NIST
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Technology Administration, U.S. Department of Commerce

INFORMATION TECHNOLOGY LABORATORY

Investigating Reliability and Robustness of Standards-Based Grid Computing Systems

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Motivation

Vision: Future global information infrastructure will rely on emerging standards for Web Services and Open Grid Services Architecture

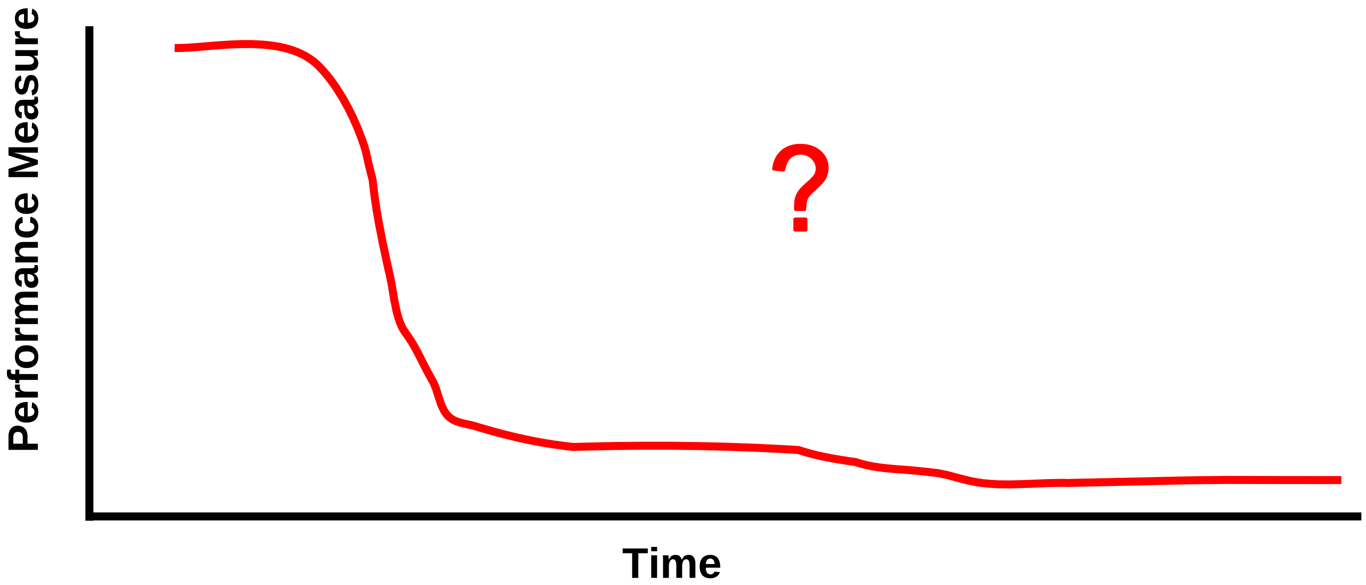
Question #1: – Will future distributed systems designed in conformance to Web Services and Grid standards achieve levels of robustness, scalability, and performance required for critical enterprise applications?

Question #2: – As industrial grid systems grow in size, can unplanned interactions among distributed components lead to emergence of undesirable patterns of behavior?

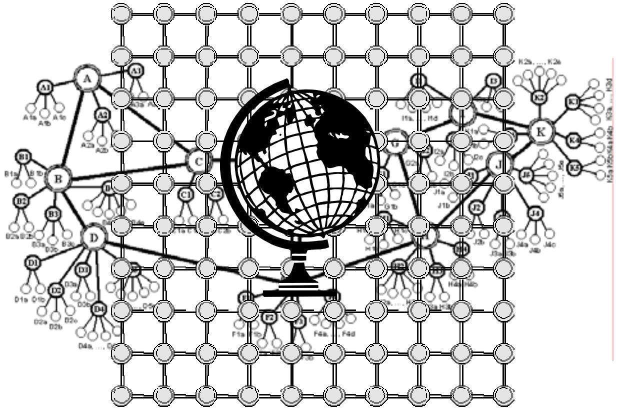
Question #3: – Can we identify areas in GGF specifications that might lead to implementation of operational Grids that are unreliable or that experience unexpected failures?

