Distributed Security Enforcement for Trusted Cluster and Grid Computing

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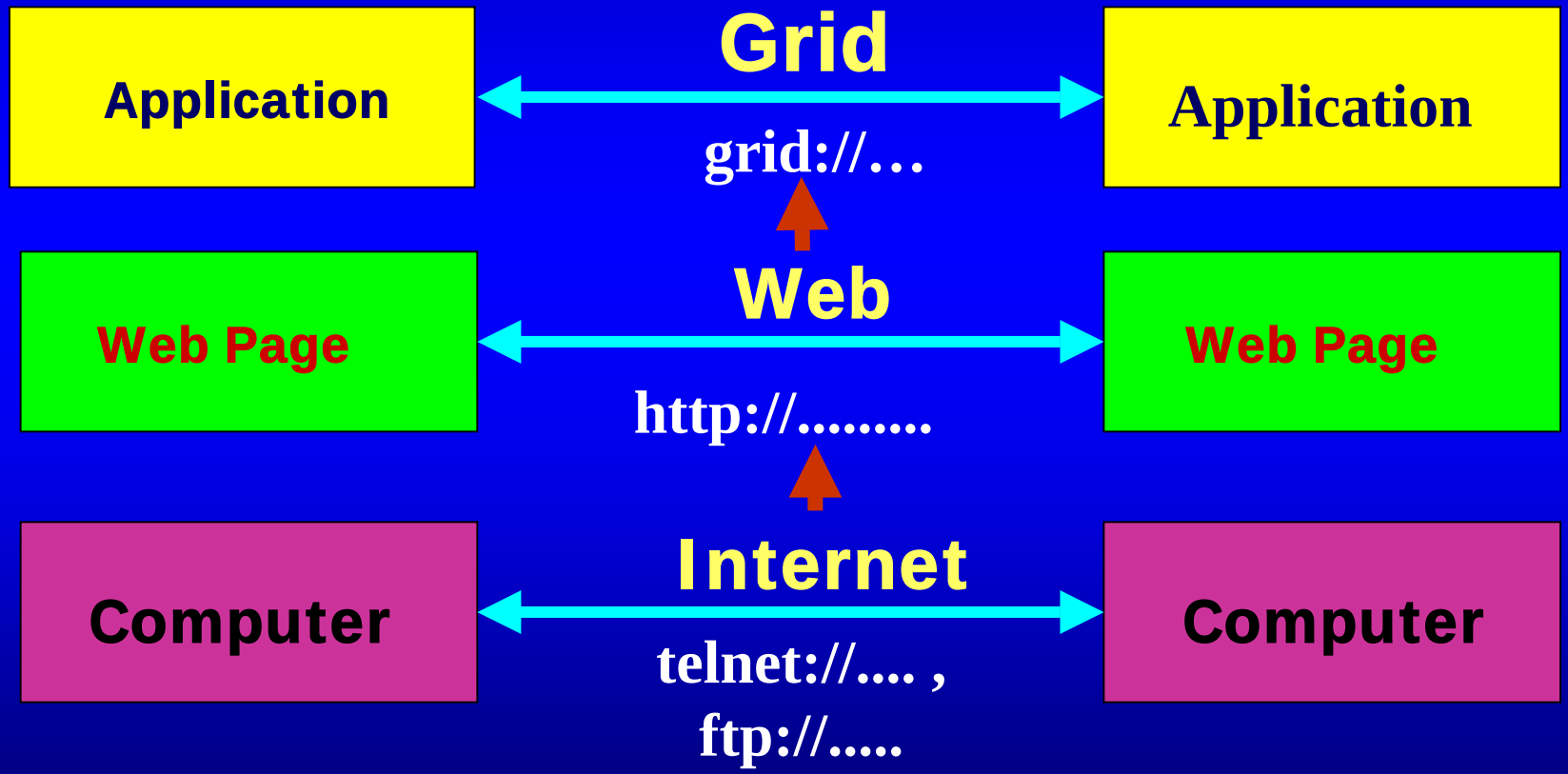
Presentation Outline:

1. Distributed GridSec Architecture
2. Virtual Private Networks for Distributed Security Enforcement
3. Anomaly Intrusion Detection with Datamining over Network Traffic
4. Security-Assured Resource Allocation
5. Wireless Access Control in Grid Computing

