

## Trusted Grid and P2P Computing:

Security Binding, Worm Containment, DDoS Defense, and New Research Frontiers and Approaches

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## Presentation Outline:

- Internet, Grid, and P2P Computing Arena
- System and Network Security Requirements
- Collaborative Internet Worm Containment
- Cardinality Counting for DDoS Defense
- Other Hot Topics for Trusted Computing
  - Fuzzy Trust Model and Reputation Systems
  - Game-theoretic Modeling of Realistic Grids
  - Grid Performance Metrics and DETER Experiments
  - Interoperability between Wired and Wireless Grids
- Concluding Remarks and Relevant Publications

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## Security and Privacy Demands in Internet, Grid, and P2P Services [6]:

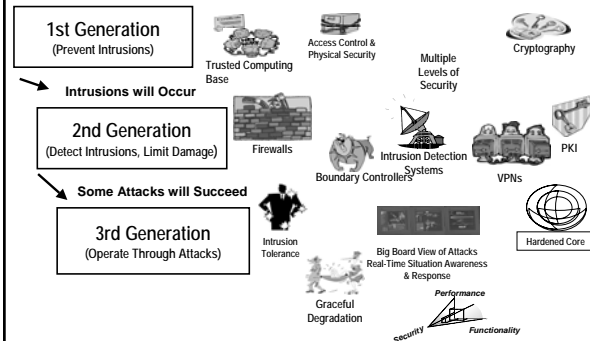
- Trusted E-Commerce over the Internet
- Secure communications in E-mail, FTP, etc.
- Protected download of digital contents (P2P)
- System Intrusions and Network Anomalies
- Firewalls, packet filters, VPN gateways, traffic monitors, security overlays, PKI services, etc.
- Self-defense toolkits, middleware, overlays for defense against viruses, worms, and flood attacks
- Anonymity, confidentiality, data integrity, access control, resolving policy conflicts, etc.

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## Three Generations of Defense Technology Towards Cyberspace Security Assurance



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## Worms and DDoS Attacks

- 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 or software vulnerability
  - Worms used to perform DDoS attacks automatically

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## 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

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## 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

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## The NetShield Architecture with Distributed Security Enforcement over a DHT Overlay (IEEE Security and Privacy Magazine, May/June 2005 [1])

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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]

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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 19<sup>th</sup>, 2001 from RouteViews
- Simulated infection progress matches quite well with Moore's experimental results

[Moore et al, INFOCOM 2003]

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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

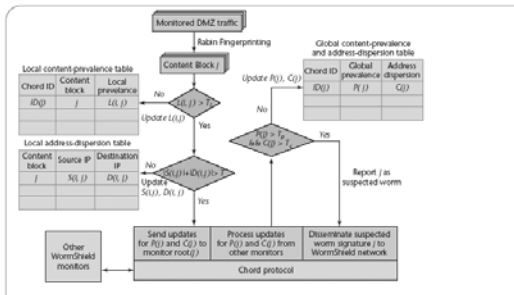


Figure 3. The worm-signature detection and dissemination process. Each WormShield monitor carries out three key mechanisms: local prevalence with address dispersion, global prevalence with address dispersion, and dissemination of suspected worm signatures.

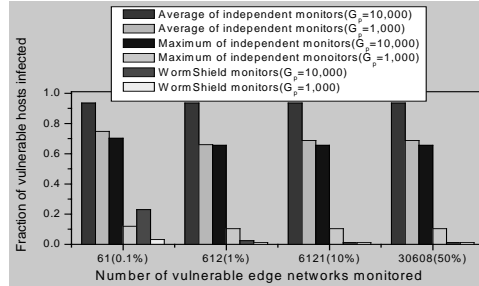
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### Effects of % Edge Networks Monitored

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

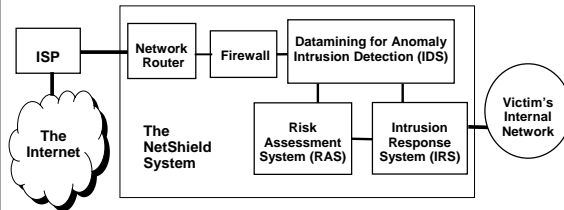


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### USC NetShield Intrusion Defense System for Protecting Local Networks of Grid Computing Resources

