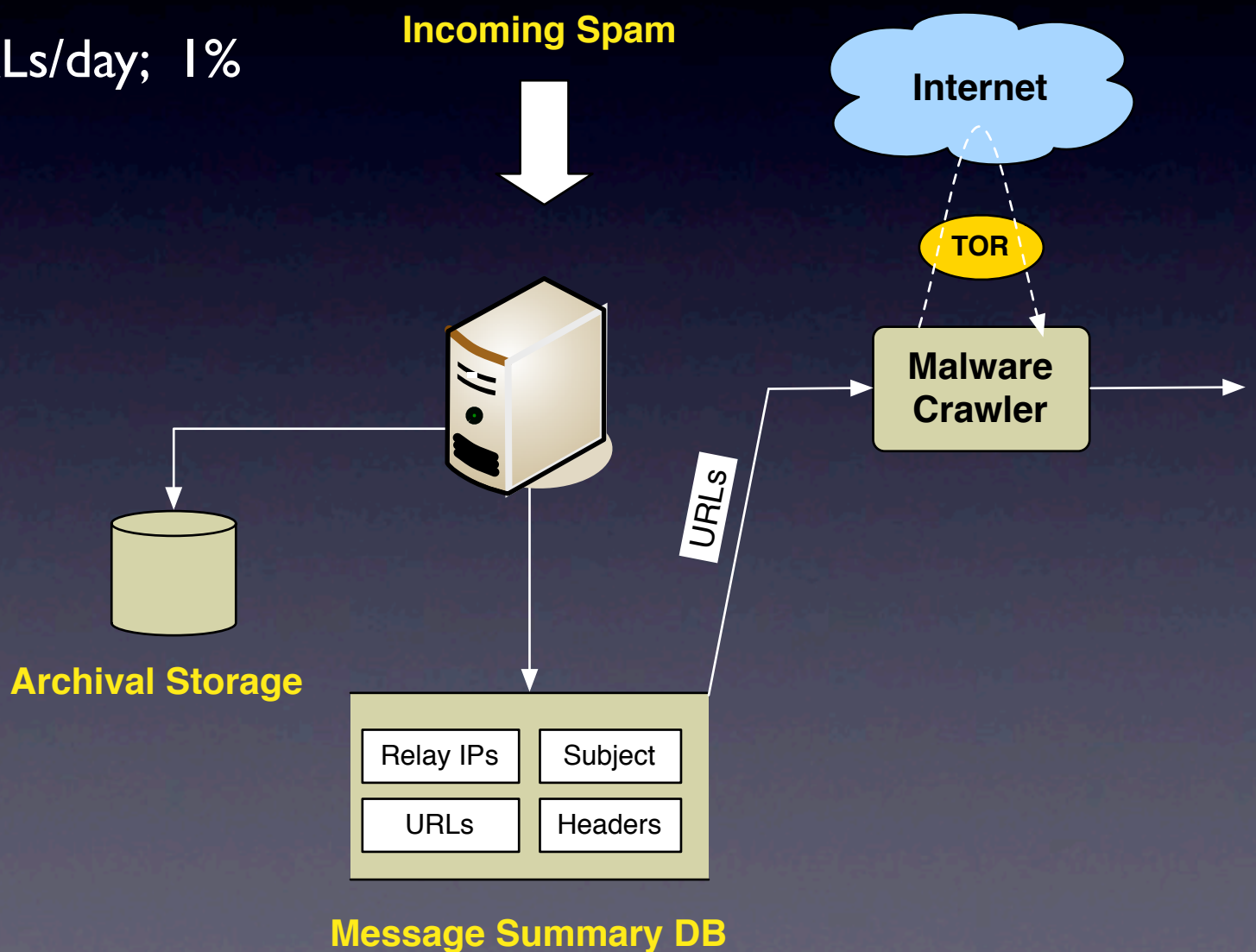
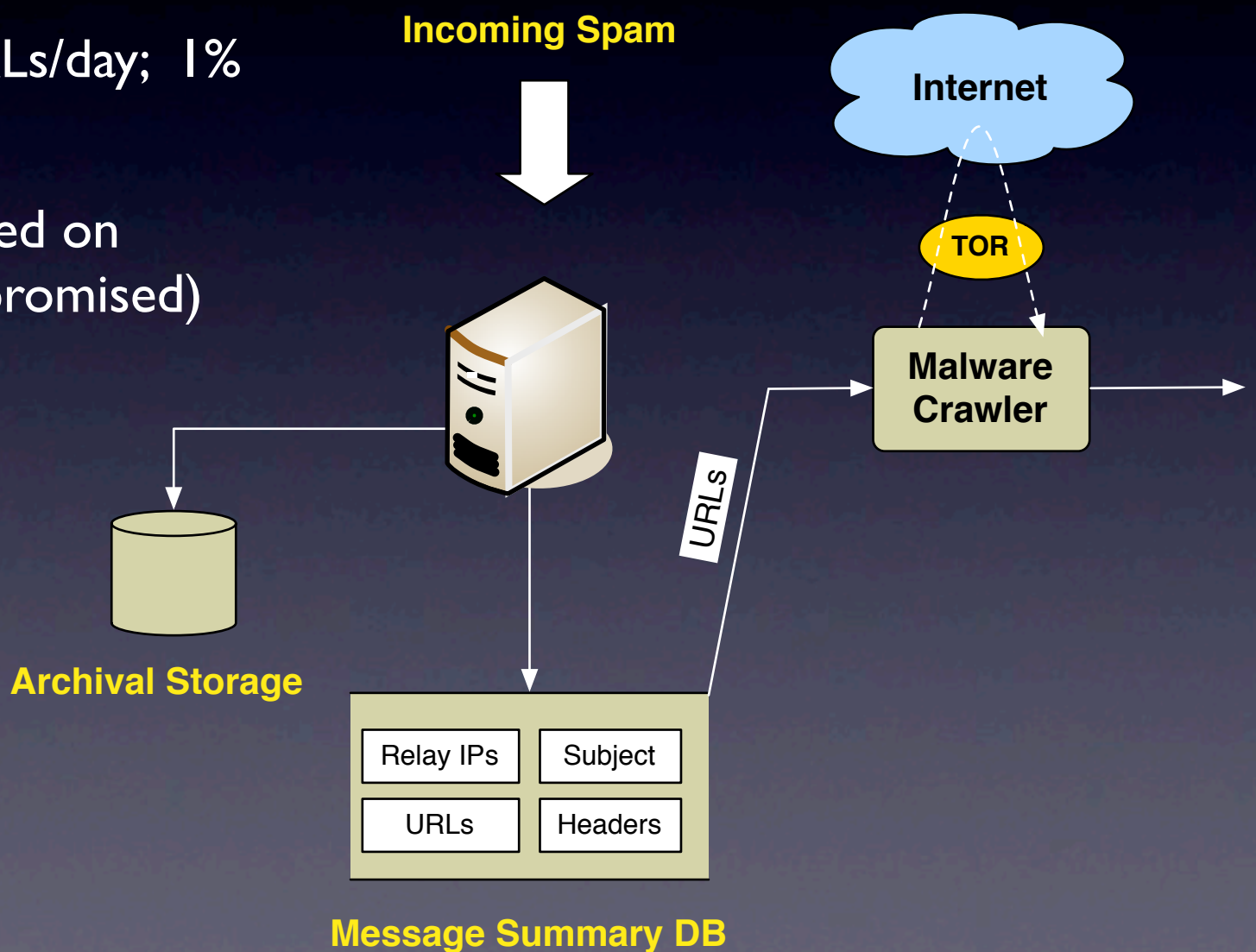
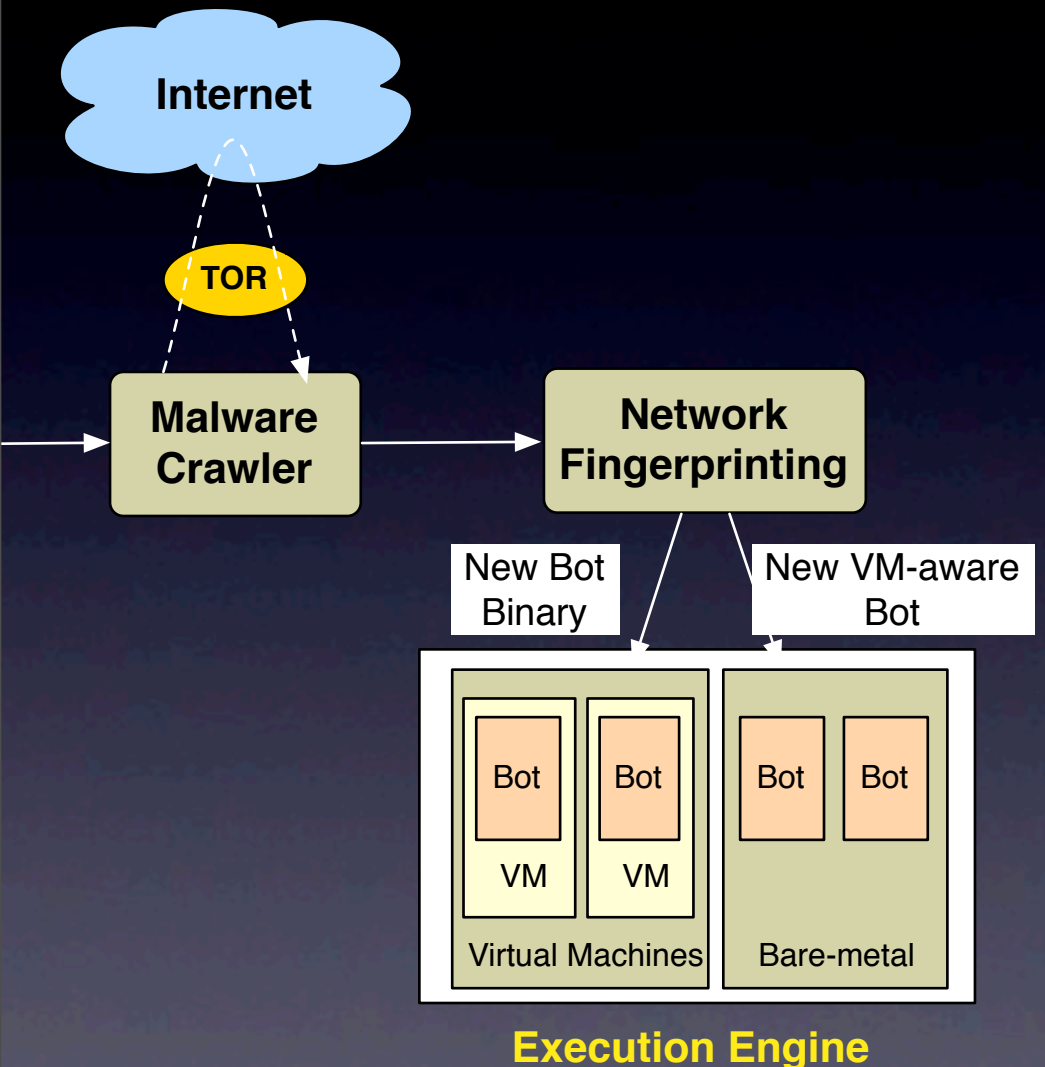


1. Malware Collection

- Augment honeypots with active crawling of spam URLs
- 100K unique URLs/day; 1% malicious
- Most URLs hosted on legitimate (compromised) webservers



