

GridSec: Trusted Grid Computing with Security Binding and Self-Defense against Network Worms and DDoS Attacks

Presentation by Kai Hwang at the *International Workshop on Grid Computing Security and Resource Management (GSRM'05)* in conjunction with the ICCS 2005, Emory University, Atlanta, May 24, 2005.

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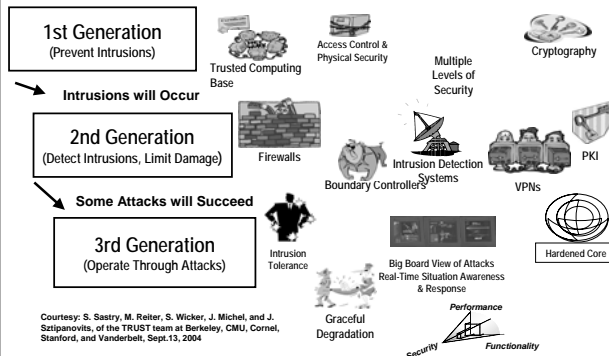
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Project web site: <http://GridSec.usc.edu/>



Presentation Outline:

- Introduction to NSF GridSec Project
- NetShield Architecture Development
- Collaborative Worm Containment
- Cardinality Counting for DDoS Defense
- Hot Topics for Trusted Grid Computing

Defense Technology Towards Cyberspace Security Assurance



Internet Epidemic Outbreaks in Recent Years

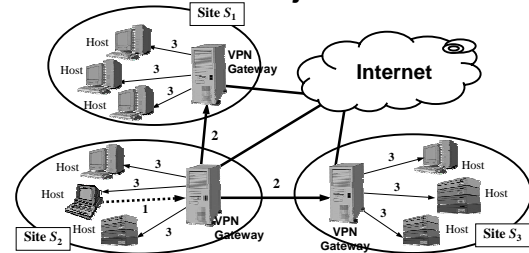
A pretty fast outbreak: Slammer (2003)

- First ~1min behaves like classic random scanning worm
 - Doubling time of ~8.5 seconds
 - CodeRed doubled every 40mins
 - >1min worm starts to saturate access bandwidth
 - Some hosts issue >20,000 scans per second
 - Self-interfering (no congestion control)
 - Peaks at ~3min
 - >55million IP scans/sec
 - 90% of Internet scanned in <10mins
 - Infected ~100k hosts (conservative)
- See: Moore et al, IEEE Security & Privacy, 1(4), 2003 for more details

Security and Privacy Demands in Internet Services and Grid Applications:

- Trusted E-Commerce over the Internet
- Secure communications in E-mail, FTP, etc.
- Protected download of digital contents
- System Intrusions and Network Anomalies
- Firewalls, packet filters, VPN gateways, traffic monitors, security overlays, PKI services, etc.
- Self-defense toolkits, middleware, overlays for defense against viruses, worms, and flood attacks
- Anonymity, confidentiality, data integrity, access control, resolving policy conflicts, etc.

GridSec: A Network Security Research Project at USC



- Steps for automated self-defense at resource site:
- > Step 1: Intrusion detected by host-based firewall /IDS
 - Step 2: All VPN gateways are alerted with the intrusions
 - Step 3: Gateways broadcast response commands to all hosts

Worms and DDoS Attacks Overview

- **Network Worms**
 - Self-propagating program across a network
 - Exploit vulnerabilities in widely-deployed homogeneous software
 - Various malicious payloads, e.g. host spam-relays, launch DDoS attacks, etc.
 - CodeRed in 2001, Slammer in 2003
- **Distributed Denial-of-Service (DDoS) Attacks**
 - Overwhelm victim's resources with high-volume traffic
 - Exploit Internet's unrestricted communication model
 - Could exploit victim's protocol vulnerability, e.g. TCP SYN flood, but do not have to, e.g. UDP flood
 - Often use worms to prepare and perform attacks automatically - CodeRed's attack against whitehouse.gov

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The NetShield Architecture with Distributed Security Enforcement over a DHT Overlay

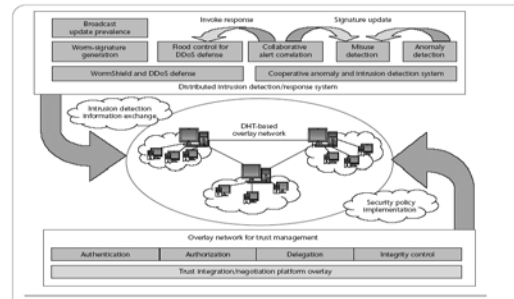


Figure 1. The NetShield system architecture and trust integration over a distributed hash table (DHT) overlay. The system performs trust management across multiple administrative domains, suppresses Internet worm outbreaks, and defends against flooding DDoS attacks.

