CloudAV

Malware Analysis in the Network Cloud

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Introduction

- Jon Oberheide
  - Advisor: Farnam Jahanian
  - 2nd year PhD at U of M (BS, MS)
- Research
  - Focus on modern security threats to organizational and enterprise networks
  - http://www.eecs.umich.edu/fjgroup/

Roadmap

- **Motivation and Limitations of Antivirus**
- AV as an In-Cloud Network Service
- Deployment and Evaluation
- Discussion and Future Directions

Modern Security Threats

- Security threats costly to organizations
  - Sensitive data theft, PII leakage
  - Detection and cleanup of compromised machines
  - Effective forensics takes expert skill and tools
- Threats often result of malicious software
  - Increasing sophistication and scale of malware
  - Using both technical and social techniques
  - Multi-vector C&C, propagation, and exploitation

Detect/mitigate malware → Save resources/time/money

Current Approach

Antivirus is the predominant method of detecting and mitigating malicious software

- Host-based antivirus
  - Installed on every end host in organization
  - Single vendor selection, eg. McAfee at U of M
- Attackers winning the malware arms race
  - If dedicated security vendors are having trouble, how is your department expected to keep up?

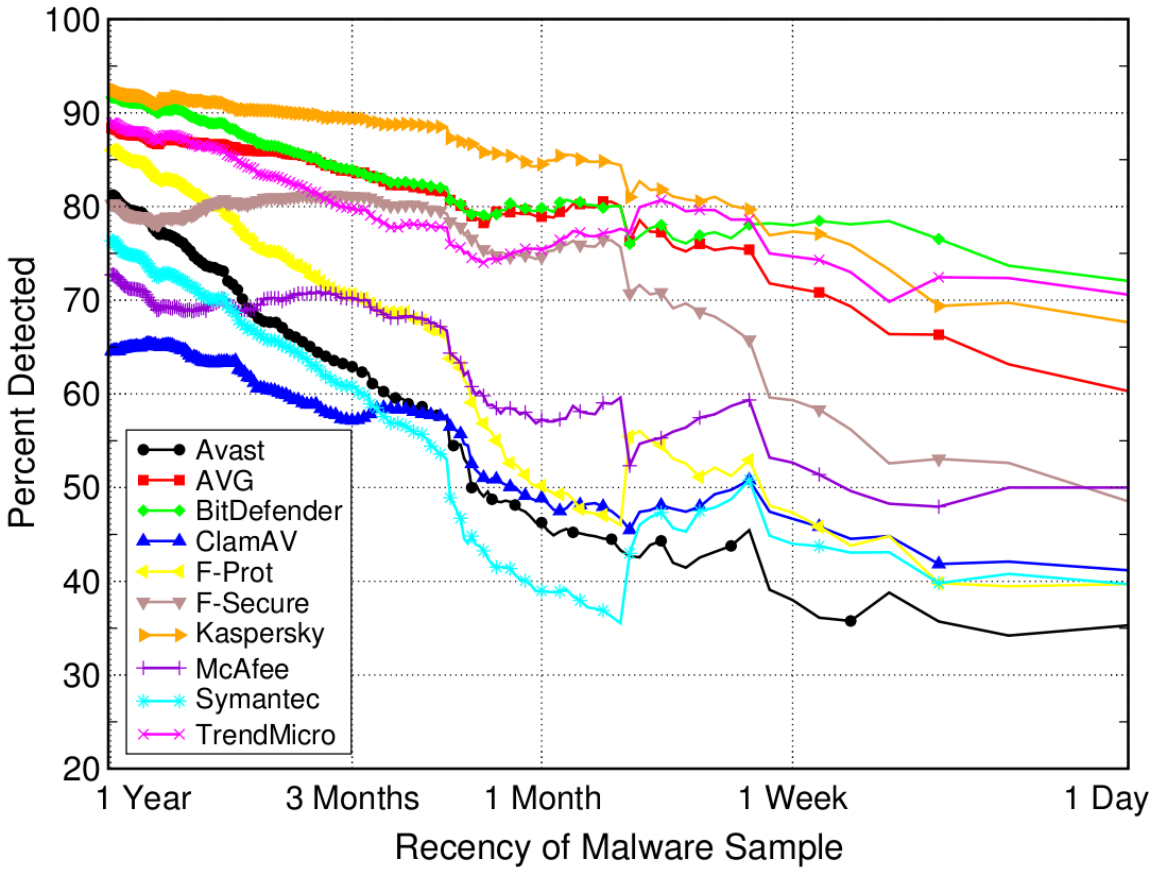
Antivirus Limitations

- Detection Coverage
  - Dismal detection rates
  - Slow response to emerging threats
  - Disjoint detection/collection methods
- Software Vulnerabilities
  - Complexity leads to security risk
  - Local and remote exploits
  - Inherently high privileges

Antivirus	Detected
Avast	**84.7%**
ClamAV	**59.7%**
F-Prot	**79.9%**
F-Secure	**86.6%**
Kaspersky	**85.3%**
McAfee	**54.9%**
Symantec	**81.9%**
Trend Micro	**82.0%**

Arbor Malware Library (AML) dataset of 7220 samples (Nov.'06 – Nov.'07)