Possibility of emergent behaviors

- **Possible Concerns:** System designs may lead to interactions under failure conditions that result in emergent behaviors and unexpected performance degradations. The scaling of grid systems may, in and of itself, result in emergent behavior that adversely affects system behavior.



Investigating Emergent Properties in Standards-based Grid Systems



Customers

- Relevant industry standards groups (GGF, W3C, OASIS)
- Government users and backers of Grid technology (DoE, DISA, and NSF)

Goals

- Understand behavior of scaled SOA grids
- Investigate emergence in large-scale SOAs
- Improve related consortia specifications wrt reliability and robustness
- Investigate control mechanisms for shaping emergent behaviors

Technical Approach and Plans

Develop models of large-scale Grid systems

- Define architectures and components based on WS and GGF specs, use cases, failure scenarios, and recovery mechanisms; implement in SLX (Wolverine Software)
- Define metrics to reveal reliability, robustness, & scalability of Grid applications
- Execute experiments for large topologies and provide results to relevant standards consortia

Project phases

- ***Micro-model experiments***: 10^3 nodes 10^4 processes with components based on selected WS and GGF specs
- ***Macro-model experiments***: 10^4 nodes 10^5 processes of selected abstractions validated against micro-model.
- ***Decentralized Feedback Control Algorithms***: Experiments to evaluate candidate control algorithms that produce desirable overall system behaviors & apply to scenarios that exhibit un-desirable emergent behaviors

Model processes and components based on selected web and grid standards

Layered Component Architecture

- ***Network Layer:*** sites located in (x,y,z)-space; z axis indicates distance in hops to a simulated inter-site transmission delay;TCP-like simulated transport protocol; model node CPU delays, buffer & port capacity
- ***Basic Web Services:*** WS- Addressing, Messaging, Reliable Messaging (to be added).
- ***WSRF:*** WS- Resource Property, Lifetime, Notification, Topics, Service Group
- ***Grid Services:*** MDS v4, WS Agreement, DRMAA, *Grid security/access not included*

