Internet Monitoring via DNS Traffic Analysis

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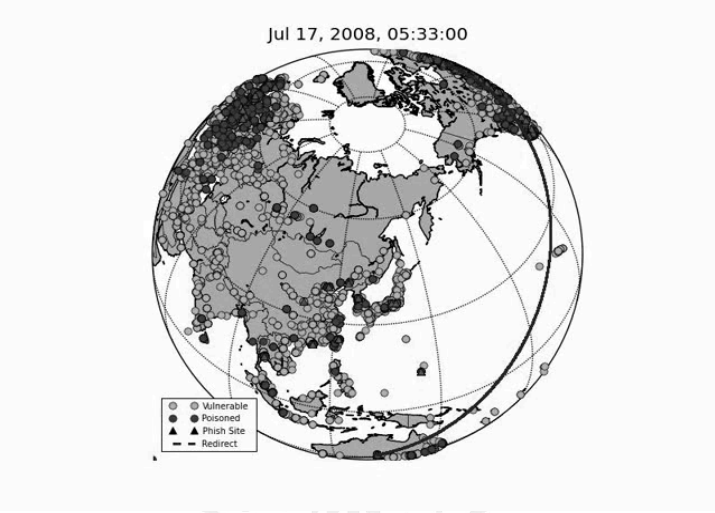
Malware Networks (Botnets)



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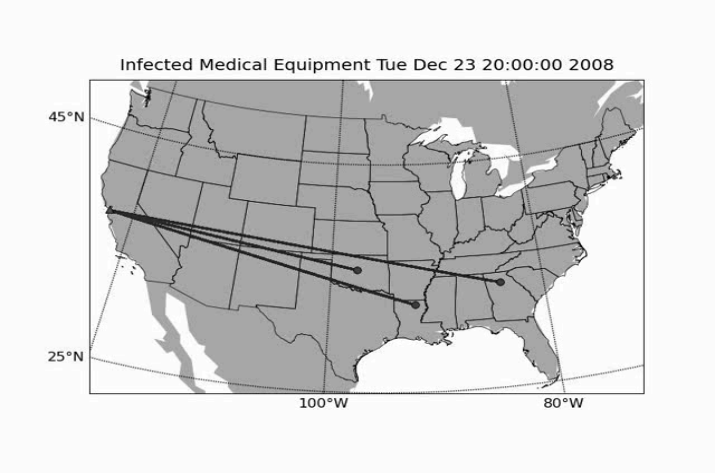
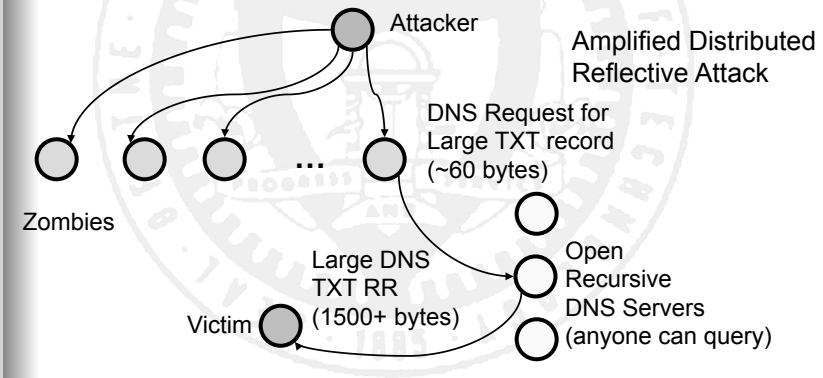
From General-Purpose to Targeted Attacks



Another Attack Example

- Botnets increasingly used for amplified distributed reflective attacks



Command and Control

- Botnet design:
  - C&C is essential to a botnet
    - Without C&C, bots are just discrete, unorganized infections
  - Goal: robustness, or, no single point of failure
    - Mobility: Command and Control (C&C) can migrate to other networks
    - Stealth: difficult to detect

