DNS is NOT Boring!
Using DNS to Expose and Thwart Attacks

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While almost every major organization in the world is being continuously attacked over the Internet from a wide variety of actors, tools, and methods, the vast majority of them are sitting on a gold mine of data that could expose and thwart those attacks and don’t even know it. That data is in the very mundane task of resolving names to network addresses otherwise known as Domain Name Service (DNS).
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Using DNS to Expose and Thwart Attacks

This session will explore how to dig data out of your organization’s DNS queries and responses, find activities like data exfiltration using DNS tunnels, malware activities, and other attacks leveraging the DNS, and provide some thoughts on how to use the organization’s DNS infrastructure itself to protect from these threats.
Agenda

Frame the issues
Talk about threats and mitigations
Review some real-world incidents
Get down-and-dirty with actual tools and data
Q&A (and requests)
“Collaboration is the key to defeating online crime and creating a trusted, secure Internet.”

Member of:
- ICANN's Security and Stability Advisory Committee
- Online Trust Alliance’s Steering Committee
- FCC Communications Security, Reliability and Interoperability Council
- Messaging Malware Mobile Anti-Abuse Working Group
- Forum of Incident Response and Security Teams (formerly FIRST Representative)
- DNS-OARC
Who Knows how to Spell DNS?
If not — Buy this Book!

By this guy...

"Response Policy Zones are the first mechanism that lets us turn DNS servers from security targets into security tools."
- Cricket Liu, Chief DNS Architect
DNS Refresher – Directed Tree

- www.r2cyber.com
How DNS Resolution Works

- Resolution process
  - Client: “What is the IP address of www.r2cyber.com?”

[Diagram showing the resolution process with labeled steps: 1. Local, 2. Resolver, 3. com, 4. R2cyber.com, 5. com, 6. Local]
And Some other Important Players

registrant
end customer who registers domain names

resellers
register on behalf of registrants but have no contractual relationship with ICANN, e.g., web hosting companies

registrars
ICANN accredited organizations that process the registration of domain names

registry operators
keep an authoritative master database ("registry") of all domain names registered for each top-level domain

ccTLD Operator
individual country authorities impose national laws, requirements and other attributes unique to a ccTLD

ICANN
non-profit corporation for domain name system management

domain registry process
So No Big Deal, Right?

• DNS is a lights-on critical service connectivity service
• History shows it to be extremely resilient
• Been around a long time now
• Looks can be deceiving
  • People tend to take it for granted
  • Not thought of a security control
  • Cost center rather than strategic tool
    • Who’s using Godaddy for their corporate domains?
DNS Attacks of all sorts remain highly impactful


Large Attack Surface

• Servers, outsourced services, chains of reliance an opportunity for attack
  • Each point of the operational authoritative DNS infrastructure
  • Vulnerabilities in the recursive infrastructure
  • The provisioning and domain management ecosystem

• Little monitoring done by most organizations
  • DNS just works
  • DNS one of very few protocols with largely unimpeded flow between networks

• Few are thinking about Jiu-Jitsu – turning the tables on the attackers
  • If they are coming at you via DNS – you can turn that into intelligence and action
DNS-Related Attacks fall into Three Main Buckets

• Attacks of the DNS infrastructure itself
  • Including leveraging your DNS to attack others

• Use the DNS protocol as it was designed but for malicious purposes

• Exploit “valid” but creative unintended uses of DNS such as DNS tunnels
Attacks on DNS Services and Operations

• Goal is to take your DNS infrastructure offline or to impact operations
• Flooding/DDoS
  • Your DNS is the target
  • Reflective amplification using your infrastructure
• Hijacking
• Spoofing
• Vulnerability exploits/reconnaissance

Just a few quick thoughts on these issues
Dyn Attack – Did we all Relearn our Lessons?

• Massive interdependencies on someone else’s DNS – could be 2-3 layers of services
• Did your own DNS go dark?
• What happened to diversity?
  • Internal vs. External
  • Multiple providers
  • DIY backups
Who’s your (Go)Daddy?