Evolutional Path of Network-based Computing

to eliminate Resource Islands

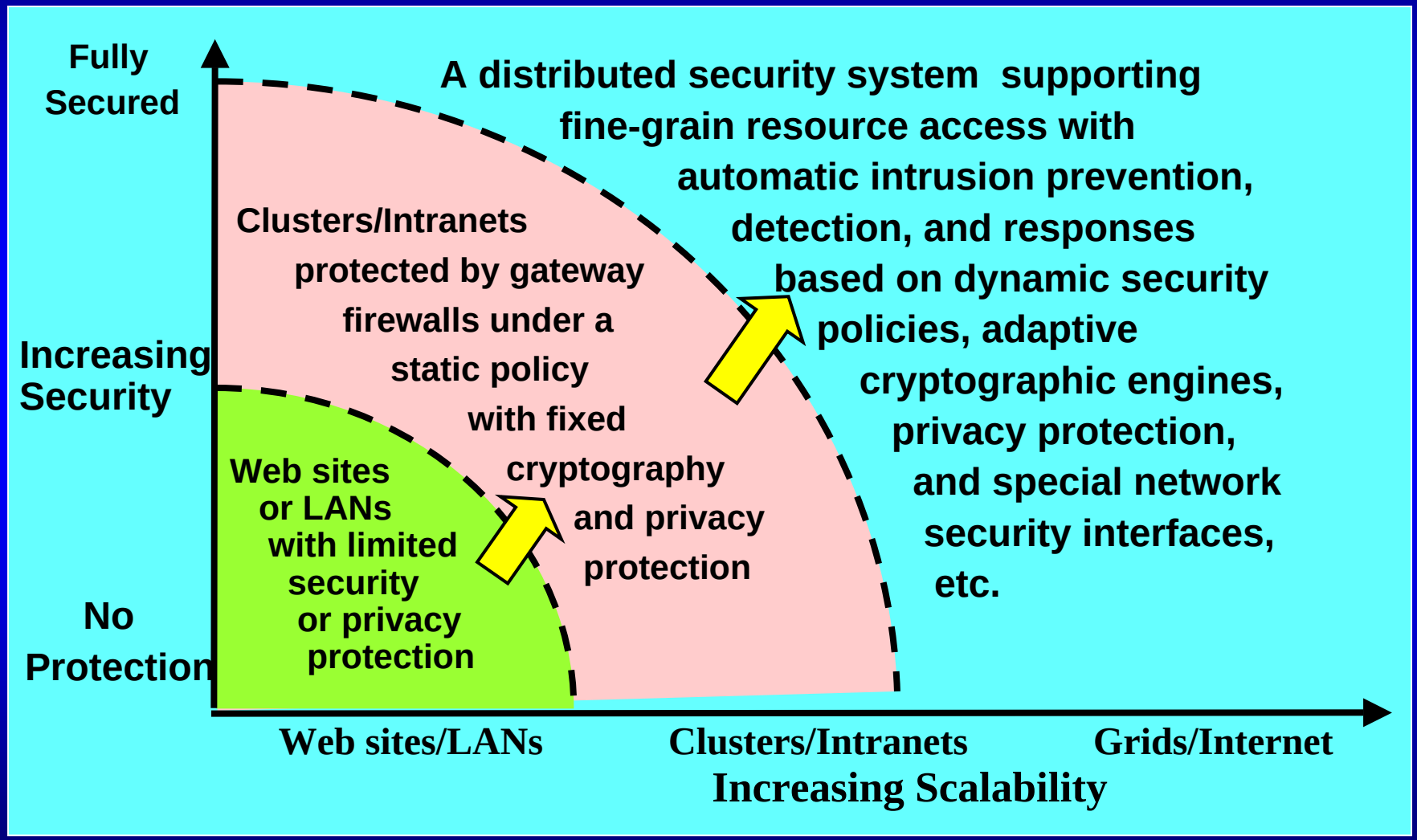


Courtesy: Dr. Zhiwei Xu, Chinese Academy of Sciences

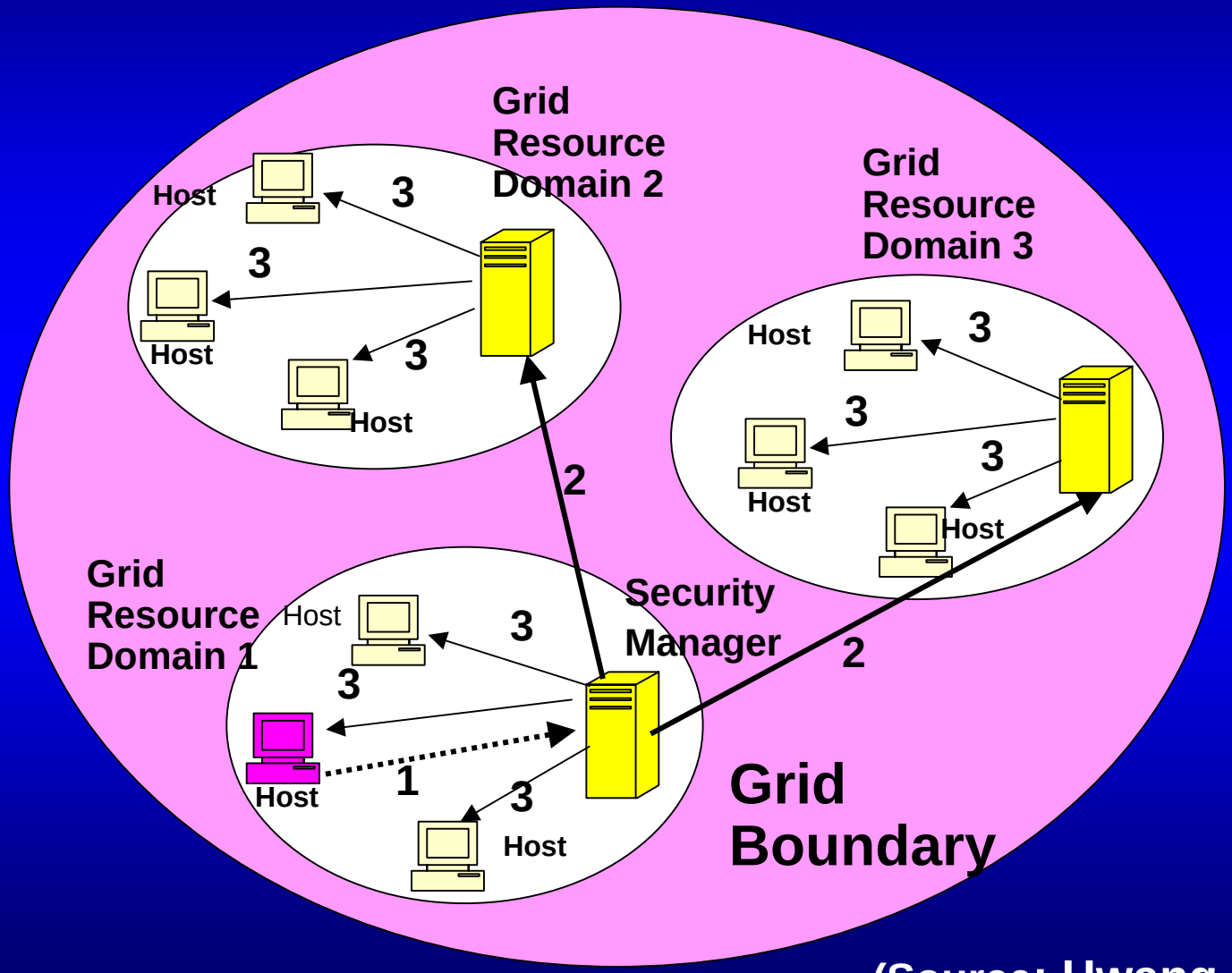
Trust, Security, and Privacy

- **Trust vs. Risk –** The foundation of security and privacy in both human society and Cyberspace
- **Distributed Computing Security –** More effective with a centralized policy enforced with a distributed control
- **Internet Privacy –** Must be protected with tradeoffs between security constraints and privacy demand

Security vs. Scalability



Distributed GridSec Architecture



Step 1: ·····▶ Intrusion detected by a local micro-firewall

Step 2: ——▶ All security managers alerted with the intrusion

Step 3: ——▶ Security managers broadcast response command to all hosts under their jurisdiction.

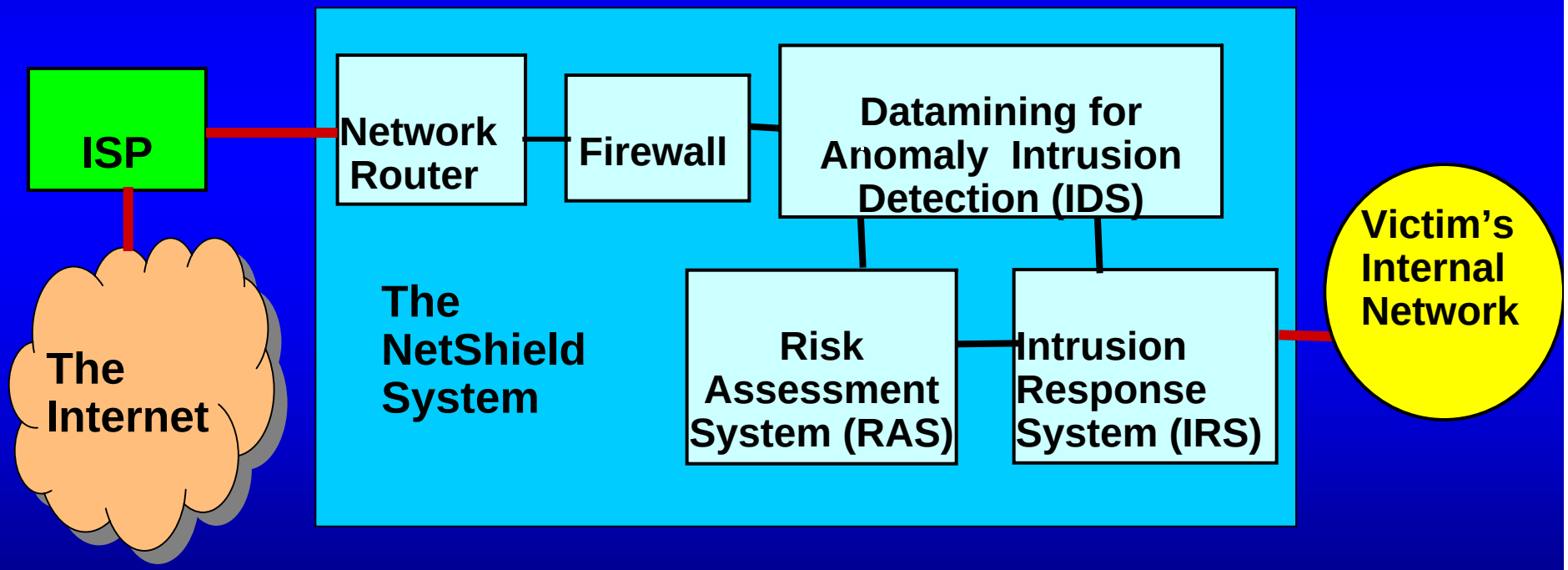
(Source: Hwang, et al [1])

GridSec Design Objectives:

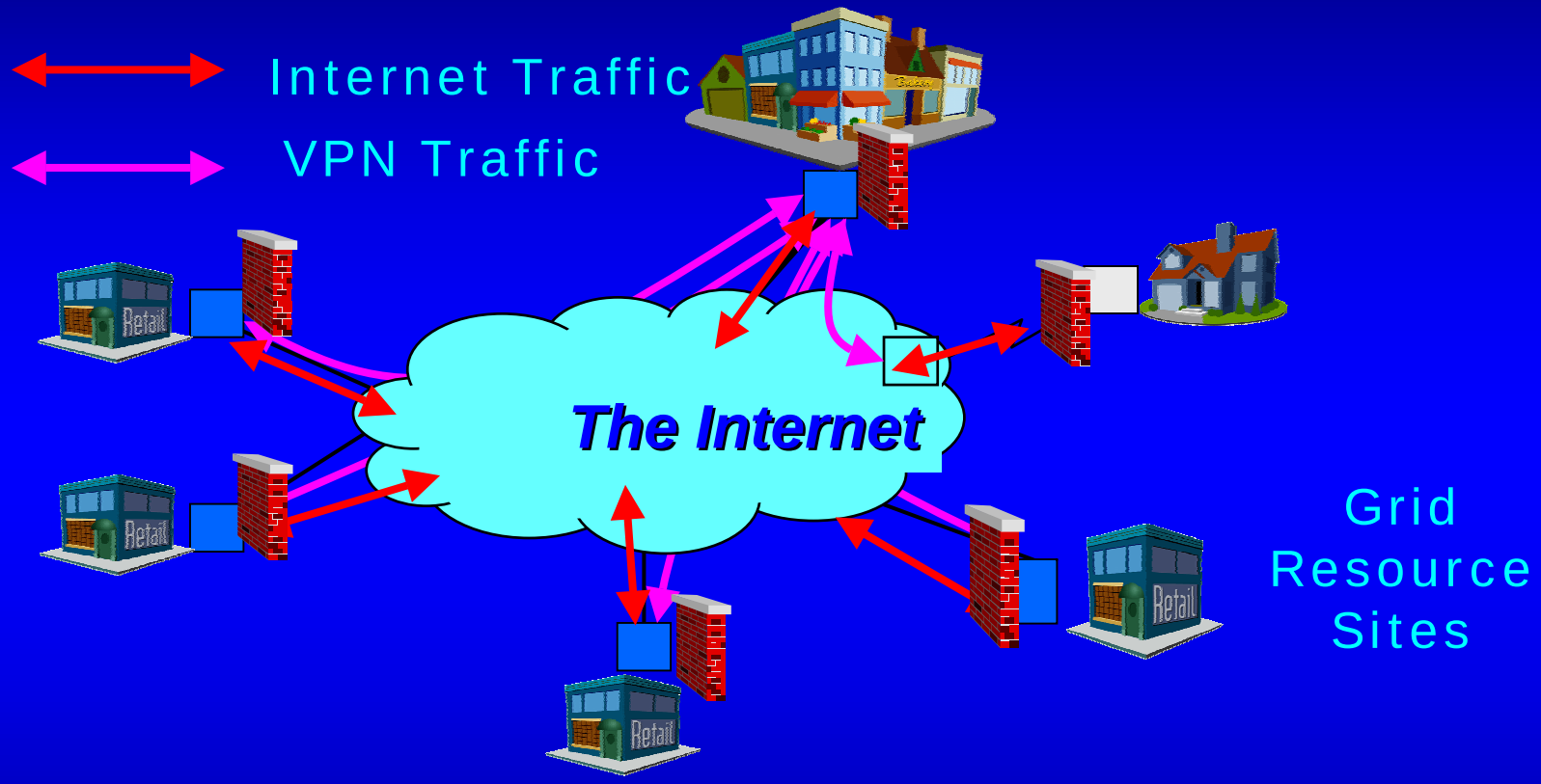
- Remove the security barrier hindering distributed grid computing - Offering a new trust model
- GridSec offers distributed intelligence in trust management on top of Globus, AppLes, NimRod etc.
- Dynamic grid resource allocation optimized with respect to computing power, security demand, and cost limit
- Benefiting E-commerce, digital government, public safety, and global economy over the Internet using GridSec-based VPN tunneling