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Internet Worm Containment :

Reduce Vulnerability: Preventing worms by upgrading software quality and reducing the system vulnerability.

Scan Detection: Filtering traffic destined at detected ports where worms appear to be scanning and spreading.

Hygiene Enforcement: Discovering infected hosts and keep susceptible hosts off network.

Signature Inference: Detecting payload content substrings to generate and disseminate signatures automatically and throttle to slow down the spread.

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The WormShield Built with a DHT-based Overlay with Six Worm Monitors [1]

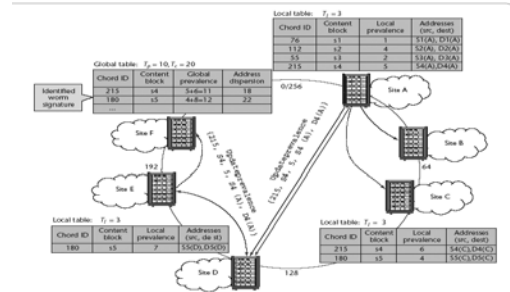


Figure 2. The WormShield architecture. In this example, six worm monitoring sites are deployed in six edge networks. This DHT-based overlay system performs distributed worm monitoring, anomaly detection, signature updating, alert correlation, and automated intrusion response.

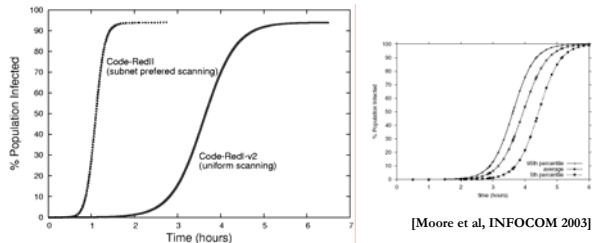
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Simulation Results

- Simulated CodeRed-like worms on an Internet configuration of 105,246 edge networks and 338,562 vulnerable hosts
- Use BGP table snapshot on July 19th, 2001 from RouteViews
- Simulated infection progress matches quite well with Moore's experimental results



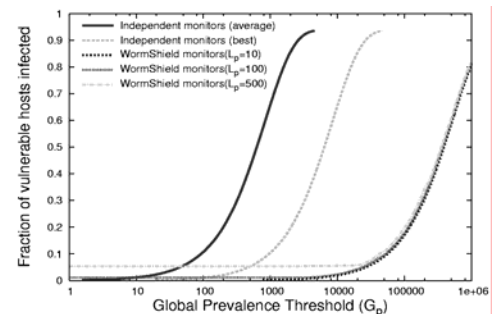
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Effects of Global Prevalence Threshold

- Collaborative monitors detect signatures about 10 times faster than using independent monitors when $G_p=10,000$



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WormShield Signature Generation Process

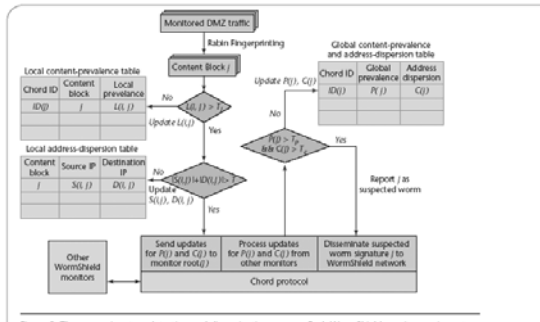


Figure 3. The worm-signature detection and dissemination process. Each WormShield monitor carries out three key mechanisms: local prevalence with address dispersion, global prevalence with address dispersion, and dissemination of suspected worm signatures.

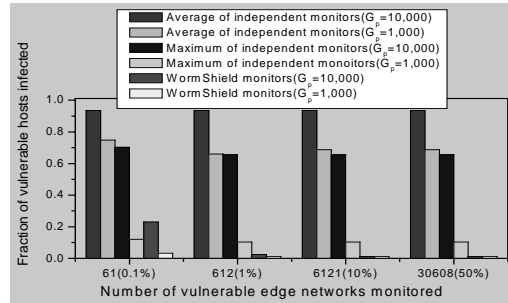
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Effects of % Edge Networks Monitored

- About 27 times reduction of infected hosts as 1% of vulnerable edge networks being monitored

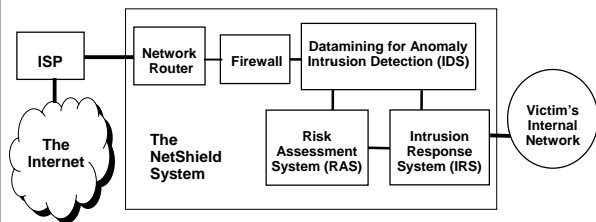


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USC NetShield Intrusion Defense System for Protecting Local Network of Grid Computing Resources

