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

Presentation by Kai Hwang at the
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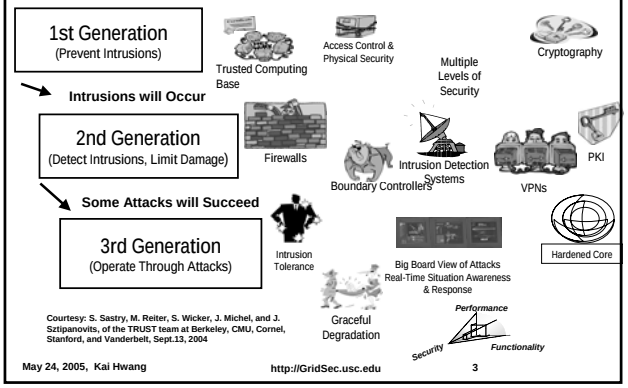
Project web site: http://GridSec.usc.edu/

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



Courtesy: S. Sastry, M. Reiter, S. Wicker, J. Michel, and J. Sztipanovits, of the TRUST team at Berkeley, CMU, Cornel, Stanford, and Vanderbelt, Sept.13, 2004

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)

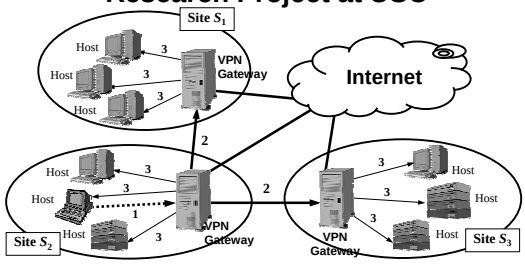
- ***Nimda, CodeRed, Slammer, Blaster, etc.***
- **CodeRed affected 360,000 web servers in 16 hours**
- **Slammer was the fastest worm at large - it scanned 90% of the Internet in less than 10 minutes.**

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**

The NetShield Architecture with Distributed Security Enforcement over a DHT Overlay

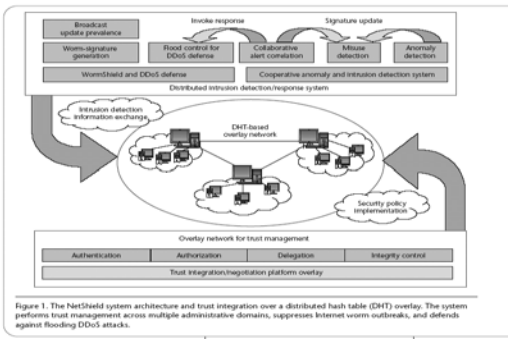


Figure 1. The NetShield system architecture and trust integration over a distributed hash table (DHT) overlay. The system performs trust management across multiple administrative domains, suppresses Internet worm outbreaks, and defends against flooding DDoS attacks.

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.**

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

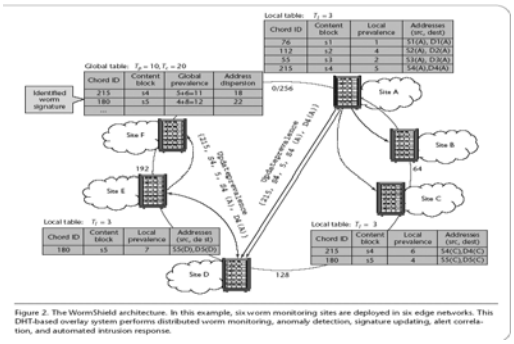
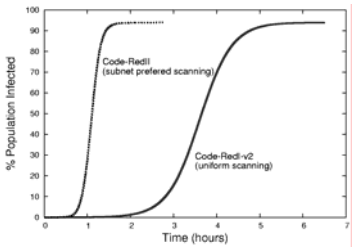
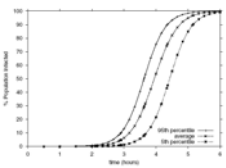


Figure 2. The WormShield architecture. In this example, six worm monitoring sites are deployed in six edge networks. This DHT-based overlay system performs distributed worm monitoring, anomaly detection, signature updating, alert correlation, and automated intrusion response.