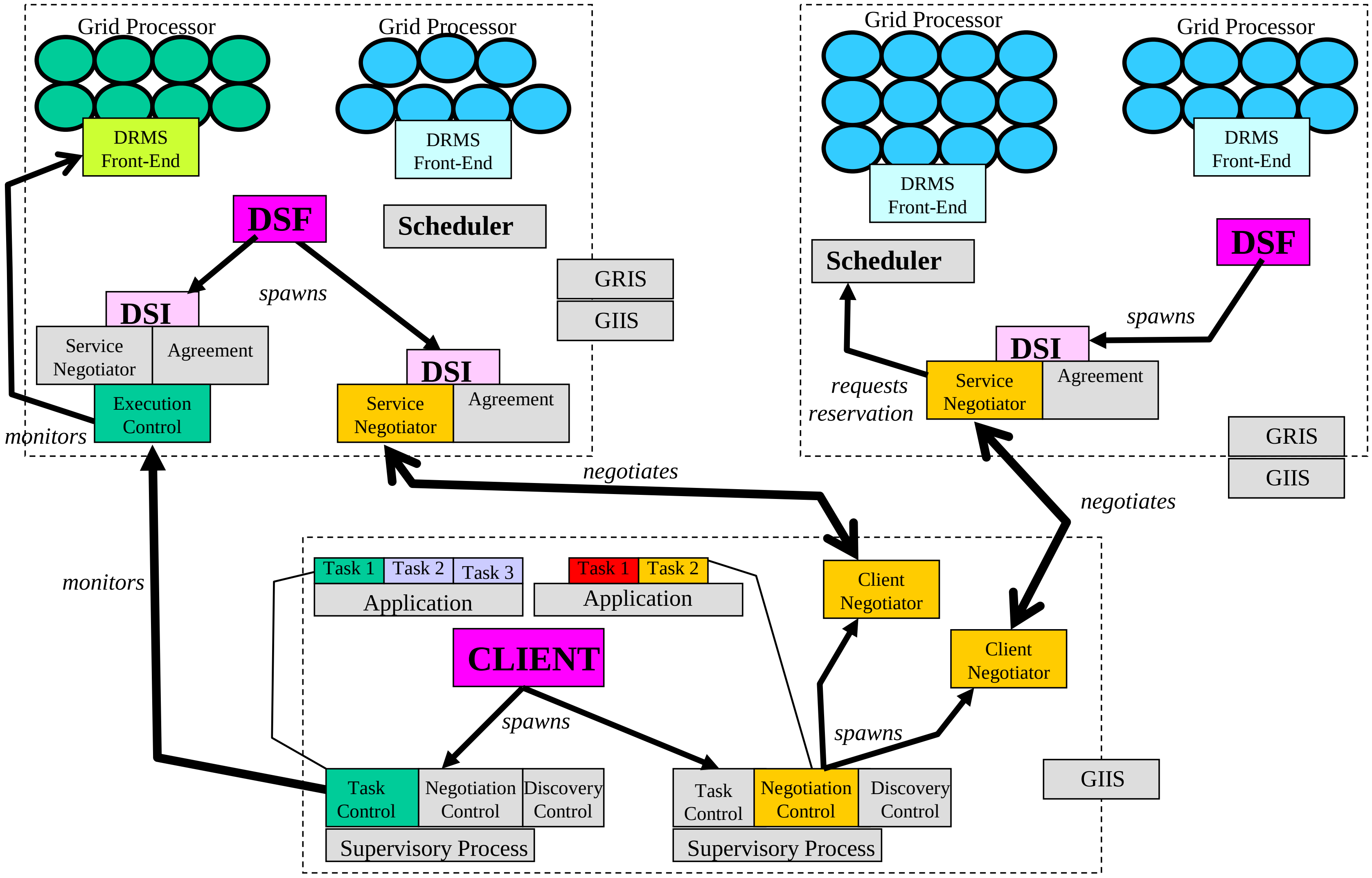
Major Grid Entities

- ***Service Providers:*** combine service & Agreement Factory WS resource (WS Agreement)
  - processor components (DRMS front-end): vectored S-computer or cluster
  - each site has scheduler for processors, GRIS, & GIIS
- ***Clients:*** discover providers by querying GIIS for required service types, rank discoveries by earliest availability (no economy scheduling, yet)**,** spawn WS resource negotiators to seek agreements, submit & monitor jobs.

Client Grid Applications

- ***Application types (5):*** workflows of 1-4 tasks, each with parallelizable sub-computations;
- ***Tasks:*** 3 types defined by required service type, task parallelism, & compute cycles
  - matched to processor component with suitable parallelism
  - Assume single agreement for resource requirements (no co-reservation)
- ***Workload:*** regulated by initial assignment of applications to clients; capacity determined by *client application requirements / (total processor capacity * time)*

Schematic showing operation of simulated grid



How does system respond to DNS spoofing under different negotiation strategies?

Negotiation Strategies

- ***Single-reservation request*** (SRR) - WS Agreement (sec. 9.2, Create Pending Agreement)
- ***Multiple-reservation request*** (MRR) - non-obligating offers, follow-up offers, and agreement superseding; based on draft WS-Agreement-Negotiation; no related agreements for co-allocation, etc. - yet?

