Fuzzy Trust Integration for Security Enforcement in Grid Computing

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Website: http://GridSec.usc.edu/

Presentation Outline:

- Research Motivations
- Fuzzy Logic based Trust Integration
- The SARAH for Resource Optimization
  - (Secure Grid Outsourcing)
- Grid Performance with Trust Integration
- Lessons Learned and Future Research

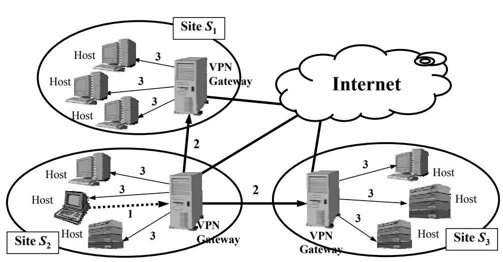
Motivations

- Grid applications demand not only resources, but also trusted resources to avoid security crashes at remote sites in an open and risky Grid environment
- Benefiting many security-sensitive Grid applications:
  - Scientific explorations, health-care
  - Public safety, cyber crime control, homeland security
  - Digital government, distance education, social community, national information services
  - Grids for business, enterprises, and e-commerce

Trusted Grid Computing Requirements

- Trusted resource allocation, sharing, and scheduling
- Secure communications among Grid sites, clusters, and protected download operations among peer machines
- Intrusion resistance, attack repelling, etc
- Fortification hardware/software (firewalls, packet filters, VPN gateways, traffic monitors, etc.)
- Self-defense toolkits/middleware (Distributed IDSs, risk assessment, response automation)

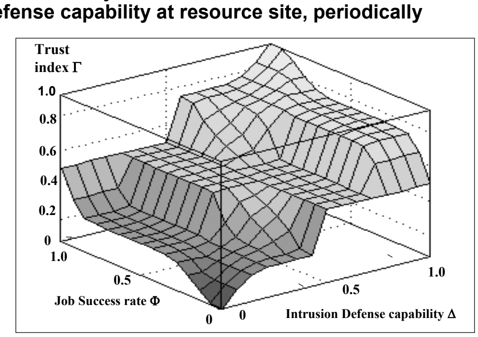
GridSec: A Grid Security Project at USC



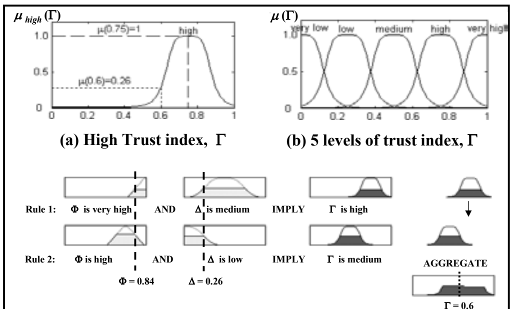
Self-defense Steps at resource site :
Step 1: ····► **Intrusion detected by host-based firewall /IDS**
Step 2: ──► **All VPN gateways are alerted with the intrusion**
Step 3: ──► **Gateways broadcast response commands to all hosts**

Trust Index of Grid Resource Site:

derived from job success rate and intrusion defense capability at resource site, periodically



Fuzzy Logic for Trust Integration

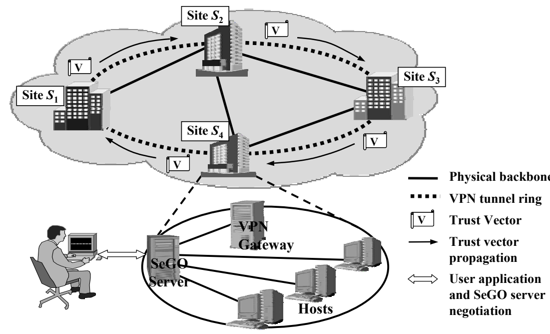


(a) High Trust index, Γ

(b) 5 levels of trust index, Γ

(c) Fuzzy inference procedure

Trust Integration over VPN Ring



A Trust Integration Example

Eq. 1 $t_{ij}^{new} = \alpha t_{ij}^{old} + (1-\alpha)s_{ij}$

Eq. 2 $\Delta(S_j) = \Delta(S_j) + \varepsilon(\Delta)$

Eq. 3 $V_j^{new} = \frac{m-1}{m} V_j^{old} + \frac{1}{m} V_i$

$$\begin{pmatrix} 0.3 & 0.2 & 0.3 & 0.4 \\ 0.5 & 0.4 & 0.5 & 0.5 \\ 0.7 & 0.7 & 0.6 & 0.7 \\ 0.8 & 0.8 & 0.9 & 0.8 \end{pmatrix}$$