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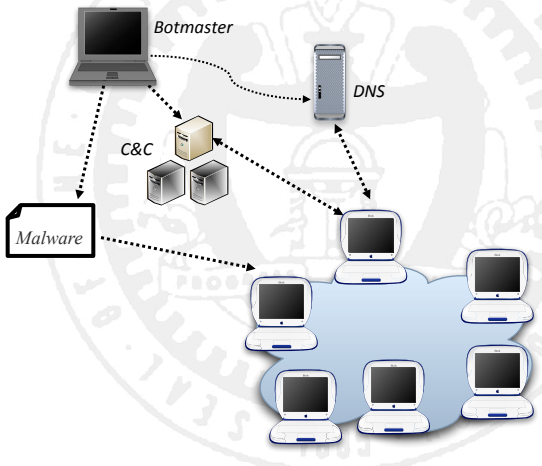
Use of DNS by Malicious Networks



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Example: Aurora

- Widely reported to be December 2009/ Jan. 2010 attack on Google
- Numerous C&C domains

Domain	Authority Creation Date (UTC)
bej.servegame.com	Dec. 15, 2009 21:26:22
bej.zapto.org	Dec. 15, 2009 21:25:48
ms77.zapto.org	July 13, 2009
qzl001.servebeer.com	Dec. 15, 2009 20:07:40
blog1.servebeer.com	Dec. 15, 2009: 21:28:55

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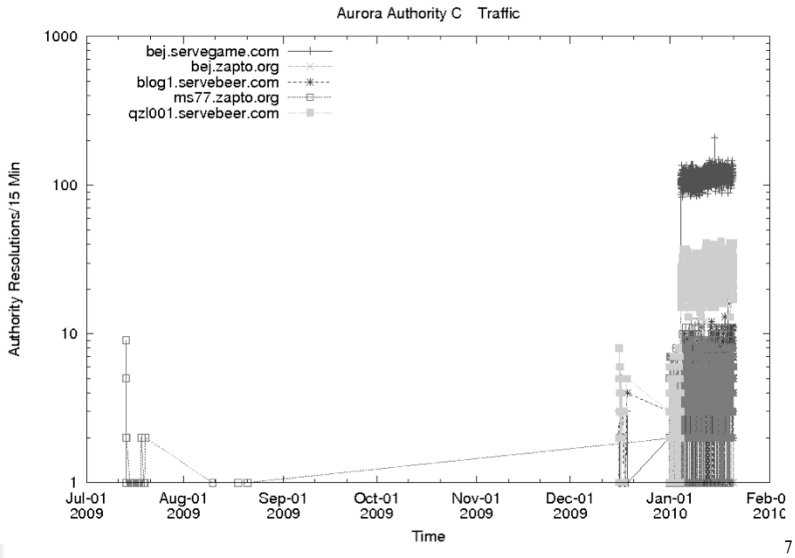
Aurora C&C Resolutions



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Dynamic DNS Reputation Across the DNS Hierarchy

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Overview

- Motivation
  - Static DNSBL increasingly ineffective
  - Need a dynamic, comprehensive reputation system outputs reputation scores for domains
- Intuitions
  - Legitimate uses of domains/sites are different from botnet uses, and the differences can be observed in DNS query traffic
    - Patterns/reputation of Requesters, Resolved IPs, Network providers
- Approach
  - Extract temporal and statistical features from DNS traffic, compute/learn models

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Notos

- Network and zone based features that capture the characteristics of resource provisioning, usages, and management of DNS domains
- Models of legitimate and malicious domains for computing reputation scores for new domains
- Accuracy: can correctly classify new domains with a very low FP% (0.3846%) and high TP% (96.8%)
- Predictability: able to detect and assign a low reputation score to fraudulent domain names, several days or even weeks before they appear on static blacklists
- 2010 USENIX Security Symposium