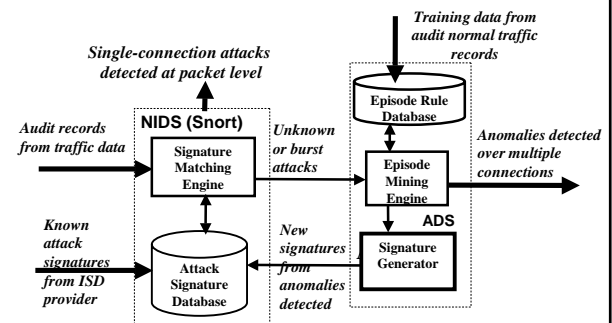


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A Collaborative Anomaly and Intrusion Detection System (CAIDS), built with the Snort and an Anomaly Detection System at USC Internet and Grid Computing Lab in 2004 [2]

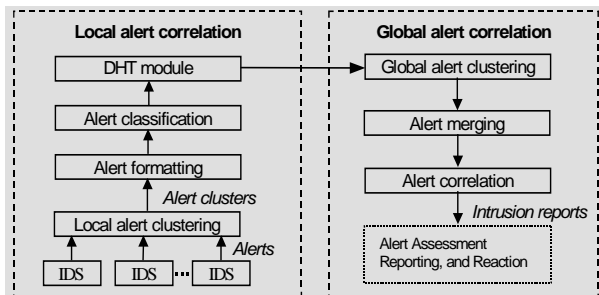


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Alert Operations performed in local Grid sites and correlated globally

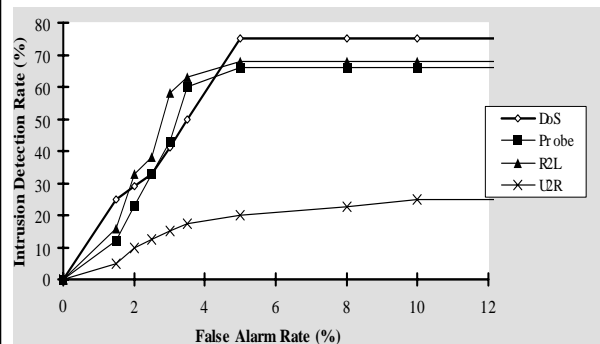


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ROC Curves for 4 Attack Classes on The Simulated CAIDS



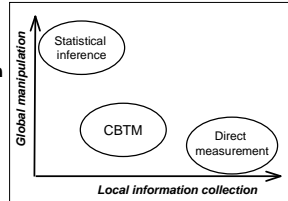
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Cardinality-Based Traffic Matrix Estimation

- Traffic Matrix (TM) for diagnosing deliberate network anomalies
- Need to obtain TM in a fast and accurate manner
- Both packet-level TM (PTM) and flow-level TM (FTM)
 - Unusual increase in small flows, e.g. flooding attacks and scanning worms
- Limitations of existing TM estimation approaches
 - Not accurate enough (10% avg. error)
 - Not fast enough (hourly)
 - PTM only
- Two steps: local information collection by global manipulation
 - Statistical inference
 - Direct measurement
- Cardinality-Based TM Estimation (CBTM) – A balanced method



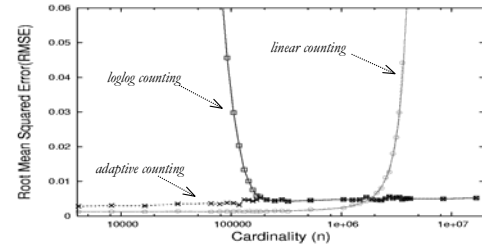
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Scalability of Adaptive Counting

- **Root Mean Squared Error (RMSE)**, reflects both bias and standard error
- Same memory (320Kbit) for three algorithms
- Cardinalities vary from 4K to 16M
- Scalable to both small cardinalities and large ones



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Packet-Level and Flow-Level Internet Traffic Monitory for Worm and DDoS Flooding Control

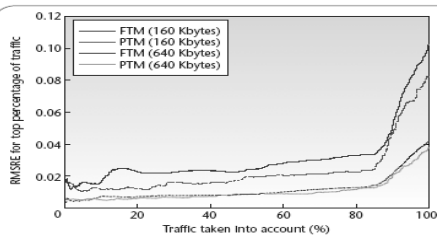


Figure 5. Root mean squared relative error (RMSRE) of packet-level (PTM) and flow-level traffic matrix (FTM) elements for various percentages of traffic. It is generally easier to accurately estimate large TM elements than small ones; accuracy improves significantly for PTM and FTM as the top percentage of traffic taken into account decreases.

