Notos: Building a Dynamic Reputation System for DNS

Manos Antonakakis, Roberto Perdisci , David Dagon, Wenke Lee, and Nick Feamster

College of Computing

Georgia Institute of Technology

Atlanta, Georgia

ONR MURI

Review Meeting

June 10, 2010

Problems with Static Blacklisting

- Malware families utilize large number of domains for discovering the “up-to-date” C&C address
  - Examples are the Sinowal, Bobax and Conficker bots families that generate tens of thousands new C&C domains every day
  - IP-based (dynamic or not) blocking technologies cannot keep up with the number of IP addresses that the C&C domains typically use
  - DNSBL based technologies cannot keep up with the volume of new domain names the botnet uses every day
- Detecting and blocking such type of **agile botnets** cannot be achieve with the current state-of-the-art

Outline

- Notos
  - Notations, Passive DNS trends, and anchor-zones
  - Network based profile modeling
  - Network and zone based profiles clustering
  - Reputation function
  - System implementation
  - Results
- Conclusions and Future Work

Notos

- Network and zone based features that capture the characteristics of resource provisioning, usages, and management by domains.
  - Learn the models of legitimate and malicious domains
- Classify new domains with a very low FP% (0.3846%) and high TP% (96.8%).
  - Days or even weeks before they appear on static blacklists.