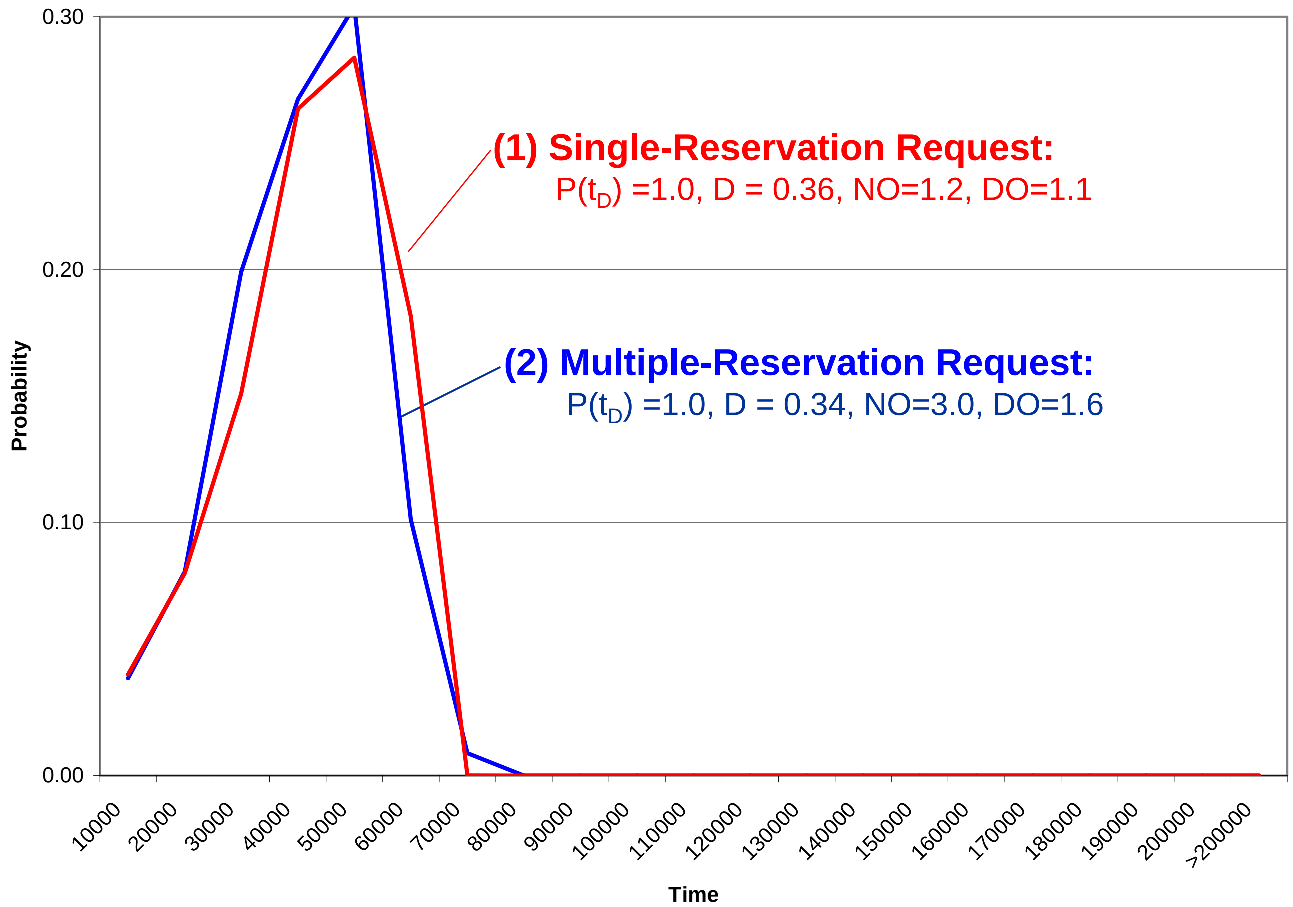
Introduction of Spoofing

- Miscreant alteration of DNS to redirect messages to false addresses
- ***Failure Response strategy:*** identify spoofers and do not repeat