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

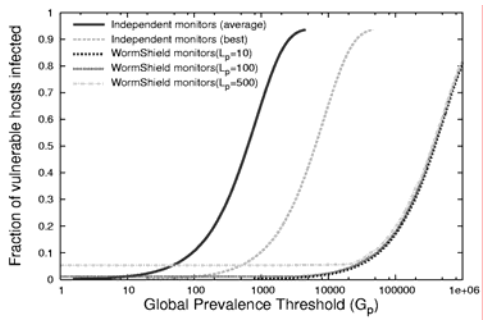




[Moore et al, INFOCOM 2003]

Effects of Global Prevalence Threshold

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



WormShield Signature Generation Process

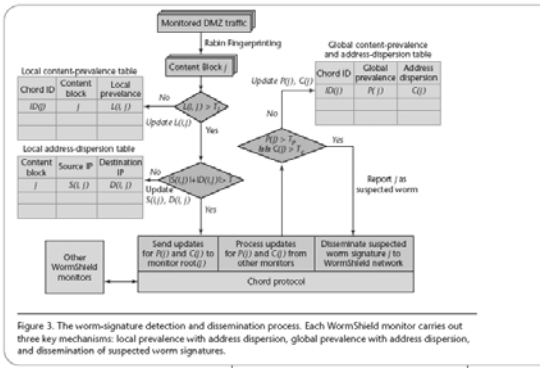
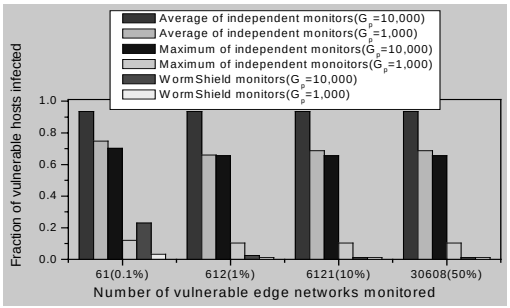


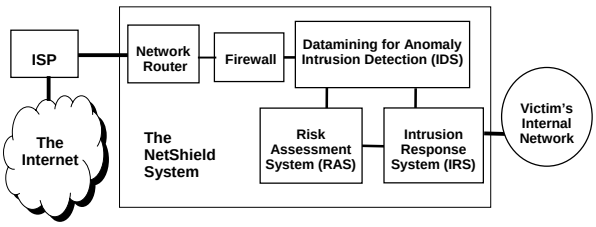
Figure 3. The worm-signature detection and dissemination process. Each WormShield monitor carries out three key mechanisms: local prevalence with address dispersion, global prevalence with address dispersion, and dissemination of suspected worm signatures.

Effects of % Edge Networks Monitored

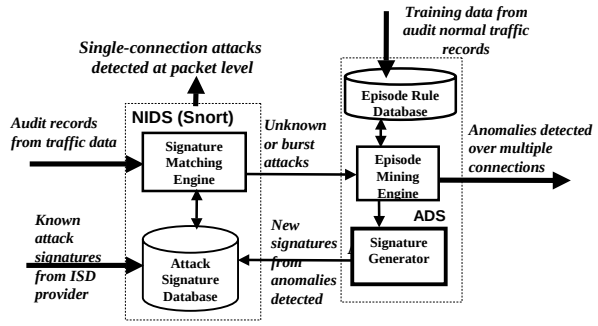
- **About 27 times reduction of infected hosts as 1% of vulnerable edge networks being monitored**



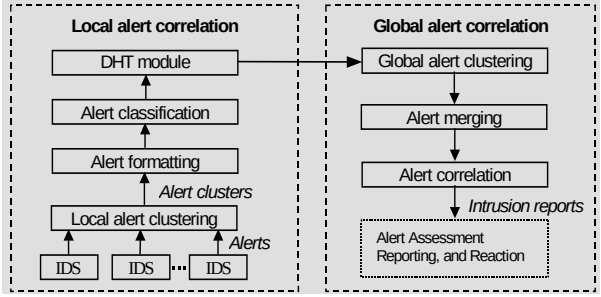
USC NetShield Intrusion Defense System for Protecting Local Network of Grid Computing Resources



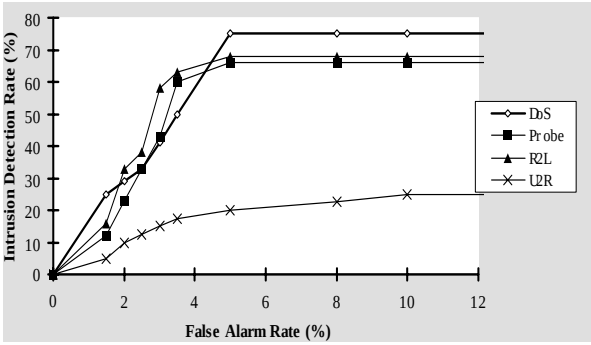
A Collaborative Anomaly and Intrusion Detection System (CAIDS), built with the Snort and an Anomaly Detection System at USC Internet and Grid Computing Lab in 2004 [2]



