Presentation on Self-Managed Systems : An Architectural Challenge

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What is self-managed software architecture?

- Components automatically configure their intercommunication based on an overall architectural specification in order to achieves the goals of the system, with minimum explicit management

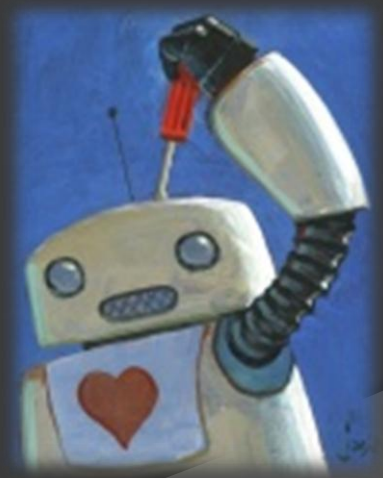
Self Managed Systems

- Self-configuration
- Self-adaptation
- Self-healing
- Self-monitoring
- Self-tuning

Self-* or autonomic systems

Self-configuration

- Components should configure themselves to satisfy specification or report that they cannot



Self-healing and self-adaptation

- In the case of changes in the requirement specification, operational environment, resource availability or faults in the environment or system:
- Reconfigure
- Degrade gracefully
- Report an exception

Why an architecture-based approach?

- Generality
- Level of abstraction
- Potential for scalability
- Builds on existing work
- Potential for an integrated approach

Others use architectural approach too

- Oreizy : uses architectural approach- adaptation and evolution management
- Garlan and Schmerl: use architectural models for self-healing
- Dashofy, van der Hoak and Taylor use architecture evolution manager for run-time adaptation and self-healing in ArchStudio
- Gomaa and Hussein: use of dynamic software reconfiguration and reconfiguration pattern for software product families

…

Architectural Model for Self-management

- Robotics
- Sense-plan-act (SPA)
- Garlan's self-healing system:
  - Monitoring
  - Analysis/resolution
  - Adaptation
- Gat:
  - Control: Reactive feedback control
  - Sequencing: Reactive plan execution
  - Deliberation: Planning

Control Layer

- Consists of:
  - Sensors
  - Actuators
  - Control loops

Control Layer Responsibilities

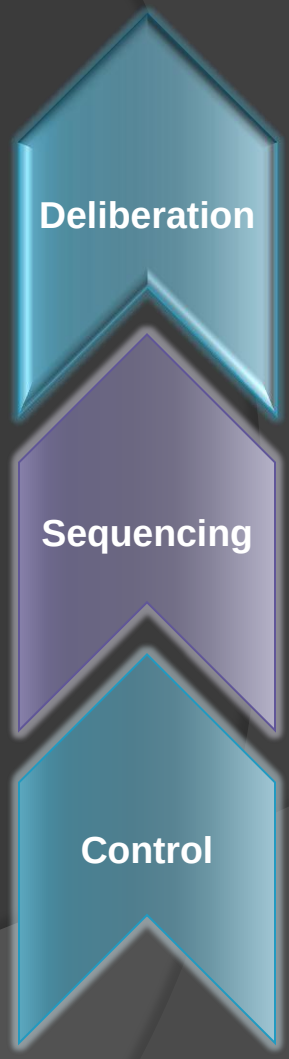
- Self-tuning
- Event and status reporting to higher levels
- Operations to support modification
- Component addition, deletion and interconnection
- When the current configuration of components is not designed to deal with a situation, the layer detects this failure and reports it to higher layers.