Experiment

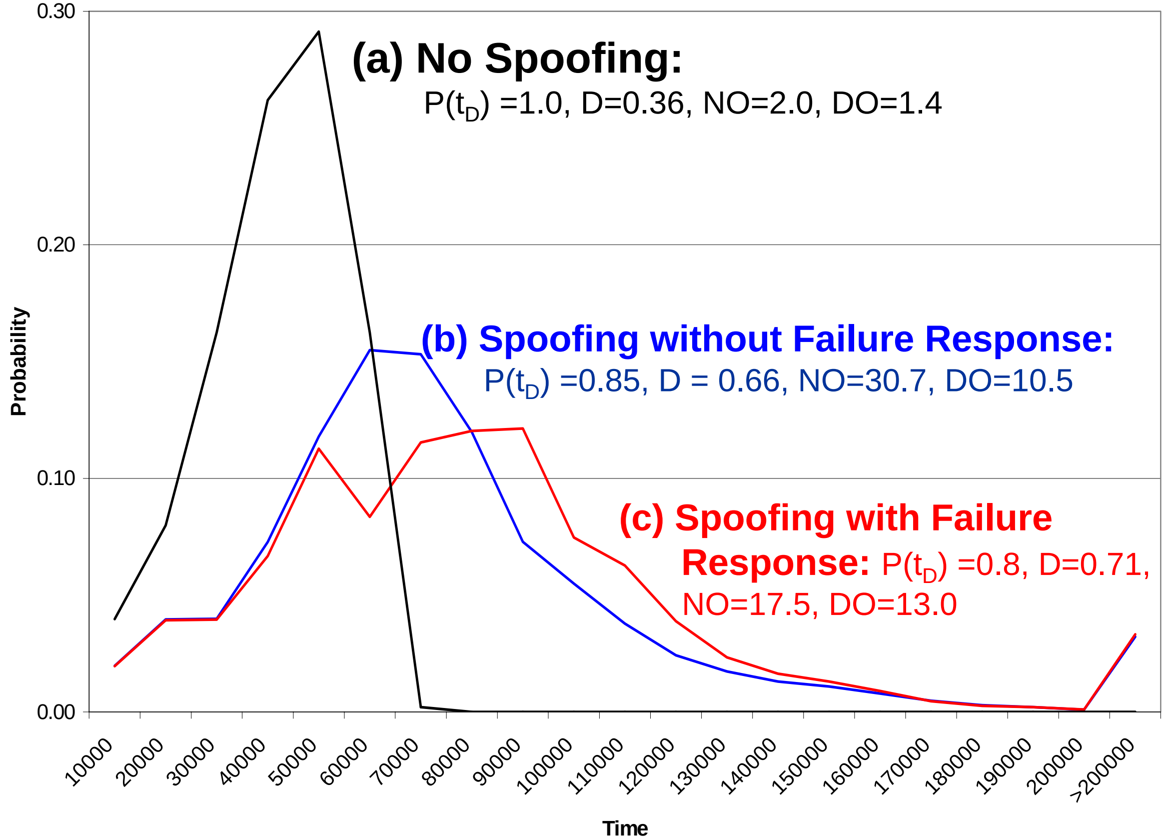
- At 50% capacity, 30 providers, 12 clients, 200 nodes - simulate 200,000s period (2+ days) with 24 hour deadline t_D using identical seed generation
- Model spoofing of service factories (p=50%); record performance with & without failure response
  - ***Primary metrics:*** probability of completion $P(t_D)$, application duration (D), negotiation (NO) & discovery overhead (DO) computed as multiple of min number of messages
  - ***Multidimensional time series analysis*** – select variables (number reservations created, number completions, etc.) to monitor over time.

Performance of Single-Reservation Request (SRR) and Multiple-Reservation Request (MRR) with no spoofing



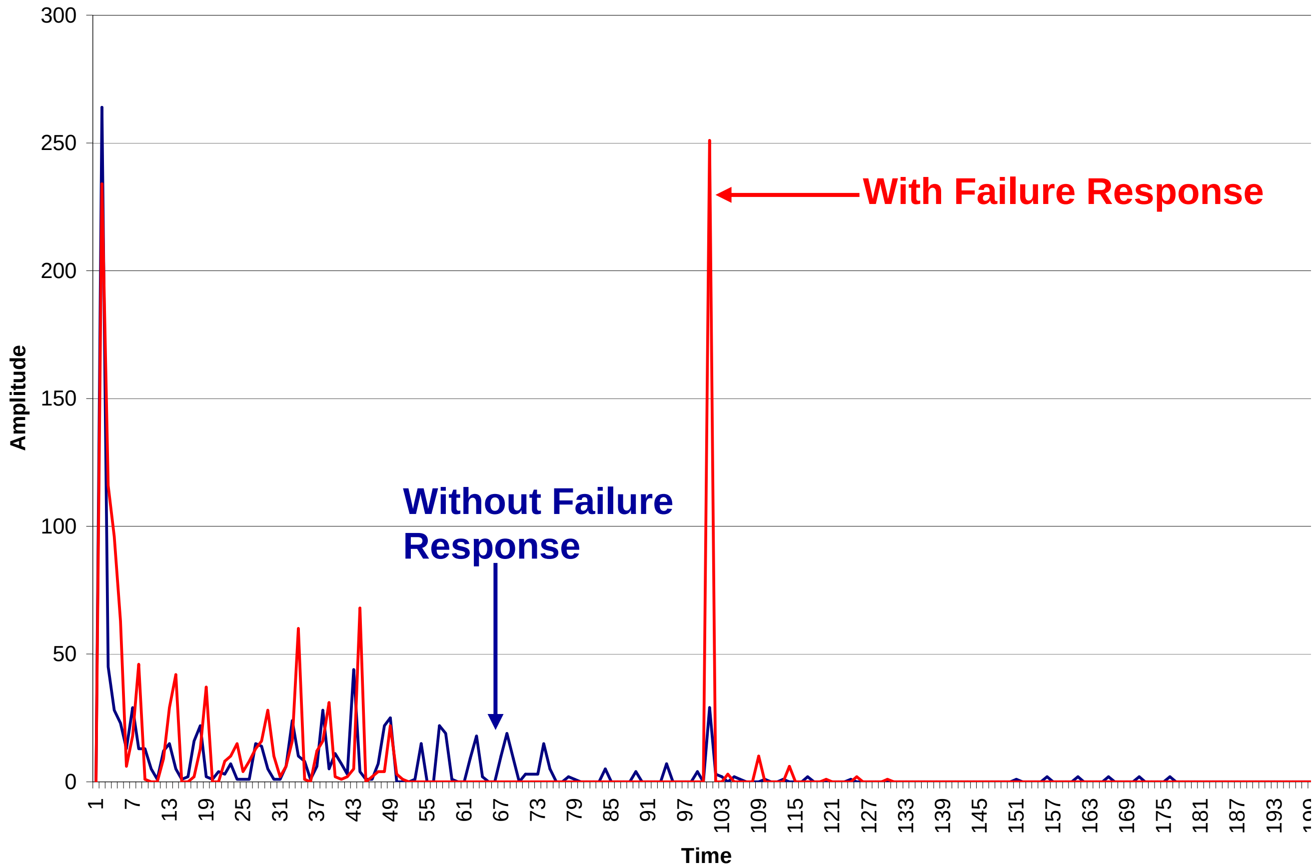
Comparative Probability Density Functions (PDFs) for application completion times and selected primary metrics for two negotiation strategies (over 200+ repetitions)