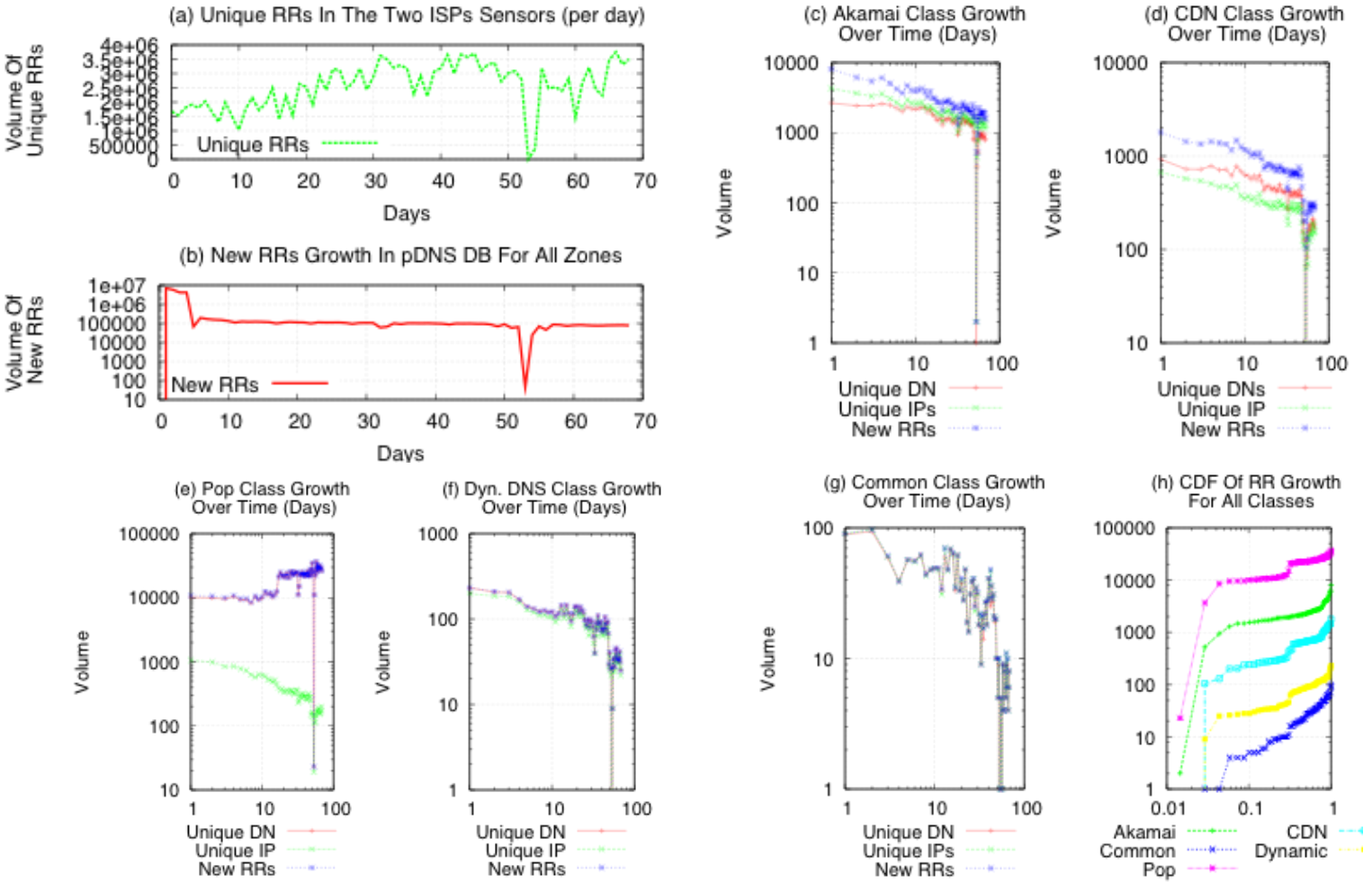
Notation & Terminology

- 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 that historically have been 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

Passive DNS data

- Successful DNS resolutions that can be observed in a given network
- Data set has traffic from 2 ISP sensors - one in west coast and one in east coast, also data from SIE
- We observe that different classes of zones demonstrate different passive DNS behaviors
- The number of new domain names and IPs we observe every day is in the range of 150,000 to 200,000