Sequencing Layer

- Reacts to changes in state reported from lower levels
- Execute plans with new control behaviors and new operating parameters for existing control layer behavior
- Execute an action or sequence of actions to handle the new situation

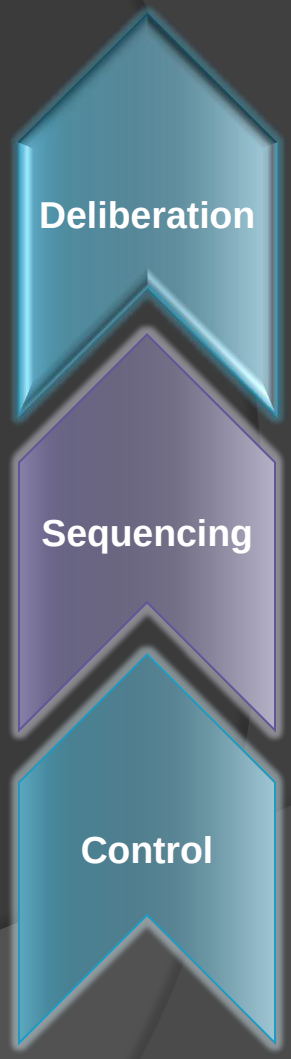
Sequencing Layer Capabilities

- Introduce new components
- Recreate failed components
- Change component interconnections
- Change component operating parameter



Sequence Layer Characteristic

- Essential characteristic of change management layer is that it consist of a set of pre-specified(pre-computed) plans which are activated in response to state change.
- If a situation is reported for which a plan does not exist, this layer must invoke the services of higher planning layer.

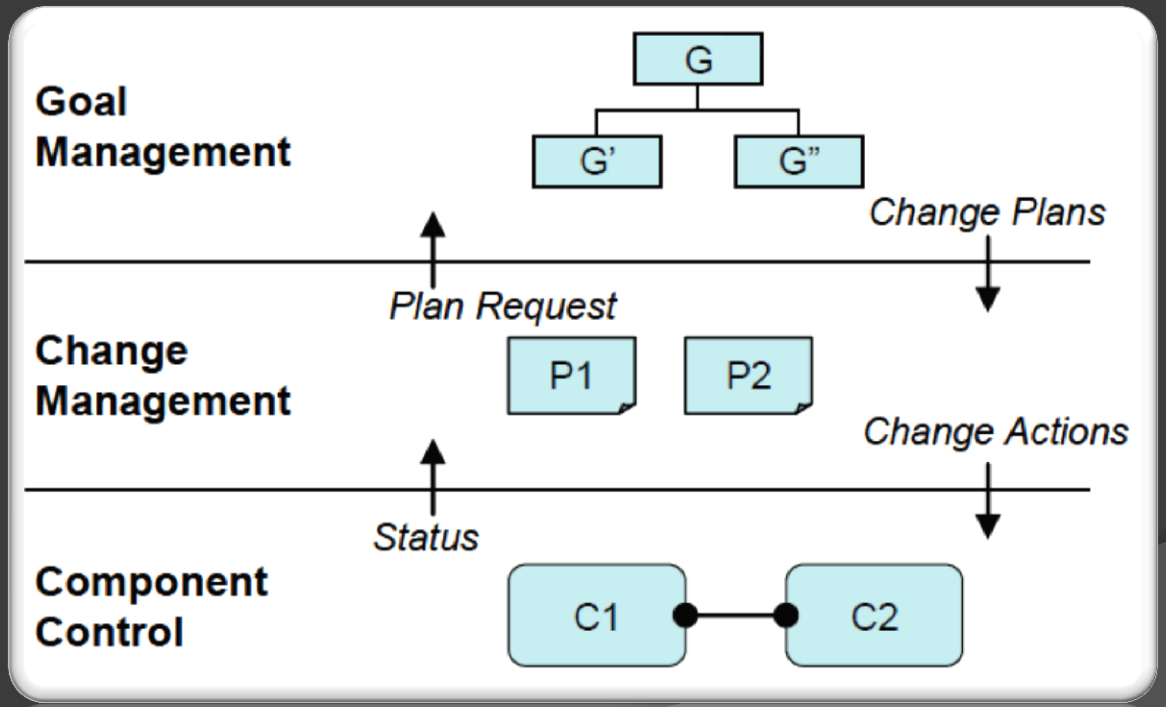


Goal Management (Deliberation)

- Time consuming computation
  - Planning based on the current state to achieve the specification of high level goal
    - i.e. By current position of the robot and map of its environment -> producing a route plan for execution by sequencing layer
    - Changes like obstacles that are not in the map cause re-planning
- Produces change management plans according to requests from the layer below and introduction of new goals