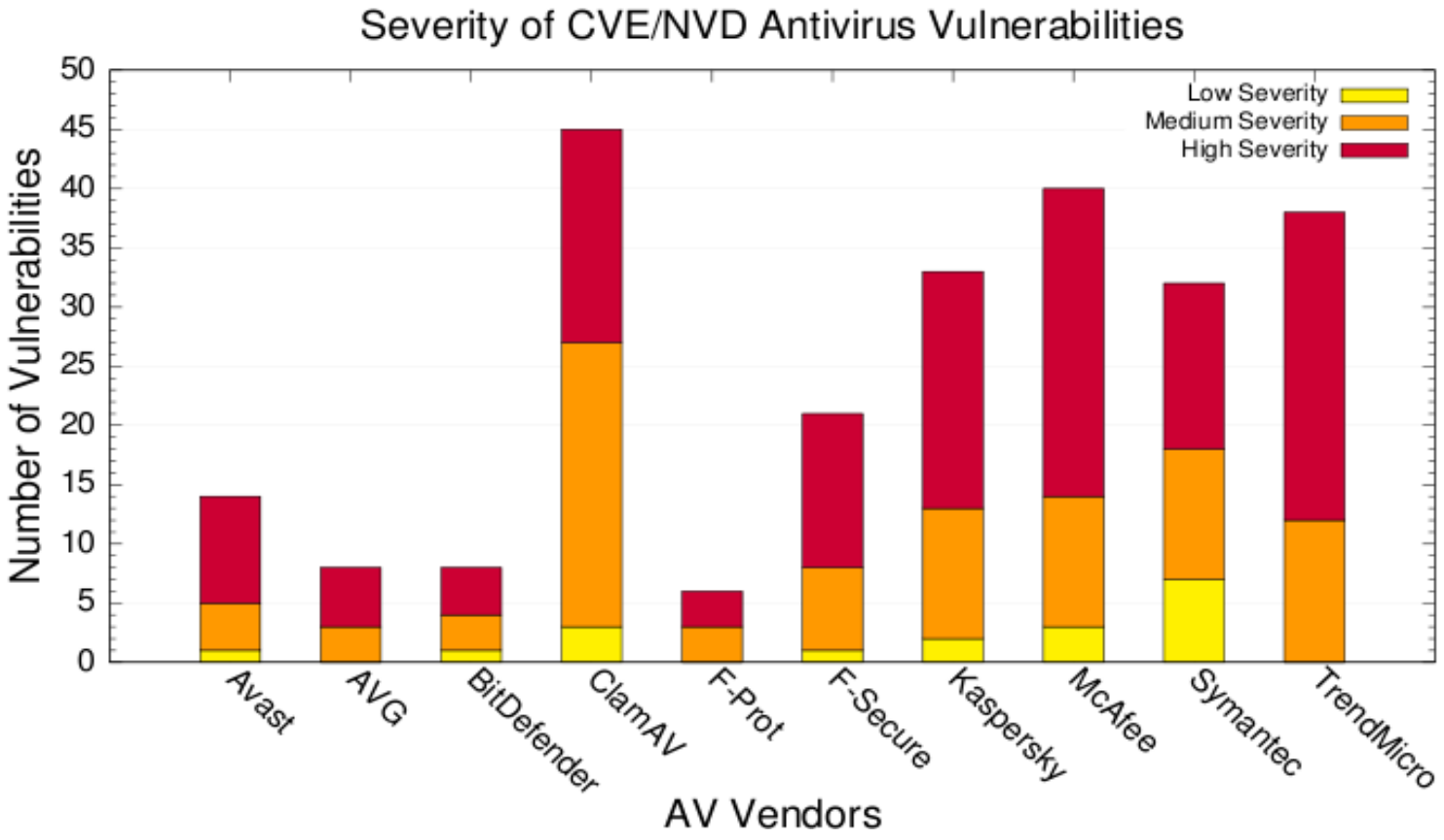
Detection Degradation



Antivirus detection coverage degrades significantly as threats approach 0-day

Software Vulnerabilities

Antivirus software is listed as one of the top 20 threats of 2007 according to SANS



Antivirus Limitations

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Leverage detection capabilities from multiple vendors

Need isolation between end host and analysis engines

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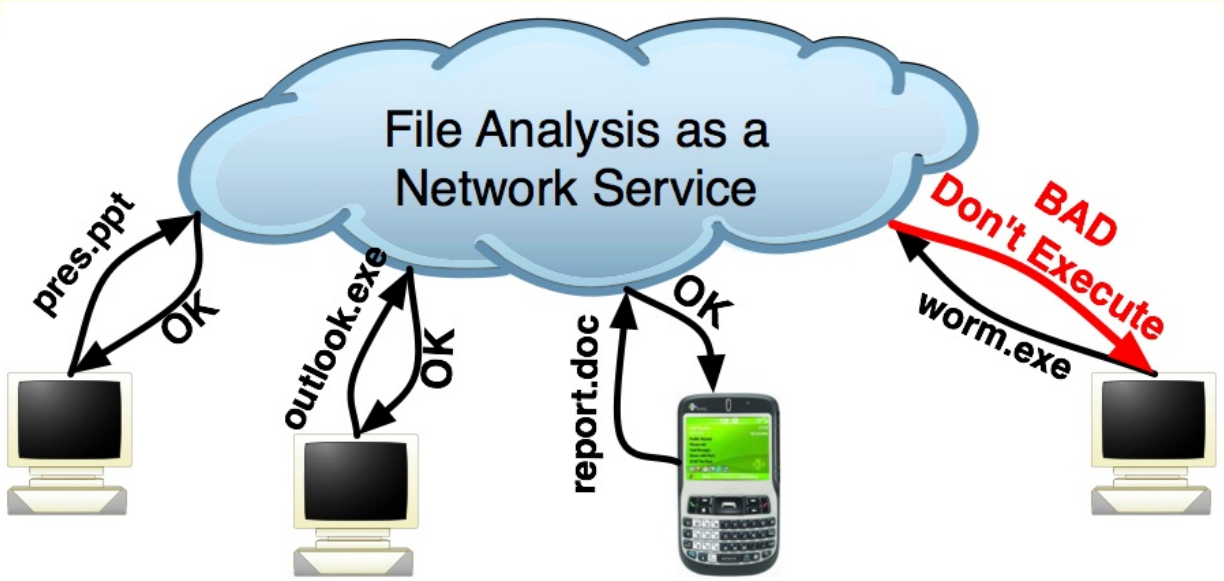
AV as a In-Cloud Network Service