Alert Operations performed in local Grid sites and correlated globally

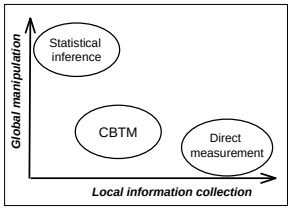


ROC Curves for 4 Attack Classes on The Simulated CAIDS



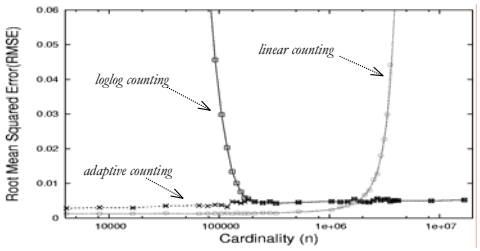
Cardinality-Based Traffic Matrix Estimation

- 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



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



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

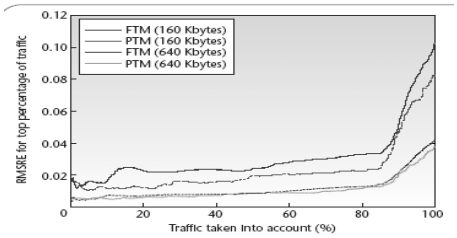


Figure 5. Root mean squared relative error (RMSRE) of packet-level (PTM) and flow-level traffic matrix (FTM) elements for various percentages of traffic. It is generally easier to accurately estimate large TM elements than small ones; accuracy improves significantly for PTM and FTM as the top percentage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

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

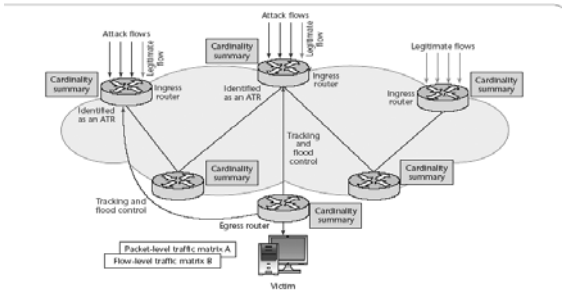
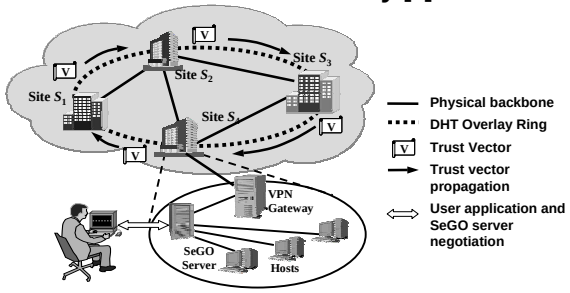


Figure 6. Traffic matrix monitoring for tracking attack-transit routers (ATRs). Collaborative routers can perform distributed tracking of ATRs by correlating the packet-level (PTM) and flow-level traffic matrix (FTM). Here, the egress router identifies two potential ATRs by correlating the PTM and FTM.

Hot Topics for Grid Security Research:

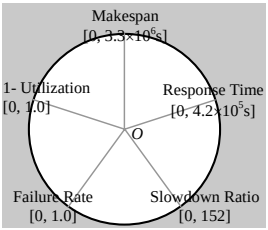
- The Fuzzy Trust Model for security binding and trust integration [3] and the Game-theoretic Model for modeling selfish and non-cooperative Grids [4].
- Large-scale security benchmark experiments on the NSF/HSD DETER testbed towards sustainable cybertrust in real-life Internet and Grid applications.
- 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.

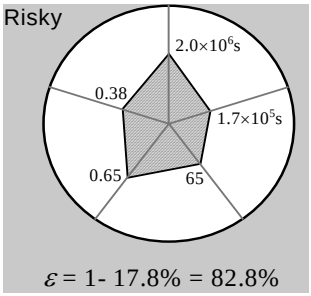
Fuzzy Aggregation for Trust Integration over a DHT Overlay [3]



Cooperating gateways working together to establish VPN tunnels for trust integration

Performance Metrics for Trusted Grid Computing

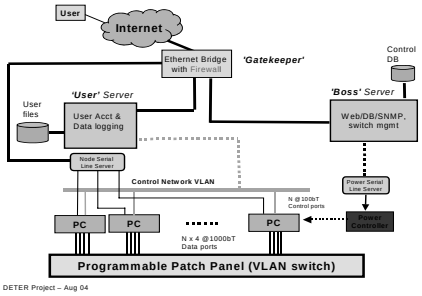




Effects of Fuzzy Trust Integration

ε = 1- 17.8% = 82.8%

DETER Testbed Benchmark Experiments



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

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.**

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**