2. Network Fingerprinting



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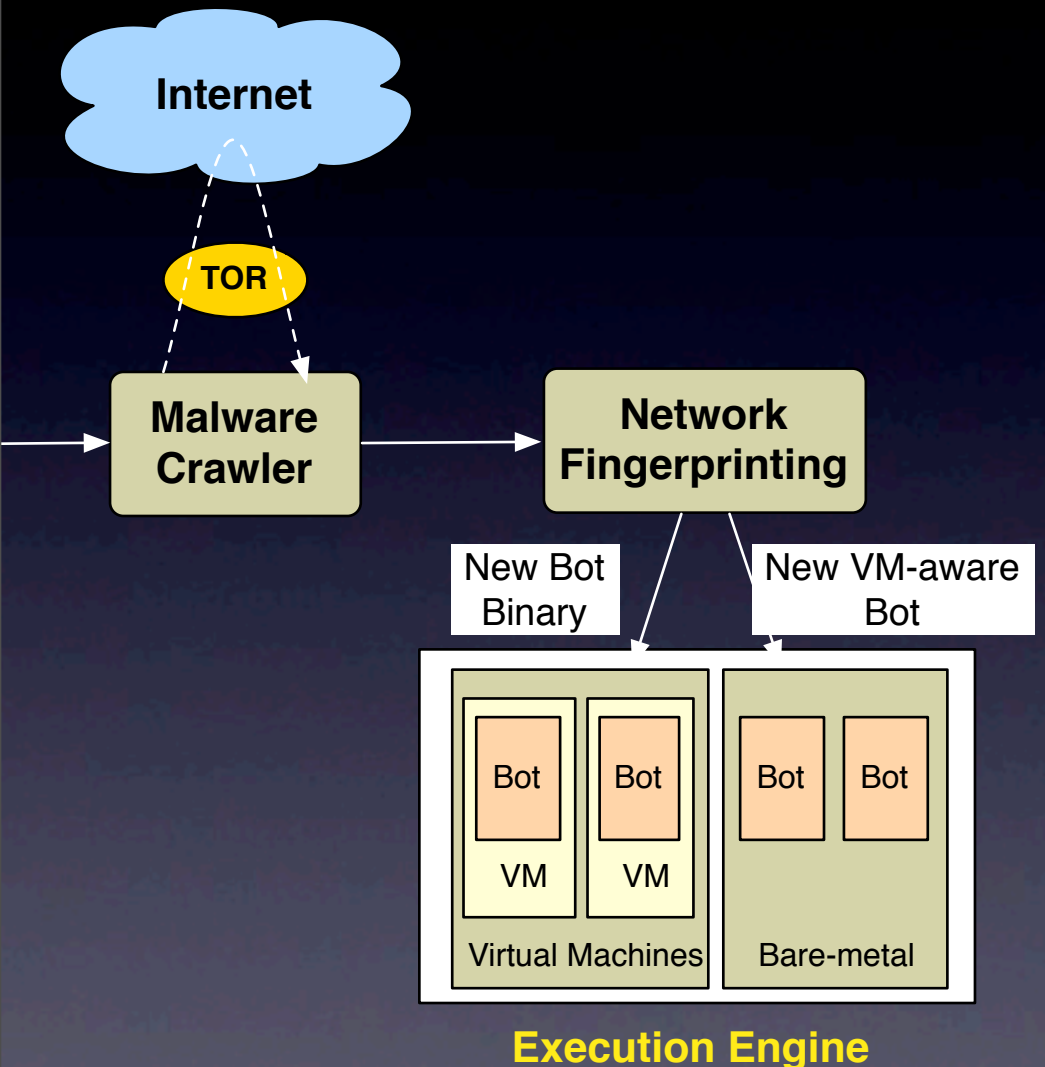

- Goal: find new bots while discarding duplicates

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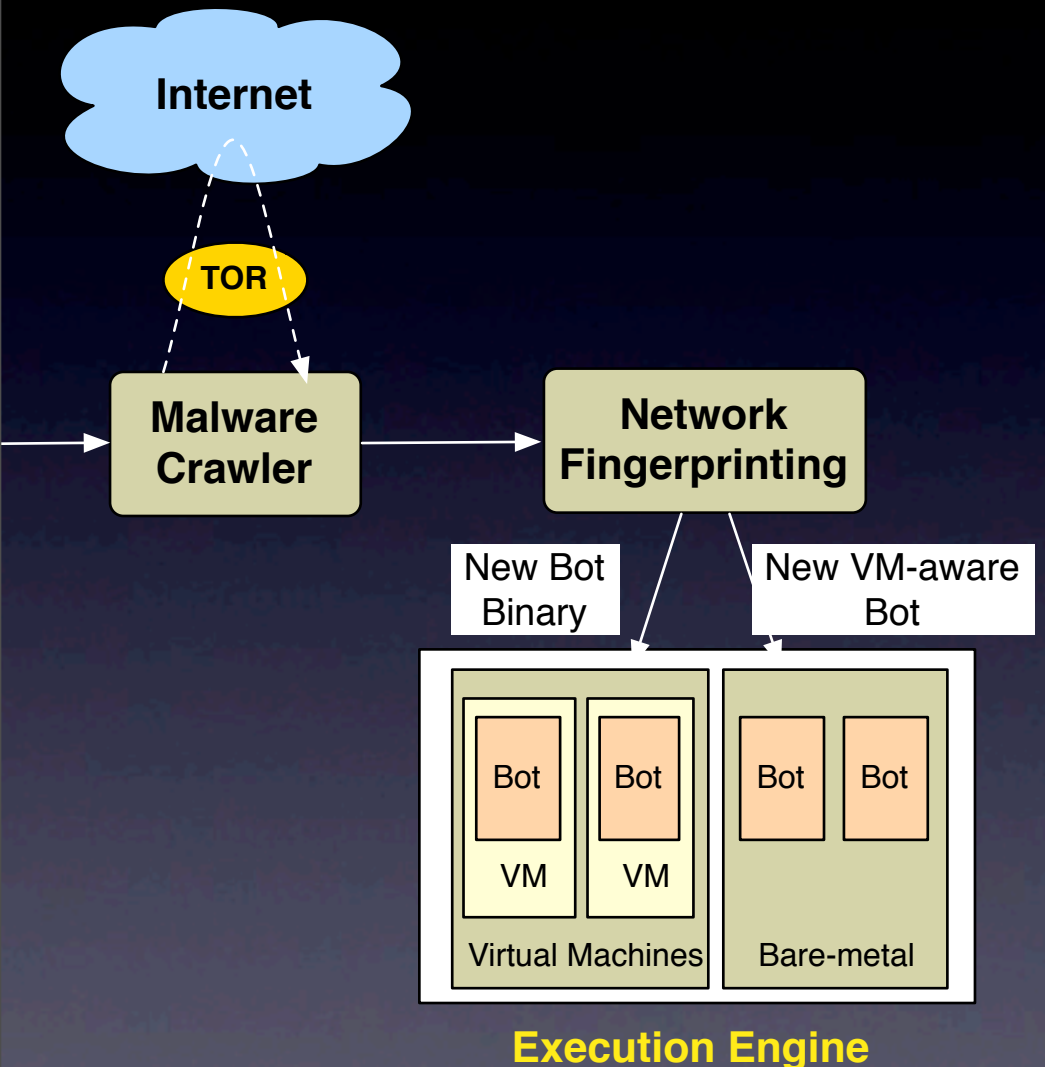
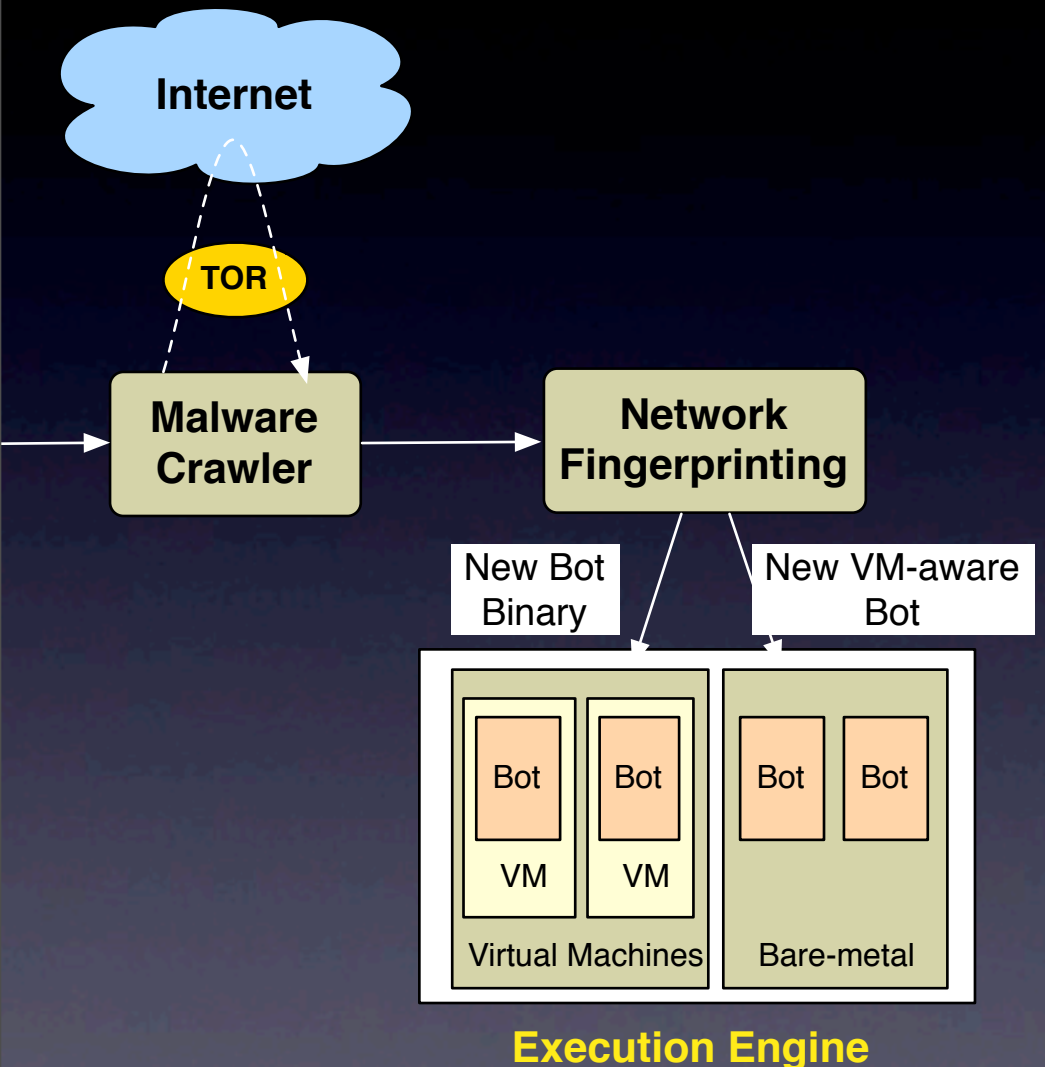


- Goal: find new bots while discarding duplicates
- *Simple hash* is insufficient

2. Network Fingerprinting



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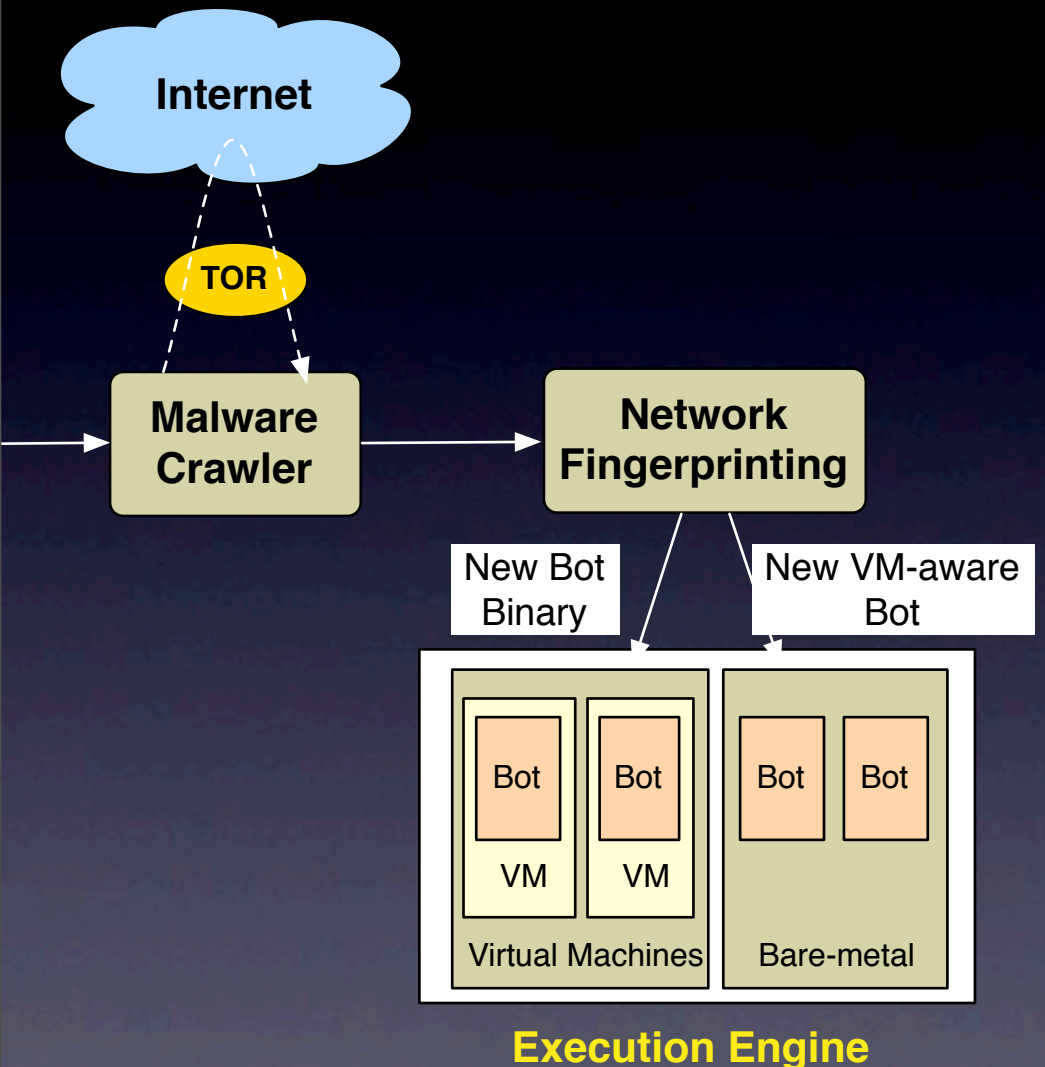