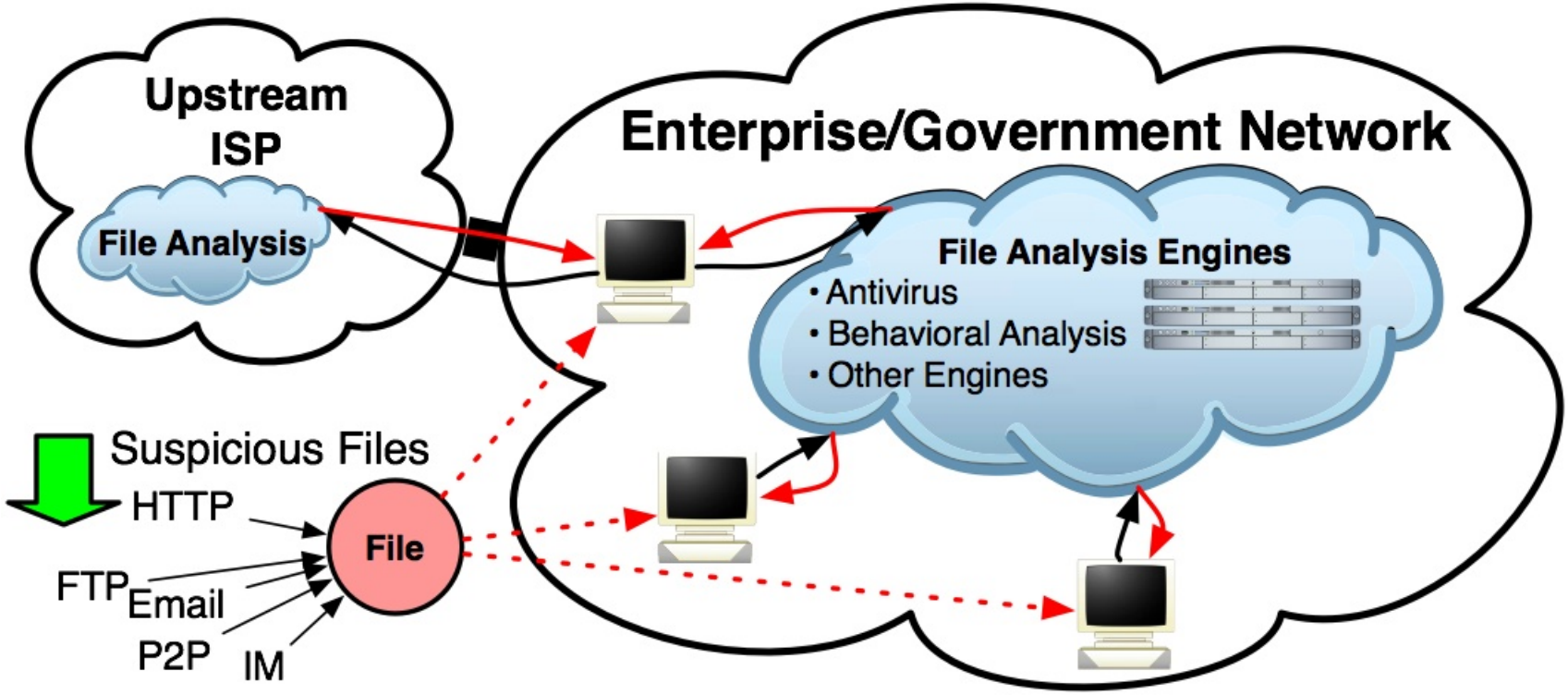
Network Component

Host Component



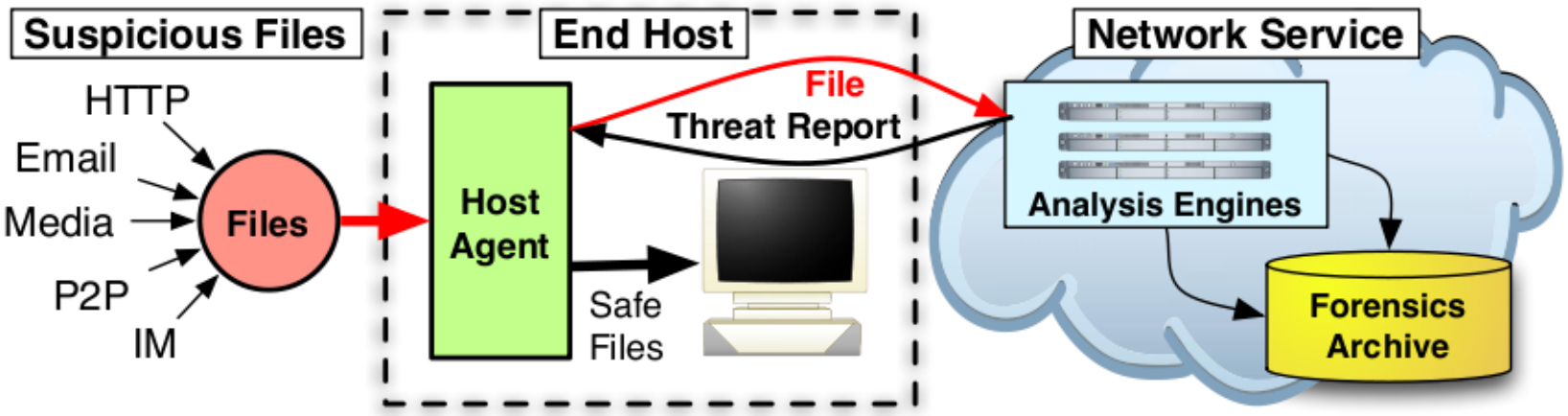
- By providing antivirus as an in-cloud service:
  - Analyze files using **multiple detection engines** in parallel
  - Collect **forensic data** for post-infection assessment
  - Centralize **policy enforcement** and management
  - **Simplify host software** for wide deployability