(a) Initial trust matrix

$$\begin{pmatrix} 0.3 & \mathbf{0.2} & 0.3 & 0.4 \\ 0.5 & \mathbf{0.4} & 0.5 & 0.5 \\ 0.7 & \mathbf{0.8} & 0.6 & 0.7 \\ 0.8 & \mathbf{0.9} & 0.9 & 0.8 \end{pmatrix}$$

(b) Update V_2 at column 2 using Eqs. 1 and 2

$$\begin{pmatrix} \mathbf{0.4} & \mathbf{0.3} & \mathbf{0.4} & \mathbf{0.5} \\ \mathbf{0.6} & \mathbf{0.5} & \mathbf{0.6} & \mathbf{0.6} \\ 0.7 & 0.8 & 0.6 & 0.7 \\ 0.8 & 0.9 & 0.9 & 0.8 \end{pmatrix}$$

(c) Enhance $\Delta(S_1)$ and $\Delta(S_2)$ at rows 1 and 2 using Eq.3

$$\begin{pmatrix} 0.4 & 0.3 & 0.4 & \mathbf{0.5} \\ 0.6 & 0.5 & 0.6 & \mathbf{0.5} \\ 0.7 & 0.8 & 0.6 & \mathbf{0.6} \\ 0.8 & 0.9 & 0.9 & \mathbf{0.8} \end{pmatrix}$$

(d) Update V_4 at column 4 using Eqs.1 and 2

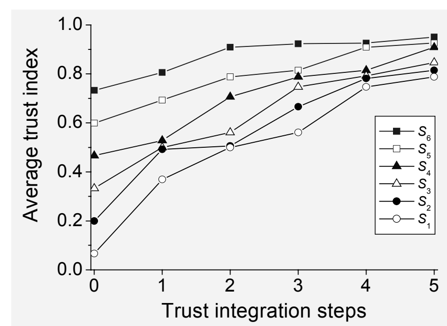
$$\begin{pmatrix} \mathbf{0.5} & \mathbf{0.4} & \mathbf{0.5} & \mathbf{0.6} \\ \mathbf{0.6} & \mathbf{0.6} & \mathbf{0.6} & \mathbf{0.6} \\ \mathbf{0.7} & \mathbf{0.8} & \mathbf{0.7} & \mathbf{0.7} \\ 0.8 & 0.9 & 0.9 & 0.8 \end{pmatrix}$$

(e) Enhance $\Delta(S_1)$, $\Delta(S_2)$ and $\Delta(S_3)$ at first 3 rows using Eq.3

$$\begin{pmatrix} \mathbf{0.6} & \mathbf{0.6} & \mathbf{0.6} & \mathbf{0.6} \\ \mathbf{0.7} & \mathbf{0.7} & \mathbf{0.7} & \mathbf{0.7} \\ \mathbf{0.8} & \mathbf{0.8} & \mathbf{0.8} & \mathbf{0.8} \\ \mathbf{0.9} & \mathbf{1.0} & \mathbf{1.0} & \mathbf{0.9} \end{pmatrix}$$

(f) Enhanced matrix after update all trust vectors

Effects of Trust Integration



Trusted Resource Allocation

- Based on the fuzzy trust model, a *Secure Grid Outsourcing* (*SeGO*) scheduler was developed for Grid resource allocation:
  - $S_i = (P_i, V_i, C_i)$, representing the *computing power*, *trust vector*, and *unit service cost*.
  - *Job* = (*W*, *D*, *T*, *B*), representing the *workload*, *execution deadline*, *minimum trust requirement*, and *budget limit.*
- The optimization process is modeled as a nonlinear programming problem, with the objective to maximize the *Grid Efficiency*:

$$E = \sum_{i=1}^{m} W_i t_{ij} \Big/ \sum_{i=1}^{m} W_i C_i = \sum_{i=1}^{m} x_i P_i L t_{ij} \Big/ \sum_{i=1}^{m} x_i P_i L C_i$$

SARAH : Security-Assured Resource Allocation arcHitecture

Algorithm 3: *SARAH* (R_j, *Job* = (W, D, T, B))

Input: Submit ***Job*** = (W, D, T, B) to resource site R_j at time τ, R_j requests resources from all m sites.

