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

- 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

Make ordinary computers do extra-ordinary things together
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

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
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