• Entire bank hijacked this year via hijacking
• What domain registrar are you using?
• What controls do you have in place (locking and change management at various levels)
  • Registries and registrars are outside your control – yet they are critical to your DNS infrastructure
• Domain “shadowing” a big deal these days – hijacking “light”
You ARE Employing anti-Spoofing, Right?

• Spoofing still a major problem
• BCP 38 & 84 as relevant now as ever and a bit easier to do

• Oh, and while I’m at it DNSSEC is getting a lot easier to provision – you should probably do it now if you haven’t already!
Don’t Forget E-mail

• SPF & DKIM work fairly well – solve some basic issues with spoofing of your domains in the e-mail stream

• DMARC actually works pretty darn well
  • Advance notice of campaigns against your customers/employees/constituents
  • Get ahold of IOC’s from bounced messages
  • Telemetry may tell you a lot about nature of those spoofing you for attacks
  • Great for detecting some spear-phishing campaigns

• These all require integration and maintenance in DNS
Bad Guys Use the DNS Too!

• Because they have to – just like us
• Obvious stuff like look-alike domains for phishing and dropping exploits
• Provisioning infrastructure – most botnets are SaaS platforms...
• Resiliency of campaigns - traditional firewalls block IP space
• Easy to stand-up new infrastructure with automation
Phishing via Malicious Domains is “in” Again

• Soon to be released APWG report will show around 40% of phishing attacks involve a fraudulently registered domain name
  • I’ve been crunching the data for weeks now!
  • Numbers way up
• Some domains being aged well over a year
  • Most attacks still on fresh domains, but cannot rely on age anymore
• IDN Homographic attacks still not a major issue
• Lots of data available on what attacks are out there!
Malware Exploiting DNS

- Over 91% percent malware uses DNS*
  - To maintain command and control
  - To exfiltrate data
  - To redirect traffic
- Nearly all the crypto* stuff uses DNS based C&C
- Blow right through standard firewalls that are busy looking at IP addresses and other traffic
- Provisioning of DNS infrastructure for all sorts of criminal activity is highly automated and specialized

*Source: Cisco 2016 Annual Security Report
Fast Flux Variations on a Theme...

• Basic fast flux hosting
  • IP addresses of illegal web sites are fluxed using the authoritative nameserver for the domain

• Name Server (NS) fluxing
  • IP addresses of DNS name servers are fluxed at the registrar

• Double flux
  • IP addresses of web sites and name servers are fluxed

• CDN networks use this technique too
  • False positives abound when just looking at basic flux data
Anatomy of a Fast Flux Attack

1. Bot herder infects hosts, gathers herd into botnet

2. Bot herder "leases" botnet to "customer"

3. Customer "acquires" phishing kit from malware author

4. Via a registrar, customer registers nameserverservicenetwork.tld and boguswebsitesexample.tld

5. Via a registrar, customer fluxes NS records for nameserverservicenetwork.tld to TLD zone file with $TTL 180

6. Customer uses C&C to load zone file onto selected bots; flux host A records for boguswebsitesexample.tld have $TTL 180

7. Customer uses botnet C&C channel to load bogus web site onto hosts identified in the zone file for boguswebsitesexample.tld

8. Customer spams phishing email to lure victims to bogus web site

STEPS 5-7 repeat as TTLs expire...
Domain Generation Algorithms (DGAs)

• To avoid losing botnet control due to server take-over, botnet authors often use the DNS for establishing communications
• Since domains can be shut-down, create an algorithm that changes the domain used for communications regularly
• You can generate hundreds or thousands of domains to make it impossible to pre-register them all – just need one to work
• Very noisy though – malware tries to reach many NX-domains every day as algorithm changes.
• Look very “odd” since characters used are generated mathematically and typically end up not being anything like natural language
• If you have the malware, you can reverse it to get the algorithm
DGA History