Performance degradation caused by spoofing activity in simulated Grid with 50% clients SRR and 50% MRR



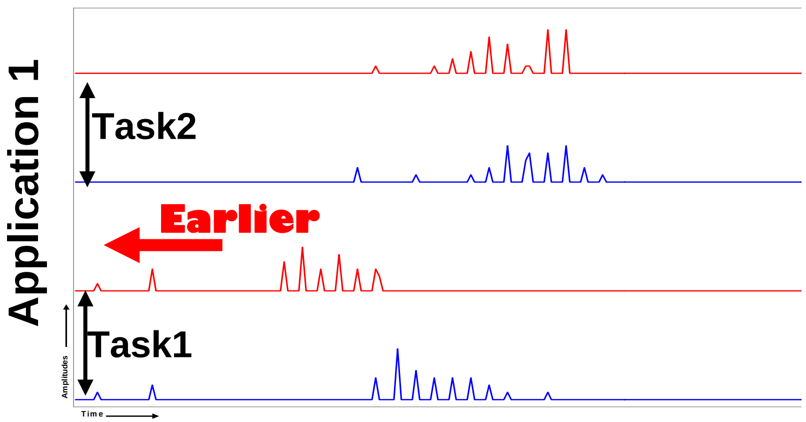
Comparative Probability Density Functions (PDFs) for application completion times and selected primary metrics given: (a) No spoofing (b) spoofing without failure response, and (c) spoofing with failure response. (200+ repetitions)

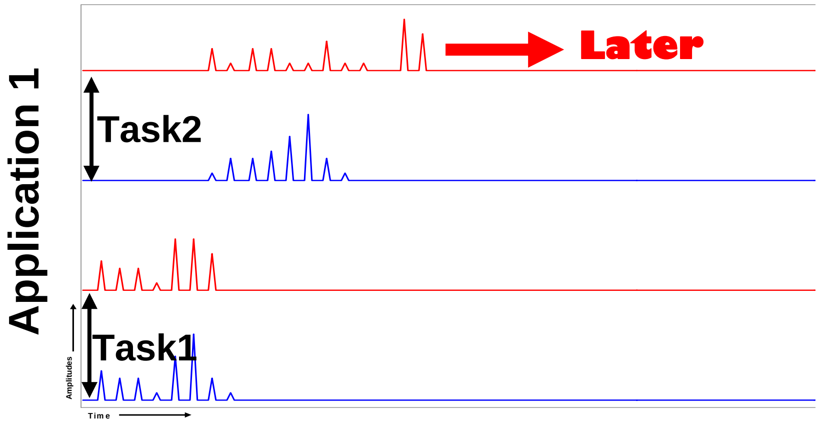
Time series in simulated Grid for reservations created with and without failure response strategy



Two Time Series: (a) Reservations Created without Failure Response and (b) Reservations Created with Failure Response for simulated grid with 50% clients SRR and 50% MRR.