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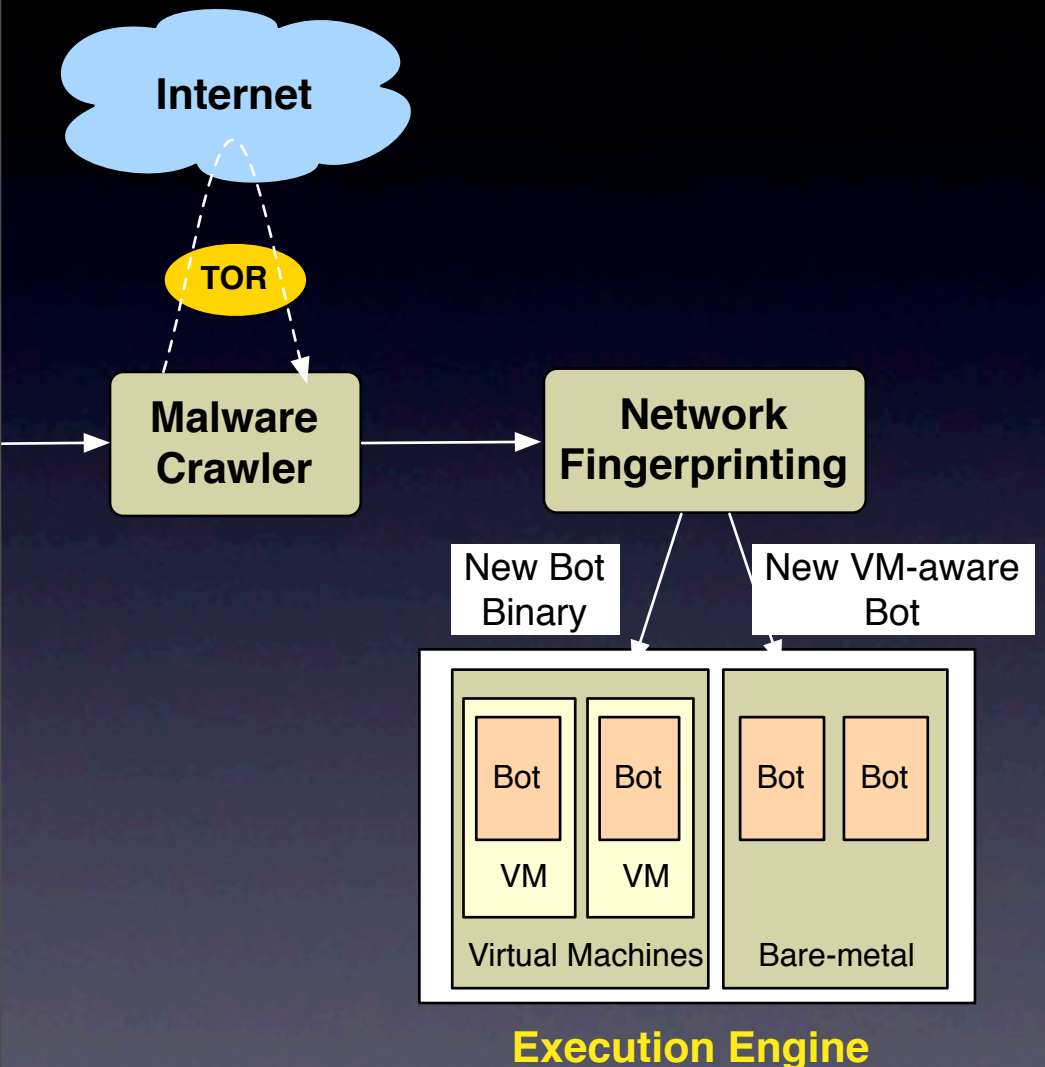

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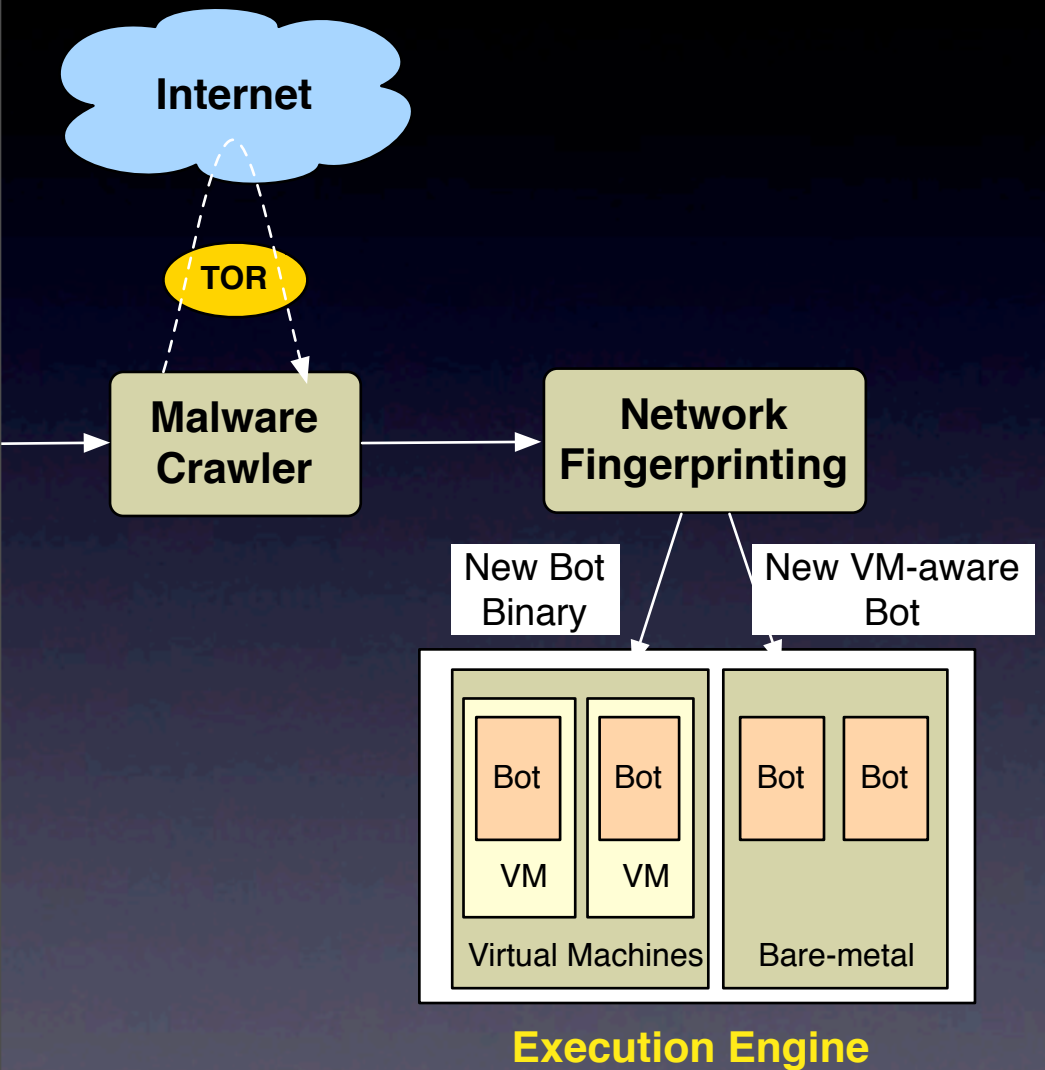

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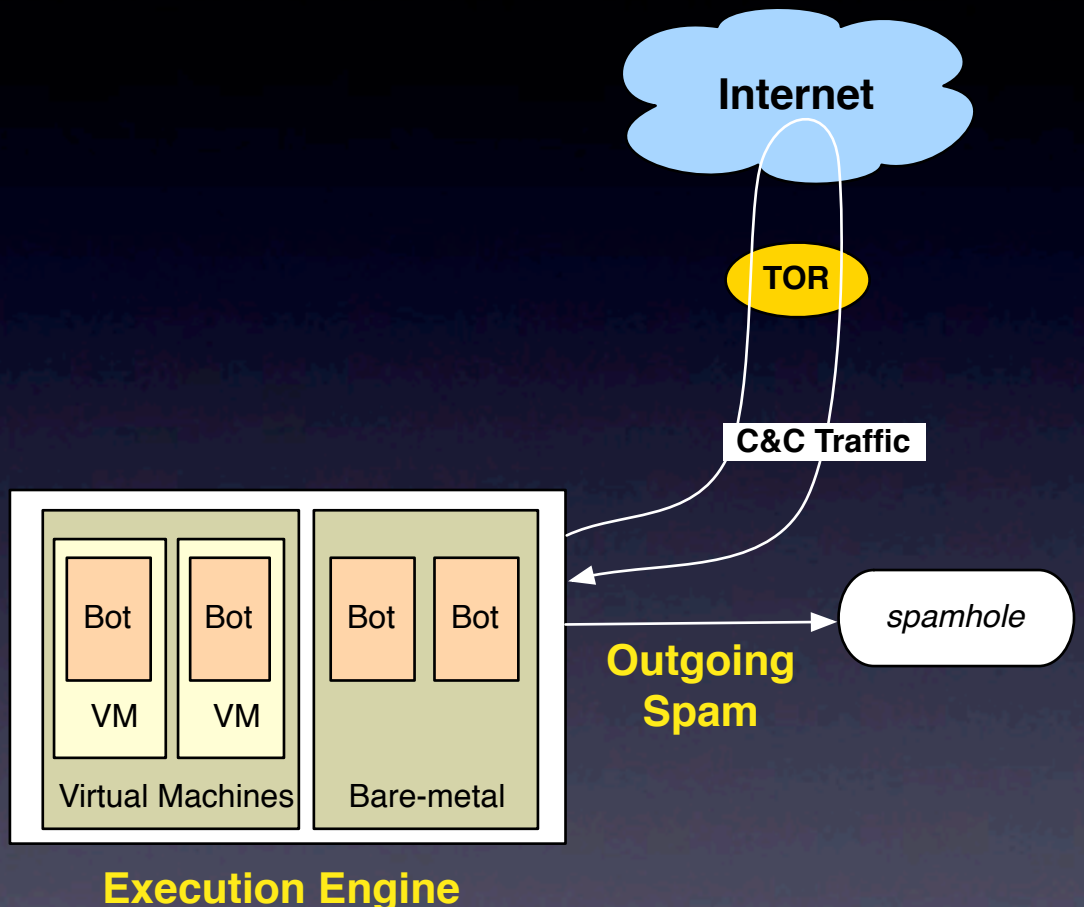
- Execute multiple times as some bots issue *random flows* (e.g., Google searches)

3. Monitor Running Bots

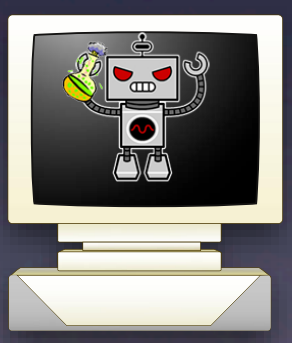


- Execute bots and trap all spam they send
- But need to *manually tweak* bots to get them to run

Manual Adjustments

- SMTP verification
  - One bot sent email to special server, which is verified later by the C&C server

Special mail server



C&C server

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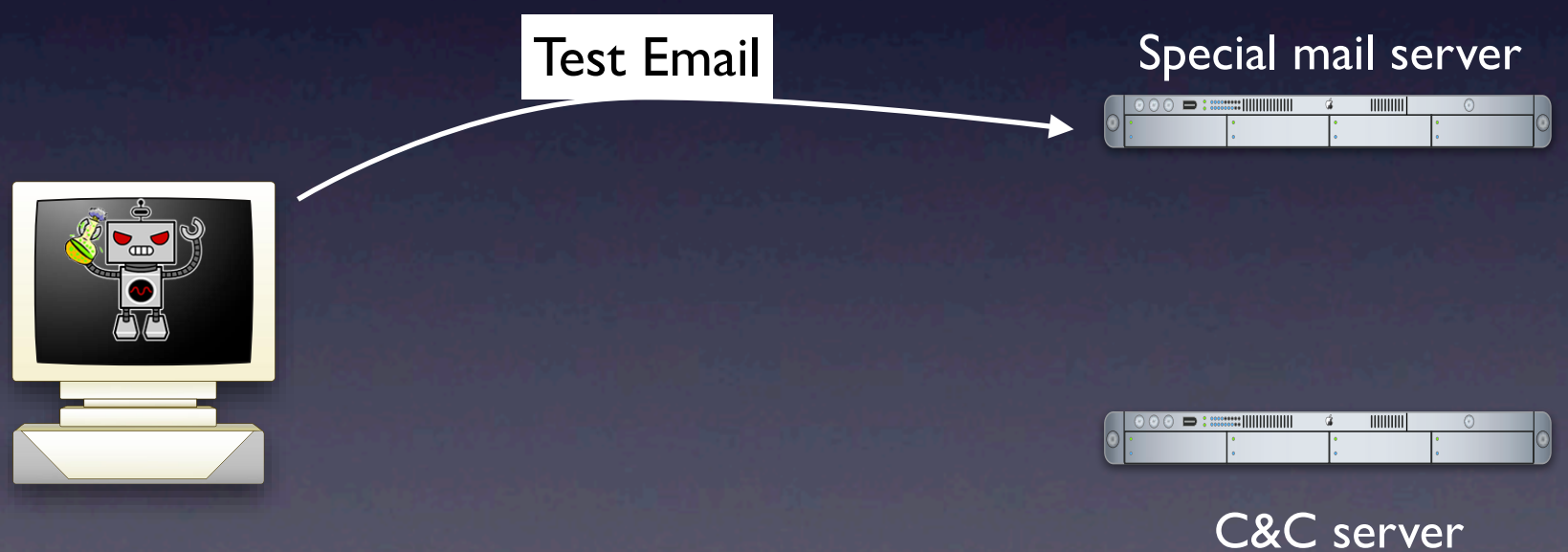

