Spam BASICS

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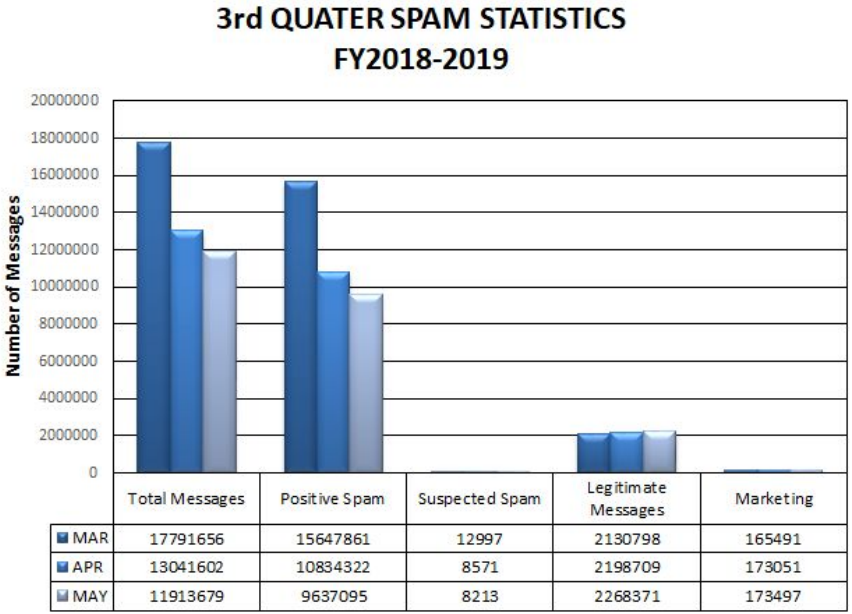
Spam

- A registered trademark
- Unwanted message was inspired by the 1970 SPAM Monty Python's Flying Circus.
- Was first applied to messages that were used to **scroll other messages off** user screens
- To respect the trademark, we call it "spam" rather than "SPAM."

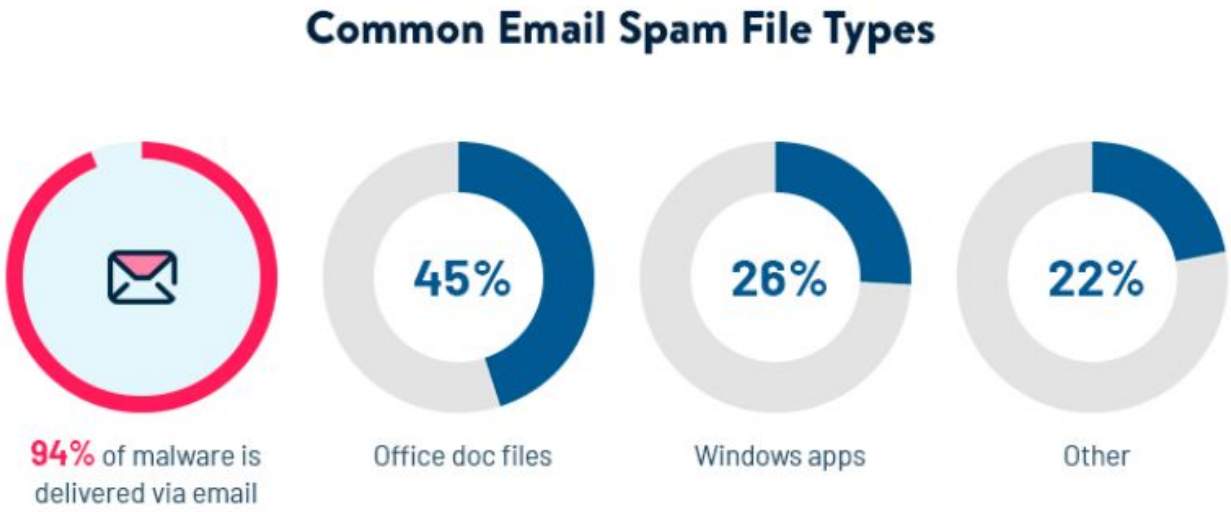
SPAM



	Total Messages	Positive Spam	Suspected Spam	Legitimate Messages	Marketing
MAR	17791656	15647861	12997	2130798	165491
APR	13041602	10834322	8571	2198709	173051
MAY	11913679	9637095	8213	2268371	173497

Source: UTEP INFORMATION SECURITY OFFICE

SPAM



Source: Verizon report 2021

SPAM

- Submit the same message to a **large group** of individuals.
- In an effort to force the message onto people who would otherwise choose not to receive this message.
- A message is spam only if it is both **Unsolicited and Bulk.**
  - Unsolicited Email is normal (examples: job enquiries)
  - Bulk Email is normal (examples: subscriber newsletters)