USC NetShield Defense System

Protecting Grid Computing Resources

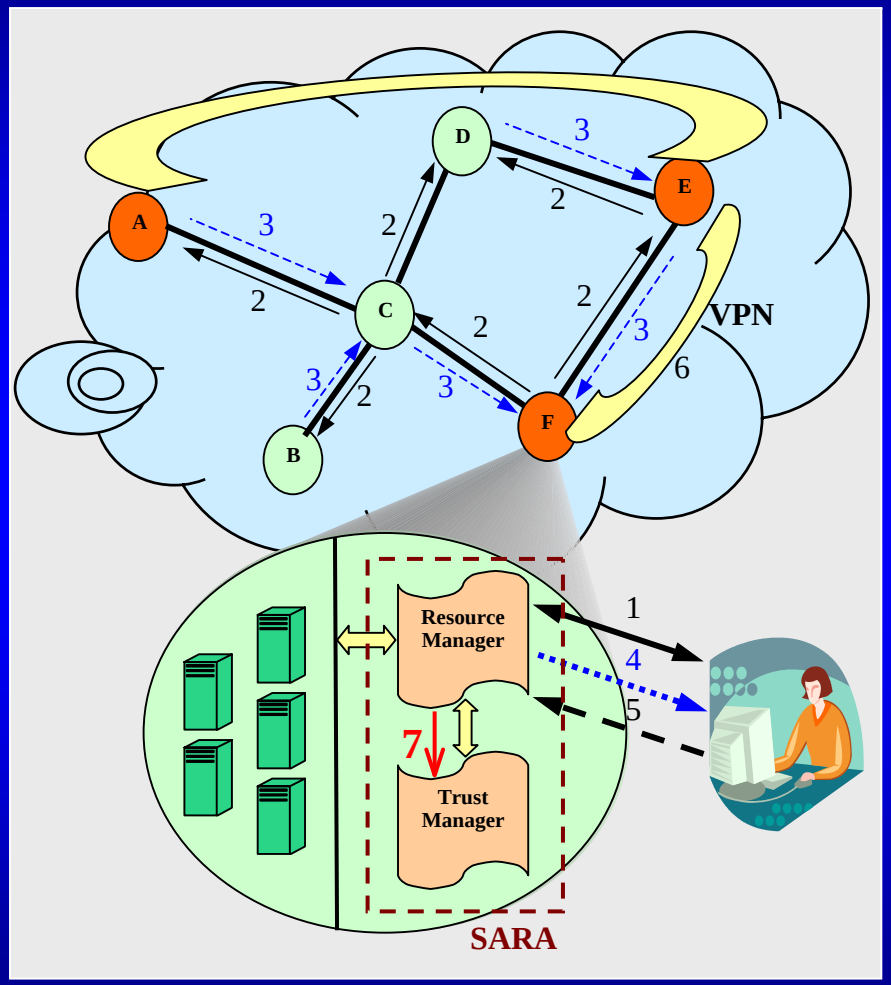


GridSec VPN : Combining both IPSec and MPLS Features for Federated Security



A VPN specially configured on a public Infrastructure based on tunneling at the IPSec network layer. Same policies as a private network supported by service provider and using **IPSec, MPLS, PKI, GridSec, attribute certificates, etc.**

Secure Grid Resource Management supported by VPN



Step 1: Two-way authentication and User request submission to resource manager (RMgr) in Grid resource site ***F*** (GRS ***F***).

Step 2: RMgr in GRS F broadcast this request RMgrs in other GRSs.

Step 3: RMgrs in other GRSs send reply to RMgr in GRS F with the current available resource information.

Step 4: RMgr in GRS F generates several possible resource allocation solutions based on the received information, and sent back to user.

Step 5: User selects one solution based on its computing power requirement and budget constraints, and reply to RMgr in GRS ***F***.

Step 6: Suppose user selects a resource allocation combination {***A***, ***E***, ***F***}, VPN connections are built between them, and user application is executed at these three GRSs.

Step 7: RMgr in GRS F monitored the execution of user application and update the trust vector according to the execution quality.

Step 8: Trust propagation: TMgr in each GRS broadcasts its trust vector periodically. TMgrs in other GRSs will update their trust vector accordingly.

Developing Virtual Private Networks for Securing Grid Computing

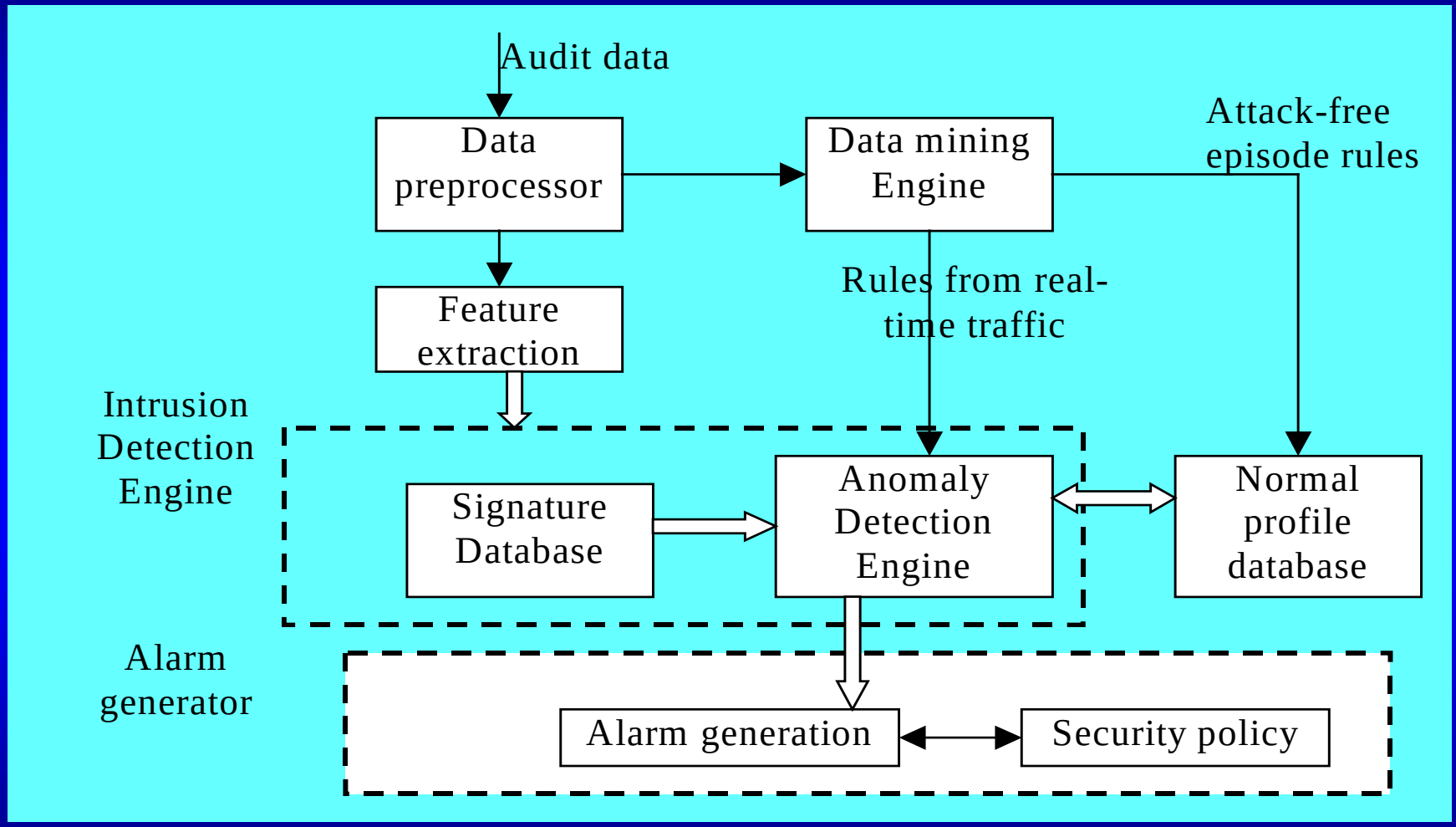
- Create encrypted tunnels between private networks used to form the Grid computing infrastructure
- The GridSec project chooses an approach combining the advantages of both IPsec-based and MPLS-based VPNs
- Aimed to satisfy the IPv6 standards proposed for both wired and wireless networks for the next-generation Internet

(Reference: Hwang, et al [1])

GridSec VPN Design: Built with Encrypted Tunnels, IPSec, and PKI over Grid or P2P Resource Sites