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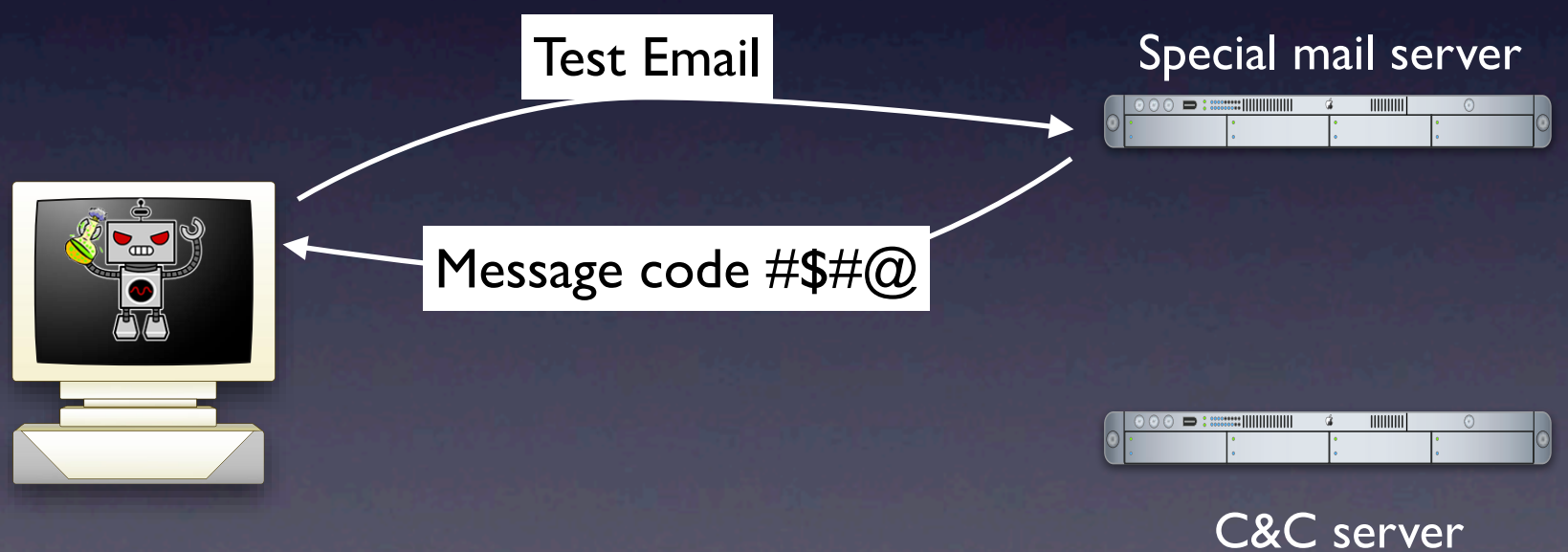

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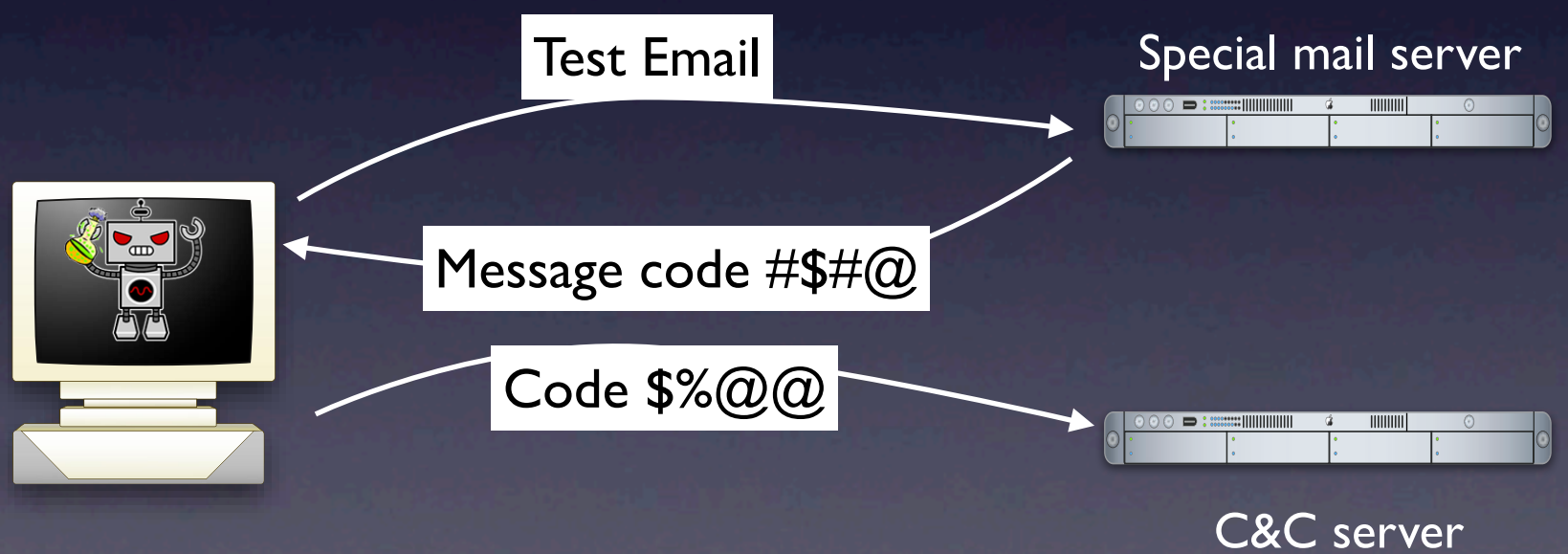

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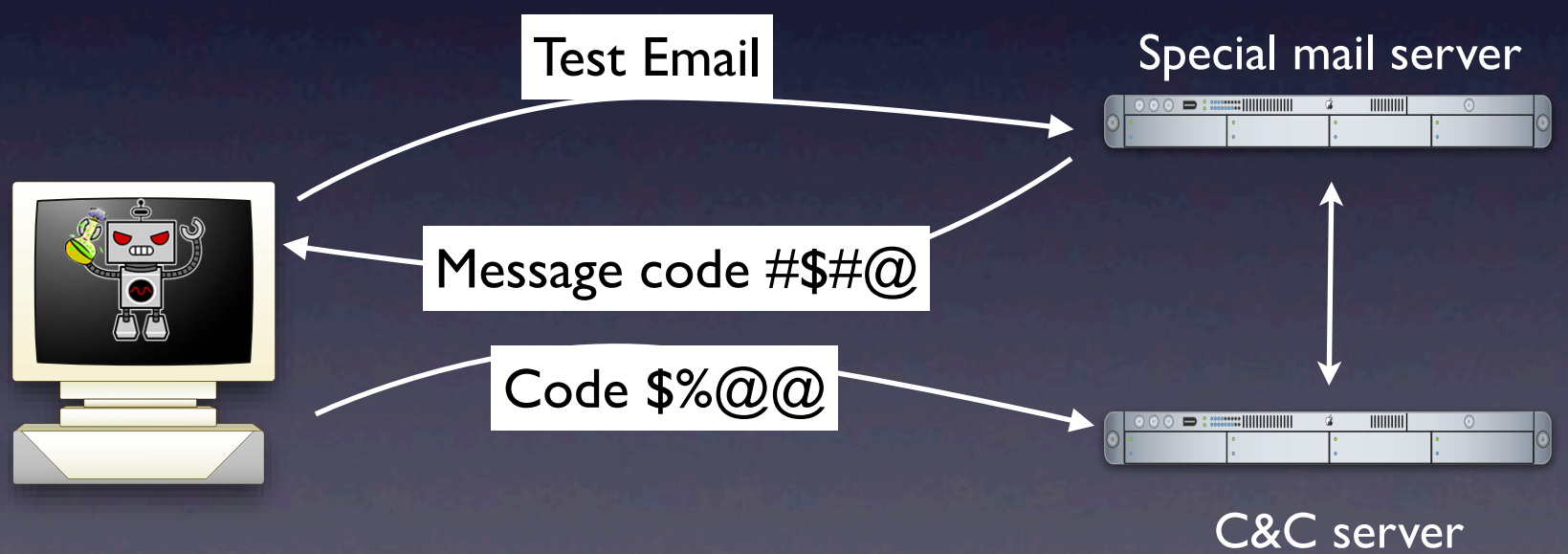

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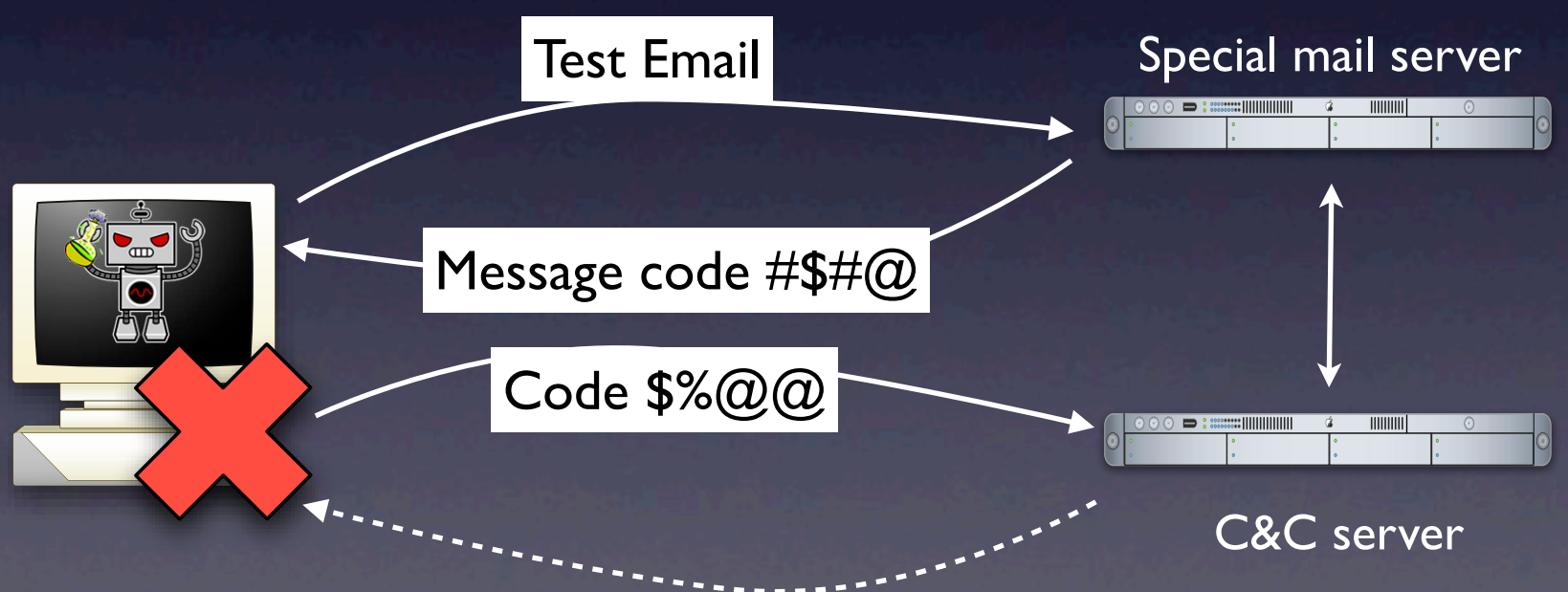
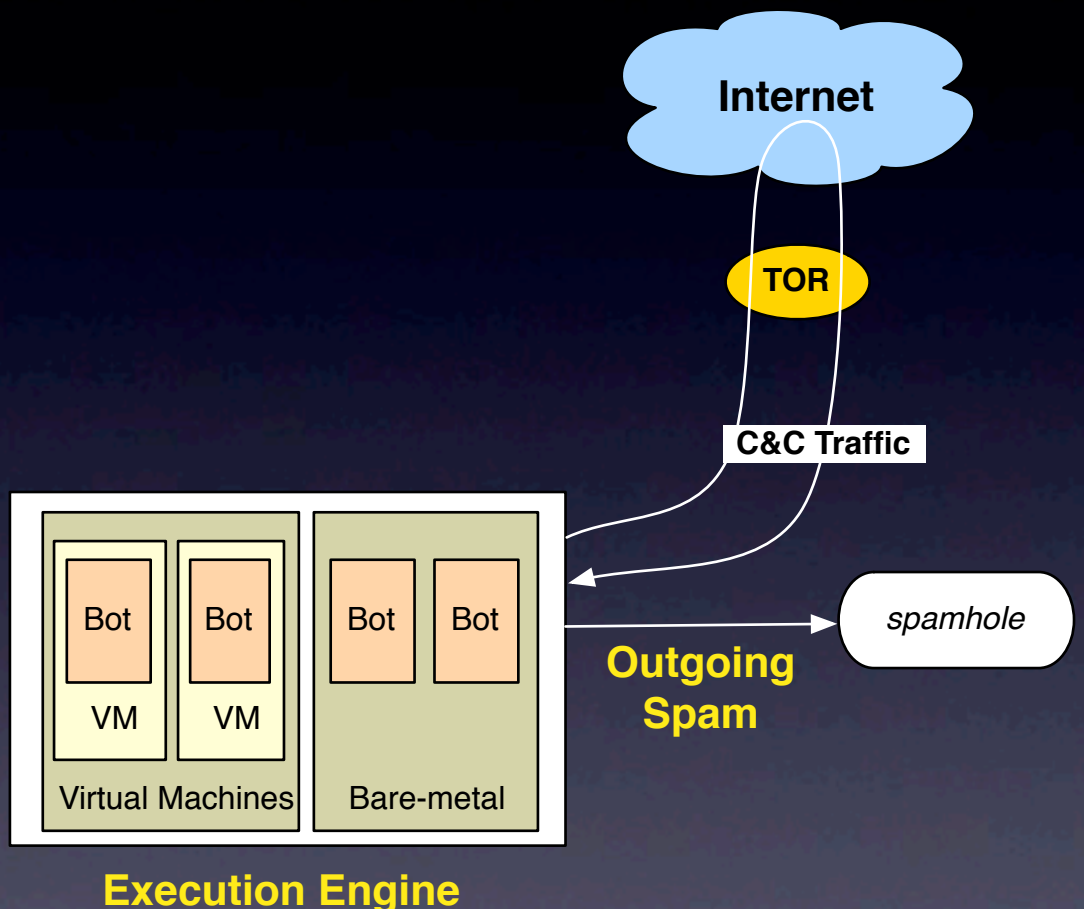