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Packet/Flow Counting for Tracking Attack-Transit Routers (ATRs)

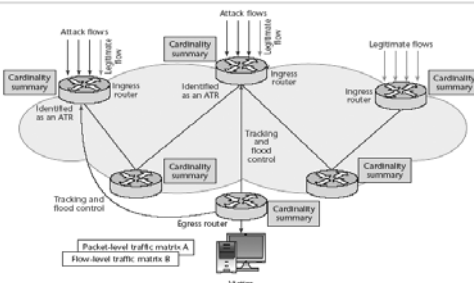


Figure 6. Traffic matrix monitoring for tracking attack-transit routers (ATRs). Collaborative routers can perform distributed tracking of ATRs by correlating the packet-level (PTM) and flow-level traffic matrix (FTM). Here, the egress router identifies two potential ATRs by correlating the PTM and FTM.

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Hot Topics for Grid Security Research:

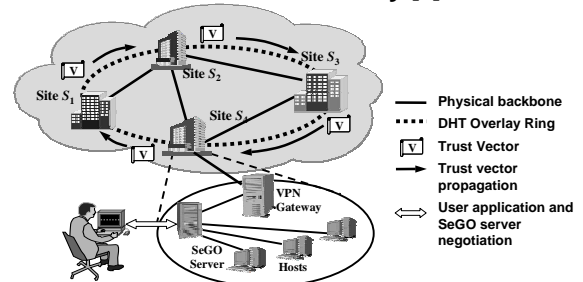
- The Fuzzy Trust Model for security binding and trust integration [3] and the Game-theoretic Model for modeling selfish and non-cooperative Grids [4].
- Large-scale security benchmark experiments on the NSF/HSD DETER testbed towards sustainable cybertrust in real-life Internet and Grid applications.
- Internet datamining for security control and for guarantee of Quality-of-Service in real-life applications – Interoperability between wired Grids and wireless Grids is a wide-open area.

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Fuzzy Aggregation for Trust Integration over a DHT Overlay [3]



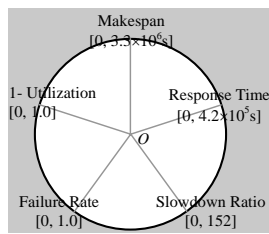
Cooperating gateways working together to establish VPN tunnels for trust integration

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Performance Metrics for Trusted Grid Computing

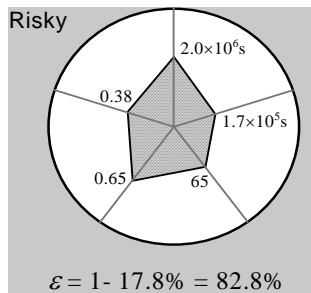


Effects of Fuzzy Trust Integration

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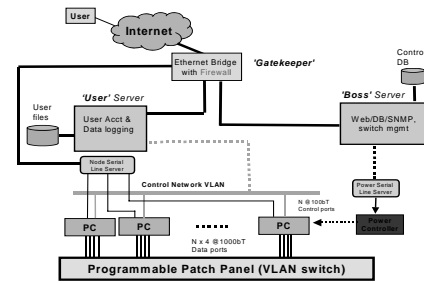
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$$\varepsilon = 1 - 17.8\% = 82.8\%$$

DETER Testbed Benchmark Experiments



DETER Project - Aug 04

DETER Testbed funded by the National Science Foundation (NSF) and the Department of Homeland Security (DHS)

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Final Remarks

- The NetShield built with DHT-based security overlay networks support distributed intrusion and anomaly detection, alert correlation, collaborative worm containment, and flooding attack suppression.
- The CAIDS can cope with both known and unknown network attacks, secure many cluster/Grid/P2P operations in using common Internet services: telnet, http, ftp, Email, SMTP, authentication, etc.
- Automated virus or worm signature generation plays a vital role to monitor network epidemic outbreaks and to give early warning of large-scale system intrusions, network anomalies, and DDoS flood attacks. Extensive benchmark experiments on the DETER test bed will prove the effectiveness.

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Related Publications: (Download <http://GridSec.usc.edu>)

1. M. Cai, K. Hwang, Y. K. Kwok, Y. Chen, and S. S. Song, "Fast Internet Worm Containment", *IEEE Security and Privacy*, May/June, 2005.
2. K. Hwang, Y. Chen, and H. Liu, "Defending Distributed Computing Systems from Malicious Intrusions and Network Anomalies", Keynote address at *IEEE Workshop on Security in Systems and Networks (SSN'05)*, in conjunction with *IEEE IPDPS 2005*, Denver, April 8, 2005.
3. S. Song, K. Hwang, and Y.K. Kwok, "Trusted Grid Computing with Security Binding and Trust Integration", *Journal of Grid Computing*, August, 2005
4. Y. K. Kwok, S. Song, and K. Hwang, "Selfish Grid Computing: Game Theoretic Modeling and NAS Performance Results", *ACM/IEEE CCGrid - 2005*, Cardiff, U.K., May 11, 2005

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