Protocol In VPN	Applications	Security Level	Security Mechanisms	Where in Network
IPSec VPN	Site-to-site VPNs, off-net VPNs, extranets, sessions (DSL, dial-in, etc.)	High	Strong encryption (3DES), data authentication (HMAC and SHA-1), user authentication (RADIUS and PKI)	Best at local loop and Edge, apply IPSec tunneling and encryption
MPLS VPN	Site-to-site VPNs	Ultra High	"Tunnel" between end-points with same VPN ID	Best within an ISP's core network
GridSec VPN	VPNs built over distributed Grid or P2P networks with multiple resource sites	Ultra High	IPSec with multi-site authentication, VPN tunnels at network layer and using PKI, AC, GSI, etc.	Intranet or extranet within a common virtual organization

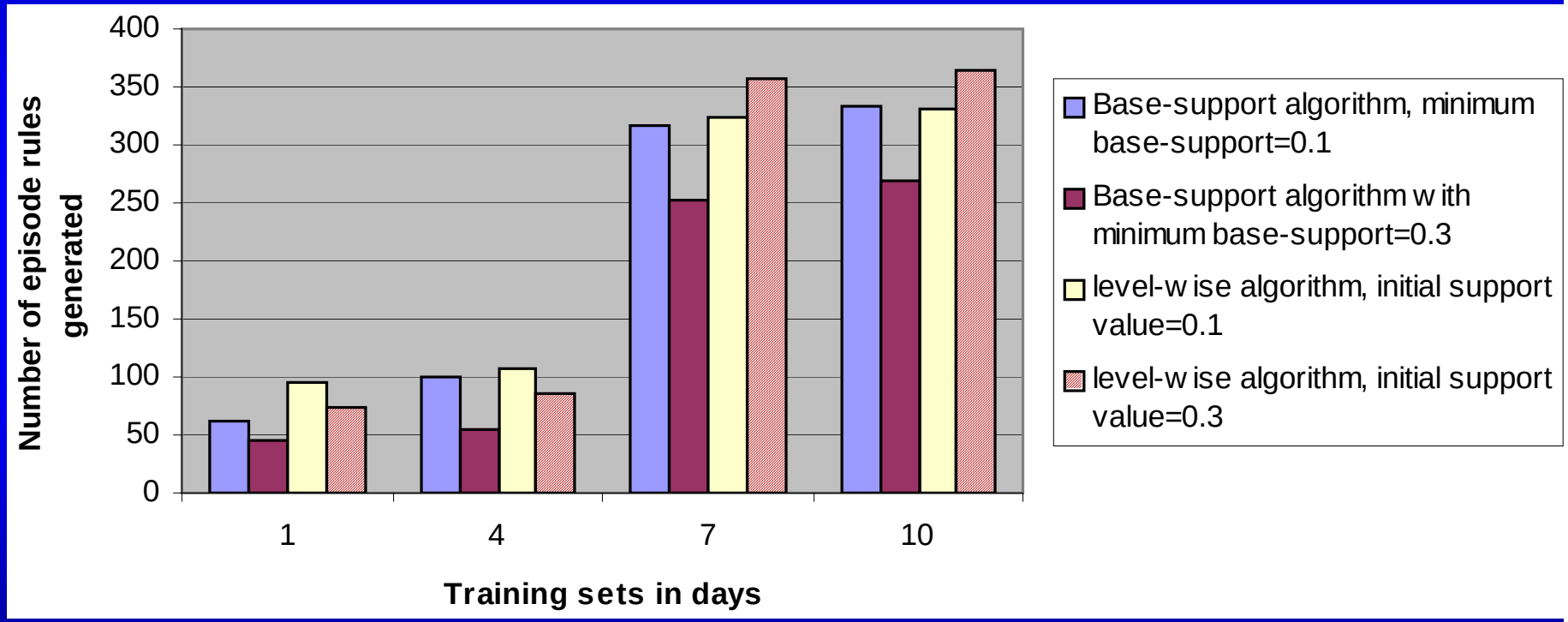
Anomaly-based IDS Architecture



(Ref.: Qin and Hwang [3])

Testing of the Base-Support Mining Algorithm on Normal TCP Traffic Connections

from the 1999 DARPA Intrusion Detection Evaluation Data Sets collected in the first 10 Days



Using our base-support mining algorithm with a minimum confidence value of 0.6 and a window size of 30 sec, compared with using Lee's Level-wise mining algorithm

Pruning of Ineffective Episode Rules

- **Transposition Law: The rule:** $L_1, L_2, \ldots, L_n \rightarrow R_1, \ldots, R_m$

  is more effective than using the rule:

  $$L_1, L_2, \ldots, L_{n-1} \rightarrow L_n, R_1, \ldots, R_m$$

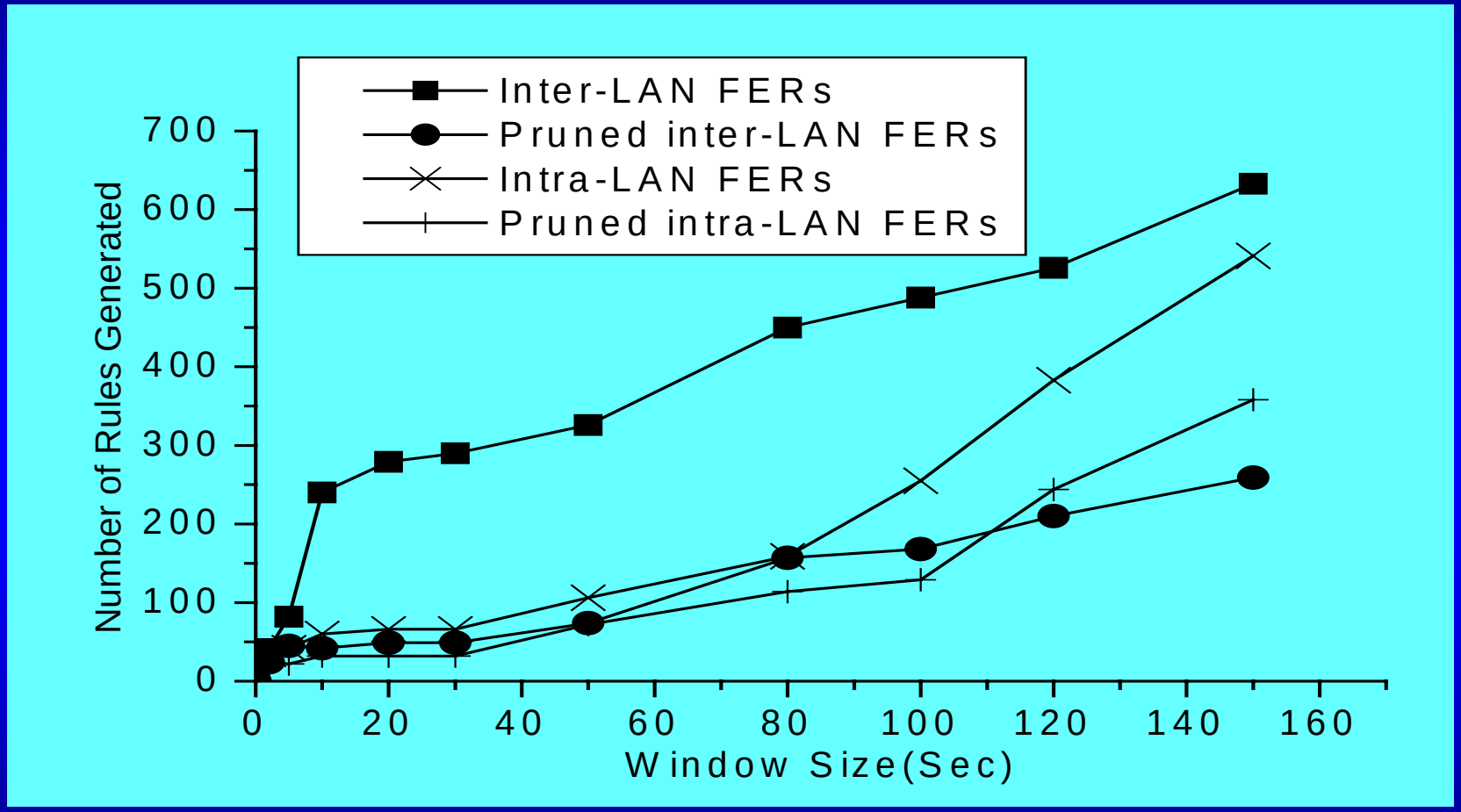
- **Elimination Law: The rule** $L_1, L_2 \rightarrow R_1\ (c_1, s_1)$ **is less effective than using :** $L_2 \rightarrow R_1\ (c_2, s_2)$, **if** $c1 \approx c2$