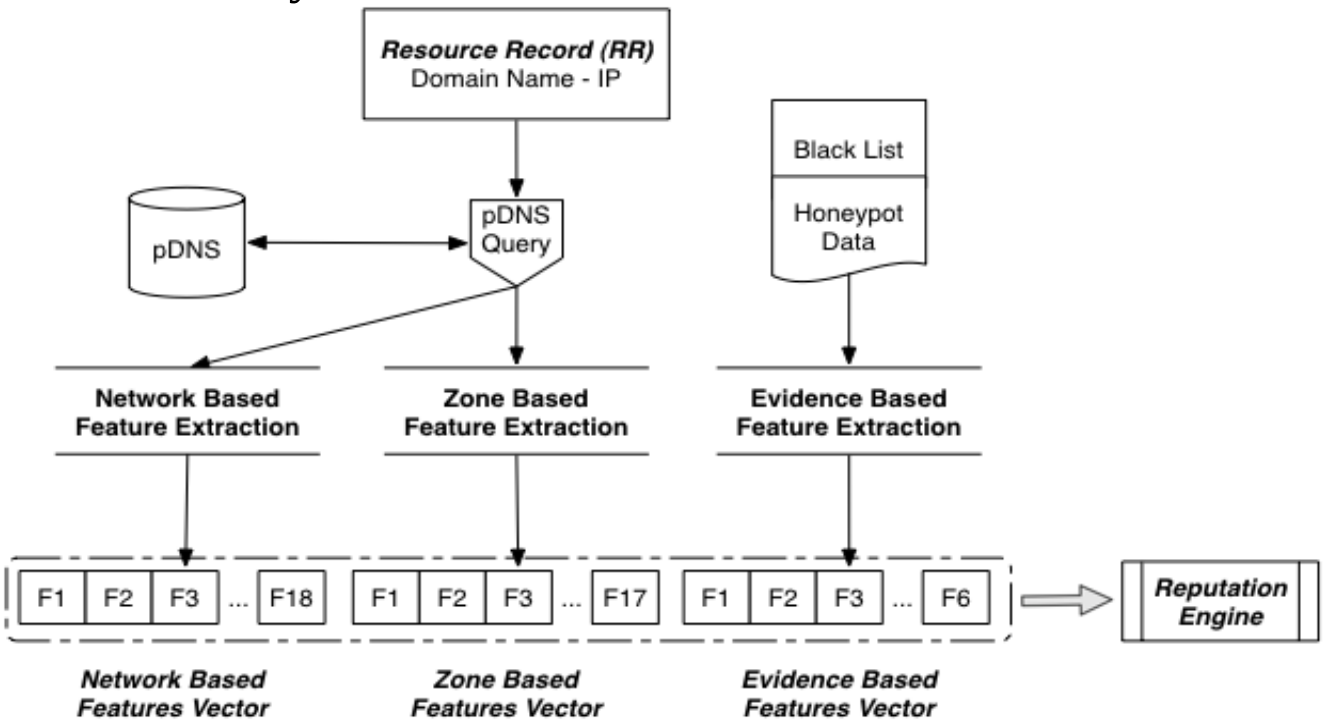
Passive DNS trends



Anchor classes in pDNS: Akamai, CDN, Popular, DYNDNS and Common

Features

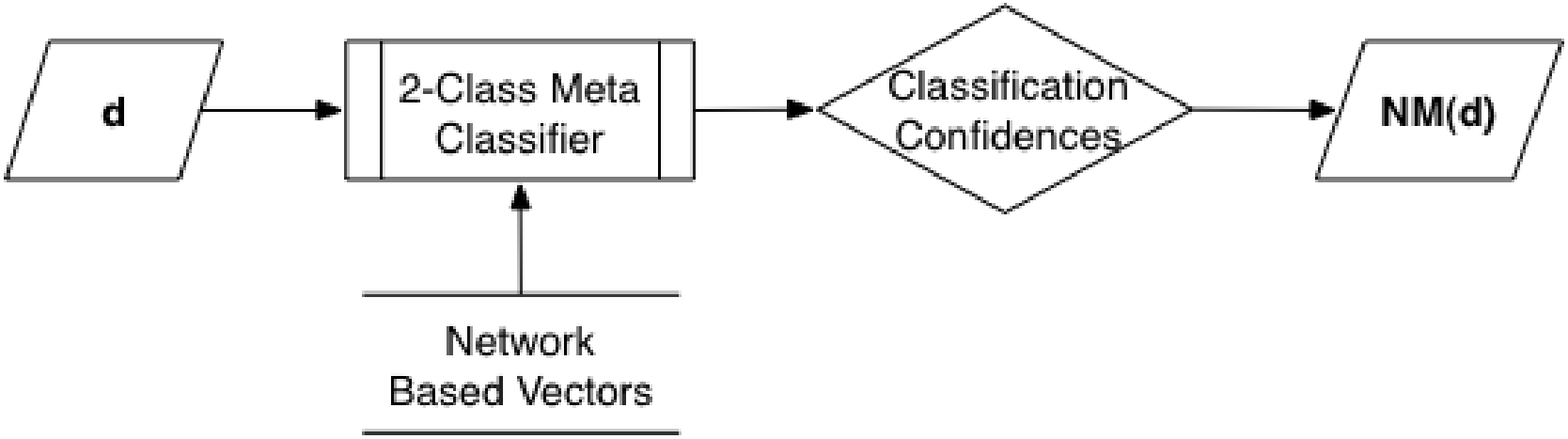
Notos computes three feature vectors for a RR, based on its RHIPs, RHDNs and Evidence data. The analysis of these feature vectors is forwarded to the reputation engine.



These 3 vectors are the Network Based Feature Vector [18], Zone Based Feature Vector [17] and the Evidence Based Feature Vector [6].

Network Profile Modeling

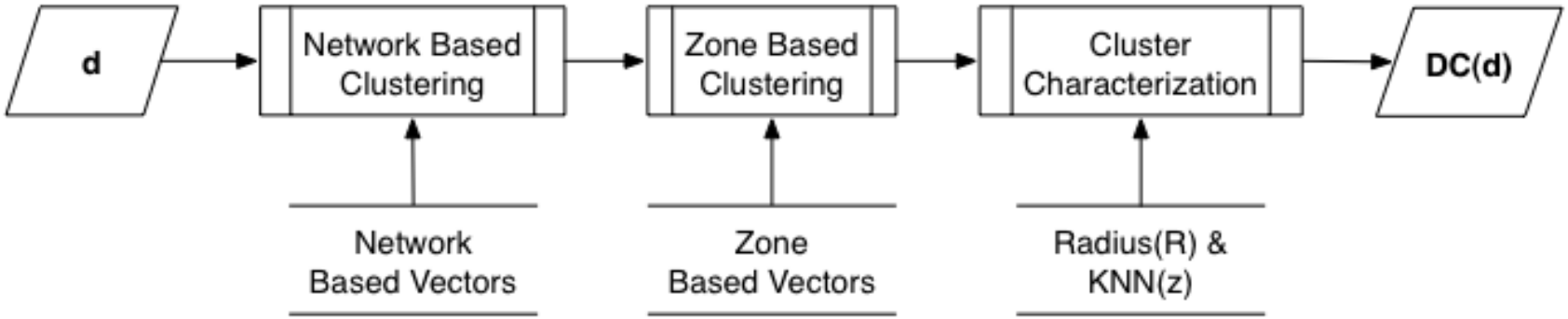
- Train a Meta-Classifier based on the 5 anchor-classes
- The network feature vector of a domain name *d* is translated into the network modeling output *(NM(d))*