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Kopis

- Passive monitoring in the upper levels of the DNS hierarchy; Internet-wide visibility
- Analyzes streams of DNS queries and responses at AuthNS or TLD servers, and extracts a set of statistical features and trains a model
- Accuracy: high detection rates (98.4%) and low false positive rates (0.3%)
- Predictability: able to identify newly created and previously unclassified malicious domain names weeks before they were listed in any blacklist
- Detected a DDoS botnet rising in networks within China almost one month before it propagated within other countries
- 2011 USENIX Security Symposium

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Notation & Terminology

- Resource Record (RR)
  - www.example.com 192.0.32.10
- 2nd level domain (2LD) and 3rd level domain (3LD)
  - For the domain name www.example.com: 2LD is the example.com and 3LD is the www.example.com
- Related Historic IPs (RHIPs)
  - All "routable" IPs historically mapped with the domain name in the RR or any domain name under the 2LD and 3LD
- Related Historic Domains (RHDNs)
  - All fully qualified domain names (FQDN) that historically have been linked with the IP in the RR, its corresponding CIDR and AS
- Authoritative domain name tuple
  - The requester (or RDNS), the domain name and the RDATA

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Passive DNS and Authoritative Data

- Passive DNS (pDNS) data collection is the harvesting of successful DNS resolutions that can be observed in a given network
- Passive DNS database contain traffic from several ISP sensors and SIE
  - Observed that different classes of zones demonstrate different passive DNS behaviors
- Obtained authoritative DNS traffic from 2 large authoritative DNS servers (AuthNS) and the Canadian TLD

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Notos

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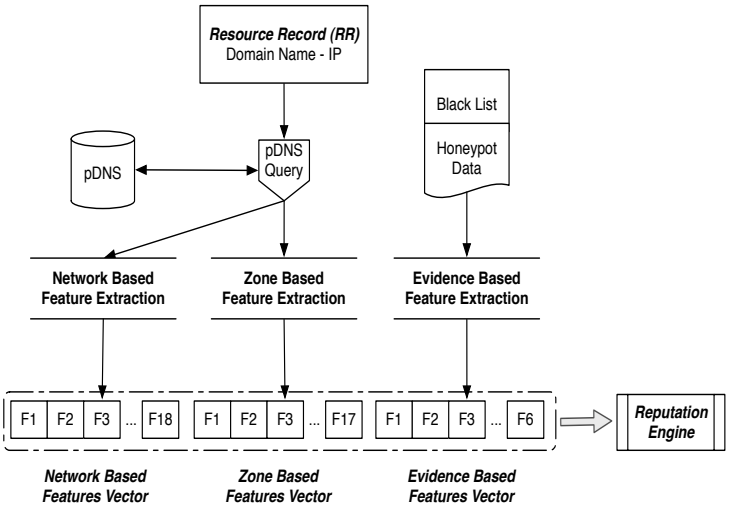
Statistical Features of Notos



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Statistical Features of Notos

- Network-Based Features:
  - Extracted from the set RHIPs
  - E.g., the total number of IPs historically associated with a domain, the diversity of their geographical location, the number of distinct autonomous systems (ASs) in which they reside, etc.
- Zone-Based Features:
  - Extracted from the set RHDNs.
  - E.g., the average length of domain names in RHDNs, the number of distinct TLDs, the occurrence frequency of different characters, etc.
- Evidence-Based Features:
  - E.g., the number of distinct malware samples that contacted the domain, and the same for any of the resolved IPs, etc.