- **Transitive Reconstruction Law: The rule:** $L_1 \rightarrow R_1, R_2$

  becomes ineffective, if we have the following rules

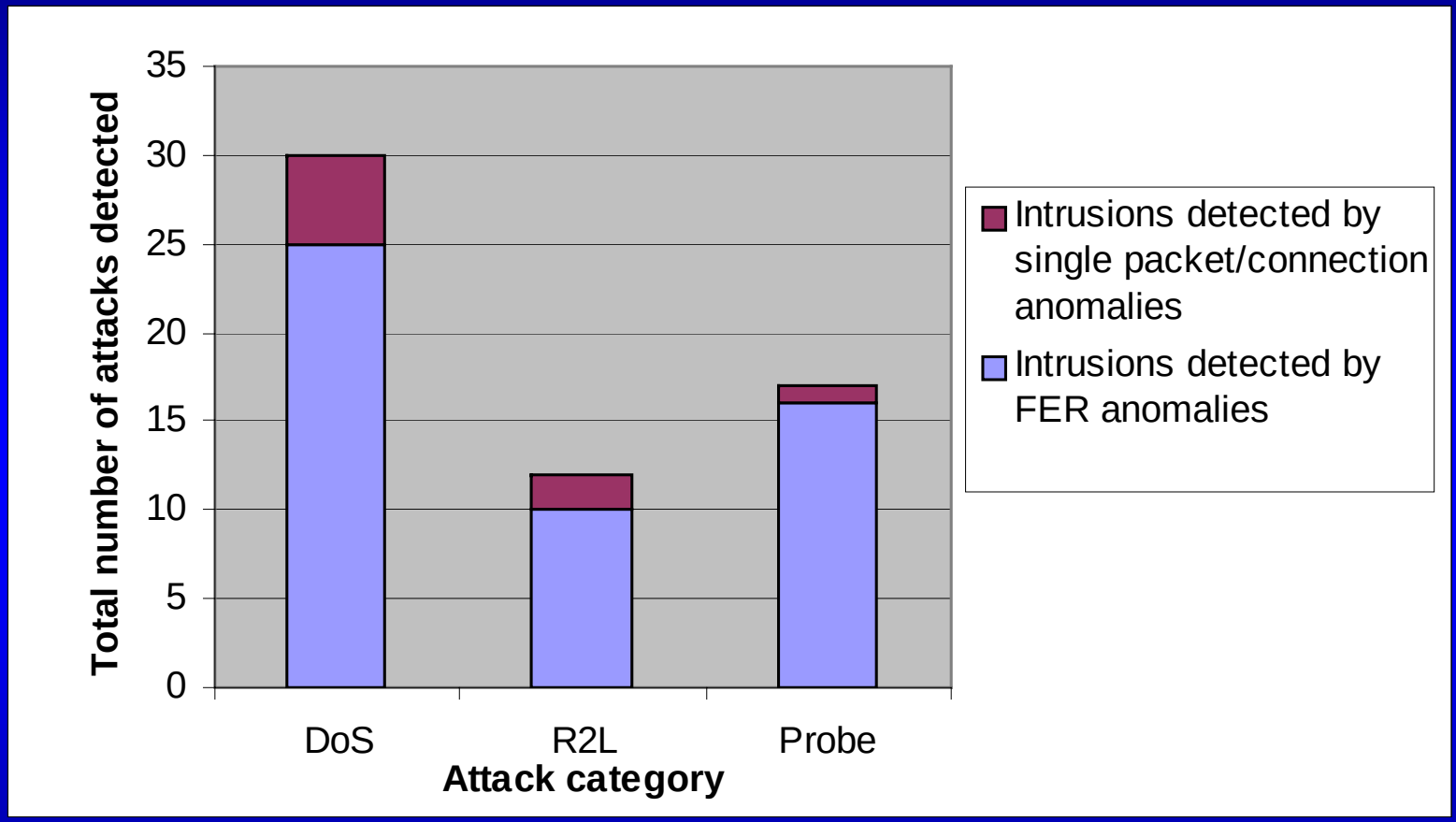
  $L_1 \rightarrow R_1$ **and** $R_1 \rightarrow R_2$ **already in the rule set**

Effects of Pruning on the Growth of Frequent Episode Rules for Inter-LAN and Intra-LAN Traffic Events



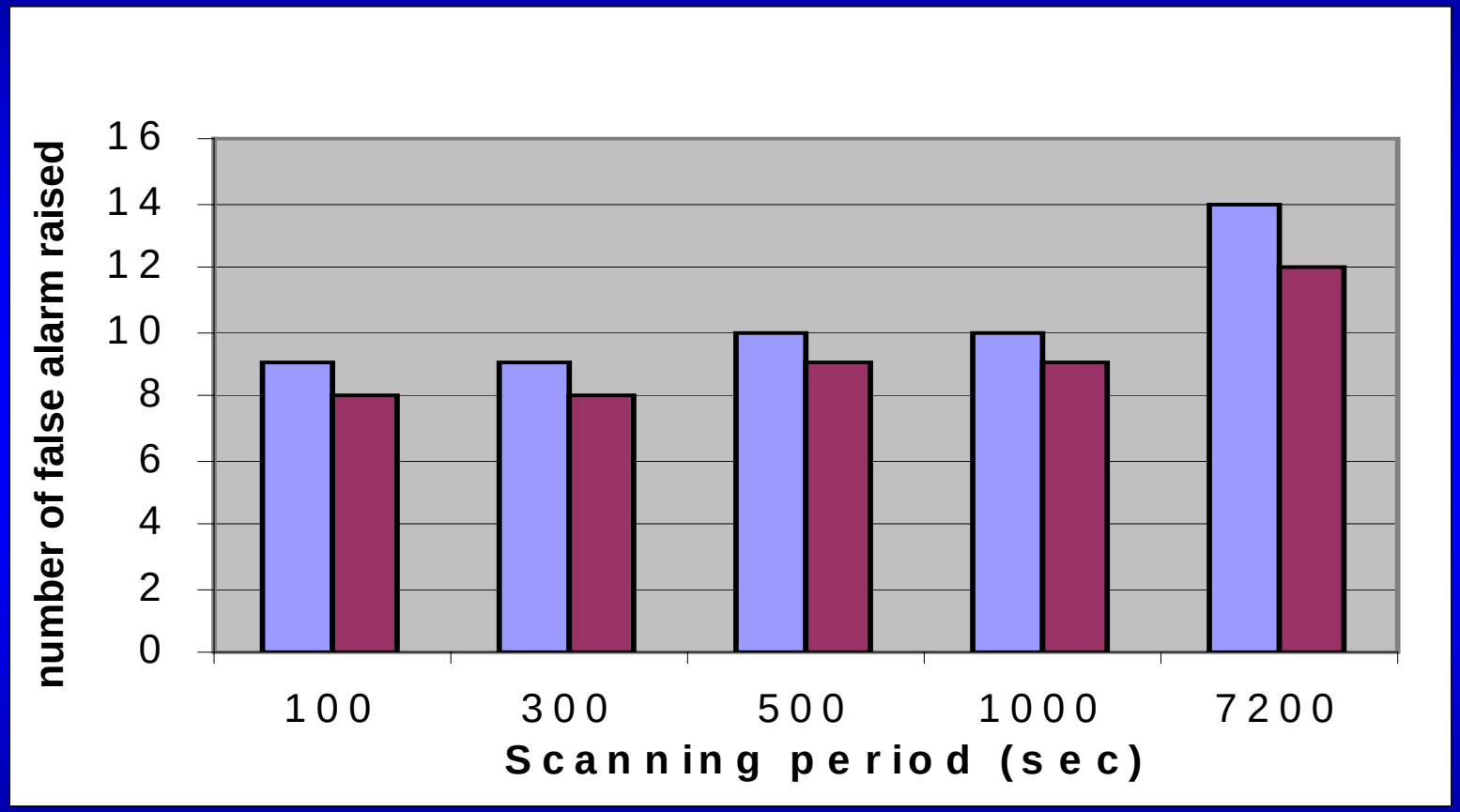
The base-support = 0.1, the minimum confidence = 0.6, the reference attributes = destination, and axis attributes = service

Anomaly Intrusion Detection Rate



Intrusive attacks detected by single packet per connection versus checking the frequent episode rules

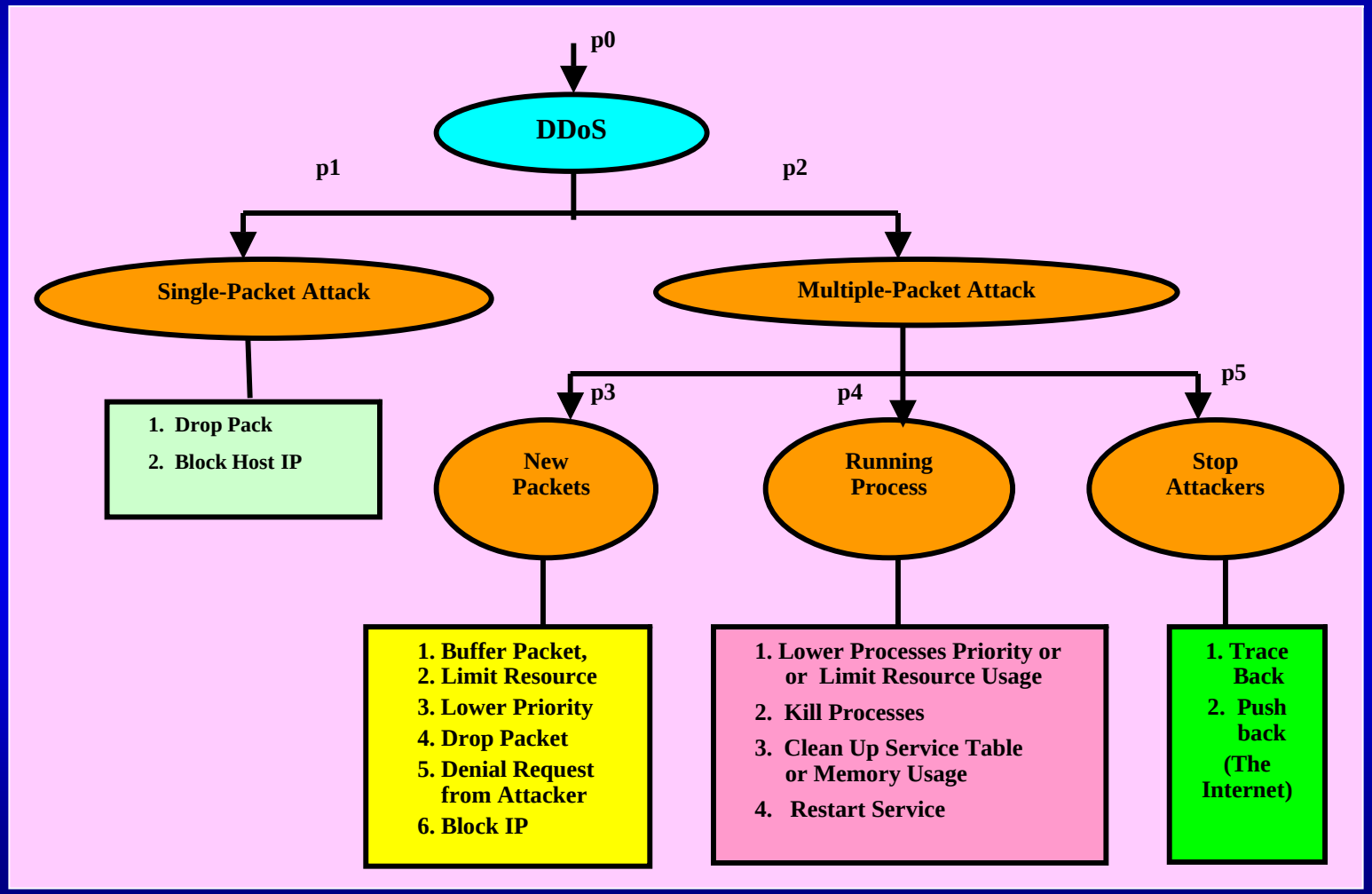
Effect of Pruning on Reducing the False Alarm Rate in Anomaly Intrusion Detection