• Early 2008 – Kraken one of the first malware families to use a DGA
• Mid 2008 – World’s largest botnet “Srizbi” uses DGA algorithm
  • FireEye sinkholes for two weeks to keep out of criminal hands - abandoned
• Late 2008 – Conficker first discovered
  • Sinkhole efforts successful but malware authors escalate to creating over 250,000 potential domains per day in 2009.
• 2010 – Texas A&M University researchers publish paper on detecting DGA domain names
• 2012 – Georgia Tech and Damballa release whitepapers on new DGA use and detection methods using machine learning
• 2015 – DGA tracker website online
• 2016 – Registrar of last resort stood-up to sinkhole many DGA’s
Sophisticated DGA Example

- Recent Crowdstrike analysis of an advanced DGA-based malware (http://bit.ly/1fa2wLb)
- All variants of family contain identical 384-word list of common English words, decrypted at run time
- Domain names created by concatenating two pseudo-randomly selected words and appending “.net” to the end
### DGA Dictionary

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Hiding in Plain Site

- Exfiltration via DNS growing - more botnet C&C via DNS signaling
DNS and Data Breach

• DNS tunnels are commonly used to send sensitive information out

• Data can be exfiltrated by embedding data directly in DNS queries

Average material loss per breach incident
$7.6 M

% of survey respondents who have experienced DNS data exfiltration
46%

% of survey respondents who have experienced DNS tunneling
45%

Source: SC Magazine, Dec 2014, “DNS attacks putting organizations at risk, survey finds”
Data Exfiltration Examples

A large developer of video games had malware inside the network that tried to exfiltrate data via DNS queries using spoofed addresses.

A large automaker’s main concern is loss of intellectual property that could erode its competitive advantage, and the company is very keen on preventing it from happening via DNS.

A large bank failed an audit because of lack of protection for data over DNS.

A large insurance company is concerned about liability because it is aware that DNS is not protected.
Data Exfiltration via DNS Queries

- Sophisticated attack that anyone can use – built into different types of malware kits (FrameworkPOS, Game over Zeus)
- Infected endpoint gets access to file containing sensitive data
- It encrypts and converts info into encoded format
- Text is broken into chunks and sent via DNS using hostname.subdomain or TXT records
- Exfiltrated data is reconstructed at the other end
- Can use spoofed addresses to avoid detection
Domain Shadowing

*a Hybrid Attack*

- Abuse legitimate domain’s good reputation
- Break into registrar or DNS management account
- Insert “evil” hostnames but leave main domain and www alone
- Used primarily for exploit kits
- Stealing *reputation*
OK, That’s Kinda Depressing – What do we do?
Traditional Security Tools ≠ DNS Security

• Traditional security tools often cannot detect attacks via DNS that threaten your enterprise network
  • Traditional firewalls IP-address centric
  • DLP and other breach tools don’t look at DNS for exfil

• DNS resolution is lights-on service – hard to hand off to security product
  • DPI on DNS? Not at scale

• Critical parts of infrastructure outside network and your operational and/or legal control
Instrumenting Your Network

• If you want to stop “bad things” you have to look for them first!

• DNS logging at the resolver
• Passive DNS replication
• DNS Tap (dnstap.info)
• DPI techniques
• Log data and push into other analysis infrastructure
  • Custom database or analysis tools like ELK stack or Splunk
  • SIEM
  • Cloud to handle scale and allow for machine-learning
  • Build your own Passive DNS (PDNS) database!
DITL Yourself!

• Day-in-the-life-of-the Internet
• DNS-OARC does this at “Internet Scale” annually
• Baseline your typical day/week/mo.
• You don’t know what’s “weird” unless you know what’s normal
• Keep stuff like PDNS around forever if possible
Lock Down DNS Channels

• Lots of people use different DNS servers than yours
  • Intentionally for “speed”
  • Their “free app” made the change for $$$ purposes
  • Off-network
  • Bad guy actions (remember DNS Changer?)