How Email Works

- The Simple Mail Transfer Protocol (**SMTP**) is an internet standard communication protocol for electronic mail transmission.

```
S: 220 smtp.example.com ESMTP Postfix
C: HELO relay.example.com
S: 250 smtp.example.com, I am glad to meet you
C: MAIL FROM:<bob@example.com>
S: 250 Ok
C: RCPT TO:<alice@example.com>
S: 250 Ok
C: RCPT TO:<theboss@example.com>
S: 250 Ok
C: DATA
S: 354 End data with <CR><LF>.<CR><LF>
C: From: "Bob Example" <bob@example.com>
C: To: Alice Example <alice@example.com>
C: Cc: theboss@example.com
C: Date: Tue, 15 Jan 2008 16:02:43 -0500
C: Subject: Test message
C:
C: Hello Alice.
C: This is a test message with 5 header fields and 4 lines in the message body.
C: Your friend,
C: Bob
C: .
S: 250 Ok: queued as 12345
C: QUIT
S: 221 Bye
{The server closes the connection}
```

How Email Works

- Sender (SMTP client) establishes a reliable communication channel
- Initiation
- Receiver and bounce address
- Data transmission
- Session ended

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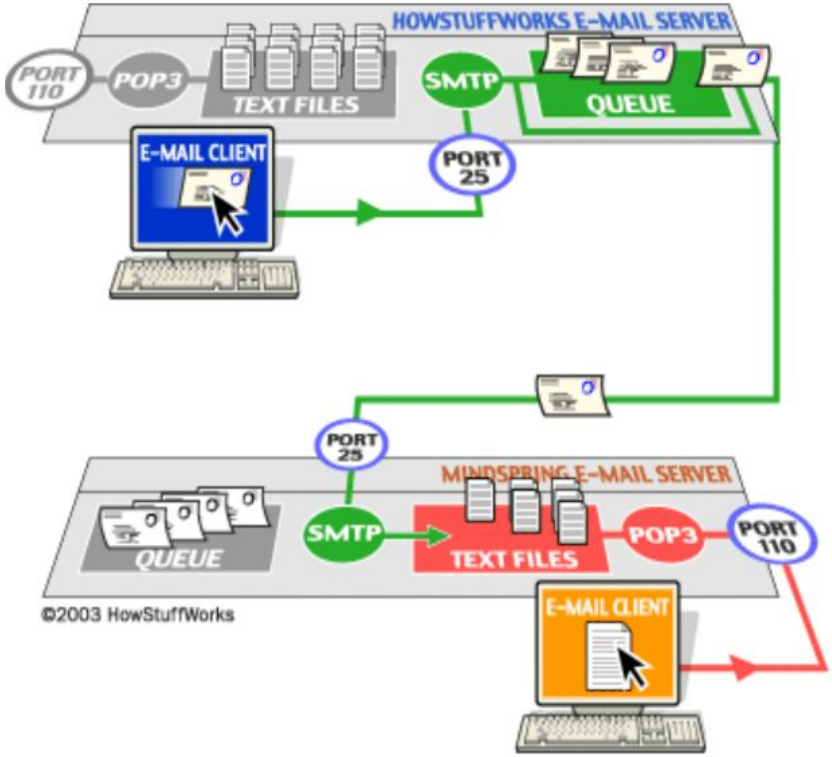
How Email Works



Why SPAM still a problem?

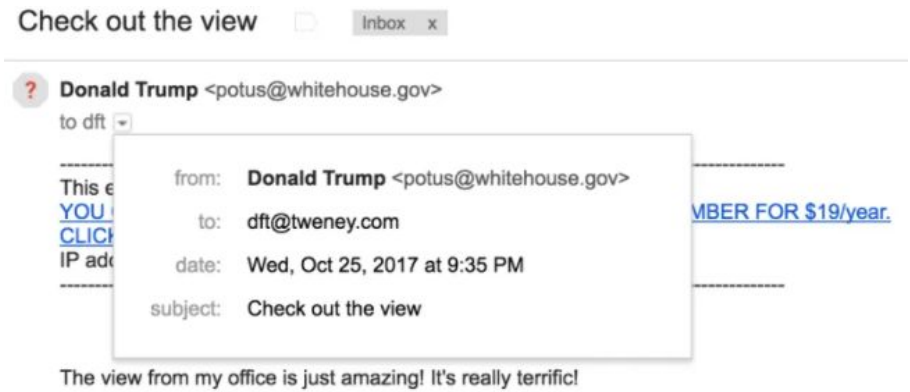
- Email system design
  - Headers allow spoofing
- Identity concealing
  - Bot-networks
  - Open proxies
  - Open mail relays
  - Untraceable Internet connection
- Available bulk email tools