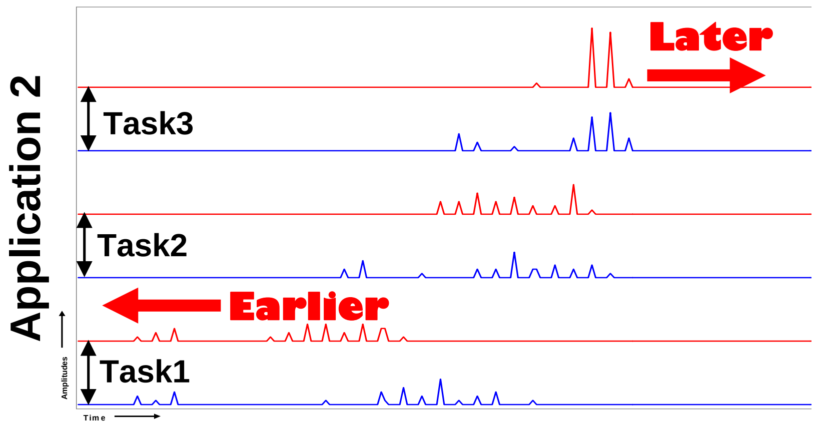
Time series for application/task completion for two application types with no failure response (lower blue) and with failure response (upper red)

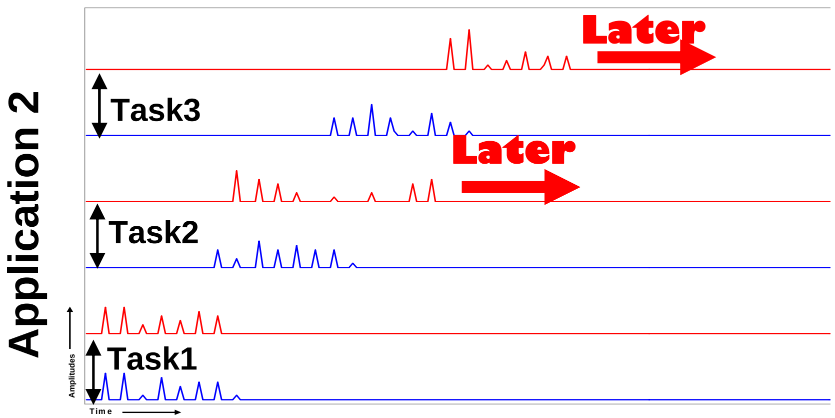




Single-Reservation Request (SRR)

Multiple-Reservation Request (MRR)





Conclusions and continuing/future work

- Under “normal” operating conditions SRR and MRR exhibit comparable performance with expected differences in overhead
- Not surprisingly, spoofing causes overall performance to degrade; both SRR and MRR degrade predictably
- However, unexpected further degradations occur when reasonable failure response action is introduced
  - “Reordering” of schedule results in overall increase in run times, (SRR clients are helped more at expense of MRR clients).
  - Emergent phenomena are difficult to explain and resolve with traditional metrics; require more sophisticated techniques such as multidimensional analysis to discern and explain causes
- Possible next steps
  - Incorporate additional GGF and WS specs
  - Formalize multidimensional analysis approach
  - Experiment with additional scenarios & scheduling algorithms to create economic model of grid computing, multiple/related agreements?

→ Should GGF have an RG on Grid Reliability and Robustness?