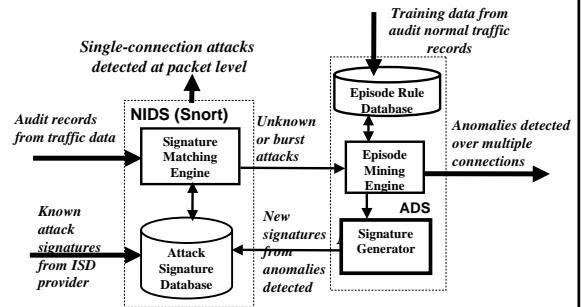


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### A Collaborative Anomaly and Intrusion Detection System (CAIDS), built with the Snort and a custom-designed Anomaly Detection System at USC Internet and Grid Computing Lab in 2004 [2]

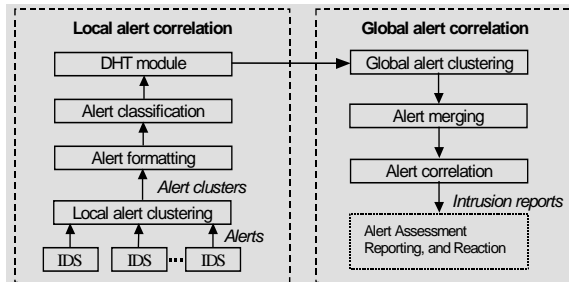


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### Alert Operations performed in local Grid sites and correlated globally

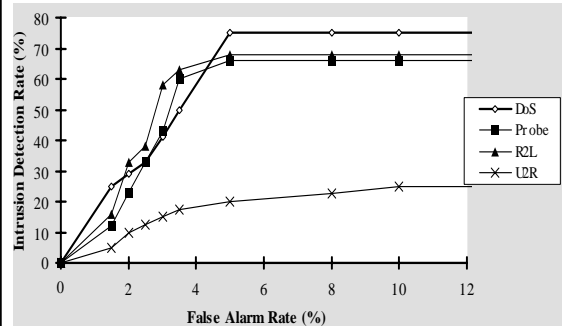


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### ROC Curves for 4 Attack Classes on The Simulated CAIDS



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

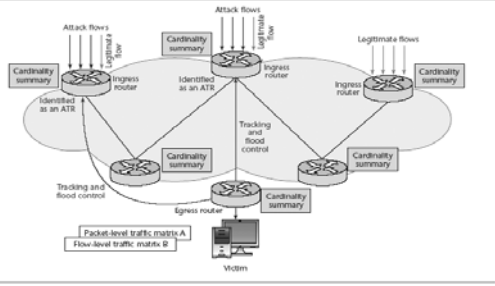


Figure 6. Traffic matrix monitoring for tracking attack-transit routers (ATRs). Collaborative routers can perform distributed tracking of ATRs by correlating the packet-level (PTM) and flow-level traffic matrix (FTM). Here, the egress router identifies two potential ATRs by correlating the PTM and FTM.

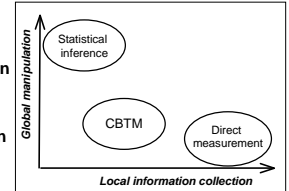
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## Cardinality-Based Traffic Matrix Estimation

- 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



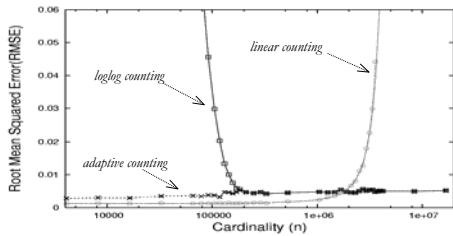
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## Scalability of Adaptive Counting

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



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

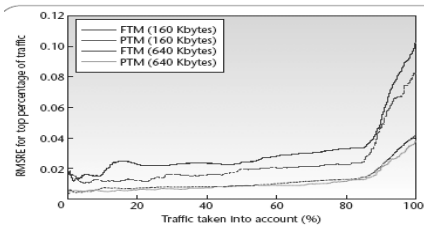


Figure 5. Root mean squared relative error (RMSRE) of packet-level (PTM) and flow-level traffic matrix (FTM) elements for various percentages of traffic. It is generally easier to accurately estimate large TM elements than small ones; accuracy improves significantly for PTM and FTM as the top percentage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

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## Other Hot Topics on Security Research

for Realistic Grid Platforms and P2P Networks:

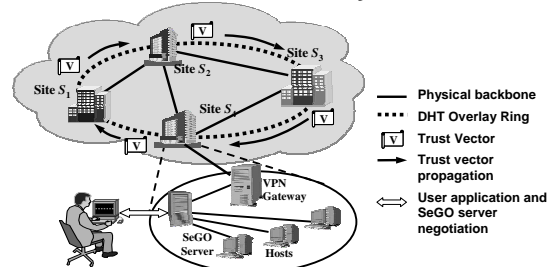
- Fuzzy trust Model for security binding in Grids [3] and reputation system for P2P services over the Internet [4]
- Game-theoretic Model for modeling selfish and non-cooperative Grids in real-life world [5].
- NSF/HSD DETER testbed – An isolated Internet simulator built at USC/ISI and UC Berkeley for Large-scale security benchmark experiments
- Interoperability between wired Grids and wireless Grids - a new challenge for pervasive Grid/P2P computing.