Email system design

- SMTP designed for a trusting world
  - email is **not private**
  - can be **altered** en route
  - **no way to validate** the identify of the email source
    - **MAIL FROM** under total control of sender
    - Recipient's mail server only sees IP address of direct peer (recorded in the first **From** header)
- SMTP-AUTH (IETF RFC 4954)
  - an extension of the SMTP

Email system design

- Headers are unreliable, can be used for spoofing
  - Insert fictitious email addresses in the From: lines




```php
<?php
$to      = 'nobody@example.com';
$subject = 'the subject';
$message = 'hello';
$headers = 'From: webmaster@example.com' . "\r\n";
mail($to, $subject, $message, $headers);
?>
```

Identity Concealing: Bot-networks

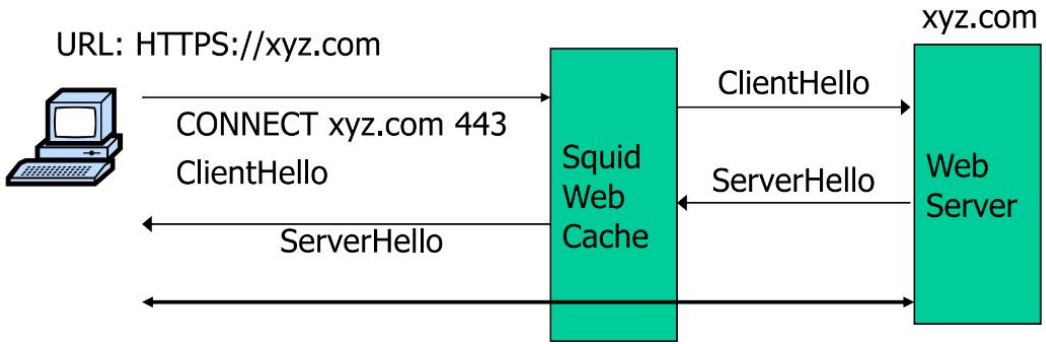
- Compromised machines running malicious software
- Once infected, spammer can send spam from it
- The bot software **hides itself and periodically checks for instructions** from the administrator
- Emails appear to come from **legitimate users**
- Example botnets:
  - Phatbot had 400,000 bots
  - Bobax : assimilated machines with high speed Internet connection

Identity Concealing: open proxies

- An open proxy is one which will create connections for any client to any server, without authentication
  - SOCKS
  - HTTPS
- Possible for a computer to be running an open proxy server without knowledge of the computer's owner
- More difficult to detect when chain of open proxies used

Identity Concealing: open proxies

- Web caching proxy (HTTP/HTTPS proxy) e.g., Squid

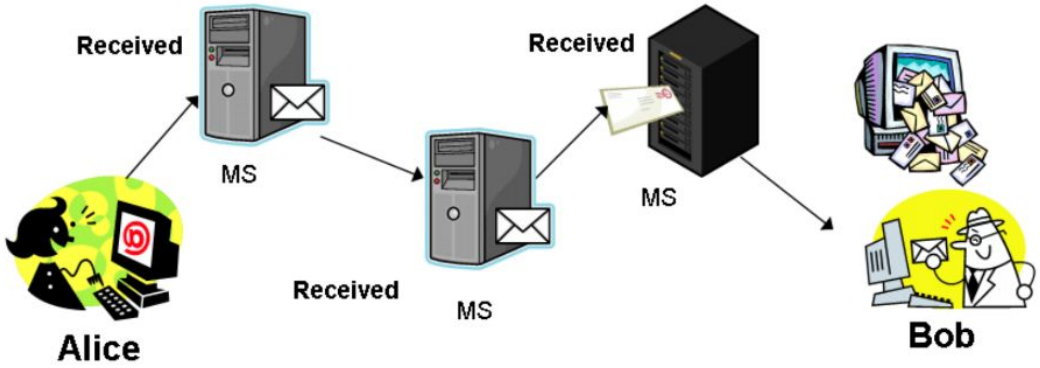


- To spam:

```
CONNECT SpamRecipient-IP 25
SMTP Commands
```

- Squid becomes a mail relay ...

