Grid Qualities and Properties

Metrics and Norms

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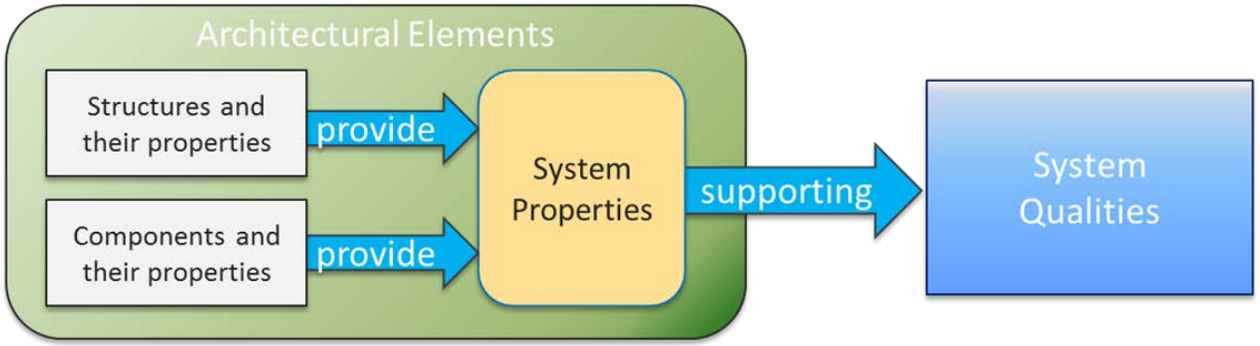
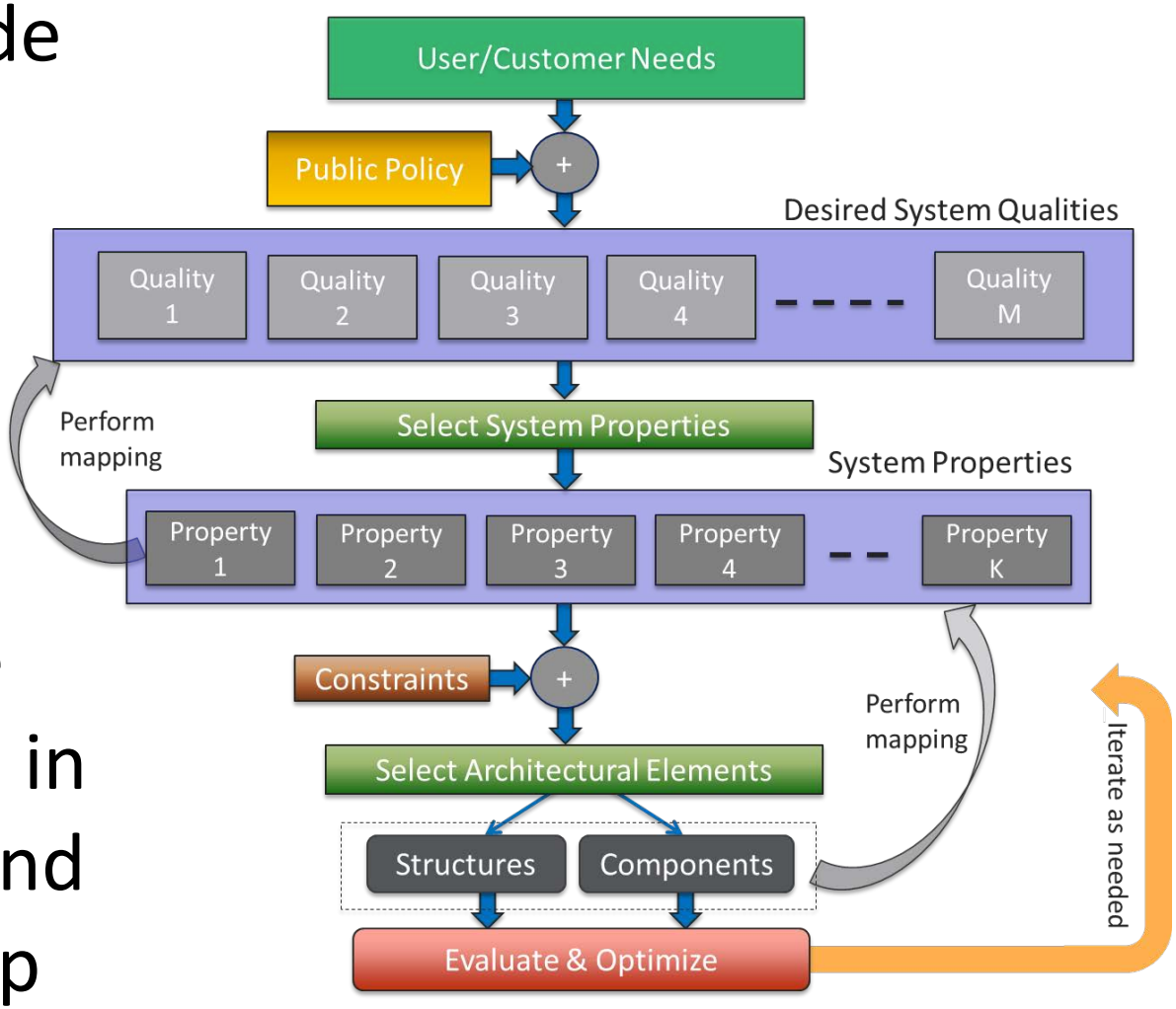
Qualities and Properties