Deployment Model



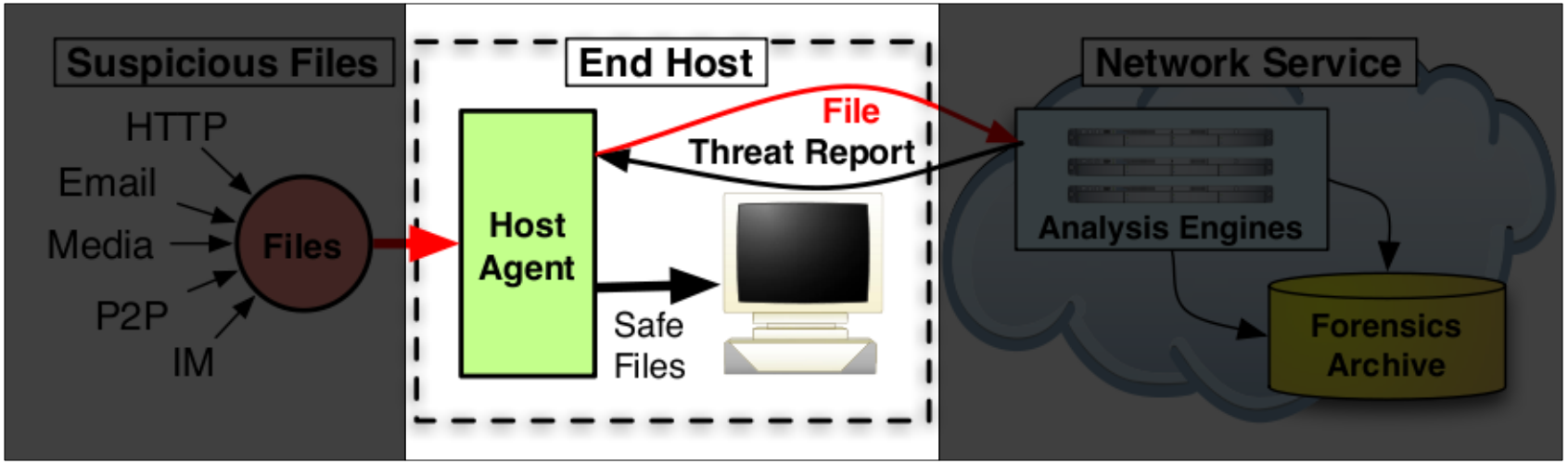
- Network service can be deployed inside an organization or by an upstream ISP

Architecture



- ***Lightweight host agent*** runs on desktops, laptops, and other devices
- ***Network service*** hosts the backend file analysis engines and fields requests from the host agent.
- ***Archival and forensics service*** stores information on file analysis results and provides a query and alerting interface

Architecture



- ***Lightweight host agent:***
  - Access to each file is trapped and diverted to a handling routing
  - Generate a unique identifier for the file (eg. cryptographic hash)
  - Compare UID to local and remote cache of previously analyzed files; send file to network service if not in either cache

Simplified Host Agent

Key insight: separate acquisition of files from detection routines; move complexity off end host

- Small code base → reduced vulnerability footprint
- Isolation from vulnerabilities present in the detection engines
- Easier to port to new operating systems

Simplified Host Agent

Cross Platform

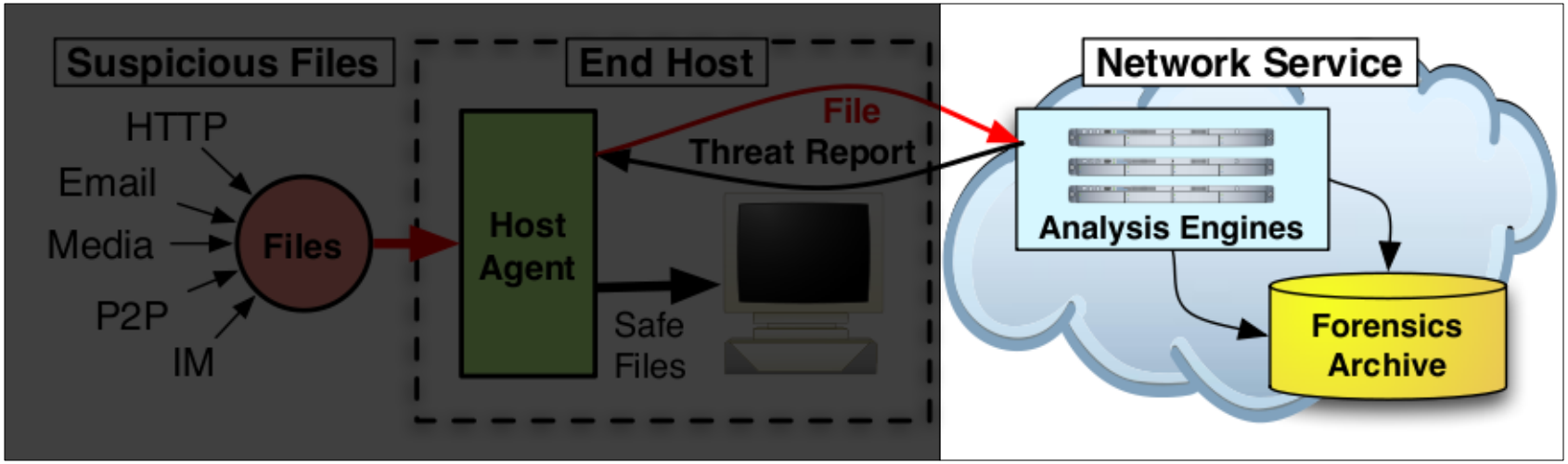



Mobile Devices

Mail Server Frontends




Architecture

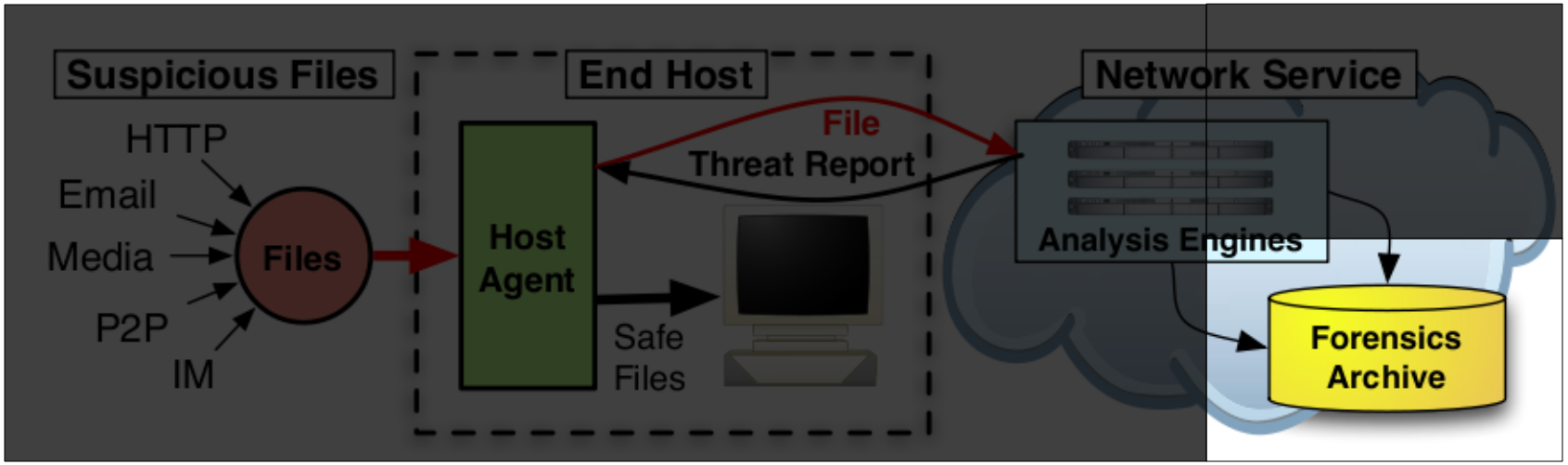


- ***Network service:***
  - Receives incoming analysis requests from host agent
  - File analyzed by collection of engines (N-version protection)
  - Central management of signatures updates and security policies
  - Shared remote cache maintained in network service