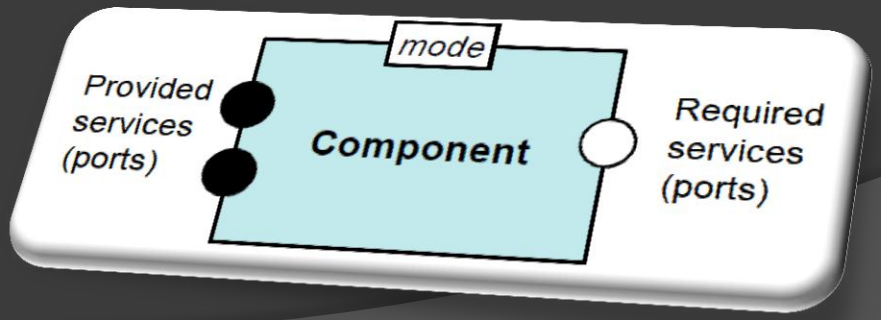
Three layer model of self-managed systems

- Immediate feedback actions at the lowest level and the longest actions are at the top level



Component Control Layer

- A component implements the set of services that it provides (may use other services to implement them)
- Mode: abstracted view of internal state of a component



Operations on Components

create C: T
- create component instance **C** from type **T**.

delete C
- delete component instance **C**.

bind C_1.r – C_2.p
- connect required port **r** of component C_1 to provided port **p** of component C_2.

unbind C_1.r
- disconnect required port **r** of component C_1

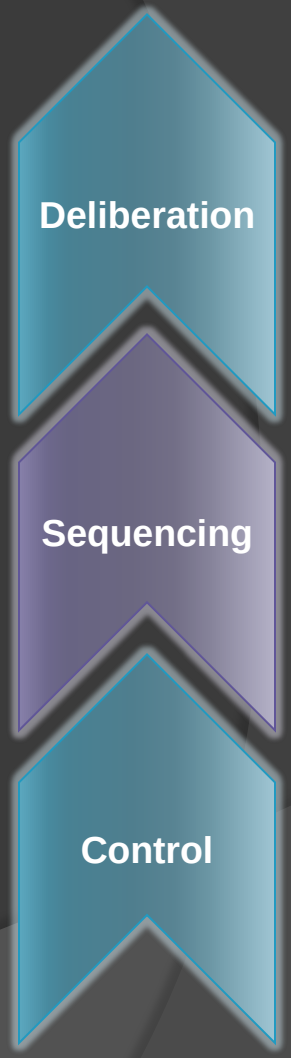
set C_1.m to *val*
- set mode **m** of component C_1 to *val*.

Research Challenge in Component Control Layer

- Preserving safe application operation during change.
  - i.e change in a mechatronic system controlling a vehicle.

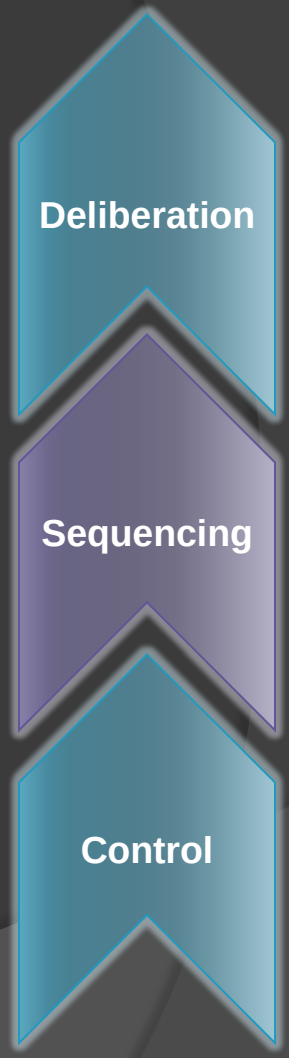
Change Management Layer

- Responsible for executing changes in response either to changes in state reported from the lower layer or in response to goal changes.
- This layer is a precompiled set of plans and tactics that respond to a predicted class of state change.
  - i.e in fault tolerant system, failure of a component may cause a duplicate server to immediately switch from standby to active. Change management should make another standby server.