Identity Concealing: Open Mail Relays



- An email server configured to allow **anyone** on the Internet to relay email through it.
- Network address of spammer appears in one of the Received: headers
- Add **fake** Received: headers

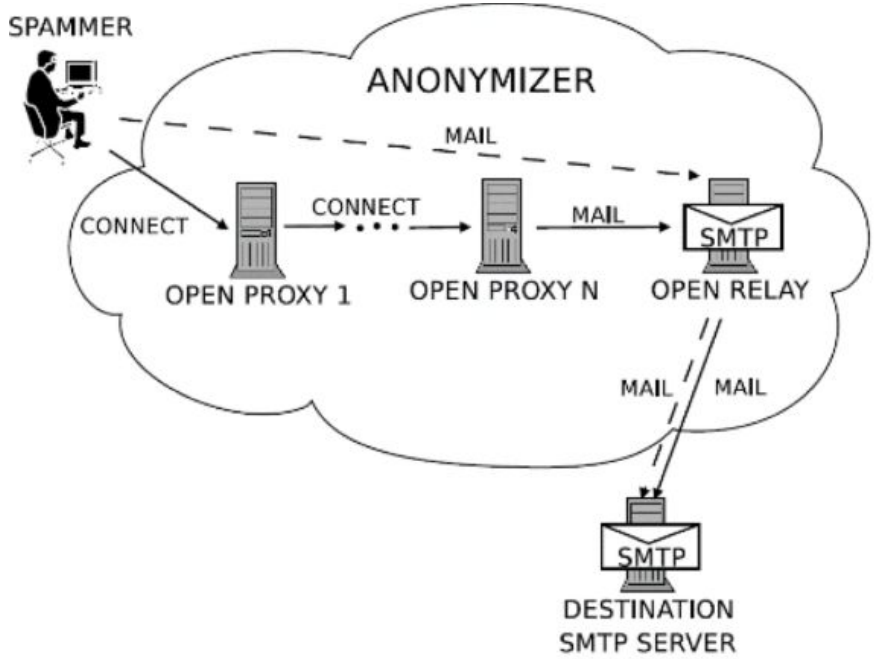
Open Relays vs. Open Proxies

- HTTP proxy design problem:
  - Port 25 should have been blocked by default
    - Otherwise, violates principle of least privilege
- Relay vs. proxy
  - Relay takes list of address and send msg to all
  - Proxy: spammer must send msg body to each recipient through proxy.

  ===> zombies typically provide hacked mail relays

Combining Open Proxy and Open relay

- Establish TCP connection with Open Proxy1
- Connect with Open Proxy2
- Send email to Open Relay through this chain
- Forward to destination SMTP server

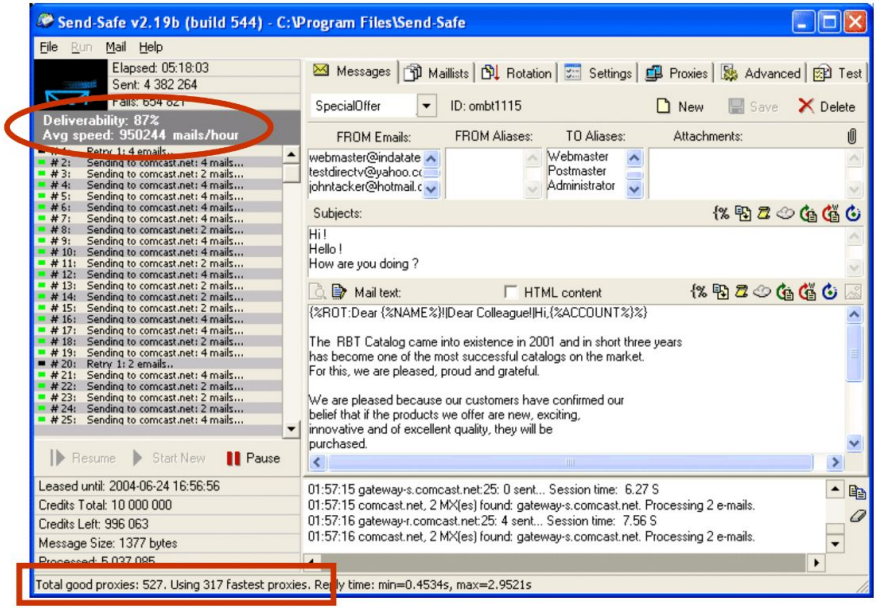


Identity Concealing: Untraceable Internet Connection

- Public Internet cafes
- Free/stolen wireless connections
- Connections need not identify users
- Hence they need not hide network address
  - Send email directly to spam recipients
  - No way to associate email accounts with the spammer

Bulk Email Tools (Spamware)

- SPAMWARE automates:
  - Message personalization
  - Mailing list and proxy list management



SPAM COUNTERMEASURES

- Blacklists
- Graylists
- Puzzles and CAPTCHA
- Sender verification
- Spam filter

SPAM countermeasures: Blacklists

- RBL: Realtime Blackhole Lists
  - Includes servers or ISPs that generate spams
  - e.g., spamhaus.org , spamcop.net
- Effectiveness (stats from spamhaus.org):
  - RBL can stop about 15 - 25% of incoming spam at SMTP connection time
  - Over 90% of spam with message body URI checks
- Spammers evade blacklists by hiding its source IP address