N-Version Protection

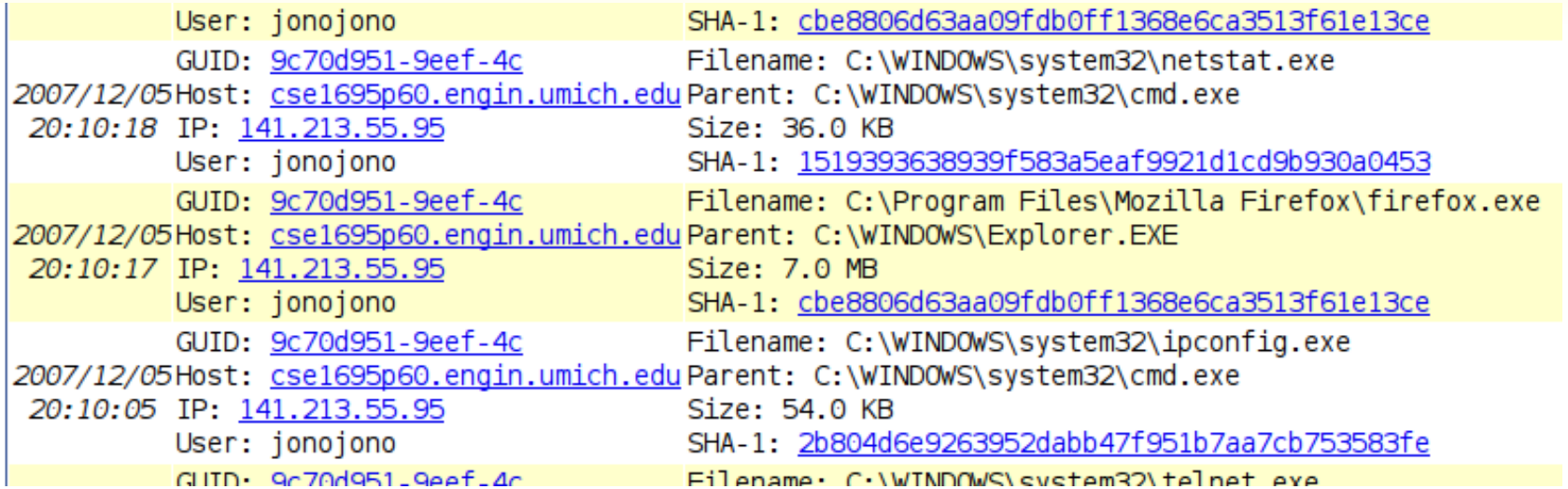
- N-version programming
  - Multiple, independent implementations for robustness and reliability
  - Observation: independent implementations are unlikely to suffer same failures/bugs
- N-version protection
  - Multiple, independent implementations for the detection of malware
  - Observation: independent vendors have heterogeneous detection routines, malware collection methodologies, and response times
  - Leverage heterogeneity to increase coverage

Architecture



- ***Archival and Forensics Service:***
  - Forensics tracking of file access
  - Network-wide policy enforcement (for example: block unwanted applications, prevent execution of an email attachment)
  - Management interface for alerting and report generation

Forensics Archive



	User: jonojono	SHA-1: cbe8806d63aa09fdb0ff1368e6ca3513f61e13ce
2007/12/05 20:10:18	GUID: 9c70d951-9eef-4c Host: cse1695p60.engin.umich.edu IP: 141.213.55.95 User: jonojono	Filename: C:\WINDOWS\system32\netstat.exe Parent: C:\WINDOWS\system32\cmd.exe Size: 36.0 KB SHA-1: 1519393638939f583a5eaf9921d1cd9b930a0453
2007/12/05 20:10:17	GUID: 9c70d951-9eef-4c Host: cse1695p60.engin.umich.edu IP: 141.213.55.95 User: jonojono	Filename: C:\Program Files\Mozilla Firefox\firefox.exe Parent: C:\WINDOWS\Explorer.EXE Size: 7.0 MB SHA-1: cbe8806d63aa09fdb0ff1368e6ca3513f61e13ce
2007/12/05 20:10:05	GUID: 9c70d951-9eef-4c Host: cse1695p60.engin.umich.edu IP: 141.213.55.95 User: jonojono	Filename: C:\WINDOWS\system32\ipconfig.exe Parent: C:\WINDOWS\system32\cmd.exe Size: 54.0 KB SHA-1: 2b804d6e9263952dabb47f951b7aa7cb753583fe
	GUID: 9c70d951-9eef-4c	Filename: C:\WINDOWS\system32\telnet.exe

- Contextual file access info
  - Temporal and causal relations between events
  - Drill down to *who/what/where/when* of infection
- Detailed runtime behavioral profiles
  - Enhanced *what*: feedback from behavioral engines
  - Assists in post-infection cleanup and risk assessment

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Implementation – Host Agent

- Platforms:
  - Windows 2000/XP/Vista, Linux 2.4/2.6, FreeBSD 6
  - Milter frontend interface (Sendmail, Postfix)
  - Nokia Maemo mobile platform
- Win32 host agent
  - Win32 API hooking (jmp insertion, IAT/EAT patching)
  - ~1500 LOC, 60% managed code
  - Co-exists peacefully with existing AV engines
- Linux/BSD host agent
  - Python, < 300 LOC, LSM syscall hooking