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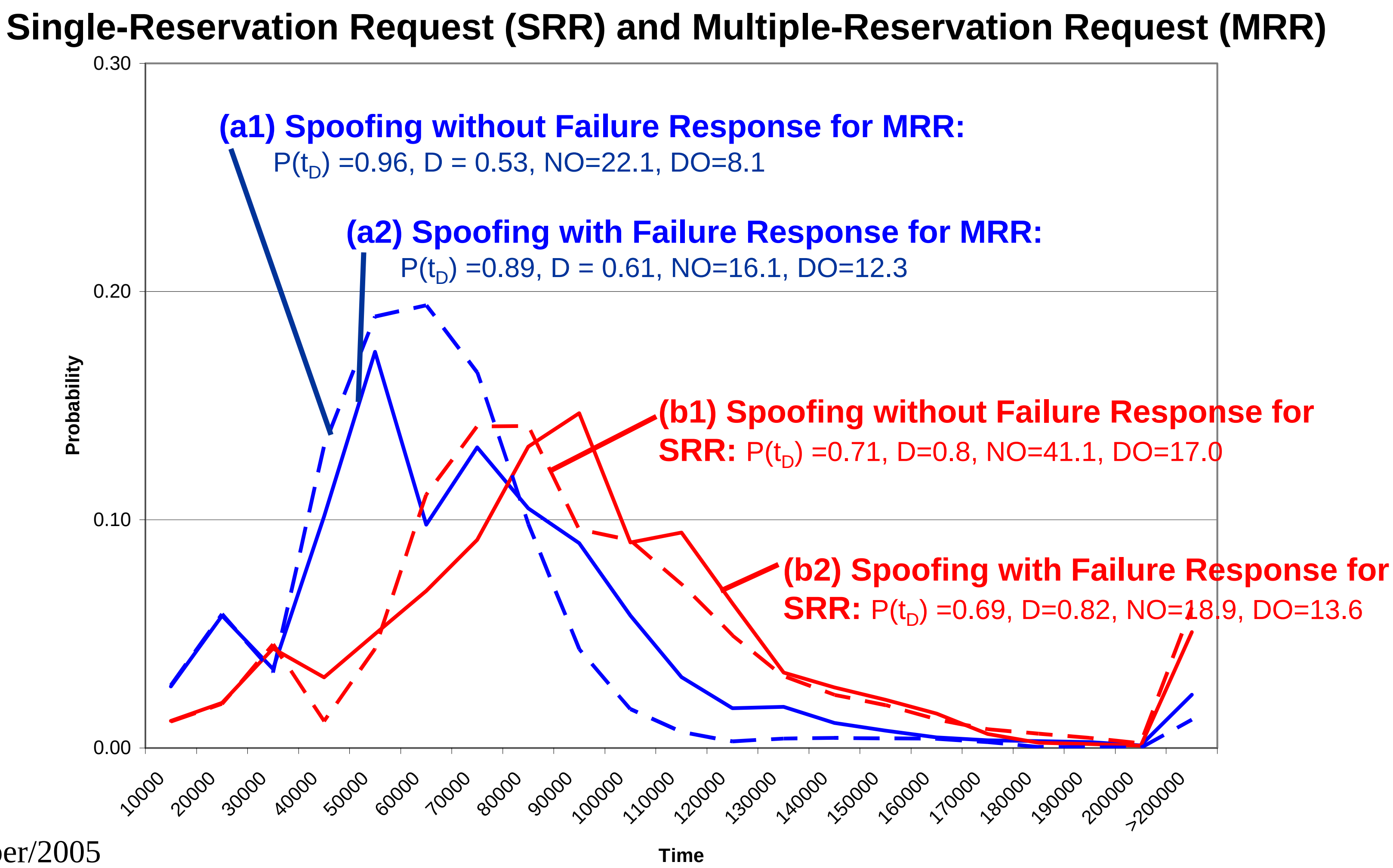
EXTRA SLIDES

Performance degradation caused by spoofing activity decomposed by failure response and negotiation strategy



Research Group for Reliability and Robustness?

- ***Motivation:*** (*from previous slides*) As grid systems are increasingly commercialized and grow in size, they are likely to be subjected to volatile and uncertain conditions that endanger or severely degrade their effectiveness in everyday use.
- ***Question to be addressed:*** How can we determine that the web-service and grid standards currently being developed will enable large-scale grids to detect and overcome failures to provide a level of reliability and robustness needed for industrial and scientific purposes?
- ***RG Focus/Purpose:***
  - Identify issues related to reliability and robustness in grid computing systems designed in conformance to Web Services and Grid standards
  - Make recommendations, and explore methods, for improving reliability and robustness of standards-based grid systems developed for critical enterprise applications and production systems.