Blue bar: Detection without rule pruning

Purple bar: Detection with rule purning

Intrusion Response Strategies for Defending against DDoS Attacks



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Optimal or Suboptimal Resource Allocation Vectors ($x1$, $x2$) with different Performance/Cost Ratios

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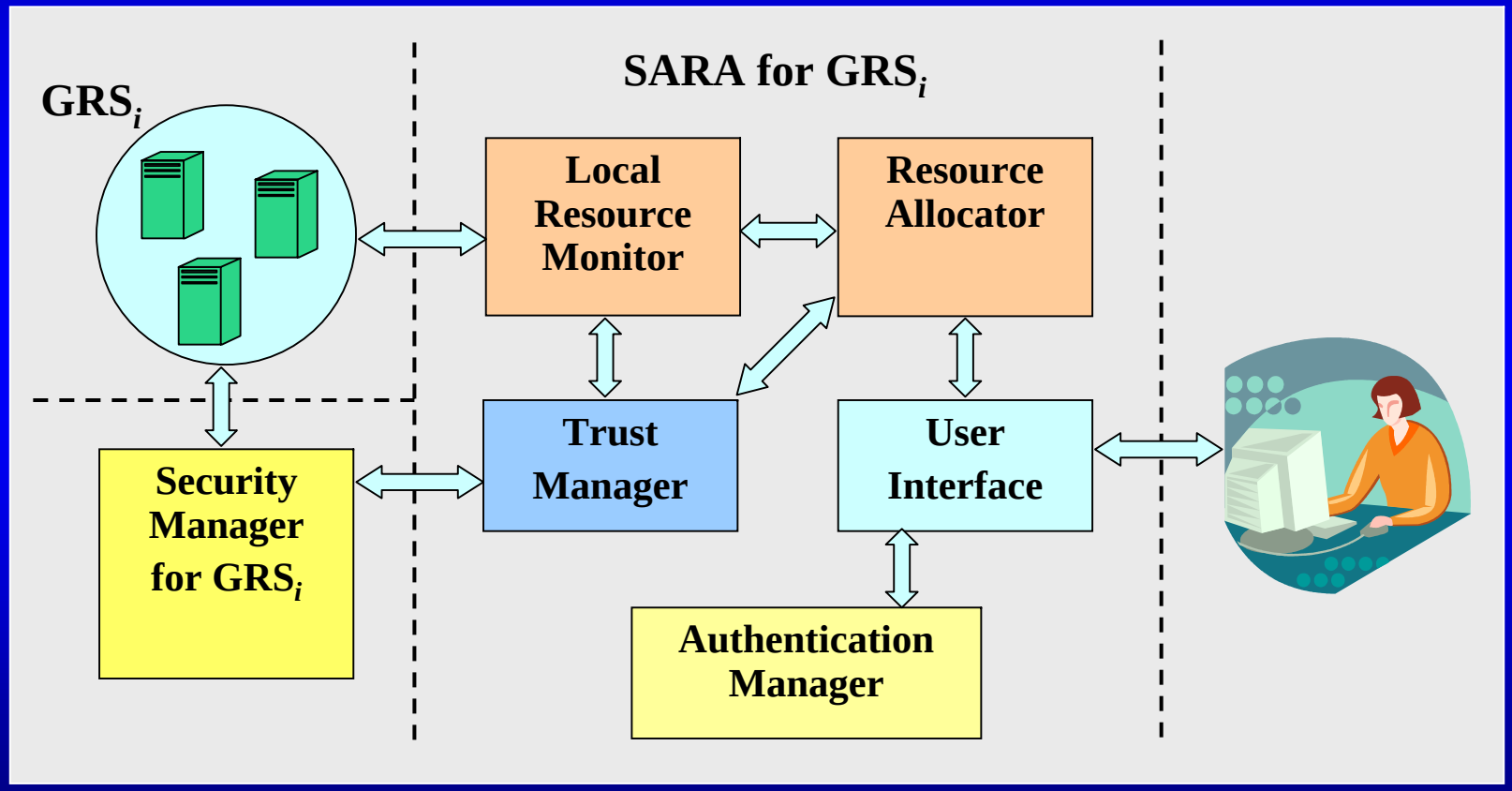
SARA: A Trust Model for Securing Grid Resources Allocation



Example: Allocating Resources from Two Grid Sites

Application Demand: (P_o, T_o, C_o) = (4Tflops, 0.6, $2.25M)

Resource Sit No. 1: R_1 = (1.6Tflops, 0.8, $500K, 6 hosts)

Resource Sit No. 2: R_2 = (1.2Tflops, 0.7, $220K, 5 hosts)

Objective function (Integer Programming):

$$P = t_1 p_1 x_1 + t_2 p_2 x_2 = 0.8 \times 1.6 x_1 + 0.7 \times 1.2 x_2 = 1.28 x_1 + 0.84 x_2$$

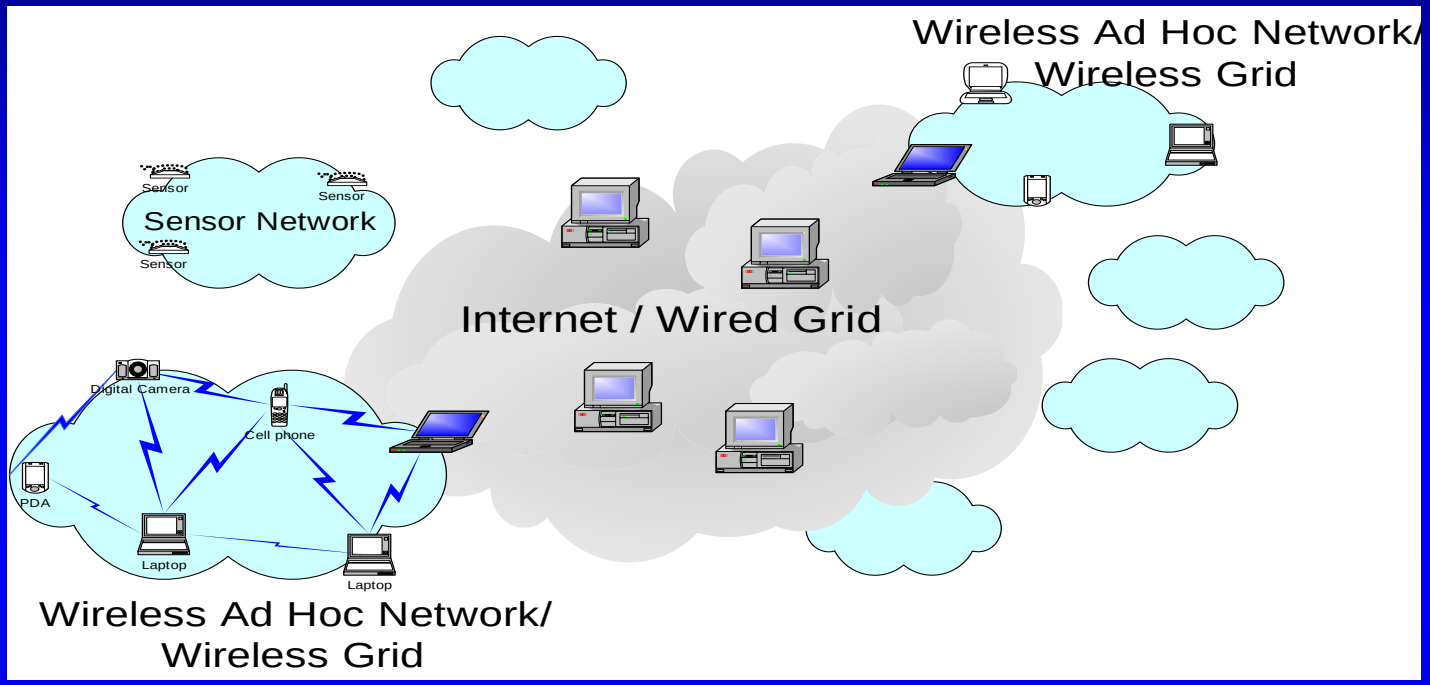
Subjective to the following constraints:

$$c_1 x_1 + c_2 x_2 = 500 x_1 + 220 x_2 \le \$2,250K$$

$$p_1 x_1 + p_2 x_2 = 1.6 x_1 + 1.2 x_2 \ge 4\text{Tflops}$$

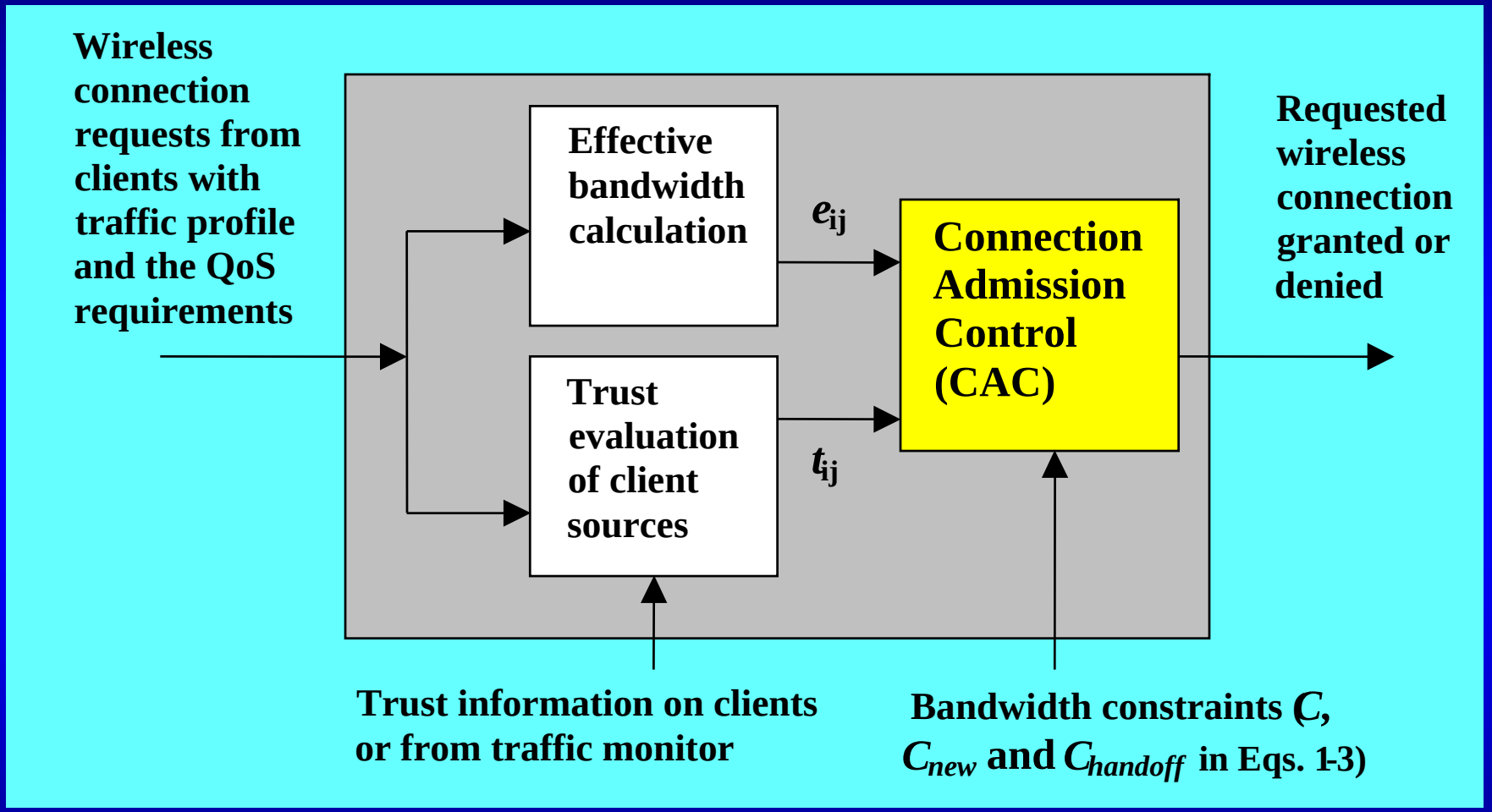
$$0 \le x_1 \le 6 \text{ and } 0 \le x_2 \le 5$$

Wireless Access Control of Grid Resources



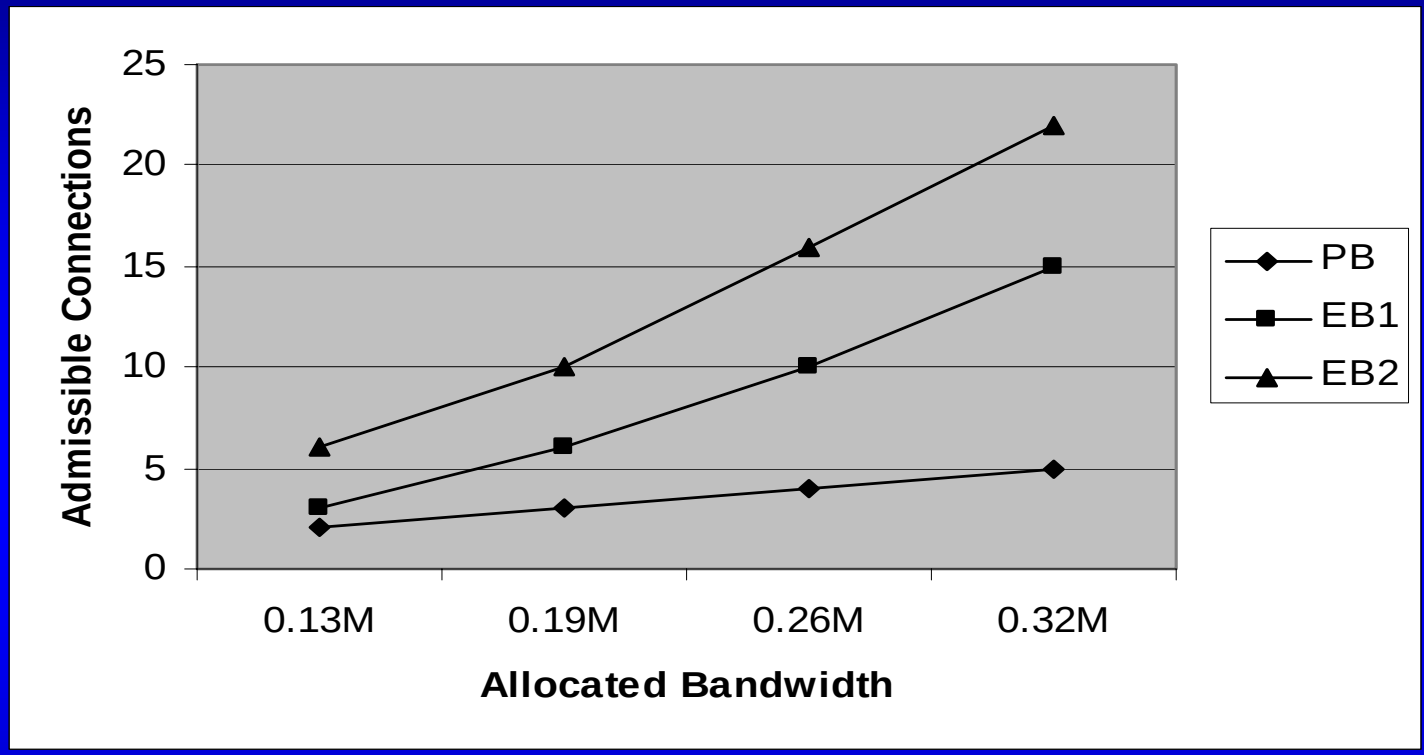
- Air interfaces, admission control, disconnection handling, wireless PKI, security binding, and QoS all demand extensive R/D
- The GridSec VPN supports both wired and wireless communications in distributed cluster, grid , and pervasive applications