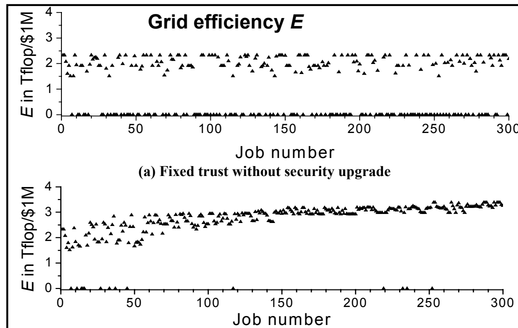
Output: Workload distribution (W_1, W_2, …, W_m) and estimated execution time L for ***Job*** based on allocation $X = (x_1, x_2, …, x_m)$ generated.

(1) R_j sends requests to obtain available resources information from all sites;
(2) **for** $i = 1$ **to** m
(3) **if** ($t_{ij} < T$) $x_i = 0$.
(4) **end for**
(5) Estimate execution time $L = D - \tau$;
(6) Generate the allocation vector $X = (x_1, x_2, …, x_m)$, which maximize $E = \sum_{i=1}^{m} x_i P_i L t_{ij} \Big/ \sum_{i=1}^{m} x_i P_i L C_i$, subject to the following constraints $\sum_{i=1}^{m} x_i P_i L \geq W$, $\sum_{i=1}^{m} x_i P_i L C_i \leq B$, and $0 \leq x_i \leq 1$;
(7) **for** $i = 1$ **to** m $W_i = x_i P_i L$;
(8) **return** (W_1, W_2, …, W_m, L) with allocation $X = (x_1, x_2, …, x_m)$.

Performance Evaluation

- In a computational Grid environment, we execute mainly coarse-grain supercomputing applications.
- The performance of the SeGO scheme was evaluated by a discrete event-driven Grid simulator developed at USC to model the trust integration and the resource optimization processes.
- We use typical workload parameters measured at USC Center for High Performance Computing and Communications. Both user jobs and resource parameters are configured to reflect real-world situations.

Trust Integration Performance Gain

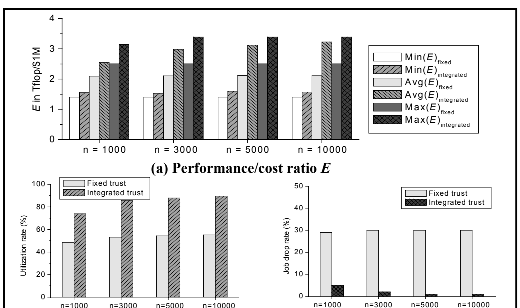


(a) Fixed trust without security upgrade

(b) Integrated trust with security enhancement

Scaling Effects of Job Number (n)

-- n = 1000, …, 10000 Jobs for Parallel Execution on 20 Grid Sites

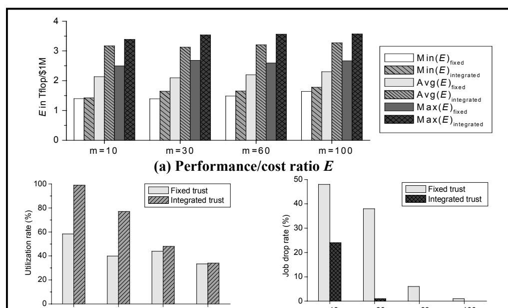


(a) Performance/cost ratio E

(b) Resource utilization rate (c) Job drop rate

Scaling Effects of Grid Size (m)

---- 5000 Jobs Parallel Execution on m = 10, 30, 60, 100 sites



(a) Performance/cost ratio E

(b) Resource utilization rate (c) Job drop rate

Conclusions:

- **Fuzzy trust integration reduces platform vulnerability: Our fuzzy trust model guides the defense deployment across distributed Grid sites. This lays the foundation of distributed security enforcement in Grids.**
- **Trusted Grid resource allocation and configuration: the SARAH has been extended into a SeGO scheduler that can be applied to upgrade the AppLeS and NimRod/G schedulers in security reinforcement.**
- **Our work will benefit many Grid applications in scientific explorations, health-care, public safety, national security, digital government, etc.**

Related Research Challenges

- **Real-life benchmark workloads such as NAS, PSA, and others are being tested on a plug-in Grid testbed scattered at USC, ISI, and several Grid sites at our collaborators in China, France, and Australia.**
- **A production SeGO scheduler will be converted from the SARAH scheme based on a mixed fuzzy trust integration and game-theoretical approach**
- **Security-driven heuristics and fast genetic algorithms developed to achieve trusted on-line job scheduling in computational Grids**