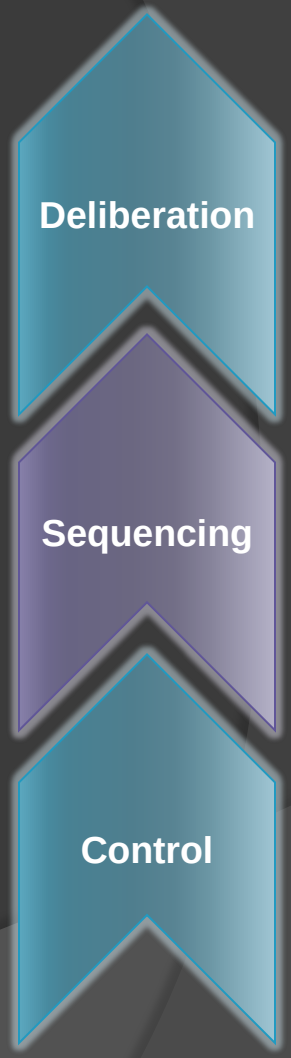
Research Challenge

- Distribution and decentralization defines the difference between self-management of complex software systems and existing work on robotic systems.
- Distribution raise issues like:
  - Latency
  - Concurrency
  - Partial failures
- Coping with distribution and arbitrary failures lead to the need for some level of local autonomy while preserving global consistency.



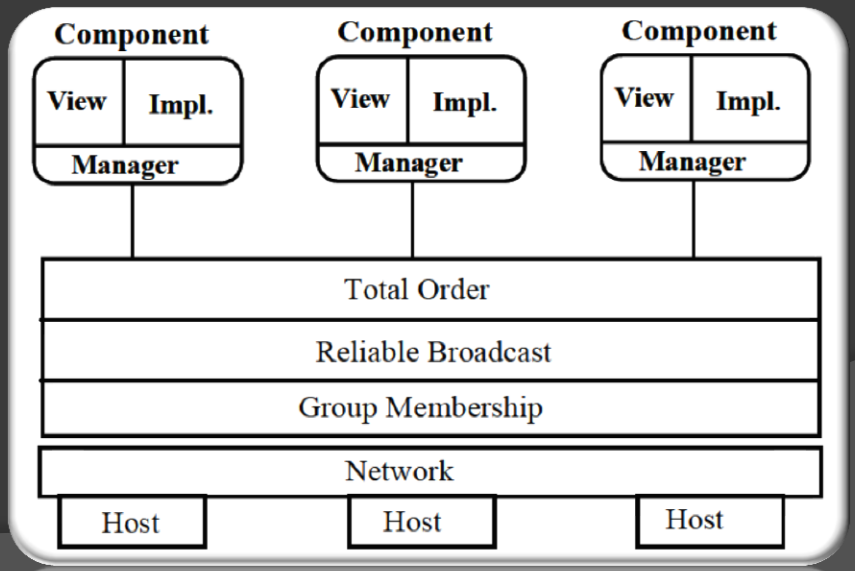
Distribution and Decentralization are troublemaking!

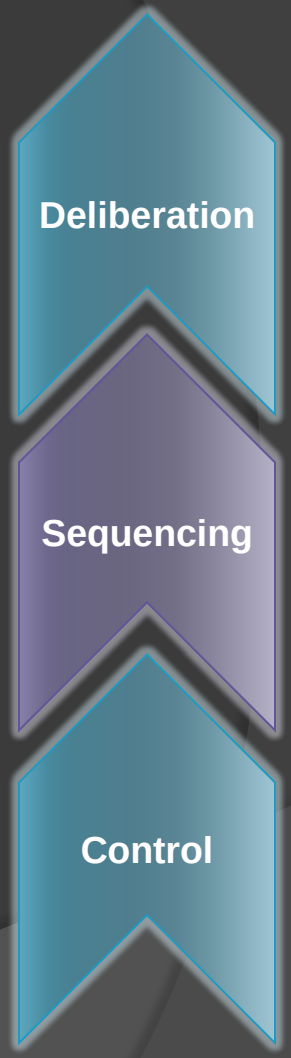
- Due to distribution obtaining consistent view of the system state to make change decisions is hard.
- Decentralization of control makes robust execution in cases with partial failure, difficult.