Coaxing Bots to Run



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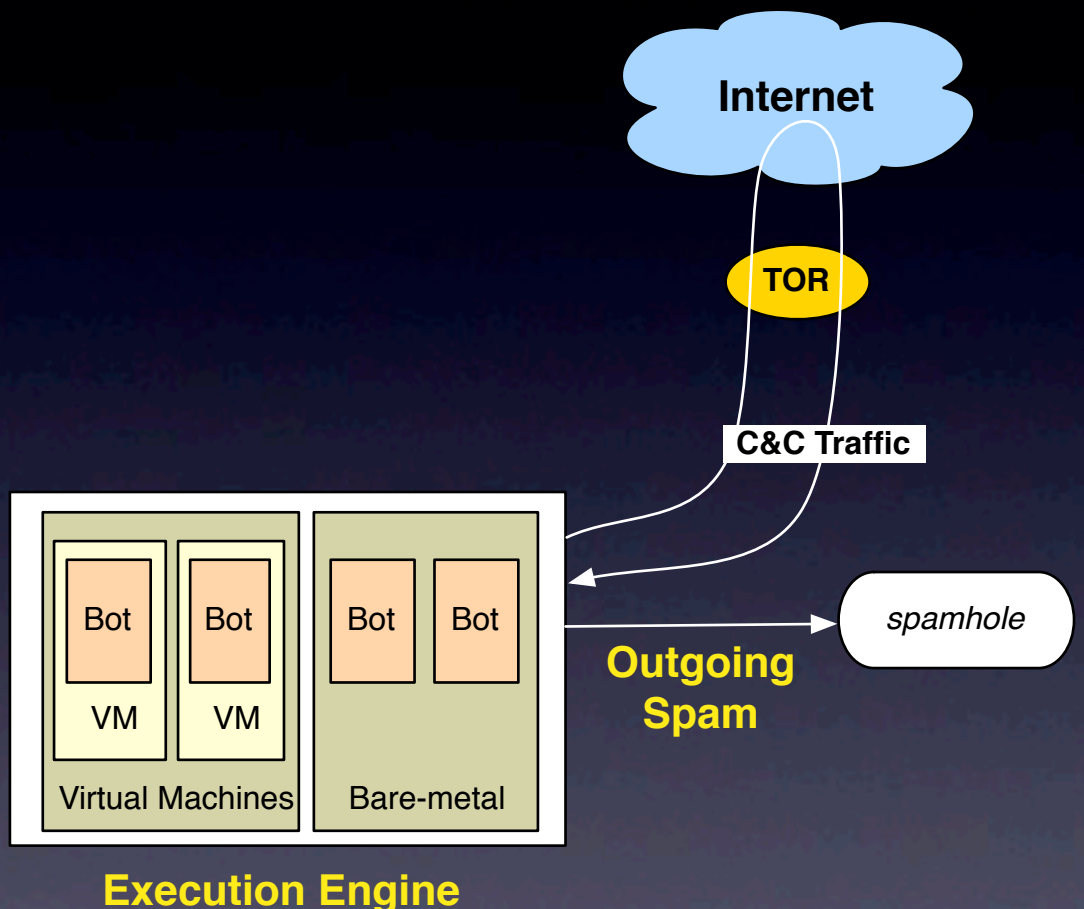

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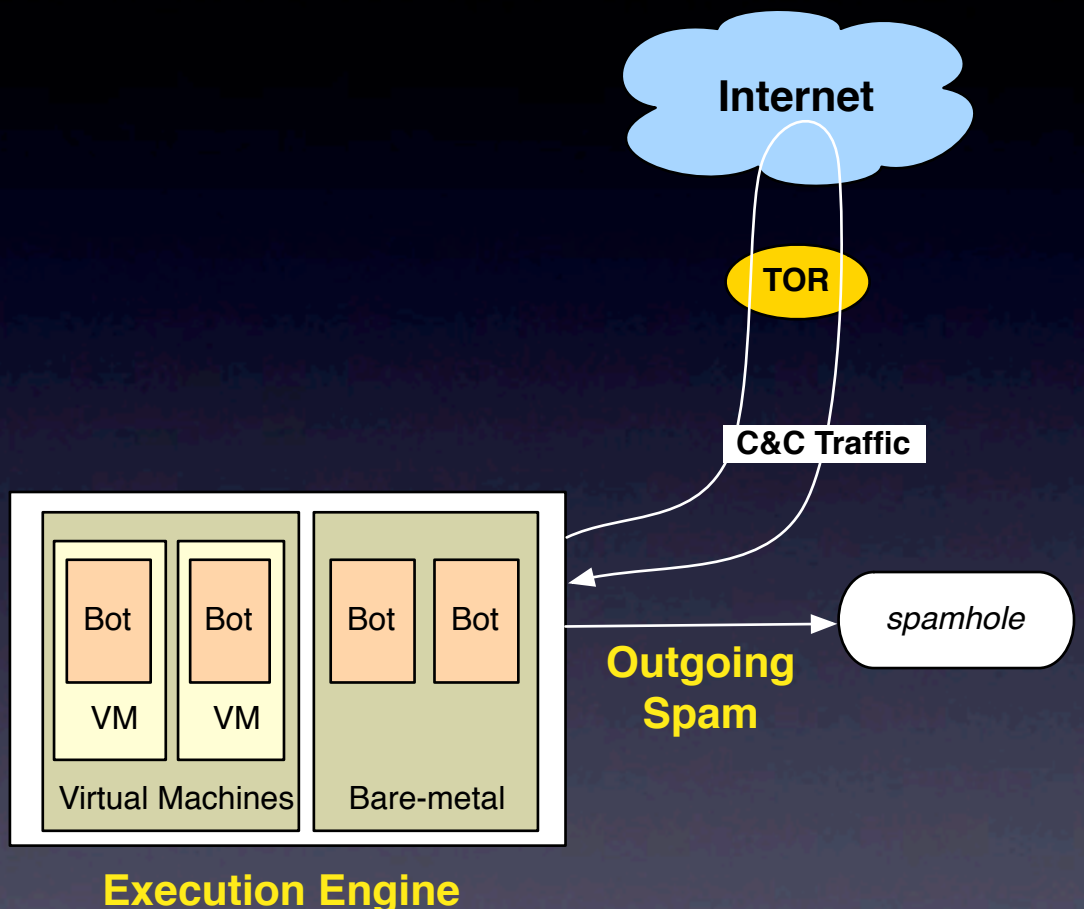

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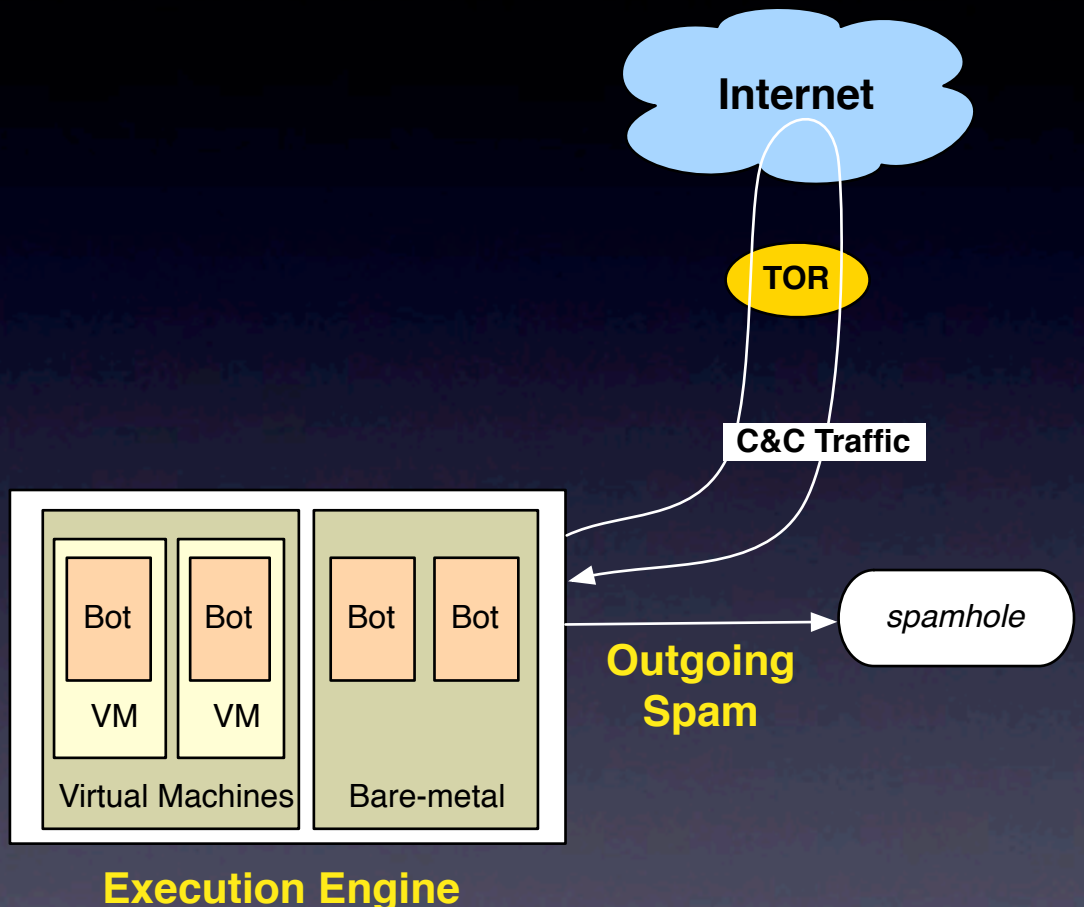

