FY2001 ONR CIP/SW URI

Software Quality and Infrastructure Protection for Diffuse Computing

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The SPYCE Team

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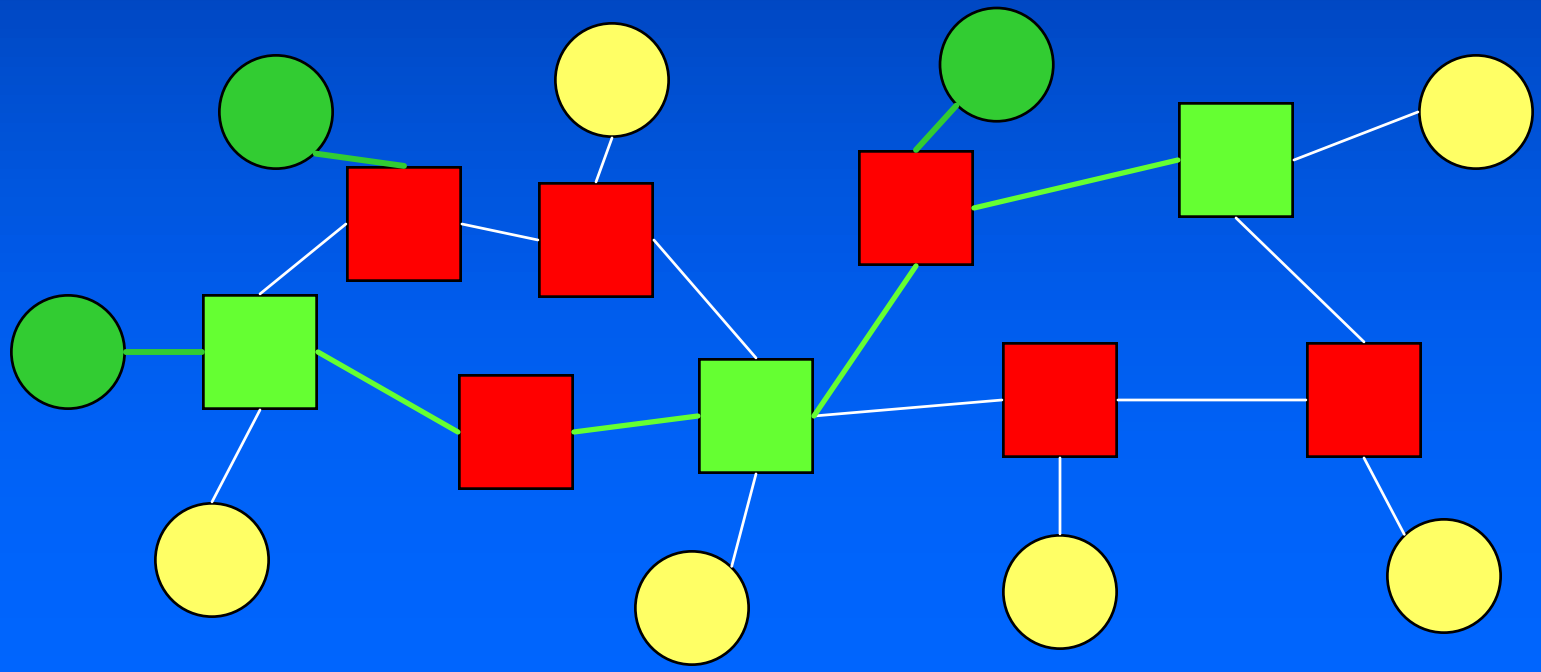
Diffuse vs Pervasive, Ubiquitous

- Pervasive Computing
  - Access to information from anywhere
  - Many humans, one information network
- Ubiquitous computing
  - Lots of little devices everywhere
  - One human, many little computers
- Diffuse Computing
  - Development of services: compute, store, …
  - Accessing and combining services robustly
  - Teams of users, many machines at-the-ready

Where is Diffuse Computing?