The *NM(d)* is a feature vector composed from the confidence scores for each different anchor-class

Domain Clustering

The network and zone based feature vectors of a domain *d* are used to produce the domain clustering output *(DC(d))*



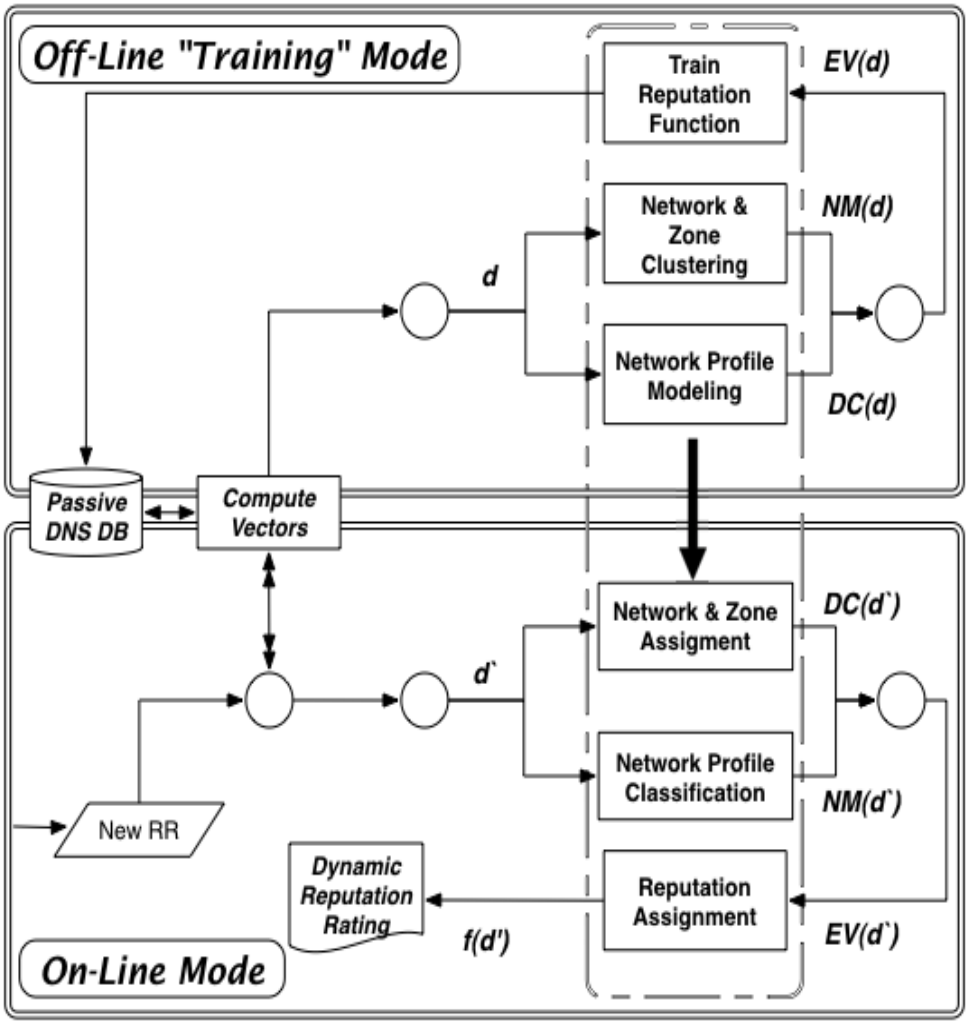
In this step we are able to **characterize** unknown domains within clusters based on already labeled domains **in close proximity**. The *DC(d)* is a 5-feature vector characterizing the position of *d* in the cluster.