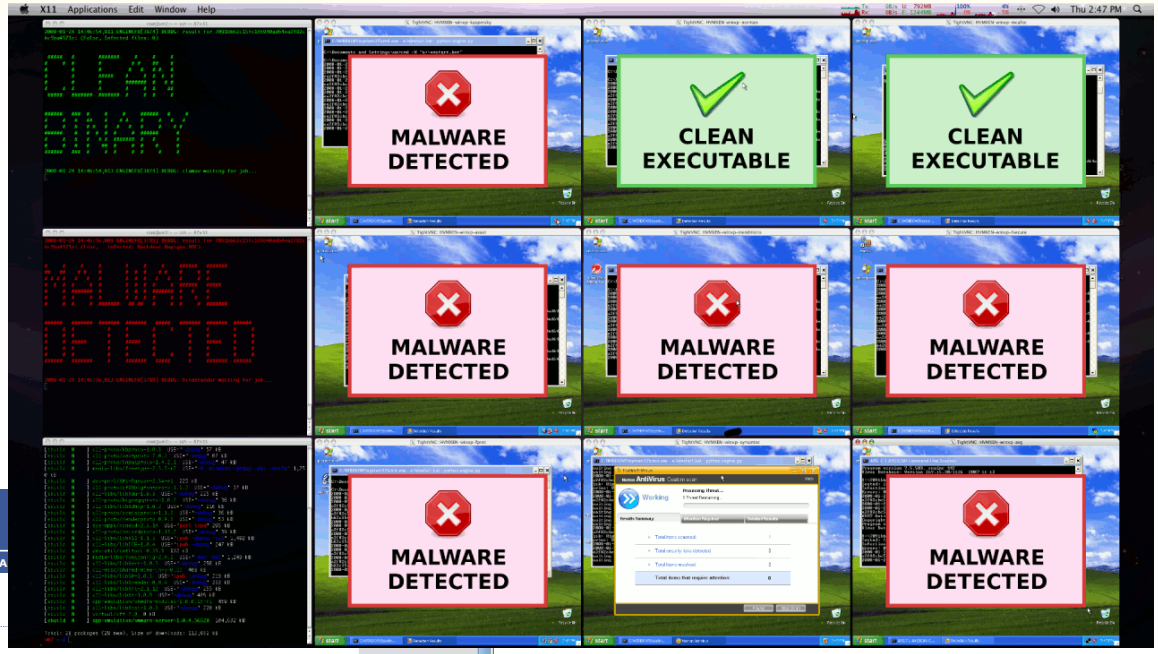
Implementation – Network Service

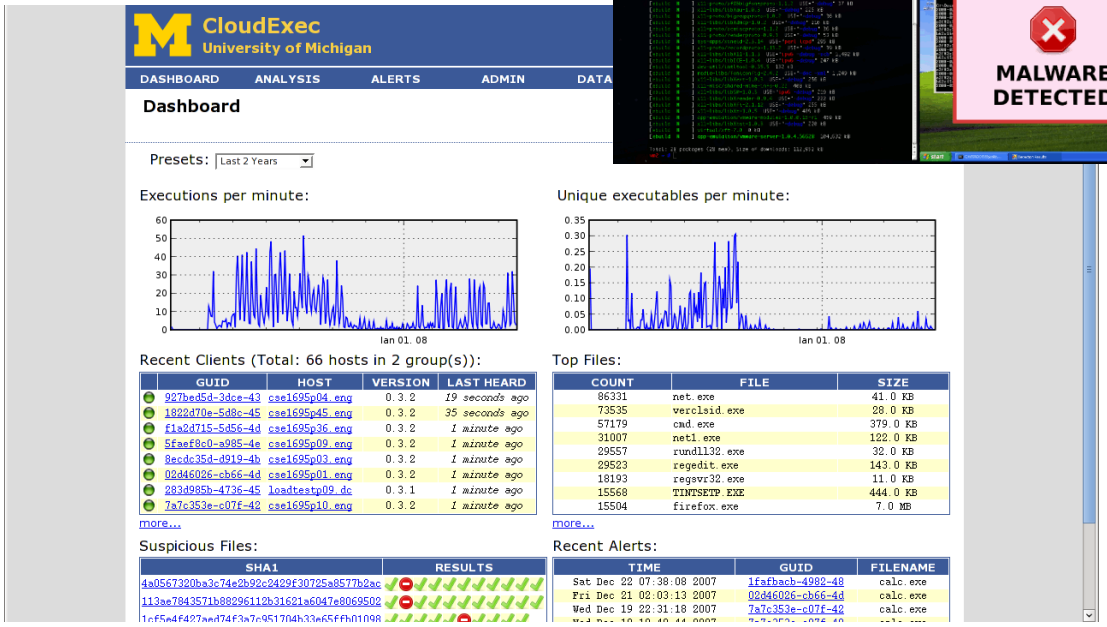
- Backend analysis engines
  - 10 antivirus engines:
    - Avast, AVG, BitDefender, ClamAV, F-Prot, F-Secure, Kaspersky, McAfee, Symantec, Trend Micro
  - 2 behavioral engines
    - Norman Sandbox, CWSandbox
- Hosted in Xen VM containers
  - 9 WinXP HVM, 3 Linux domU paravirt
  - Isolation/Recovery: in case of engine compromise
  - Scalability: dynamically spin up/down instances

Management Interfaces

Web interface:

- Forensics Drilldown
- Policy Enforcement
- Flexible Alerting
- Report Generation





VM Monitoring:

- Real-time System Status
- Xen VM Management
- Visualization Eye-Candy!