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## Fuzzy Aggregation for Trust Integration over a DHT-based Overlay Network [3]



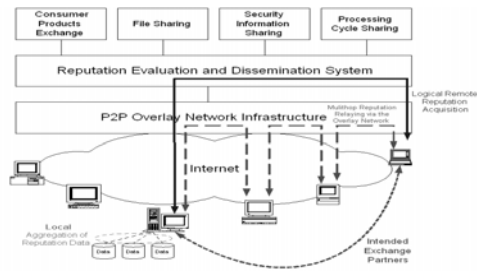
Cooperating gateways working together to establish VPN tunnels for trust integration

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## Trusted P2P Transactions with Fuzzy Reputation Aggregation [4]



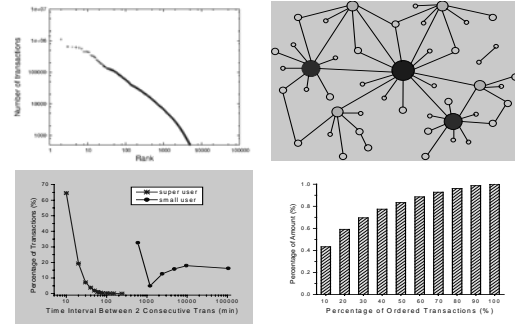
e-Trust: A peer reputation system built with a P2P overlay network for trusted commodity exchanges over the Internet, like eBay transactions

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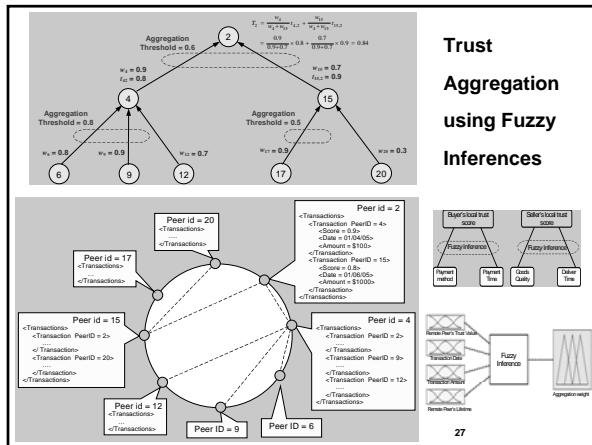
## eBay transaction trace by ranks, hot spots, request interval, and transaction amounts.



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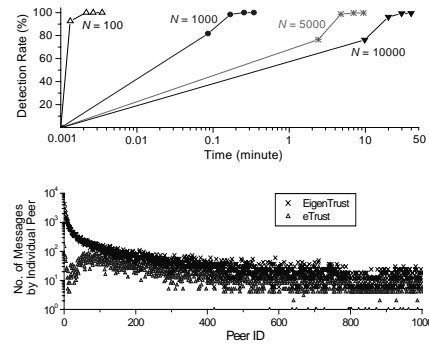
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Trust Aggregation using Fuzzy Inferences

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## Simulated Performance of the eTrust system compared with the EigenTrust system in processing eBay traces



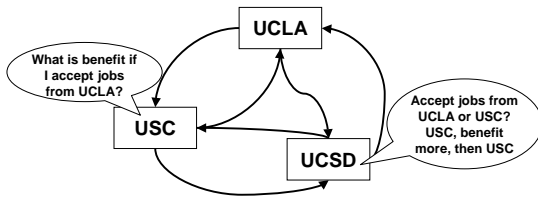
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## Game-Theoretic Approach to Solving the Selfish Grid Computing Problem

Game theory is intended to provide a theory of strategic behavior when all parties in the game interact directly, rather than through the third party, and with the goal to maximize all the individual benefits.