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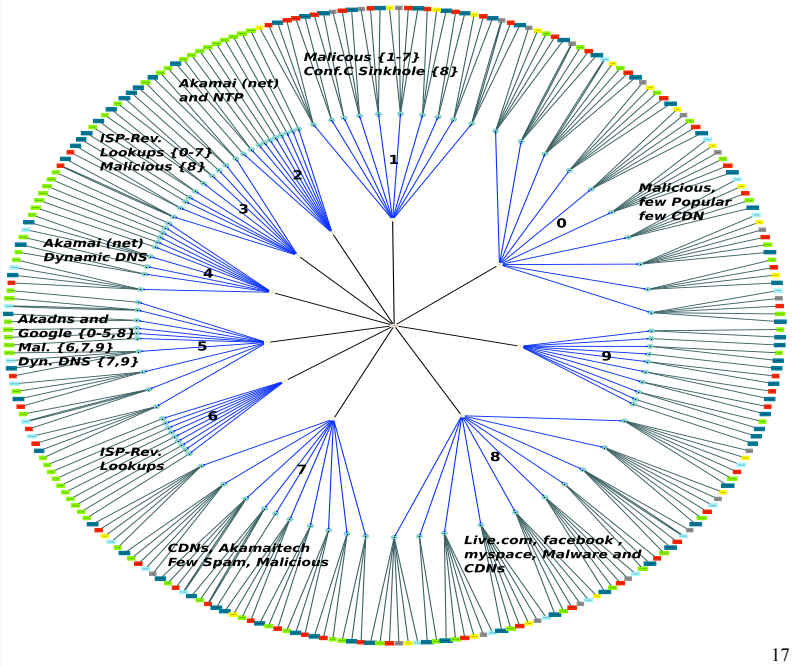

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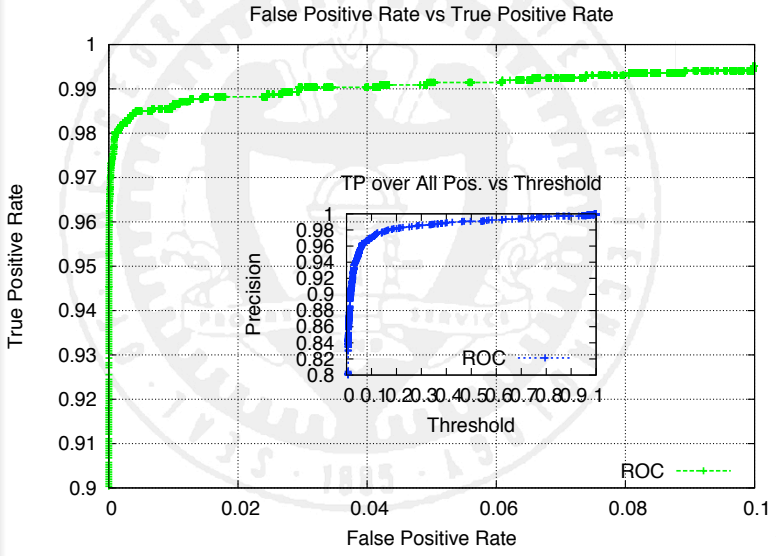
Notos' Reputation Function



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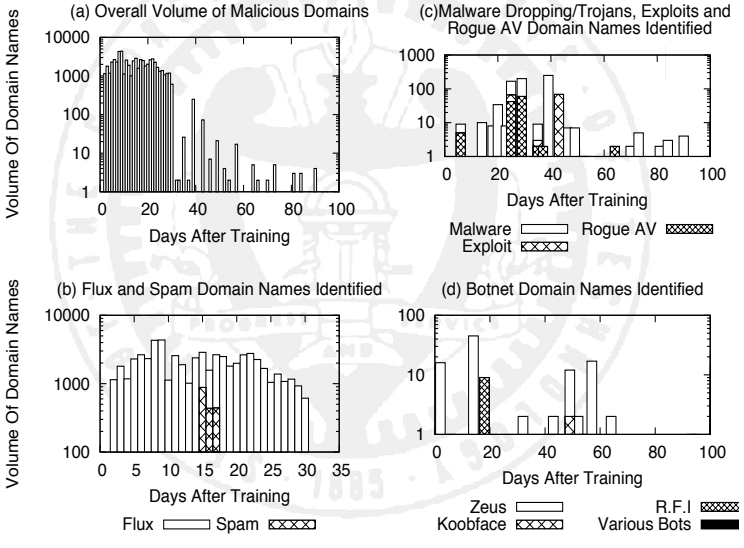
Notos' Reputation Function