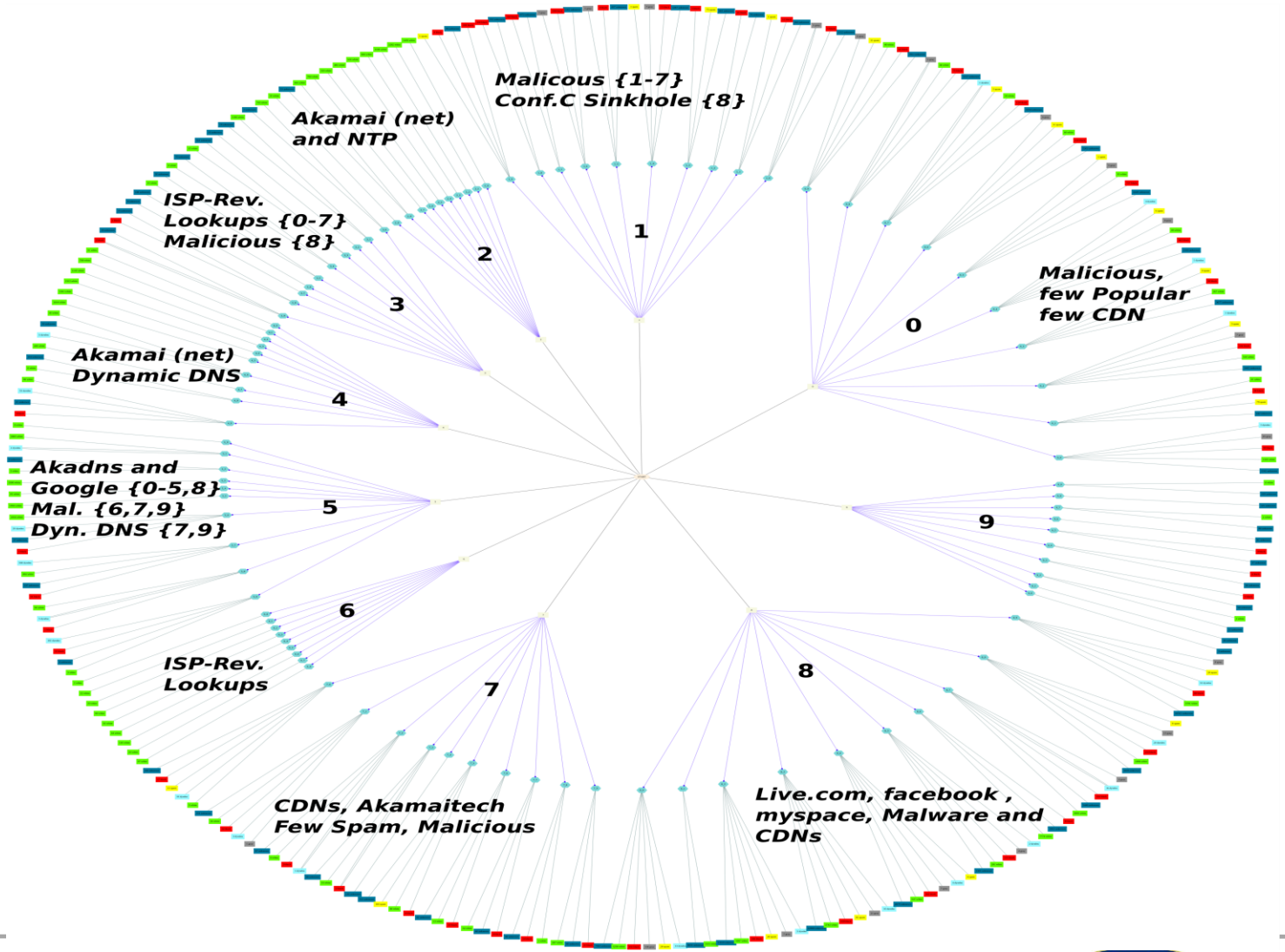
Reputation Function

- Each domain *d* in our dataset is transformed into three feature vectors by Notos: *NM(d)*, *DC(d)* and *EV(d)* (evidence profile output); these vectors assemble the reputation vector *v(d)*
- The reputation function *f(v(d))* assigns a score to the domain name *d* between [0,1]
- The reputation function is a statistical classifier (Decision Tree with Logistic Boost - after model selection)
- The reputation function is trained using labeled domain data