SPAM countermeasures: Graylists

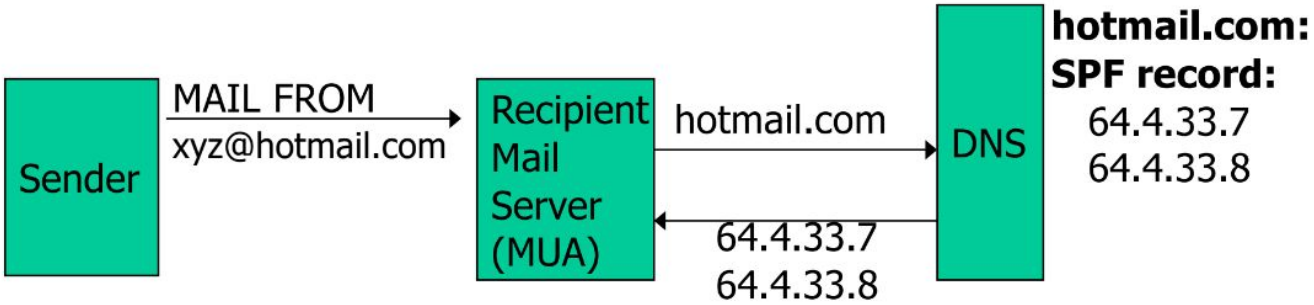
- Recipient's mail server records triples:
  - (sender email, recipient email, peer IP)
  - Mail server maintains DB of triples
- First time : triple not in DB
  - Mail server sends 421 reply: "I am busy"
  - Records triple in DB
- Second time (after 5 minutes): allow email to pass
- Triples kept for 3 days (configurable)
- Easy to defeat but currently works ok

SPAM COUNTERMEASURES: PUZZLES AND CAPTCHA

- General DDoS defense techniques
- Puzzles : slow down spam server
  - Every email contains solution to puzzle where
  - challenge = (sender, recipient, time)
- CAPTCHA - Every email contains a token
  - Sender obtains tokens from a CAPTCHA server
    - Say: 100 tokens for solving a CAPTCHA
  - CAPTCHA server ensures tokens are not reused
- Either method is difficult to deploy

SPAM COUNTERMEASURES: SENDER VERIFICATION I: SPF

- SPF: sender policy framework
- Goal: prevent spoof email claiming to be from Hotmail
  - Why? Bounce messages flood HotMail system