• You can use your network infrastructure to help
  • Redirect Port 53
  • Monitor for those hitting dodgy resolvers
  • Tricks available to determine if your users are circumventing your DNS
    • Cookies and/or embedded URLs with unique, tracked hostnames are your friend!
Arm Yourself with Knowledge

• Know what to look for, how severe it is, so you can react appropriately

• Lots of data on DNS reputation available
  • Open source
  • Commercial feeds
  • Sharing communities

• Can get data bundled in various solutions

• Mine your own data
  • Know what “normal” is
  • Look for suspicious activities
  • Know what is hitting “just you”!!

• Pivot off known attack infrastructure to find more
Applying Knowledge

• DNS Firewall to implement feeds and learnings in DNS resolution path
  • Lowest overhead, fastest response
• Next-gen Firewall can block via deep packet inspection (DPI)
• Some applications in IDS products
• Specialized in-line hardware also blocks via DPI
• SIEM analysis
• Query reputation systems to understand risk on per-hostname basis

• Depending on capabilities, can apply a machine learning model to discover new attacks
Malware uses DNS at every stage

**Penetration**
Query malicious domains and report to C & C

**Infection**
Download Malware to the infected host

**Exfiltration**
Transport the data offsite
The Principles of a DNS Firewall

• Pre-load the cache with the responses you want to give and keep them there
  – Done regularly for various routing/internal uses
  – Many ways to get entries in there

• Can synthesize values or NX responses

• Monitor mode – log hits and watch activity

• Get lists of hostnames to block from somewhere
  – Develop lists in-house
  – Free (not quite as in beer)
  – Commercial services

• RPZs make this trivial, secure, and very scalable when using BIND
RPZ – Response Policy Zones

• “Most new domain names are malicious.
  • I am stunned by the simplicity and truth of that observation. Every day lots of new names are added to the global DNS, and most of them belong to scammers, spammers, e-criminals, and speculators…. Domains are cheap, domains are plentiful, and as a result most of them are dreck or worse.”
  • Paul Vixie
    • "Taking Back the DNS” July 30, 2010
    • http://www.circlerd.com/posts/20100728_taking_back_the_dns/

• RPZ (Response Policy Zones) the result

• Any BIND resolver can easily implement large-scale domain block lists
  • Scalable: Several lists, different policies per list
  • Fast: Automatically updated with real-time data

• Many commercial DNS resolvers support them https://dnsrcpz.info/

• DNS Policies now available in Microsoft Server 2016
  • Not quite as robust as RPZ, but can get the job done
Using a Managed Sinkhole with your DNS Firewall

1. Client sends DNS query to resolve malicious domain “iammalware.com”

2. Resolver with RPZ sends back an A record with sinkhole IP (e.g. 10.1.0.23)

3. Client initiates connection to “iammalware.com” which now gets directed to TT sinkhole

4. Sinkhole communicates with Policy Manager and Database to determine action based on relevant threat class and client data

5. Notification sent to user with redirect to landing page with further information

6. Alert sent to security operations center
Don’t Forget about NXD

• NXDOMAIN – Non-Existent Domain responses can be a “canary in the coalmine”
• Machines infected with DGA’s stick out very brightly
• Store them in your PDNS database (separate entry type)
  • Mine for patterns – can indicate DGA activities
  • If sent from a server authoritative for a tunneling domain, may indicate one-way data dump
• Pre-fetching and common typos may cause lots of noise here
• Bonus – alert you if part of your critical DNS infrastructure goes down
Turbo-Powering Your DNS Defenses
Threat Hunting Automation Maturity Model

- Framework I Saw at FIRST – This is Why You Come!
- Alex Pinto gave a great presentation on this on Monday
- Credit to Niddel and Alex for this one
Attributes of Interesting Data

• Known evil – categorized by reputation

• Meta data drivers to infer suspicious activities
  • Popularity of domain/hostname
  • Age of domain
  • Nameserver or hosting location reputation
  • Registrar reputation
  • TLD of domain
    • Some new gTLDs are cesspools (.top, .gdn, .bid)