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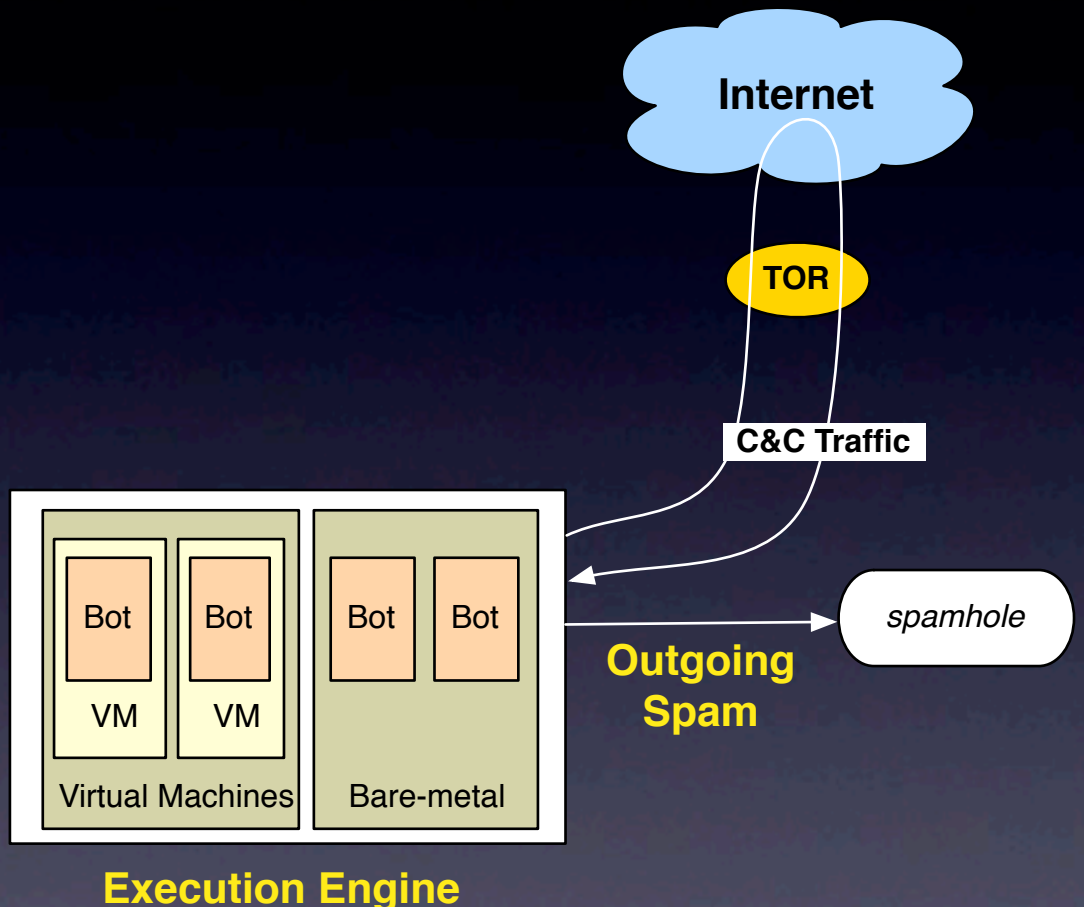

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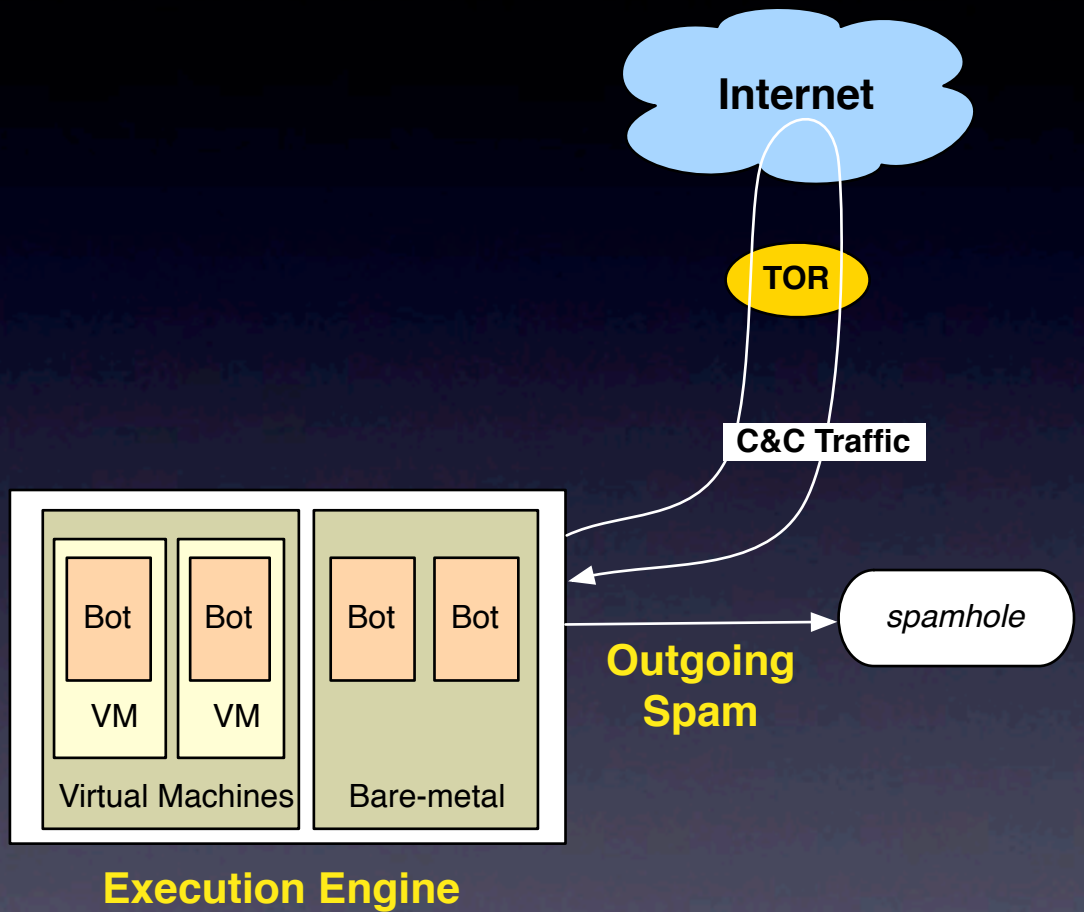

- Some bots send spam using webservices (such as HotMail)
- C&C servers are setup to blacklist suspicious IP ranges
- Bots with 100% email delivery rate are considered suspicious
- Fortunately only O(10) botnets; so manual tweaking possible

4. Clustering/Correlation Analysis

- Two sources of information:
  - Spam sent by bots running in BotLab (*Outgoing Spam*)
  - Spam received by UW (*Incoming Spam*)

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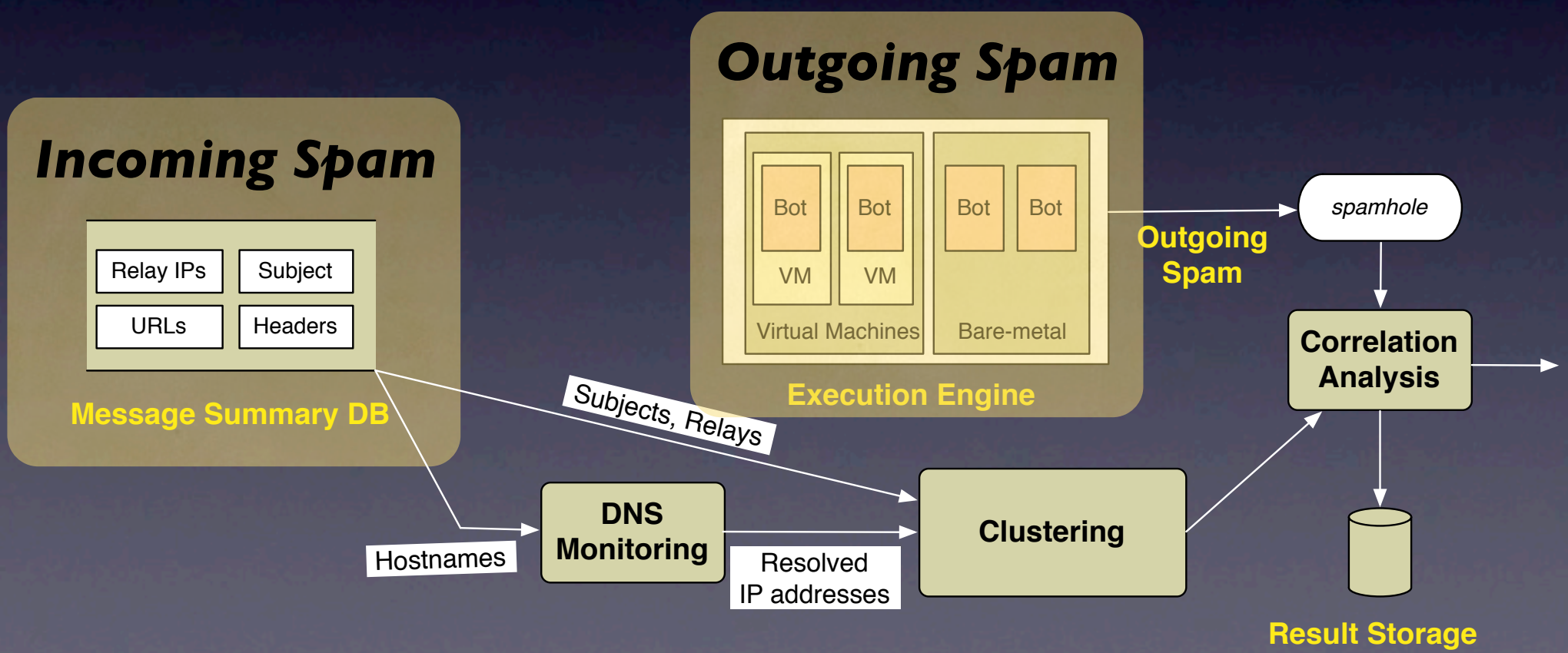

Measurements

- Analysis of *outgoing spam* feed
- Analysis of *incoming spam* feed
- *Correlation* of outgoing and incoming spam feeds

Behavioral Characteristics

Botnet	C&C Discovery	C&C servers contacted over lifetime	C&C protocol	spam send rate (msgs/min)
Grum				
Kraken				
Pushdo				
Rustock				
MegaD				
Srizbi				
Storm				

Behavioral Characteristics

Botnet	C&C Discovery	C&C servers contacted over lifetime	C&C protocol	spam send rate (msgs/min)
Grum	static IP	1		
Kraken	algorithmic DNS	41		
Pushdo	set of static IPs	96		
Rustock	static IP	1		
MegaD	static DNS name	21		
Srizbi	set of static IPs	20		
Storm	p2p (Overnet)	N/A		

Behavioral Characteristics

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Behavioral Characteristics

Botnet	C&C Discovery	C&C servers contacted over lifetime	C&C protocol	spam send rate (msgs/min)
Grum	static IP	1	encrypted HTTP	344
Kraken	algorithmic DNS	41	encrypted HTTP	331
Pushdo	set of static IPs	96	encrypted HTTP	289
Rustock	static IP	1	encrypted HTTP	33
MegaD	static DNS name	21	encrypted custom protocol (port 80)	1638
Srizbi	set of static IPs	20	unencrypted HTTP	1848
Storm	p2p (Overnet)	N/A	encrypted custom	20

Botnet Mailing Lists

- Random fetch model allows us to estimate botnet mailing list sizes
  - As we see more of the spam feed, there will be more duplicates in recipient email addresses
- If mailing list size is *N* and if bot obtains *C* addresses for each C&C query, then probability that an email address will appear again in the next *K* emails is

$$1 - (1 - C/N)^{K/C}$$

- Some mailing list sizes: MegaD's is 850 million, Rustock's is 1.2 billion, Kraken's is 350 million
- Overlap between mailing lists is small (less than 28%)

Outgoing Spam Characteristics

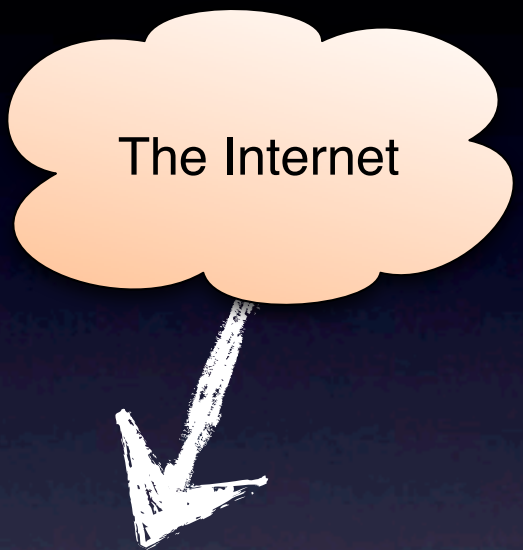
- Bots are *stateless*
  - List of recipients downloaded from C&C server is randomly chosen
  - Bots can be periodically restarted to quickly obtain information on ongoing spam campaigns
  - Some bots are buggy
- C&C servers change *infrequently*
- Some botnets are *partitioned*

Correlation Analysis

- Combine our sources of data:
  - *Outgoing spam* from BotLab
  - *Incoming spam* at UW