- Hosts
- Routers
- Diffuse Computing Elements



Why Diffuse Computing?

- Large commercial computing markets
  - Yet personalized computing support
- Huge potential of distributed architectures
  - Leverage potential of the collective
- Needs of network-centric systems
  - High assurance: *you can bet your life on it*
  - Survivable: *resists massive cyber attack*
  - Scalable: *can grow to support government*
  - Smart: *distributed control over things*
  - Affordable: *infrastructure can grow quickly*

Research Challenges in Diffuse Computing

Make ordinary computers do extra-ordinary things together

- Providing high quality solutions out of lower-quality computing and network resources working together
- New mechanisms for stability in diffuse systems
- Think about computing in terms of economics and physics metaphors
- Risk management at system level
- Components combined on an as-needed basis
- Local autonomy in ultra-large-scale distributed systems

Multi-Disciplinary Approach

- Combines 4 complementary thrusts:
  - Incentive-compatibility in distributed computing
  - Authorization mechanisms
  - Secure data storage and retrieval
  - Communication protocols
- Multi-institution experimental platform + systematic, formal treatment of underlying models, algorithms & data structures

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Market System of Autonomous Agents

- "Mechanism Design"
  - How to achieve global goals with local autonomy?
  - Drawn from economics
- Behavior of software as a system, described formally in spite of incomplete knowledge
- Initial development of this methodology

Mechanism Design

- Mechanism Design: design a system in which strategic agents behave in socially desirable ways
  - well studied in economics
- Algorithmic mechanism design [NR99]
  - takes complexity into account
- We need fault-tolerant, computationally efficient algorithmic mechanism design for hybrid distributed systems

Decentralized Algorithmic Mechanisms

Distribute the mechanism computation among all nodes in the network.

"Low network complexity" [FPS00]:

- Small total number of messages
- No link is a "hot spot"
- Small maximum message size
- Fast local processing

Feigenbaum, Papadimitriou, and Shenker (2000) study the network complexity of natural mechanisms for multicast cost sharing.

Project Coordination:
Multi-Pronged Approach to Herding Research

- Physical meetings
- Video conferences
- Teleconferences
- Email discussions

- Organization and coordination centered at UPenn

Project Meetings

- URI kickoff meeting July 7 (WDC)
- ~~Group meeting Sept 15-17 (NYC)~~
- Video conference Oct 8 (UPenn-SRI)
- First board meeting Nov 5 (UPenn)
- Group meeting Nov 30-Dec 2 (Calistoga)
- …and many more to come

Some SPYCE Accomplishments To Date

- Experimental network platform
- Initial results identifying multiple bottlenecks in real networks
- Game-theoretic understanding of simple network operations (multicast)

SPYCElab Active Networks

- Active Networks provide tremendous flexibility, but also dangerous power
- We are building a multi-institution experimental platform to explore market-based restrictions on power
- Infrastructure to test diffuse computing and/or market-based approaches

J. Smith K. Anagnostakis

Approximation and Collusion in Multicast Cost Sharing

- Multicast is an efficient method of distributing rich media, but it is difficult to share costs fairly
- We are investigating both efficient and budget-balanced mechanisms
- This is a first step toward game-theoretic understanding of network infrastructure

J. Feigenbaum A. Krishnamurthy R. Sami S. Shenker

Reliable Anonymity Networks via Calculated Reputation

- Preserving anonymity while improving reliability
- We study a reconfiguration approach based on reputations and communal random seed
- The payoff from this is to eliminate global trusted witnesses, and to provide more robust anonymity services

P. Syverson

Summary of Project: Multidisciplinary Research

- Software Quality and Infrastructure Protection for Diffuse Computing
- Building sound theoretical basis for mechanism design and analysis
- Constructing multi-institution experimental platform

Possible Impact of Successful Research on Diffuse Computing

- Multi-institution experimental platform
  - Scalable distributed markets
- Mechanism design
  - Scalable, provable incentive systems
- Approaches to defining and analyzing survivable infrastructure

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