• Fun with machine learning models
A Formula for Fast Flux

- Source: SANS institute
- Time-To-Live (TTL) < 1800 Seconds
- >4 ‘A’ Records (Address code used for storing IP addresses associated with a domain name)
- >4 ‘NS’ Records (Authoritative name server code which specifies a hostname where DNS information may be found)
- >2 Class B Networks in ‘A’ Record Result Set
- >2 Class B Networks in ‘NS’ Record Result Set
- Result Set Changes after TTL + 1 Sec

Class B Diversity

\[
\frac{192.168.30.1}{192.168.100.17} = 1 \\
\frac{10.17.194.12}{10.32.56.18} = 2
\]
DGA Detection

• Tried-and-true method: reverse the malware
  • 100% accurate
  • Know what to block/alert on when
  • Can anticipate false positive issues (collisions with legit domains)
  • Requires the malware and reverse-engineering capabilities
    • Feeds available free and commercial

• Machine learning analysis on large amounts of resolution data
  • Passive DNS replication most popular method
  • Analysis of enterprise DNS resolution can work since you have both sides of the resolution – question (questioner) and answer
  • http://bit.ly/2dnEa4Y
Example from Research: Pleiades

- **Pleiades**: a DGA-based botnet identification system
- Analyze streams of NXDomains at the recursive level
- Accurately detects and models (new and old) DGA-bots
- Our experimental results allowed us to discover six new DGA-based botnets
- HMM-based active C&C detector for new DGAs
  - Manos Antonakakis of GA Tech & Damballa
Statistical Features in Pleiades

- Group NXDomains per asset with cardinality $\alpha$
- $n$-gramFeatures
  - Frequency distribution of $n$-grams across domain
- Entropy-based features
  - Entropy of character distribution for separate domain levels, from the domains in the set
- Structural Domain Features
  - Summarizes NXDomains structure
    - Length
    - # of unique TLDs
    - # domain levels
Previously Unknown DGA’s Pleiades Found

Some of them were malware related: New-DGA-v1 was EnviServ.A and New-DGA-v6 was Simba-F, while others were not active any more.
DNS Tunneling Detection With Machine Learning

Machine learning techniques can detect sophisticated data exfiltration techniques that don’t have well-known signatures (including zero day)

1. Examine all DNS records (e.g.: TXT, A, AAAA)
2. Detects presence of data using lexical and temporal analysis
3. Certain attributes add to a threat score; others subtract from it
4. Final score classifies a request as exfiltration or not
5. If exfiltration is found, can automatically add destinations to RPZ feed or other protection data sets
6. Scales protection to other parts of the network
7. Use both sides of the DNS data resolution – many clients or a single client with many requests just as important as funky domains
How an Analytics Model Works

- **Entropy**
  - Does the request contain lots of information?  
  - Adds to score

- **Frequency/Size**
  - It is unusual to send many different requests to the same external domain.  
  - Adds to score

- **Lexical Analysis**
  - Does it appear to be encoded or encrypted?  
  - Adds to score

- **n-Gram Analysis**
  - Does the request contain words in a language?  
  - Subtracts from score

- **Proprietary methods**
  - False positive mitigation  
  - Other indicators and factors
  - Adjusts score

- Analytics algorithms are sophisticated and complex
- Simplifying greatly, certain attributes add to a threat score, others subtract from it
- All attributes are evaluated and weighted
- After all attributes are evaluated, a final score will classify a request as exfiltration or not
- If the finding is exfiltration, the destination DNS server is added to a special RPZ zone that contains the block, log, redirect policy
Detecting Domain Shadowing

• Look at third level hostnames
  • Will be weird, not “www” or “mail” under the main domain
  • Will point to different, often dodgy, IP space than main website does

• Newly seen hostnames on long-established domains

• Lots of these odd hostnames showing up at once

• Hosted at registrars with known domain shadowing problems

• Machine learning techniques again useful

• Careful to not run into advertising networks, CDN’s or some other legit infrastructure
  • White listing wise