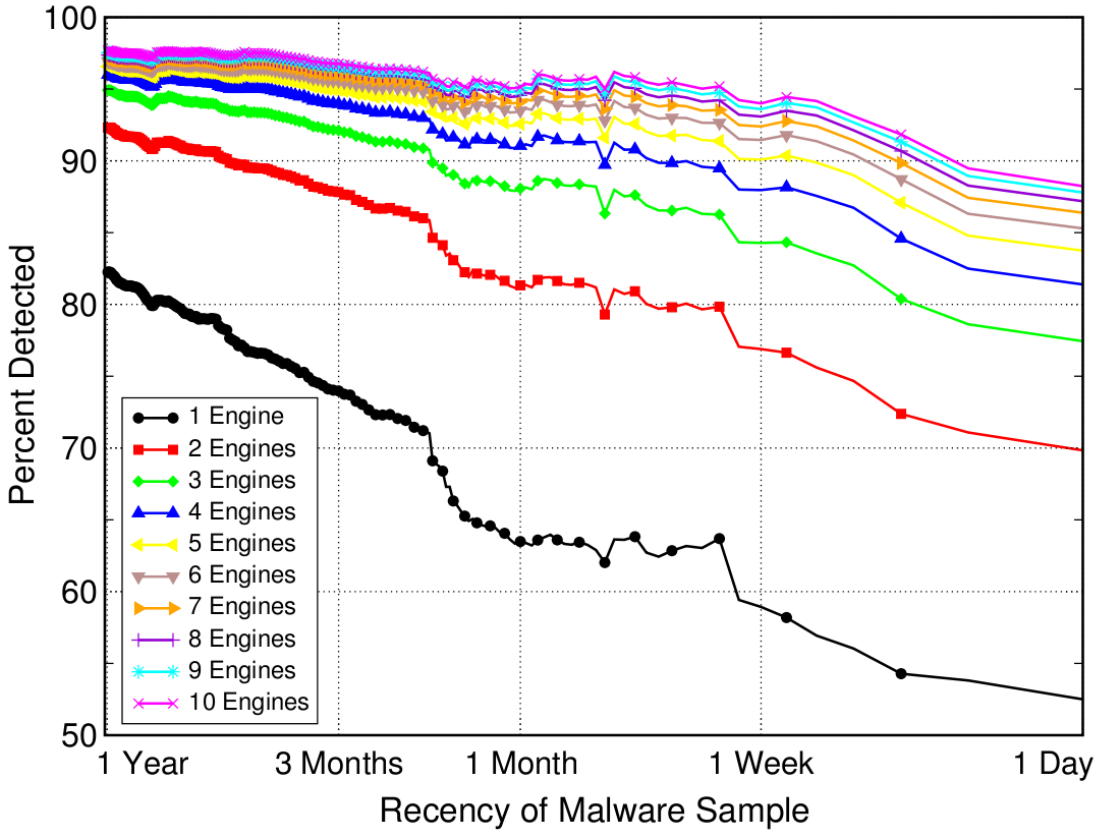
CloudAV Deployment

- Production deployment of CloudAV on campus network at U of M
- Win32 agent deployed in CAEN computing labs in CSE building and Duderstadt Center
- Observing over 20k events/day, approximately 3 million events total

Evaluation

- Malware Dataset
  - Arbor Malware Library (AML)
  - 7220 malware samples
  - Collected over a year period
  - Honeypots, honeyclients, spam traps, etc
- Deployment Results
  - CAEN deployment
  - Over 6 months of data

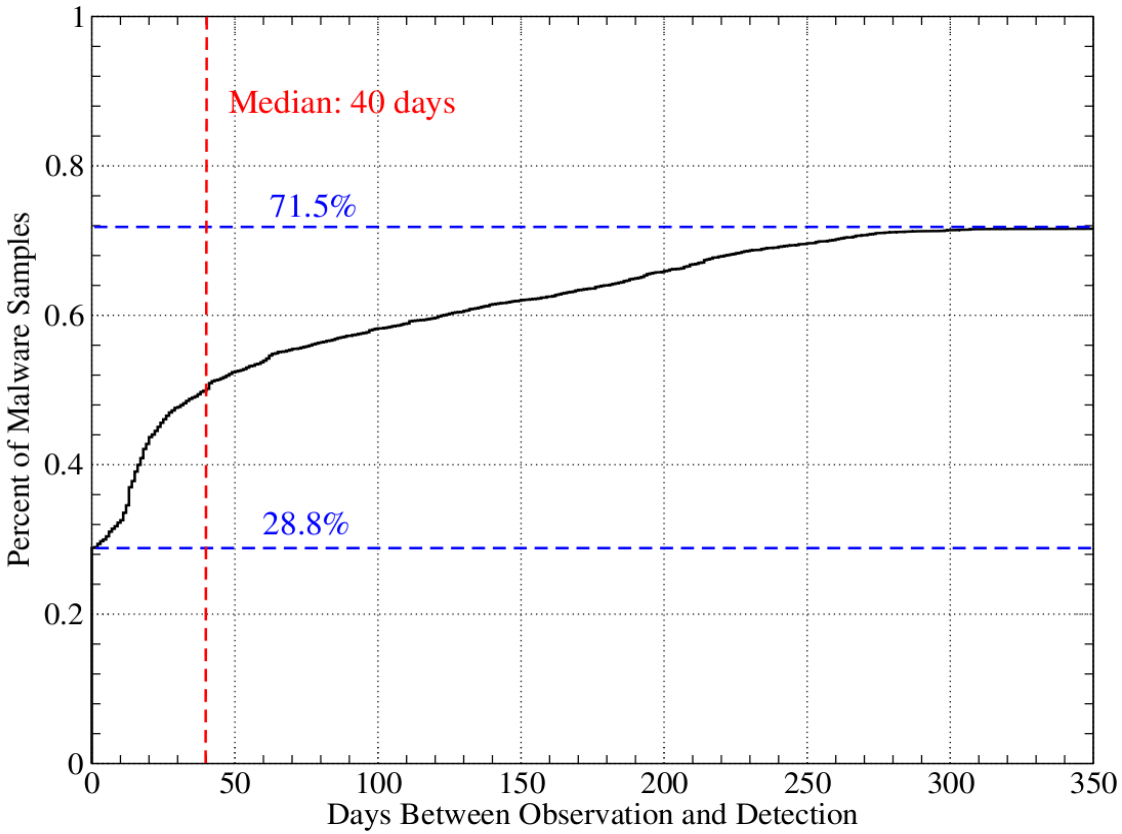
N-Version Protection



- **Single engine from 82% to 52%**
- **Ten engines from 98% to 88%**
- **For zero-day 88% vs. 52%**
- **Diminishing marginal utility**

Detection rates are calculated by taking the average rate across all combinations of N engines.