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Kopis

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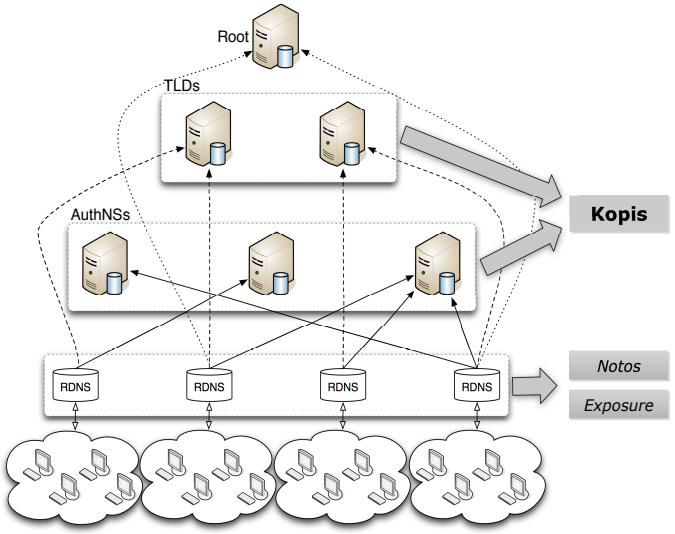
Authoritative vs Recursive Monitoring



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Statistical Features of Kopis

- Requester Diversity (RD)
  - Characterize if the machines (e.g., RDNS servers) that query a given domain name are localized or are globally distributed (based on BGP prefixes, AS numbers, country codes, etc.)
- Requester Profile (RP)
  - Distinguish between requesters located in ISP/small business and home networks
  - Assign a higher weight to RDNS servers that serve a large client population because a larger network would have a larger number of infected machines.
- Resolved-IPs Reputation (IPR)
  - Whether, and to what extent, the IP address space pointed to by a given domain has been historically linked with known malicious activities, or known legitimate services

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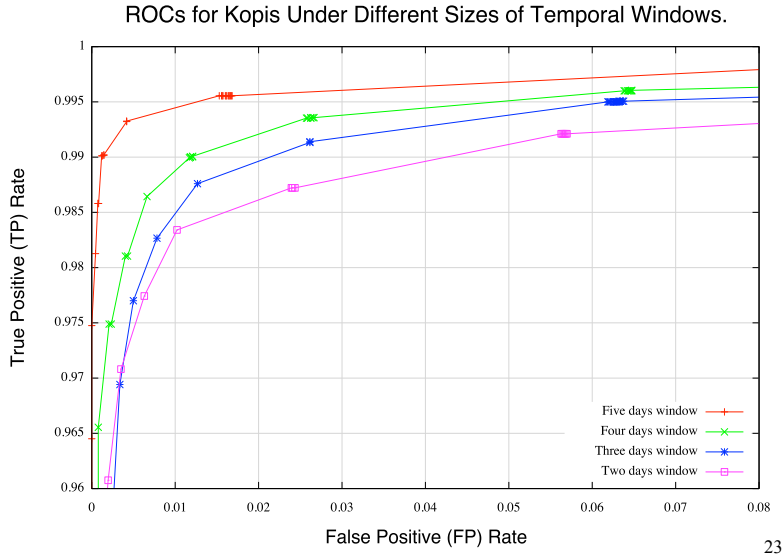
Kopis Detection Performance