• Should block the odd hosts, whitelist the main “legit” ones if popular
PDNS: Best Thing for Threat Research Since...
Inside vs. Outside

- Where do we monitor from?
Inside Monitoring

• Get all resolution attempts (minus stub caching)
  • Good for watching for volume spikes
  • Volume can be quickly overwhelming

• Know exact machine(s) making requests
  • Can track down infections to the source
  • Privacy concerns (ISPs)
Outside Monitoring

• See aggregate numbers of resolutions for the organization, ISP etc.
  • Easier data management
  • Lose volume information to caching

• Privacy and internal security concerns largely handled
On Server Monitoring

• Had been impractical (performance of DNS concerns), but capabilities are improving
• May be required with future adoption of dprive
  • New IETF standards for encrypting DNS traffic
Mapping Criminal Infrastructure

Source: ISC
Combine Techniques for Protection against Known and Unknown Threats

**Threat Data**

- Regular threat feeds are about known threats
- Constantly updated
- Tailored for high detection, low false positives
- Cover malware, phishing, ransomware, more
- Internal alerts
- DNS telemetry (PDNS DB)

**Behavioral Analytics**

- Detects threats by how the endpoint is acting
- Surfaces unknown threats
- Can take threat data and refine it
- Threat feeds can be adjusted based on findings

Threat Intelligence + Behavioral Analytics = Most Complete Protection
Engage Your Threat Intelligence Team

- Constantly bring in new threat data from around the Internet
- Expand reported threat data into infrastructure of malicious actors’
  - DNS configurations, whois, SSL Certs, SSH fingerprints – a host of techniques
  - Use infrastructure metadata (Passive DNS, zone files, hosting data) to find fresh malicious Internet presences
  - Track fast-flux infrastructure
- Reverse binaries and perform other malware analysis
  - Constantly update DGA data
  - Command & Control data
- Feed into your DNS Firewall continuously
Sharing Effect: $1 + 1 = 3$

Protect against Threats Found in Sharing Partners’ Networks

- Partners can contribute non-sensitive threat data
- You can protect yourself from all discovered threats against anyone else
- Sharing of raw, anonymized data can create a better analytics pool

Three Networks with Different Infections

Company 1

Company 2

Company N
Case study: Threat Intelligence Process

1. TTP’s identified, by internal team or others

2. Internal team performs research to find threat indicators and adds them to detection data sets and protection feeds
   For long-lasting attacks, automate on-going collection of indicators

Multigrain threat indicators
45.32.239.234
datavhg.com
dojfgj.com

https://www.fireeye.com/blog/threat-research/2016/04/multigrain_pointo.html
Case study: Threat Intelligence Process

3. Customer gets a DNS Firewall hit on an indicator:
use your tools to find out more about it
Let’s Play with Some Useful Tools!

- Infoblox TIDE
- DomainTools Iris
- Farsight DNSDB
- RiskIQ PassiveTotal
- Cisco Umbrella Investigate
- Zetalytics Zone Cruncher
- Deteque (Spamhaus) PDNS Research Portal
- BFK Passive DNS Replication

Thanks to all the vendors who gave me access to their commercial products!
Hey, I just got some...
Summary

• DNS is a critical infrastructure asset which is a constant target of attack but most still take for granted
• DNS is fundamental to the operation of malware and data exfiltration – a continuously exploited blind spot
• Many vendors and open source tools provide a range of solutions to protect DNS, disrupt malware and prevent data exfiltration
• DNS Firewalls are powerful security devices for network and user defense and breach detection
• Passive DNS is a super-effective threat research tool
• Use DNS Jiu-Jitsu to turn your hum-drum DNS infrastructure into a turbo-charged, malware crushing, network protection leviathan!
DNS is NOT Boring!
Using DNS to Expose and Thwart Attacks

Rod Rasmussen

Thank You!