- System Qualities
  - Desired characteristics of the final or end state system
  - Think of as high level requirements expressed qualitatively or quantitatively
- System Properties (externally visible)
  - System properties
    - characteristics of the system as a whole that enable key capabilities
    - system properties are what enable the system qualities to be manifest
    - system properties emerge from structure, components, and their properties
  - System properties are what enable the system qualities to be manifest



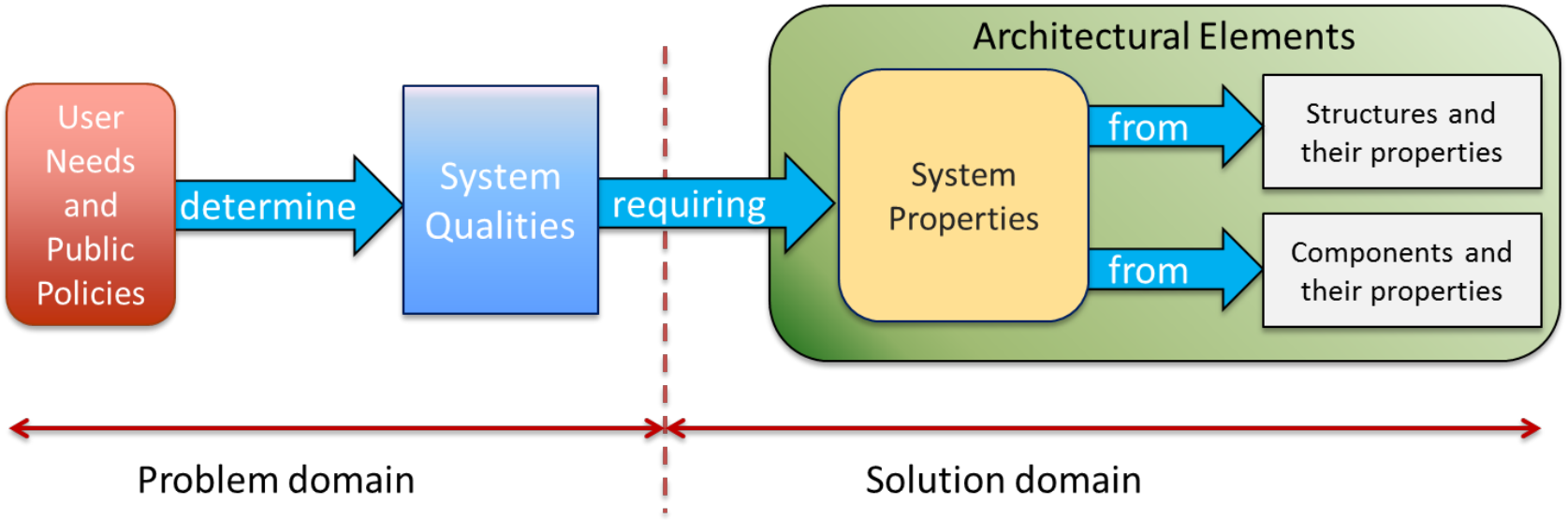
Use of Qualities and Properties

- Mappings provide traceability
- Mappings are crucial to the architecture development process because they are needed in the evaluation and optimization step



Synthesis of Qualities and Properties

- System Qualities represent the consumer viewpoint (users of the system)
- System Properties represent the provider viewpoint (developers and operators of the system)



Metrics and Norms

- Common terminology for performance measures is “metrics”
- This is a poor choice from a rigorous standpoint, but we are stuck with it
- Worse, some utility “metrics” actually measure the opposite of what they are supposed to measure
  - Most reliability “metrics” actually measure unreliability, for example
- Properly speaking, what we want are norms, in the terminology of abstract mathematical spaces
  - Norms measure the “size” of a thing
  - Metrics measure the “distance” between two things
  - Norms induce metrics
- We need norms for qualities so that we can treat architecture mathematically

GRID QUALITY CONCEPTS

The Nature of Grid Qualities

- Qualities reflect an *external* view of grid behavior
- Must span entire set of grid functions and responsibilities, not just hot button issues
- Must be as nearly non-overlapping as possible
- Must have formal definitions to eliminate ambiguity caused by use of English words with non-technical, vague, or multiple meanings
- Must provide enough granularity to support non-trivial representations and analyses