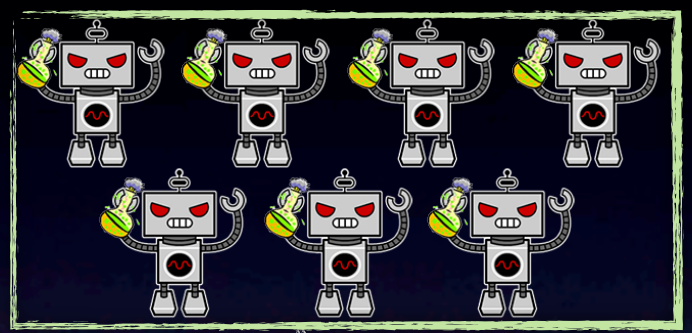
Combining our spam sources

- Incoming spam provides a different perspective
- Spam is received from almost every bot out in the world
- Local view of spam produced
- Global view of spam producers



2.5 million emails per day

Combining our spam sources



BotLab

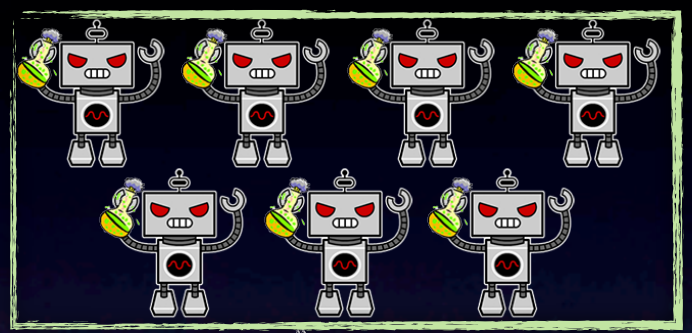
The Internet

Global view of spam produced

+

Global view of spam producers

Combining our spam sources



BotLab

The Internet

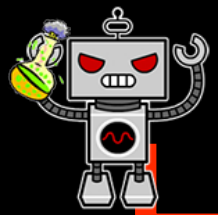
Global view of spam produced + Global view of spam producers

Challenge: create mapping between incoming spam and bot generated spam

Combining our spam sources

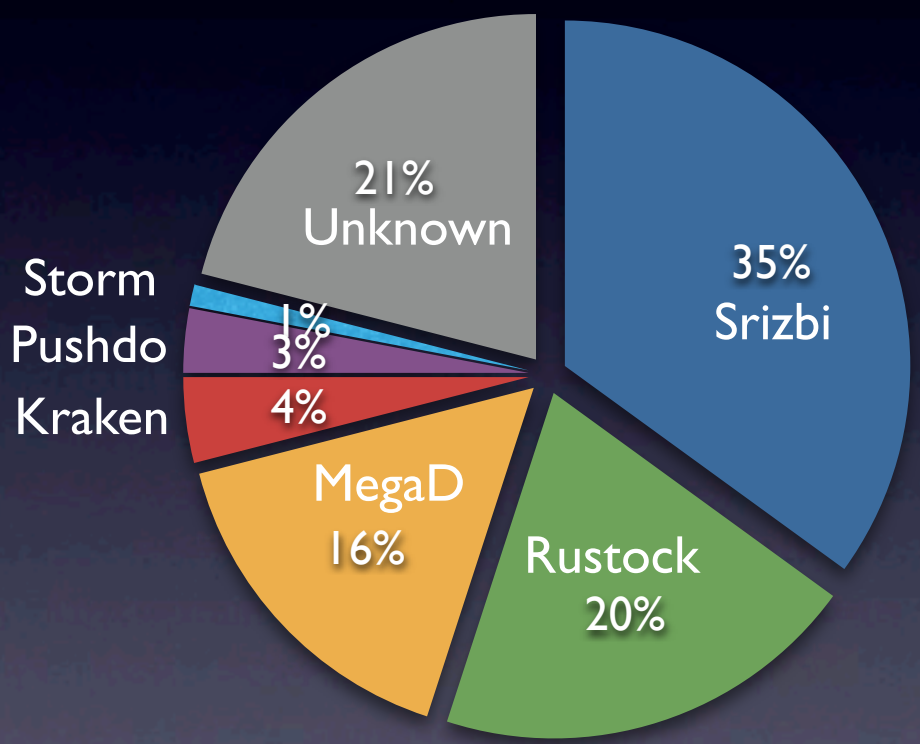
Combining our spam sources

- Observation:
  - Spam subjects are carefully chosen
  - NO overlap in subjects sent by different botnets (489 subjects/day per botnet)
- Solution: Use subjects to attribute spam to particular botnets

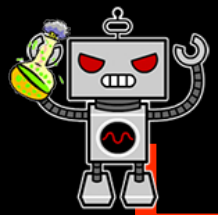


Who is sending all the spam?

The Internet



Average over 50 days



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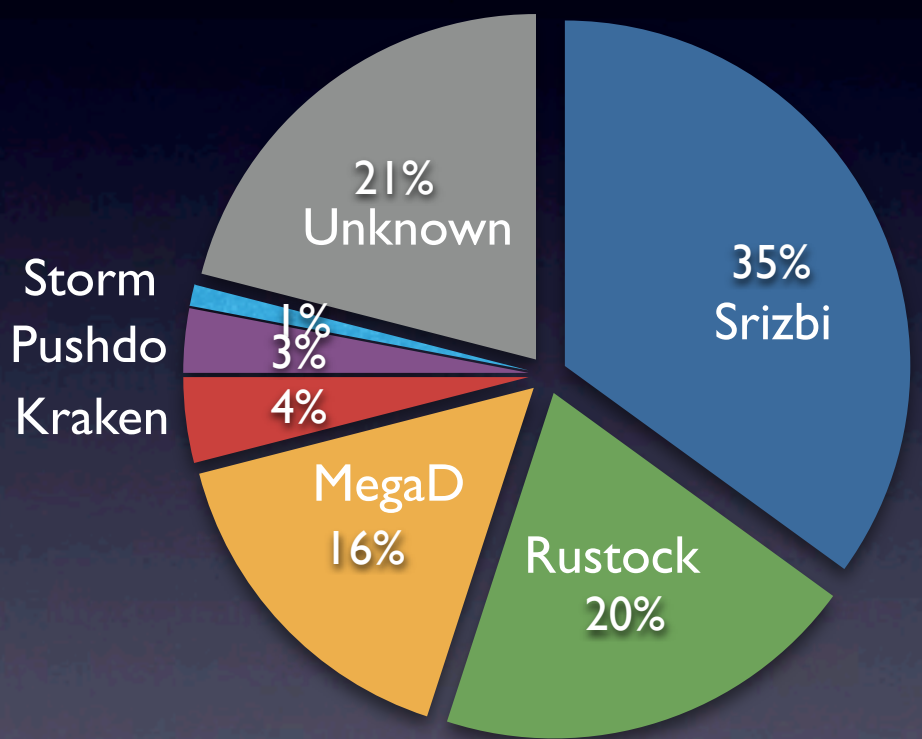

79% of the spam came from just 6 botnets!

Average over 50 days

Botnets and spam campaigns

- We define a spam campaign by the contents of the webpage the spam URL points to

Botnets and spam campaigns

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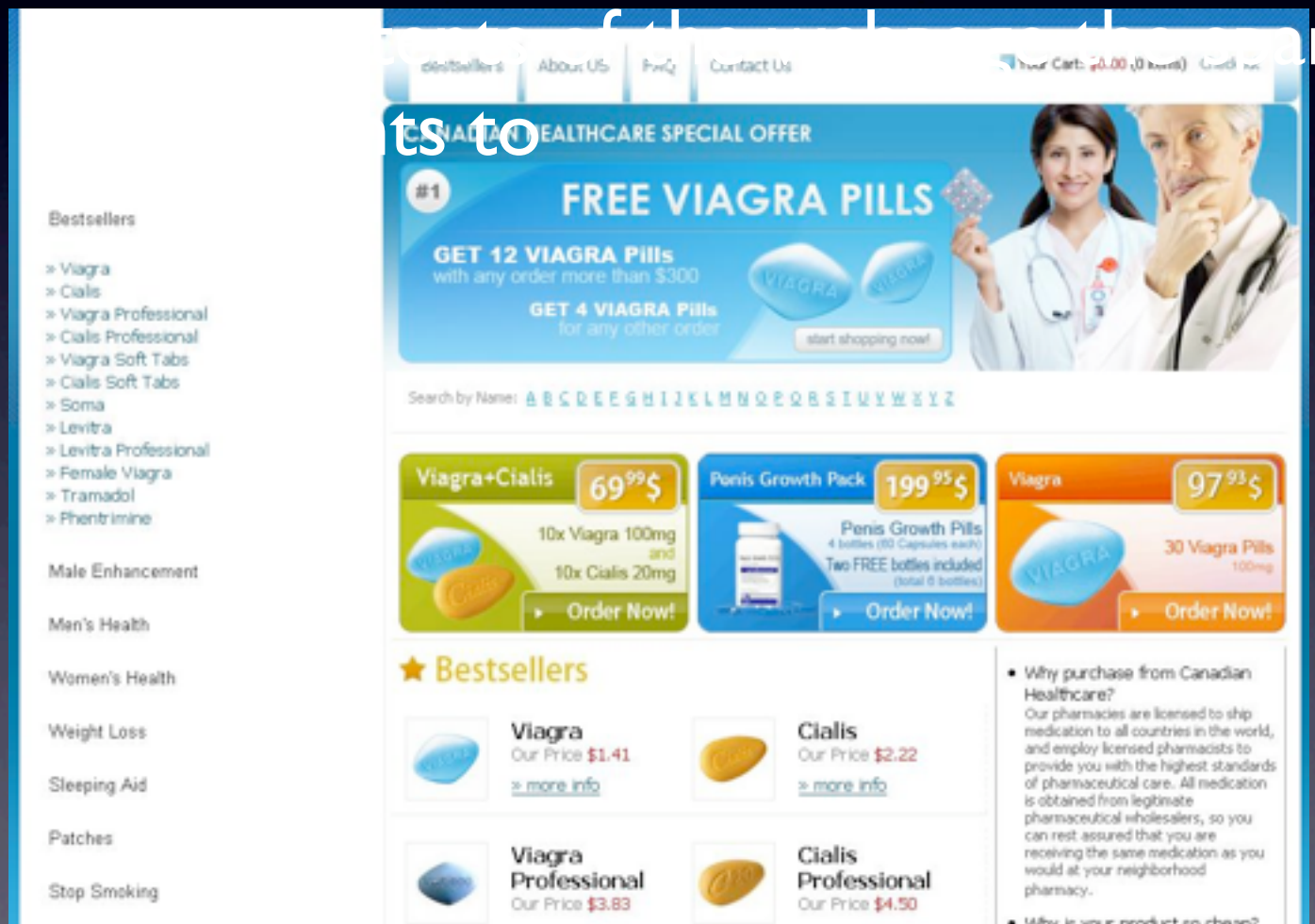

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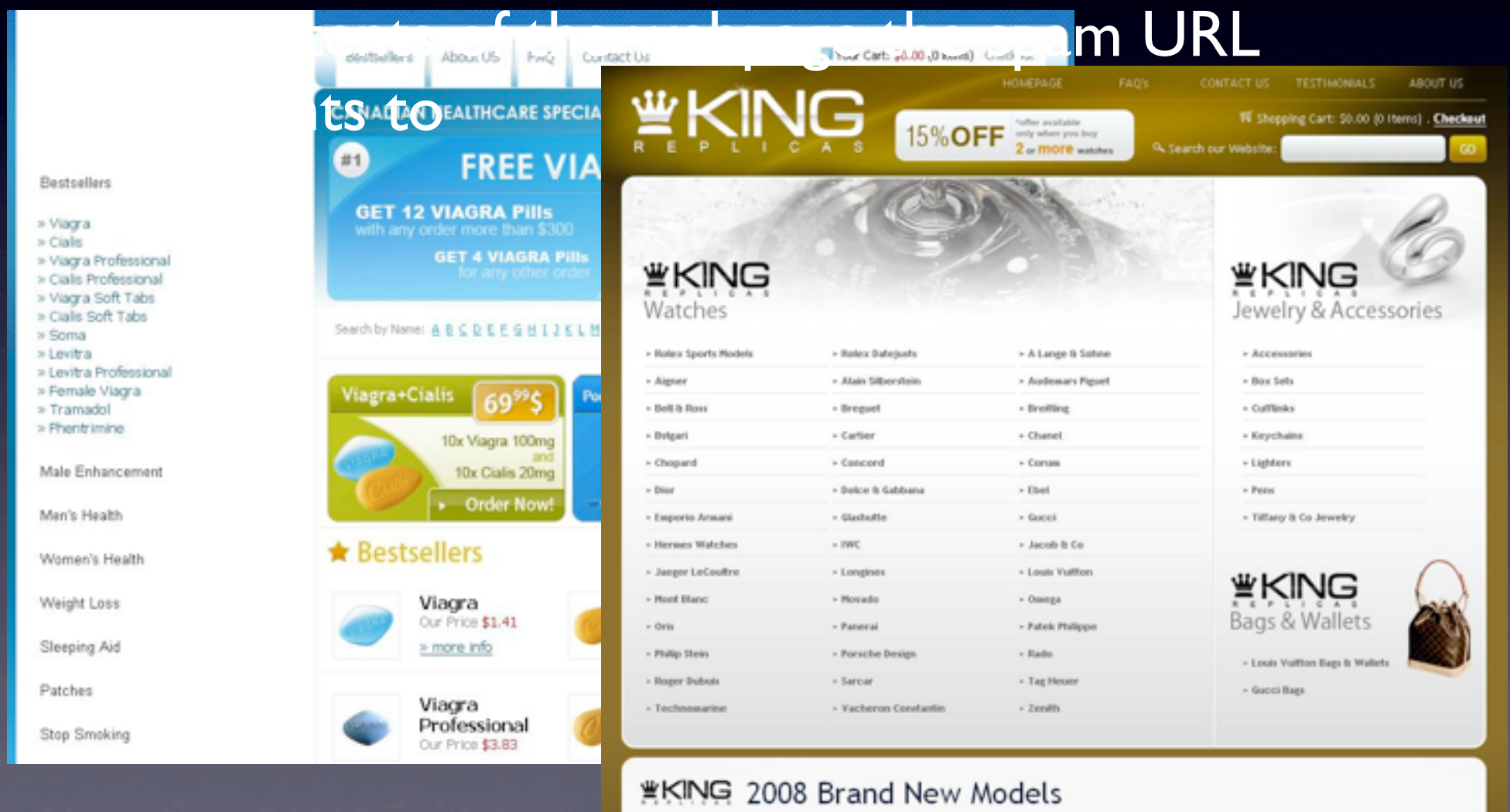
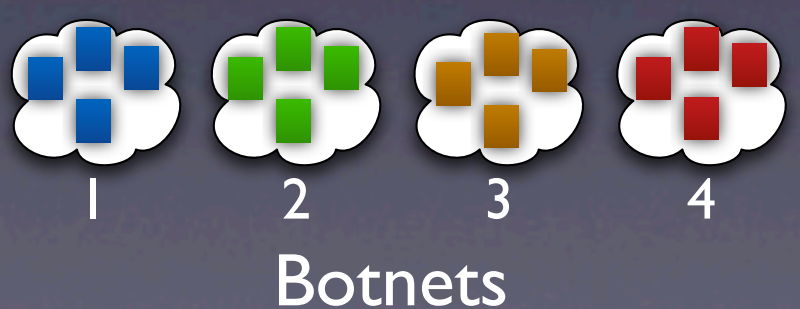