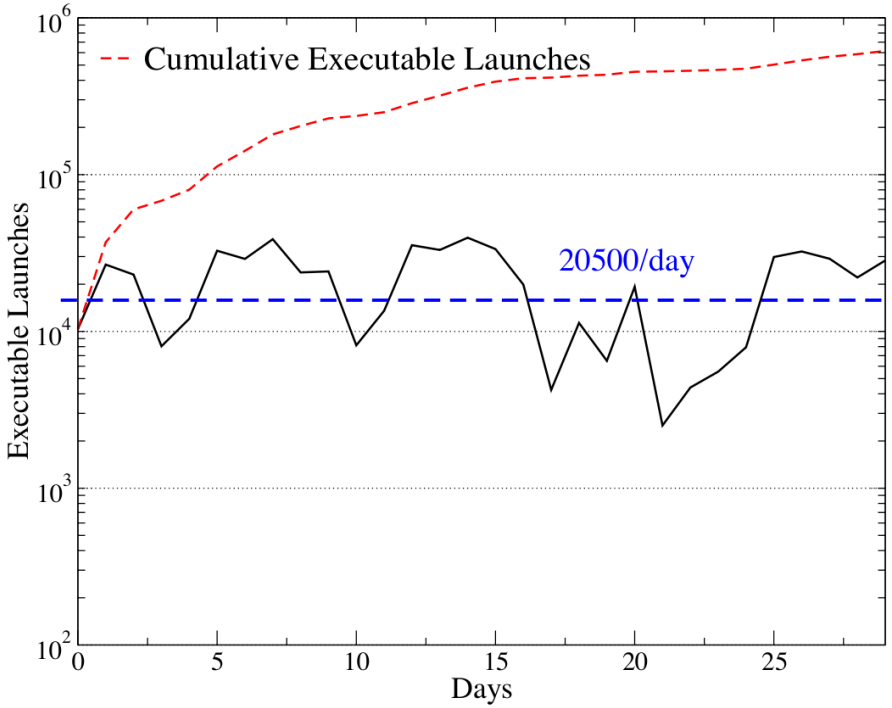
Vulnerability Window



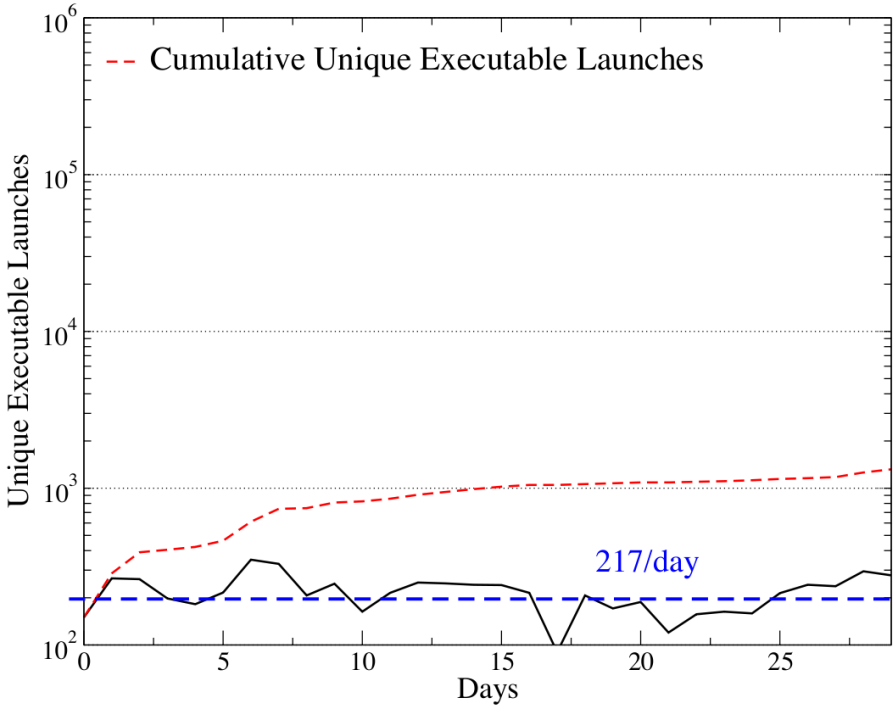
- **AML data set + year's log of McAfee DAT signature files with 1-week granularity**
- **100 new malware samples detected by McAfee per week**
- **5147 out of 7220 eventually detected by McAfee**

Average time between observation and detection of a malware sample is 48 days.

Caching and Performance



615K execution events



1300 unique executables

99.8% remote cache hit rate: files rarely need to be transferred to network service for analysis

Bandwidth and Latency

- Boot Process: 10 processes
  - Warm local: none
  - Warm remote: 8.7 kb
  - Cold remote: 406 kb
- Login process: 52 processes
  - Warm local: none
  - Warm remote: 46.2 kb
  - Cold remote: 12.5 mb
- Comparison: Active Directory (LDAP)
  - Boot: 171 kb
  - Login: 270 kb
- Average binary analysis time:
  - 1.3 seconds

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Discussion

- Disconnected operation
  - Local caching, policy decision
- False positives
  - Engine thresholds
  - Centralized whitelist management
- Detection engine licensing
  - Price/performance
  - Free engine addition (ClamAV)
  - Breaking free of vendor lock-in
- Privacy implications
  - Tunable collection and display

Threshold	False Positives	Detection
1	12	97.7%
2	5	96.3%
3	2	95.2%
4	0	93.9%

AV Vendor	1 Week
Avast	+24.6%
AVG	+8.7%
BitDefender	+3.1%
ClamAV	+0.0%
F-Prot	+12.6%
F-Secure	+15.0%
Kaspersky	+2.3%
McAfee	+14.2%
Symantec	+20.6%
Trend Micro	+12.6%

In-Cloud Security Services

The bigger picture: migrate certain security services into the network cloud

Adhoc solution → In-Cloud solution

- Inherent in-cloud advantages
  - Global visibility
  - Centralized management
- Past in-cloud services
  - Email filtering
  - DDoS mitigation
  - Inline UTM/IPS
- Future in-cloud services
  - HIDS
  - Phishing
  - Anomaly detection

Future Directions

- Novel approaches to difficult security problems
  - Enabled by evolution of network infrastructure
  - High speed interconnects, low latencies
- SSaaS: Security Software as a Service
  - Departments subscribing to centrally administered security services decreases cost/maintenance
  - Value of service increases as participants increase
  - Increases threat visibility, improved assessment
- Lastly, feedback from you!

Question and Answer

Questions?

- Contact information
  - Jon Oberheide
  - University of Michigan
  - jonojono@umich.edu
  - http://www.eecs.umich.edu/fjgroup/