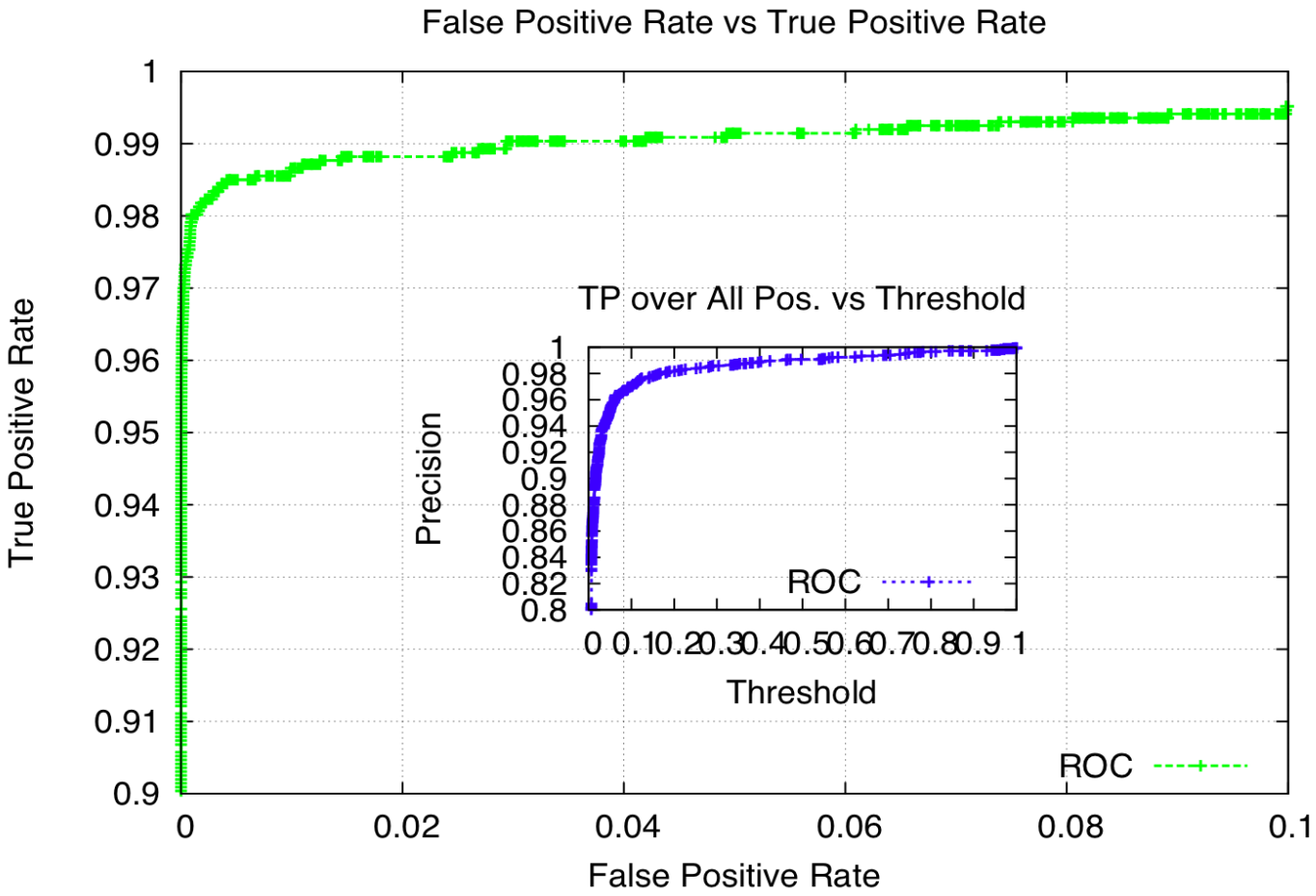
Operational Model of Notos

- Notos utilizes the **Off-line mode** to train classifiers, build the clusters and train the reputation function
- In the **In-line mode**, Notos assigns reputation to new RRs observed at the monitoring point




Malicous {1-7}
Conf.C Sinkhole {8}
Akamai (net)
and NTP
ISP-Rev.
Lookups {0-7}
Malicious {8}
Malicious,
few Popular
few CDN
Akamai (net)
Dynamic DNS
Akadns and
Google {0-5,8}
Mal. {6,7,9}
Dyn. DNS {7,9}
ISP-Rev.
Lookups
CDNs, Akamaitech
Few Spam, Malicious
Live.com, facebook ,
myspace, Malware and
CDNs
1
2
3
4
5
6
7
8
9
0

