Adaptive System Infrastructure for Ultra-Large-Scale Systems

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Past R&D Successes: Platform-centric Systems

From this design paradigm...

Legacy systems are designed to be:
• Stovepiped
• Proprietary
• Tightly-coupled, brittle, & non-adaptive
• Expensive to develop & evolve
• Vulnerable

Problem: Small changes can (& do) break nearly anything & everything
Past R&D Successes: Platform-centric Systems

…and this operation paradigm…

Real-time quality of service (QoS) requirements for platform-centric systems:

- Ensure end-to-end QoS, e.g.,
  - Minimize latency, jitter, & footprint
  - Bound priority inversions
- Allocate & manage resources statically

Problem: Lack of any resource can (& do) break nearly anything & everything
Past R&D Successes: Network-centric Systems

...to this design paradigm...

Today’s leading-edge systems are designed to be:

- Layered, componentized, & service-oriented
- More standard & COTS
- Robust to expected failures & adaptive for non-critical tasks
- Less expensive to evolve & retarget
Past R&D Successes: Network-centric Systems

…and this operational paradigm…

- Loosely coupled services
Past R&D Successes: Network-centric Systems

...and this operational paradigm...

Desired Utility Curve

“Working Range”

Resources

“Softer” Requirements

Problem: Network-centricity is an afterthought in today’s systems
Key challenges in the solution space

- Enormous accidental & inherent complexities
- Continuous evolution & change
- Highly heterogeneous platform, language, & tool environments

Key challenges in the problem space

- Network-centric, dynamic, ultra-large-scale “systems of systems”
- Stringent simultaneous quality of service (QoS) demands
- Highly diverse & complex problem domains

Conventional technologies ill-suited to meet ULS system infrastructure demands
Promising R&D Areas for Adaptive ULS System Infrastructure

- Decentralized Production Management
- View-Based Evolution
- Evolutionary Configuration & Deployment
- In Situ Control & Adaptation
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- Decentralized Production Management
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Evolutionary Configuration & Deployment

Goals

- Develop theory & concepts for ULS system configuration & deployment to distribute, customize, & install software components dependably & securely:
  - Despite an evolving mixture of proven & unproven components
  - Despite the existence of different versions of components in various deployment configurations
  - While providing the ability to rollback to proven configurations when problems are detected
Promising Research Approaches

- Models, algorithms, & tools for specifying, reasoning about, & modifying ULS system components dependencies to validate key functional properties
- System execution modeling techniques & tools to analyze & optimize system QoS before & during software updates
- Scalable protocols for automatically distributing software updates dependably & securely under hazardous operating conditions
In Situ Control & Adaptation

Goals

• Develop theories, algorithms, & services that allow ULS systems to
  • Monitor the activity of system elements & their environments
  • Perform self-testing to detect deviations in expected behavior & performance & automatically recover from them
    • e.g., by reconfiguring component behavior & configurations while the system is operating
  • Protect the system from damage when patches & updates are installed, as well as from attacks perpetrated against them during operation
In Situ Control & Adaptation

Promising Research Approaches

- Control-theoretic techniques that handle rapidly changing demands & resource-availability profiles & configure these mechanisms with service policies tuned for different operating modes.

- Scalable techniques for developing controllers that adapt ULS systems under a wide range of conditions.

- Certification techniques & processes that can ensure adaptive systems only operate within safe, correct, & stable configurations.

Ship-wide QoS Doctrine & Readiness Display
Concluding Remarks

- The emergence of ULS systems requires significant innovations & advances in adaptive system infrastructure
- Not all technologies will provide the precision we’re accustomed to in legacy small-scale systems
- Breakthroughs in computing technology & related disciplines needed to address ULS system infrastructure challenges
- Initial groundwork layed in various R&D programs

Much more research needed on adaptive infrastructure for ULS systems