Botnets and spam campaigns

- We define a spam campaign by the contents of the webpage the spam URL points to
- We found the mapping between botnets and spam campaigns to be many-to-many

Where are campaigns hosted?

- How does the Web hosting infrastructure relate to the botnets?



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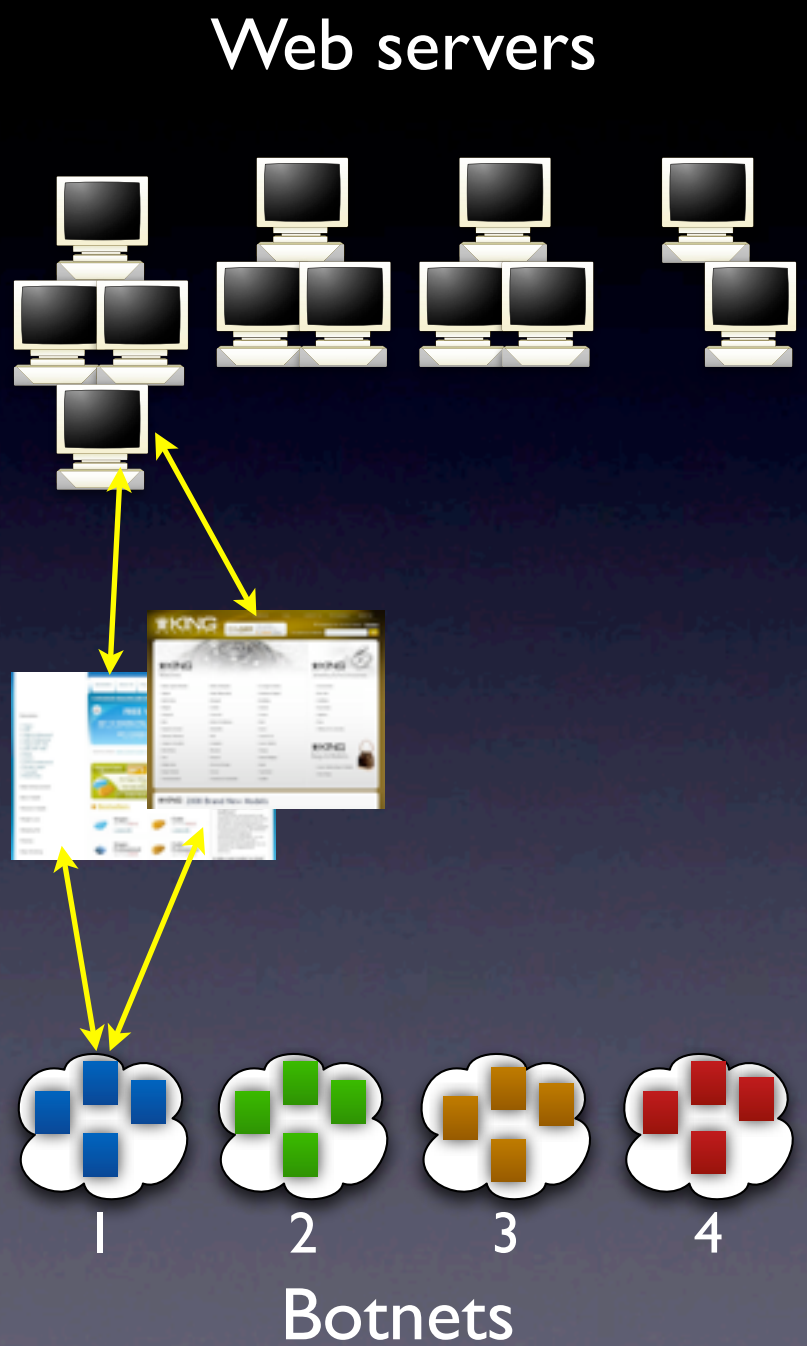

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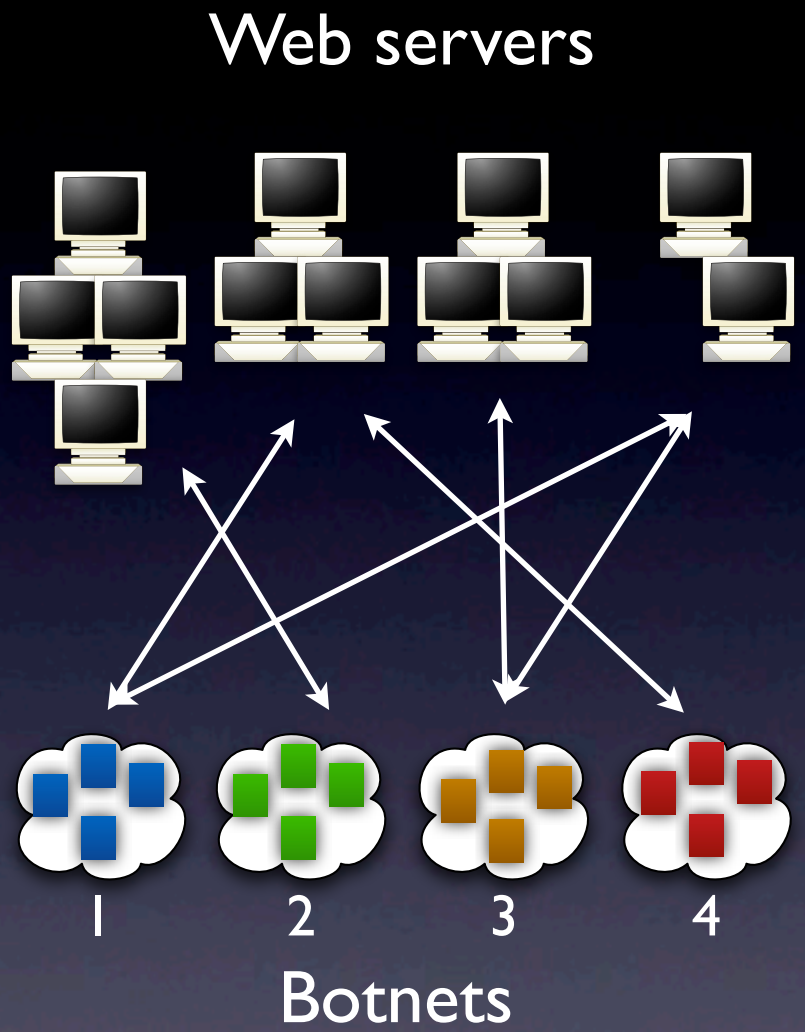
- Suggests *hosting spam campaigns is a 3rd party service* and not tied to botnets



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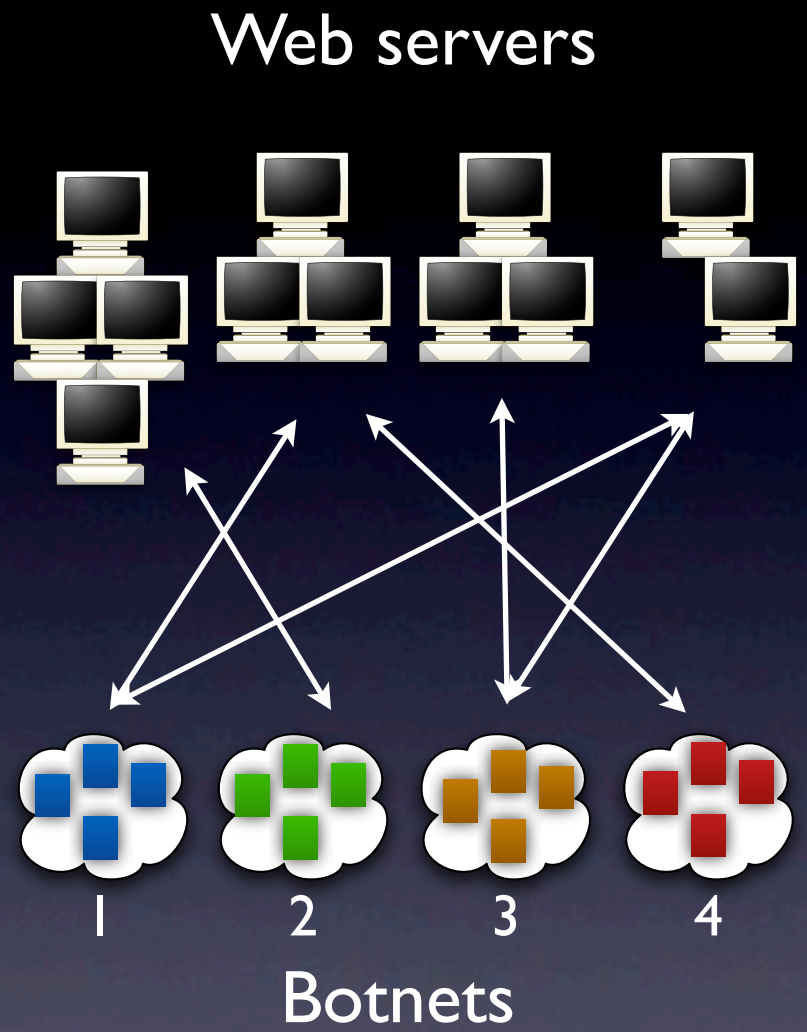

- 80% of spam points to just 57 Web server IPs

Botnet Membership

- What fraction of the botnet members can we identify in a single day at a given location?
- Again use probabilistic analysis based on the random recipient address model
  - Let *P* is the probability that a given spam message is sent to an UW email address
  - Let *N* be the number of email messages sent by a bot over a given period
  - Then probability of UW receiving a spam message:

$$1 - e^{-N*P}$$

Botnet Membership

- Even the most gentle bots send *N = 48K* messages per day
- UW receives 2.4M messages of a total world-wide estimate of 110B messages; *$P = 2.2*10^{-5}$*
- Over a 24-hour uptime, probability of identifying a botnet participant is *0.65*

Conclusions

- BotLab is an *engineering exercise* that pulls together many of the ideas proposed earlier
- Key components: *active crawling, executing captive bots, network fingerprinting, correlation*
- Enables a rich set of measurements. Results include:
  - Small number of botnets generate most of the spam
  - Complex (not one-to-one) relationships between botnets, spam campaigns, and hosting infrastructures
- BotLab also promises better defenses (safe browsing, spam filtering, bot detection, etc.)

Conclusion

- Botnets pose serious security challenges
- Requires greater understanding
- BotLab is an *engineering exercise* that pulls together many of the ideas proposed earlier
- Key components: *active crawling, executing captive bots, network fingerprinting, correlation*
- Potentially enables better defenses (safe browsing, spam filtering, bot detection, etc.)

- More questions? Just toss me an email (arvind@cs) or stop by my office (CSE 544).