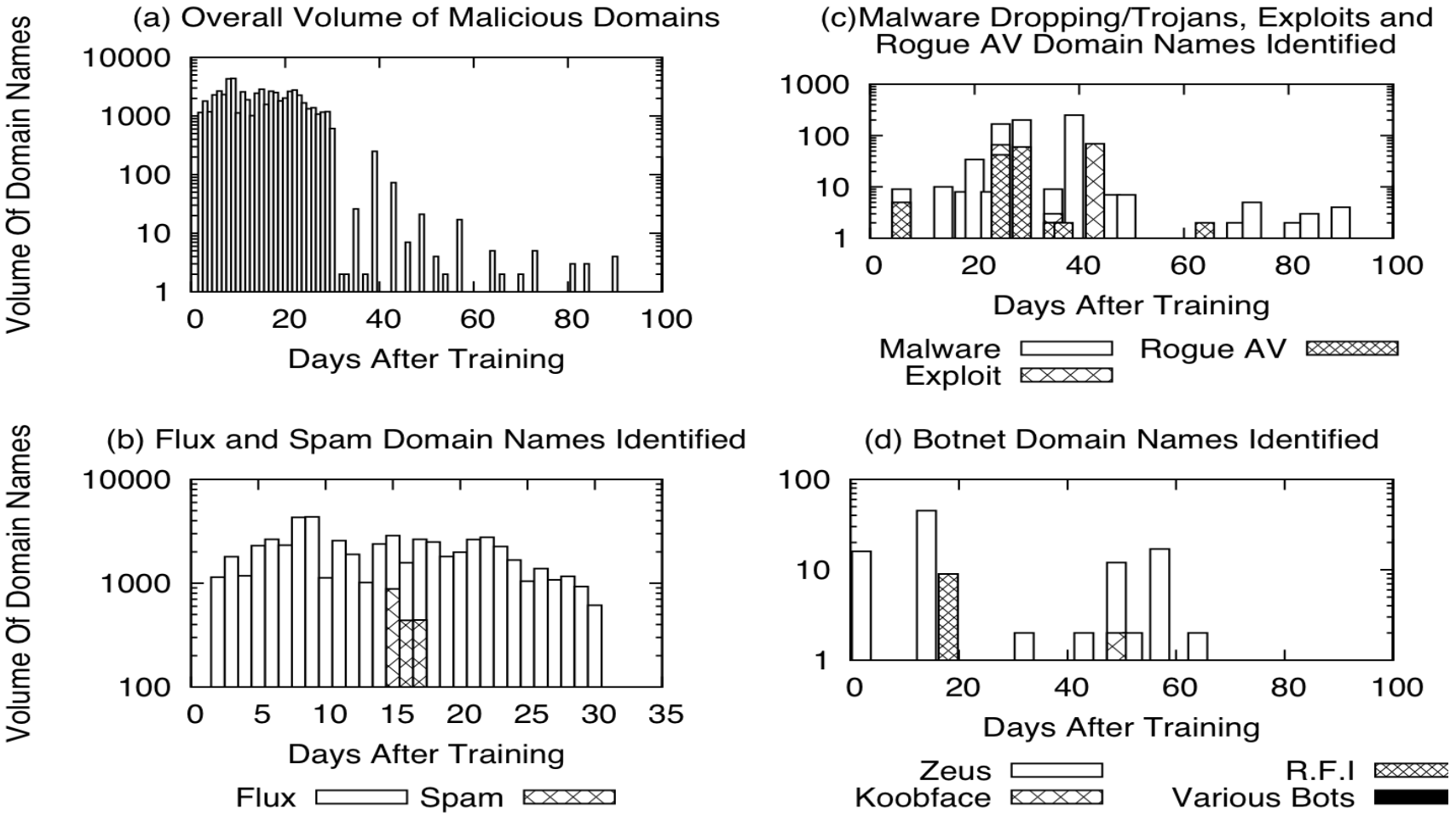
Results from the Reputation Function



FP%=0.3849% and TP%=96.8%

Results from the Reputation Function (cont'd)

of days the detection earlier than public BLs



Tech Transfer

- Damballa is actively evaluating Notos
- ISPs are interested in having us extend this line of research
- DNS vendors and other network operators
  - Have been spending millions of $ and years trying to build similar system, but fail to match Notos' capability/performance
  - Trying to get Notos technologies

Conclusions and Future Work

- Conclusions:
  - Combining network, zone, and evidence features provides the ability to dynamically associate unknown domains to known domains/networks
    - Benefits: with limited labeled domains we can identify new malicious ones, **much sooner than BLs**
- Future Work:
  - Targeted detection: use an additional clustering step based on association with specific fraudulent domain name class (RBN, Zeus, etc.) to enable targeted detection
  - Combine Notos with Spam/Flux detection systems