Design Research Area – Architecture Principles

Theories and constructs from the field of economics can endow the notion of architecture with new meaning and consequently offer structuring principles for Ultra-Large-Scale Systems.
What Is a Software Architecture?

“The **software architecture** of a program or computing system is the structure or **structures of the system**, which comprise the software elements, the **externally visible properties** of those elements, and the **relationships among** them.* ”

• Architecture is an abstraction; it is not about the details, but …
• it expresses sufficient detail to support appropriate analyses …
• vis-à-vis important (quality attribute) requirements and …
• appropriately constrains more detailed design and implementation.

“… beyond certain complexity thresholds, a traditional centralized engineering perspective is no longer adequate nor can it be the primary means by which ultra-complex systems are made real. *”

“Like cities, ULS systems will not simply be bigger systems: they will be interdependent webs of software intensive systems, people, policies, cultures, and economics. *”

Hints from Market Design

“Traditional economics views markets as simply the confluence of supply and demand. A new field of economics, known as ‘market design,’ recognizes that well-functioning markets depend on detailed rules. …”

- Market designers try to understand these differences and the rules and procedures that make various kinds of markets work well or badly.”

- Their aim is to know the workings and requirements of particular markets well enough to fix them when they’re broken or to build markets from scratch when they’re missing.* ”

Inspiration – Radio Spectrum Auction -1 *

Spectrum licenses (for use in wireless communication) were originally allocated on the basis of hearings by the FCC.

- procedure was time consuming; backlog developed
- switched to lotteries; winners could resell at high prices (winner of a license to run cellular telephones in Cape Cod sold it to Southwestern Bell for $41.5 million)

A previously unrecognized value proposition emerged

- generate revenue
- allocate efficiently
- generate public value
- encourage participate by small business, minorities, …

Inspiration – Radio Spectrum Auction -2

“Elements” are individuals, organizations and resources

- government
- license acquirers; “properties” include:
  - private value for license based on competition situation, value placed on bundles of licenses based on competitive strategy and previously acquired licenses
  - financial status
  - minority status
  - competitive situation
- game theorists (who want to put theories to practical use; the most recent Nobel Prize in economics was awarded for Mechanism Design)
- resources
Inspiration – Radio Spectrum Auction

Problem type
- resource allocation
- resource to be allocated
  - intervals of radio spectrum
  - geographic regions

“Relations” are interaction protocols defined by mechanism, alternatives considered
- open vs. closed bidding
- first vs. second price auction
- sequential vs. simultaneous (allowing for license combinations)

Potential protocol “properties” (from game theory and mechanism design)
- Bayes-Nash equilibria
- incentive compatibility
Observations - 1

Value proposition drives auction (and more generally) mechanism design

Value proposition and mechanism rules are at times learned and at times explicitly designed resulting in an interacting hierarchy of mechanisms *

- FCC policy
- Auction mechanism
- Cell phone system

Very different expertise is required for different levels of the hierarchy likely requiring different types of “architects” – the notion of a single central architecture team is “broken”.

*Aoki, M., Toward a Comparative Institutional Analysis, 2001.*
Observations -2

Economic theories
- exploit rational self-interest and scale – a natural fit for ULS systems
- inform system structure in much the same as quality attribute theories inform software architecture structure

Theories are not perfectly matched to the situations they model
- must rely on combination of theory, experiments, and experience *
- ULS system architecture must support this **

Theories from other diverse disciplines such as biology, organizational learning, and sociology are also likely to offer ULS system structuring principles.

** Conversation with Kevin Sullivan.
What Is a ULS System Architecture?

How about this?

The architecture of a ULS system is dynamic hierarchy / constellation of interacting system architectures, each with its own value propositions, element types (including individuals and organization) and associated properties (such as self-interest and private values), relations (such as those found in strategic games) and theories (such as game theory).

SEI ULS systems architecture research:
- Explore the nature of existing hierarchies / constellations
- Discover styles of ULS system architectures
- Continue exploring applicability of economic mechanisms
- Explore interaction between non-computational and computational mechanisms
- Explore institution design (Aoki)
- Explore theories from other disciplines