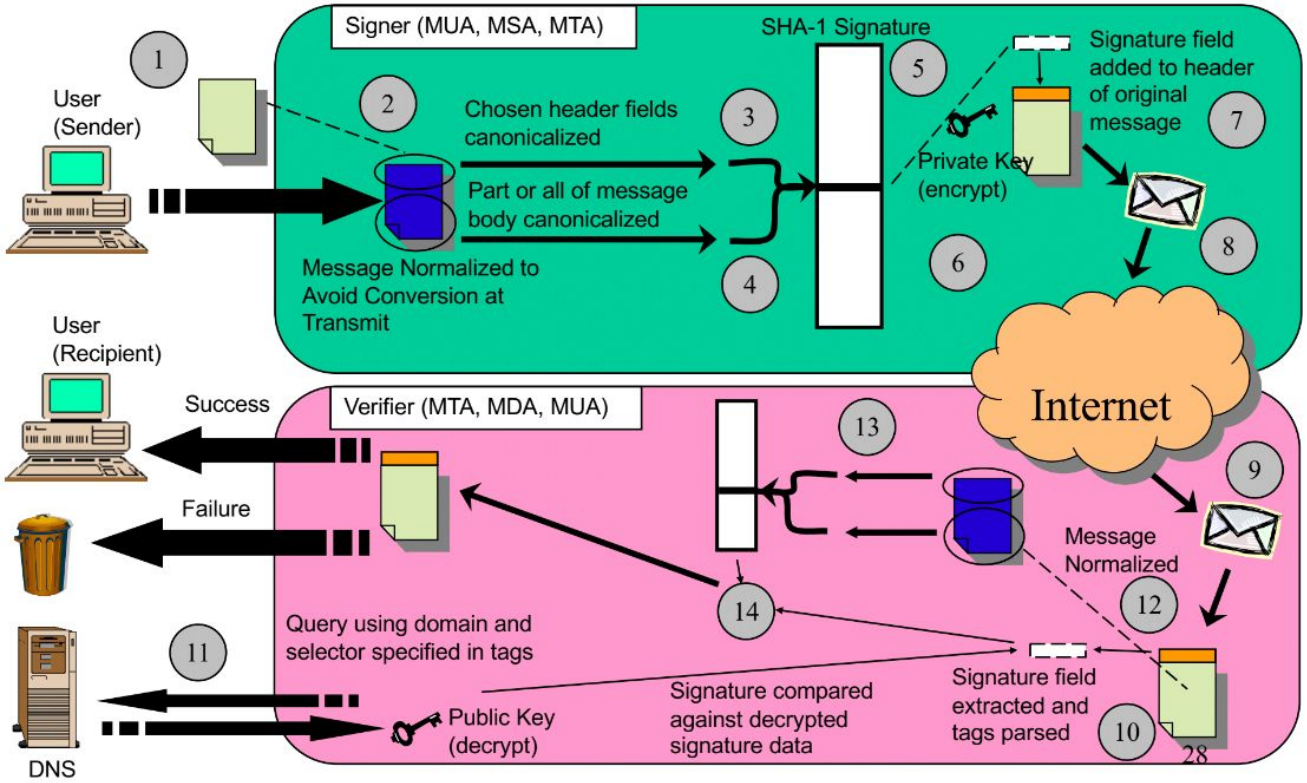


Check if SenderIP is in the list

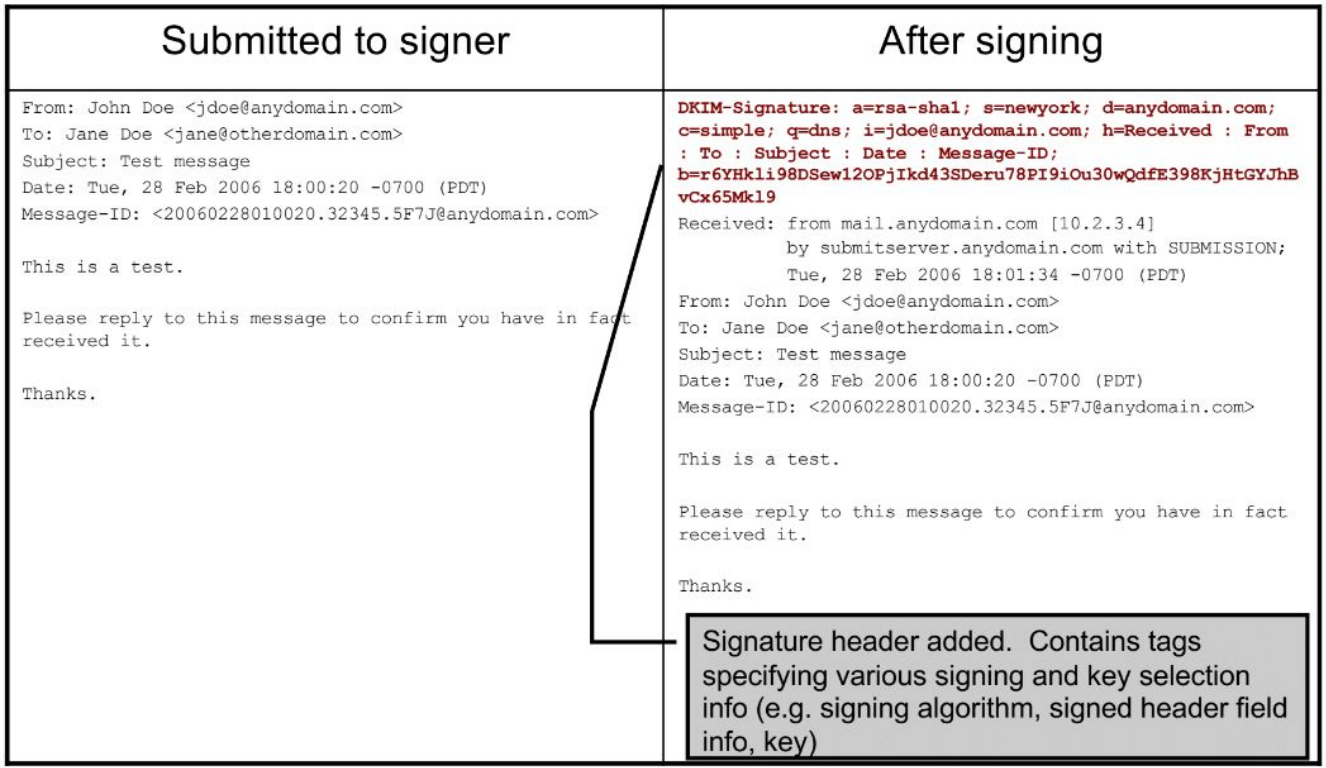
SPAM COUNTERMEASURES: SENDER VERIFICATION II: DKIM

- DomainKeys Identified Mail (DKIM)
  - Same goal as SPF
  - Harder to spoof
- Basic idea:
  - Sender's message transfer agent (MTA) signs email
    - Including body and selected header fields
  - Receiver's mail user agent (MUA) checks signature
    - Rejects email if invalid
  - Sender's public key managed by DNS
    - Subdomain: **_domainkey.hotmail.com**