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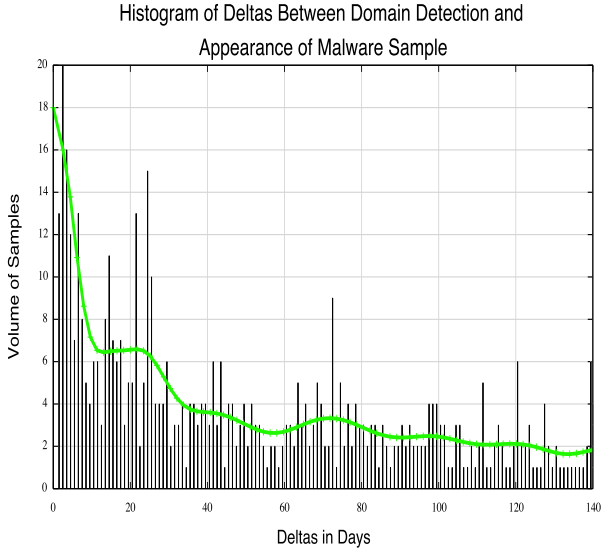
Kopis Predictability



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Analyzing Mobile DNS Traffic

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Overview

- Motivation
  - Much work on mobile malware has been on analysis of (malicious) mobile apps
  - But, how prevalence are infections on mobile devices?
- Intuitions
  - The (malicious) mobile web is a part of the (malicious) web
  - Mobile malware uses similar infrastructure (C&C) techniques as non-mobile/Internet malware
- Approach
  - Obtain DNS traffic in cellular network and identify domains looked up by mobile apps
  - Analyze information related the Internet hosts pointed by these domains

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Data and Key Findings

- Three months of data from a major US cellular provider and a major US non-cellular ISP
- Known mobile malware samples are virtually unseen: only 6,585 out of 380,537,128 devices, or 0.002%
- iOS vs. Android and other devices: equally likely to connect to suspicious domains
- To appear in NDSS 2013

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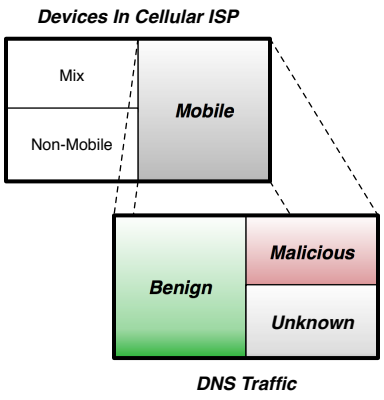
Methodology

- Identify mobile devices and attribute each DNS query to a device
- Analyze reputation of the RRs associated with the DNS queries



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Reputation Analysis

- Use Notos to analyze the hosting infrastructures of the mobile domains
  - Obtain the host IPs pointed to by the mobile domains, for each IP, extract statistical features of
    - Related historic non-cellular domains
    - Related historic mobile domains
    - Malware association
    - URLs for phising and drive-by download
    - Blacklisting incidents

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Tainted Hosts and Platforms

Device platform	% Total Requests by mobile device	% Population requesting tainted hosts	% Total tainted host requests
iOS	31.6%	8.8%	33.2%
All others (Android, etc.)	68.4%	8.2%	66.8%

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Mobile Malware Prevalence

Malware Family	# Associated Domains	# Devices
DroidDreamLight	3	44
DroidKungFu	1	6
FakeDoc	1	2145
Fatakr	1	151
GGTrackers	3	1
NotCompatible	3	762
Planton	4	286
Malware β	1	1
WalkInWat	1	95
Gone60	1	1

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Conclusion

- Malware networks rely on core Internet services, e.g., DNS, to maintain command-and-control infrastructures
  - Mobile or non-mobile
  - DNS traffic analysis can be used to identify malicious domains and infected devices
- With historical information, dynamic DNS reputation systems can even predict the maliciousness of a new domain resolution

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Credits

- David Dagon
- Manos Antonakakis
- Roberto Perdisci
- Yacin Nadji
- Yizhen Chen
- Charles Lever
- Brad Reaves

- *Nick Feamster*
- *Patrick Traynor*

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