Quality Orthogonality

- It is generally recognized that quality sets should have a characteristic variously described as:
  - Independent
  - Non-overlapping
  - Decoupled
- Well-selected quality sets that have this characteristic simplify the identification of dependency/overlapping/coupling in architectures
- Mathematically, we want the qualities in a set to be as nearly orthogonal as possible, so we should define them using Hilbert space concepts
  - This also greatly aids in performing analytical architecture: numerical evaluation and comparison, tradeoff analysis, optimization of architectures

Selecting Grid Qualities

- Use external (user) stakeholder inputs
- Architect team specifies and develops the necessary formal definitions
  - Text definition
  - Mathematical formulation
- Carry out orthogonalization if needed
  - Define necessary norms
- Illustrate with scenarios

SEVEN GRID QUALITIES

Delivers

- **Provides the amount of energy a user wants, when the user wants it, and in the form the user wants**
  - Can be formulated for time windows
  - Can be formulated for geographic or demographic windows
  - Encompasses various aspects of supply, reliability, system security, and operational excellence

Conserves

- **Uses irreplaceable resources sparingly**
  - Input-side view
  - Includes non-renewable fuels
  - Includes non-renewable elements and materials
  - Includes land and water

Preserves

- **Minimizes wastes and emissions**
  - Output side view
  - Includes spent fuels
  - Includes gases, particulates, and other by-products
  - Includes thermal emissions
  - Includes noise, vibration, and radiation emissions

Protects

- **Safeguards and secures people, assets and information**
  - Includes public and employee safety
  - Includes defense against physical and cyber attack
  - Includes protection of devices, circuits, and systems
  - Includes protection of connected non-utility assets

Adapts

- **Compensate for short time scale (parametric) changes and evolve for long time scale (structural) changes to grid requirements and operating conditions**
  - Includes fuel mix changes
  - Includes VER/DER penetration
  - Includes weather, seasonal, and climatic changes
  - Includes multiple simultaneous changes
  - Implies grid are to be flexible(susceptible of modification), versatile(having or capable of many uses, and extensible (able to be increased in scope)

Enables

- **Provide broad access to the grid and support energy innovation**
- Include ease of interface and coordination
  - Low integration barriers
- Include protection and control
- Include scalability of both endpoints and complexity
- Support new industry structures and business models

Merits

- **Provide sufficient useful capability and public good to support continued public and private investment**
- Includes ability of customers to afford service
- Includes ability to attract financing and investment
- Includes grid value under industry structure and business model changes

GRID PROPERTY CONCEPTS

The Nature of Grid Properties

- Qualities reflect an *internal* view of grid behavior
  - As seen by designers/planners/developers
  - As seen by owners/operators
- Must have formal definitions to eliminate ambiguity caused by use of English words with non-technical, vague, or multiple meanings
- Should be as nearly orthogonal as possible
- Many are selected from the “ilities” list

The “ilities” List

- Doyle’s “ilities” list

Accessibility, accountability, accurate, adaptability, affordability, auditability, autonomy, availability, credibility, process capability, compatibility, composability, configurability, correctness provability, customizable, debugability, degradability, determinability, demonstrability, dependability, deployability, discoverability, distributability, durability, effectiveness, efficiency, evolvability, extensibility, failure transparency, fault tolerance, fidelity, flexibility, inspectability, installability, integrity, interchangeability, interoperability, learnability, maintainability, manageability, mobility, modifiability, modular, nomadicity, operability, orthogonality, portability, precision, predictability, producibility, provability, recoverability, relevancy, reliability, repeatability, reproducibility, resiliency, responsiveness, reusability, robustness, safety, scalability, seamlessness, self-sustainability, serviceability, supportability, securability, simplicity, stability, standards compliancy, survivability, sustainability, tailorability, testability, timeliness, traceability, ubiquitousness, understandability, upgradability, usability

Selecting Grid Properties

- Use internal stakeholder inputs
  - planner/designer/developer
  - owner/operator
- Architect team specifies and develops the necessary formal definitions
  - Text definition
  - Mathematical formulation
- Architect team develops mapping to Qualities
  - Mapping validation from internal stakeholders

Quality/Property Mappings

- Properties can be connected to Qualities via mappings
- Properly done mappings have a structure of their own that reflects useful insights into architecture
- In general, the mappings are many-to-many but not all-to-all
- The mapping links can be binary (present or not) or have a numerical attribute
- The property to quality mapping is a two layer structure, but additional layers can and are used
  - Arch elements to properties; qualities to public policies, etc.
- Architectural elements are mapped through the properties to the qualities

Example Mapping to Utility Functions

- Early set of 4 grid modernization System Qualities
- A set of key grid properties mapped to the Qualities
- Qualities are further mapped to utility issues
- Qualities or Properties could also be mapped to Public Policies in this manner