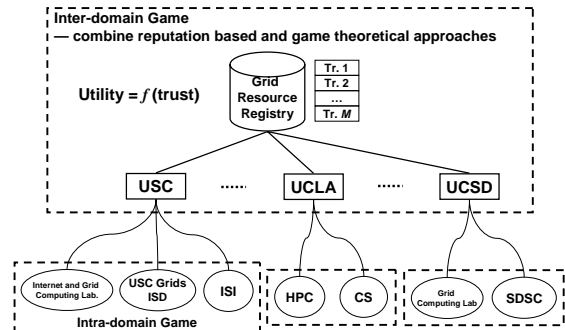


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## Hierarchical Grids

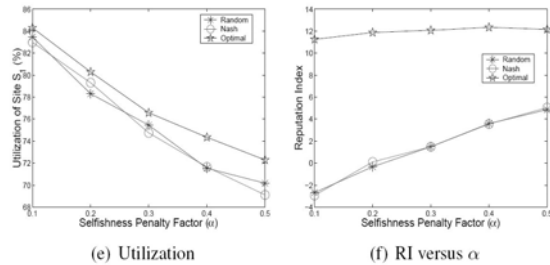


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## Grid Performance Enhancement under Different Gaming Strategies

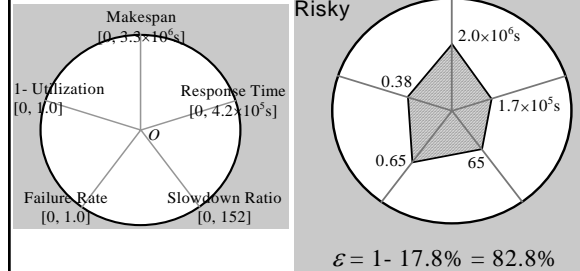


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## Performance Metrics for Trusted Grid Computing [6]

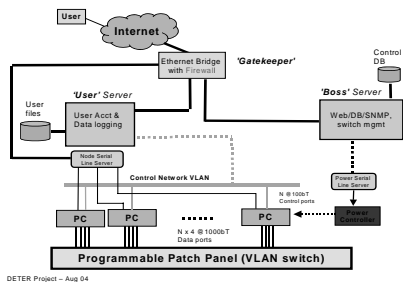


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## DETER Testbed Benchmark Experiments



DETER Project - Aug 04

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

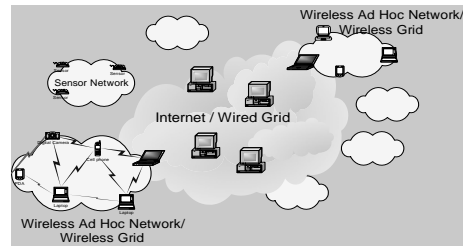
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## Wired Grids vs. Wireless Grids

### - The Interoperability Issues



- Air interfaces, admission control, disconnection handling, wireless PKI, security binding, and QoS all demand extensive research and development
- Interoperability demands to support wired and wireless communications in distributed clusters, grids, and pervasive computing applications

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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 monitoring, detection, and suppression.
- Extensive benchmark experiments on the DETER testbed will prove the effectiveness, still a long way to achieve assurance.
- Fuzzy trust model is effective to support distributed security enforcement in both computational Grids and P2P systems.
- Game-theoretic approach provides a viable solution to the selfish and non-cooperative problems in realistic network platforms
- Wireless Grids needed for pervasive applications must be built to be interoperable with existing wired backbone networks

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## Related Publications:

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

- M. Cai, K. Hwang, Y. K. Kwok, Y. Chen, and S. S. Song, "Fast Internet Worm Containment", *IEEE Security and Privacy*, May/June, 2005.
- 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.
- S. Song, K. Hwang, and Y.K. Kwok, "Trusted Grid Computing with Security Binding and Trust Integration", *Journal of Grid Computing*, August, 2005.
- S. Song, K. Hwang, R. Zhou, and Y.K. Kwok, "Trusted P2P Transactions with Fuzzy Reputation Aggregation", *IEEE Internet Computing Magazine Special Issue on Security for P2P and Ad Hoc Networks*, submitted March 2005.
- Y. K. Kwok, S. Song, and K. Hwang, "Selfish Grid Computing: Game Theoretic Modeling and NAS Performance Results", *ACM/IEEE Int'l Conf. on Cluster Computing and The Grids (CCGrid 2005)*, Cardiff, U.K., May 9-12, 2005
- K. Hwang, Y. Kwok, S. Song, M. Cai, R. Zhou, Yu. Chen, Ying. Chen, and X. Lou, "GridSec: Trusted Grid Computing with Security Binding and Self-Defense against Network Worms and DDoS Attacks", *Int'l Workshop on Grid Computing Security and Resource Management (GSRM'05)*, in conjunction with the *ICCS 2005*, Emory University, Atlanta, May 22-25, 2005.

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