SPAM countermeasures: Sender verification II: DKIM



SPAM countermeasures: Sender verification II: DKIM



SPAM countermeasures: Spam Filtering

- Goal 1: No false positives
  - i.e., valid email ranked as spam
  - 0.02% more realistic
- Goal 2: No false negatives
  - i.e., spam email marked as valid
  - 8% more realistic
- Filters must be adaptive
  - Machine learning and data mining
  - Statistical methods
- Customizable policies per user group

SPAM COUNTERMEASURES: SPAM FILTERING - CONTENT FILTERING

- Example: SpamAssasin
- a **rule-based** spam filter
  - Many rules to give scores for all fields in an email
    - e.g., Email header, special keywords in email, URLs in email
  - Final decision is the combined score compared with a threshold
  - Has false positive and false negative
    - False positive is very **damaging**! Nobody wants to lose an important email!
- Also contains Bayesian filtering to match a user's statistical profile
  - Need "ham" (wanted) and "spam" (unwanted) samples for training

SPAM COUNTERMEASURES: SPAM FILTERING - CONTENT FILTERING

- Bayesian Spam Filtering
  - Tokenize mail content into words or phrases
  - Use a classified training set of spam and ham messages to derive conditional probabilities for each token
  - Use Bayes' Theorem to **calculate a probability** that a new message is spam based on these learned conditional probabilities
- Bayes' Theorem: $P(A|B)\ P(B) = P(B|A)P(A)$

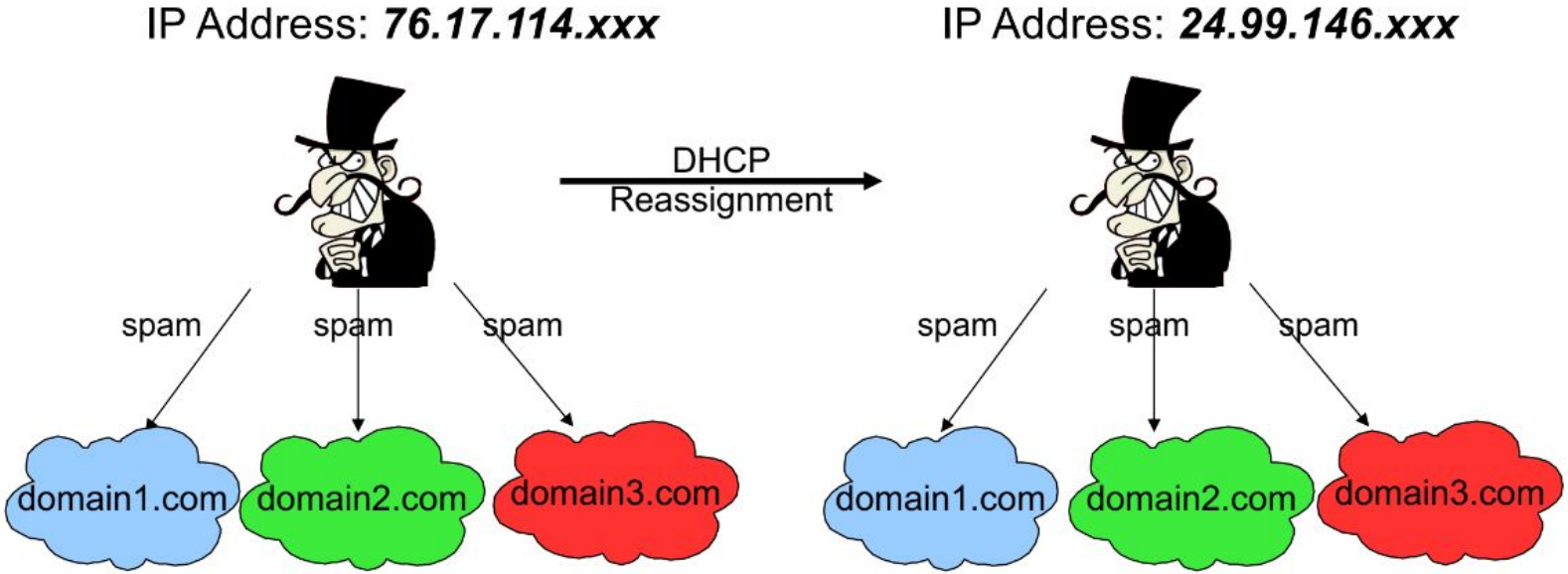
SPAM COUNTERMEASURES: SPAM FILTERING - CONTENT FILTERING

- Problems with Content Filtering
  - **Low cost to evasion**: Spammers can easily alter features of an email's content can be easily adjusted and changed
  - Customized emails are **easy to generate**: Content - based filters need fuzzy hashes over content, etc.
  - **High cost to filter maintainers**: Filters must be continually updated as content - changing techniques become more sophisticated