The Architecture for Wireless Connection Admission Control



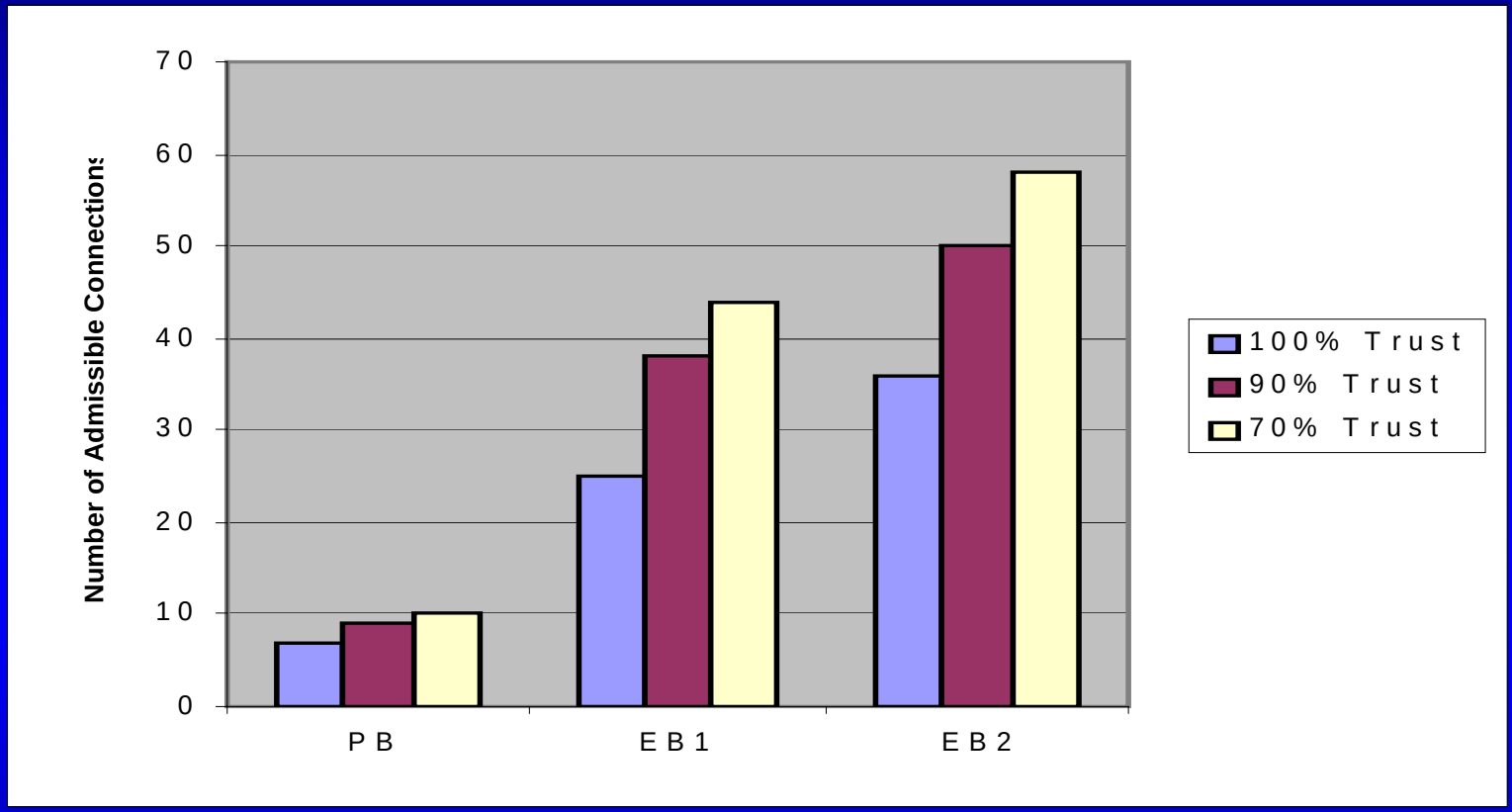
Allocate the bandwidth to satisfy the given QoS and security requirements

Secure Connection Admission
based on Effective Bandwidth Allocation



Maximum number of admissible connections under different traffic condition. PB: Peak bandwidth method with zero drop rate, EB1: Effective bandwidth method 1 with 0.1% loss probability, EB2: Effective bandwidth method-2 with 1% loss probability)

Maximum Number of Admissible Connections



EB1: Effective bandwidth method with 0.1% loss probability and EB2: Effective bandwidth method with 1% loss probability), PB: Peak bandwidth allocation method

GridSec Research Team at USC and our International Collaborators:

- Sponsored by a NSF/ITR Research Grant in the USA
- Principal Investigator: Kai Hwang at USC

  Co-PI: Clifford Neuman at Information Science Institute, USC
- Post-doctorial Researchers at ISI/USC

  Dr. Tatyana Ryutov and Dr. Dongho Kim
- Research Assistants at USC EE and CS Departments:

  Min Qin, Shanshan Song, Yongjin Kim, Rakesh Rajbanshi, Ching-Hua Chuan, Gurpreet Grewal, Mikin Macwan, Narayana Jayaram, Yushun Zhang, Rohil Tripathi, ...
- International Collaborators:

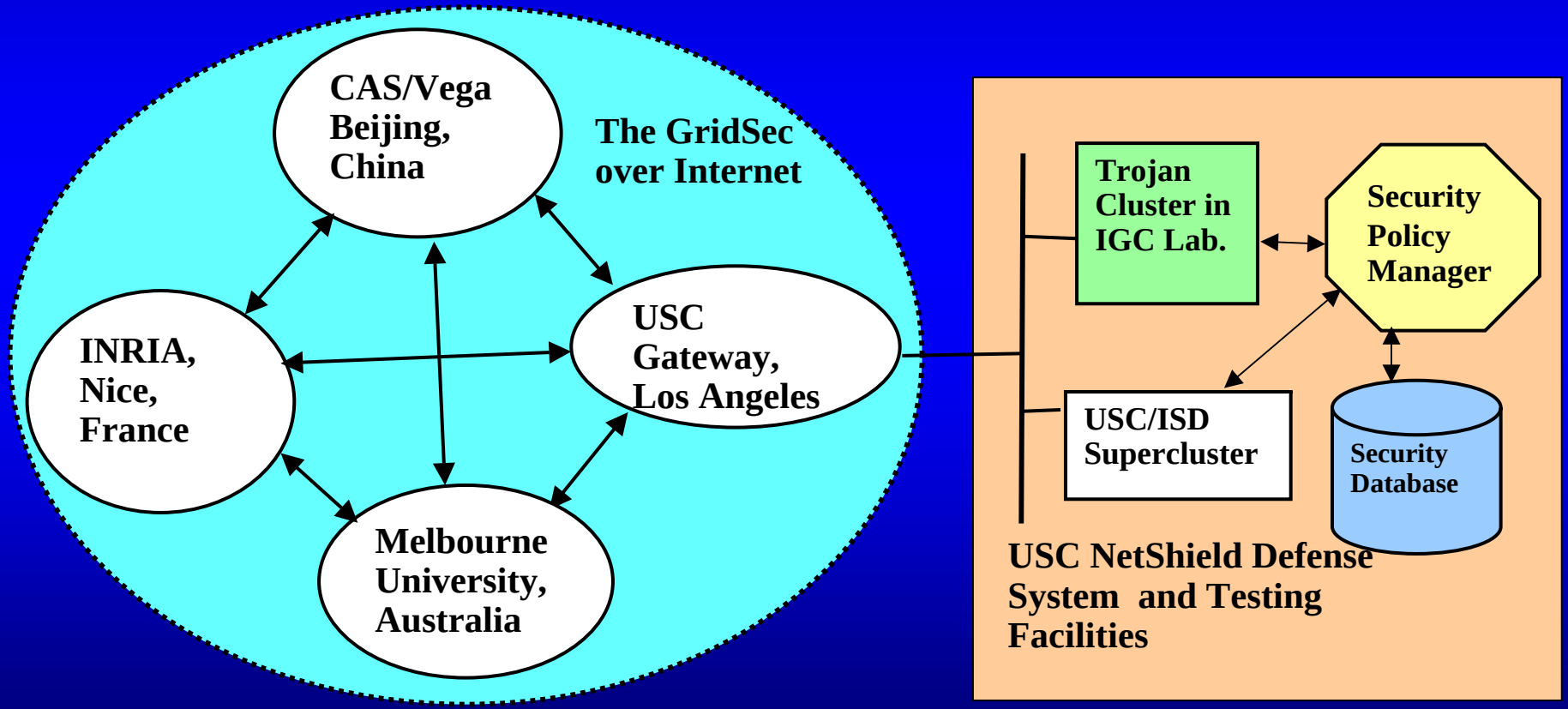
  Prof. Michel Cosnard of INRIA, France

  Dr. Zhiwei Xu of Chinese Academy of Sciences

  Dr. Rajkumar Buyya of Melbourne Univ., Australia

Global GridSec Testing Environment

International Collaborators in USA, France, China, and Australia



Intrusion Response Strategies for Defending against DDoS Attacks

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Conclusions:

- GridSec for protecting distributed resources
  - Security-assured resource allocation (SARA)
  - Local resources fortified with NetShield library
  - Remote processing through GridSec VPN tunneling
- Automated intrusion detection and response
  - Generating anomaly detection rules to build IDS
  - Adaptive intrusion response through risk assessment
  - Priority defense against DDoS and flood attacks
- Continued research tasks and future directions:
  - Testing SARA and NetShield on GridSec testbed
  - Optimize the GridSec VPN architecture
  - Explore wireless Grid computing technology
  - Integrating pervasive, cluster, and Grid computing

Recent Reports and Submitted Papers:

1. K. Hwang, et al, " GridSec: A Distributed VPN/IDS Architecture for Securing Grid Computing ", Technical Report, Internet and Grid Computing Lab., Univ. of Southern Calif., Dec. 2003 (in preparation)
2. S. Song, K. Hwang, and R. Rajbanshi, "Security-Assured Resource Allocation for Trusted Grid Computing", submitted to *IPDPS- 2004*, October 16, 2003
3. M. Qin and K. Hwang, "Effectively Generating Frequent Episode Rules for Anomaly-based Intrusion Detection", submitted to *IEEE Symposium on Security and Privacy*, Nov.3, 2003
4. Y. Kim and K. Hwang, "Secure Admission Control for Resolving Wireless Congestion in Grid Computing ", submitted to *IEEE Internet Computing Magazine*, Nov.27, 2003