SPAM COUNTERMEASURES: SPAM FILTERING - NETWORK-BASED

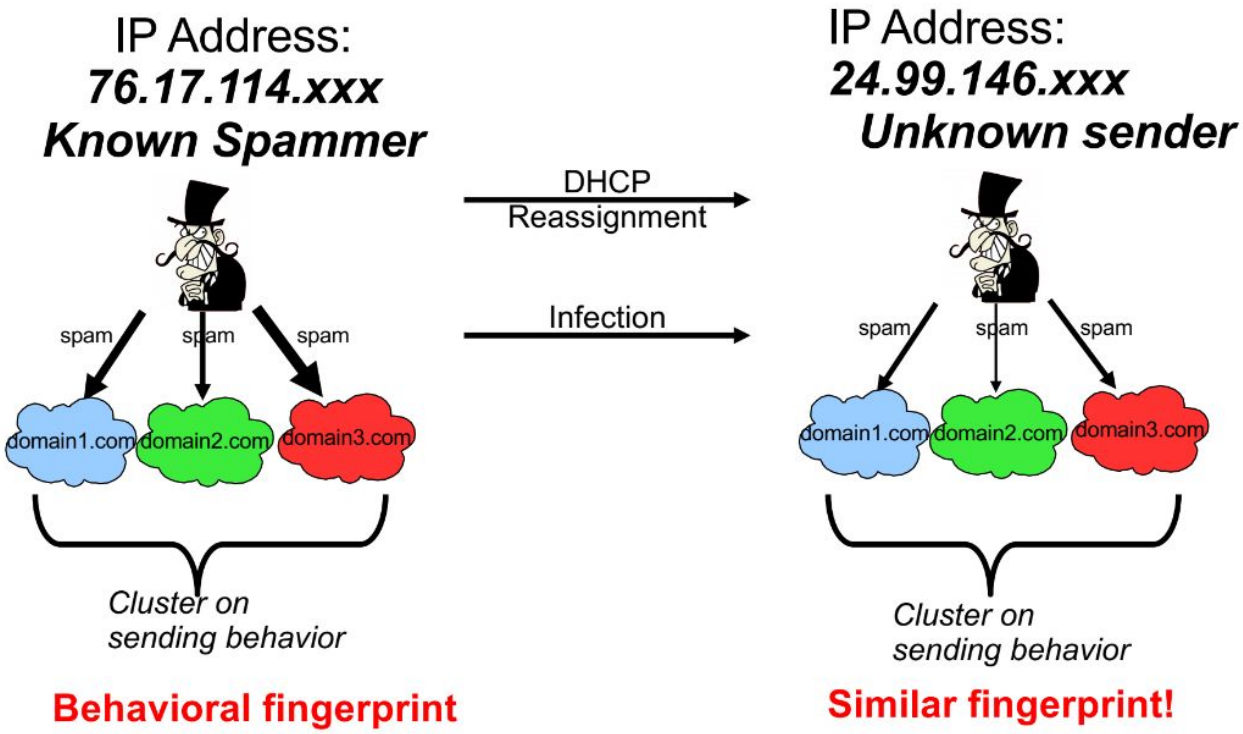
- Network-Based Filtering
  - Filter email based on **how** it is sent, in addition to simply **what** is sent
  - Network-level properties are less malleable
    - Set of target recipients
    - Hosting or upstream ISP (AS number)
    - Membership in a botnet (spammer, hosting infrastructure)
    - Network location of sender and receiver
- Key idea: find **invariants**

SPAM COUNTERMEASURES: SPAM FILTERING - NETWORK-BASED



- **Spammer's sending pattern has not changed**

SPAM COUNTERMEASURES: SPAM FILTERING - NETWORK-BASED



SPAM COUNTERMEASURES: SPAM FILTERING - NETWORK-BASED

- Feature: **Distribution** of email sending volumes across recipient domains
- Clustering Approach
  - Build initial seed list of bad IP addresses
  - For each IP address, compute feature vector
    - volume per domain per time interval
  - Collapse into a single IP x domain matrix
  - Compute clusters
- Classifying IP Addresses
  - Given “new” IP address, build a **feature vector** based on its sending pattern across domains
  - Compute the similarity of this sending pattern to that of each known spam cluster

SPAM COUNTERMEASURES: SPAM FILTERING - EVASION

- Problem: Malicious senders could add noise
  - Solution: Use smaller number of trusted domains
- Problem: Malicious senders could change sending behavior to emulate “normal” senders
  - Use additional features and combine for more robust classification
    - Temporal: interarrival times, diurnal patterns
    - Spatial: sending patterns of groups of senders

SPAM Basics

THANK YOU!
QUESTIONS?