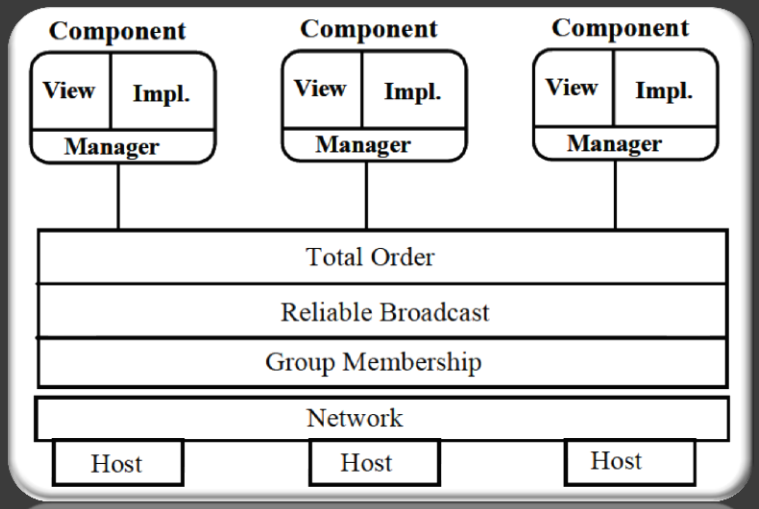
To solve these

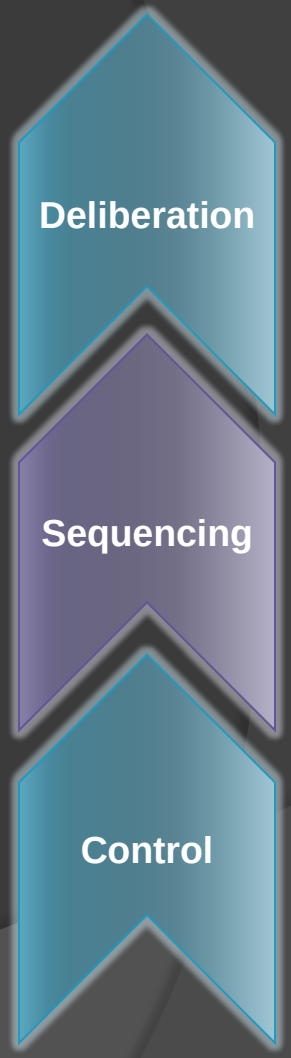
- A decentralized change management architecture makes state changes to be serialized to make sure configuration terminate in a valid state.



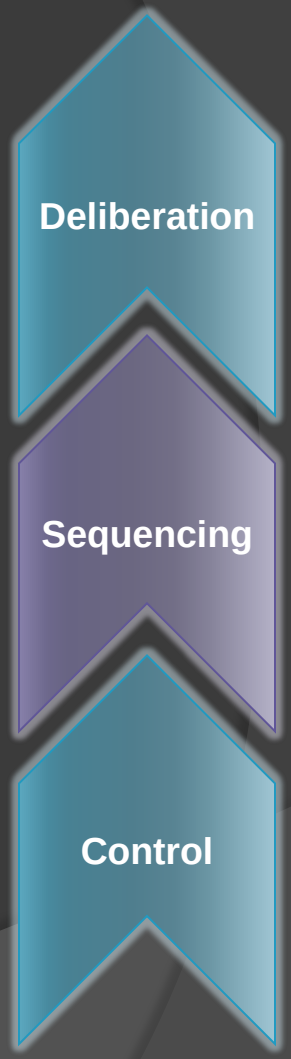


- Change management functionality is included with each component
- Each component maintained a view of an overall system and executed local changes in response to state changes in the view.
- Problems:
  - The view of the system has to be complete
  - Requires a total order broadcast bus to keep views consistent

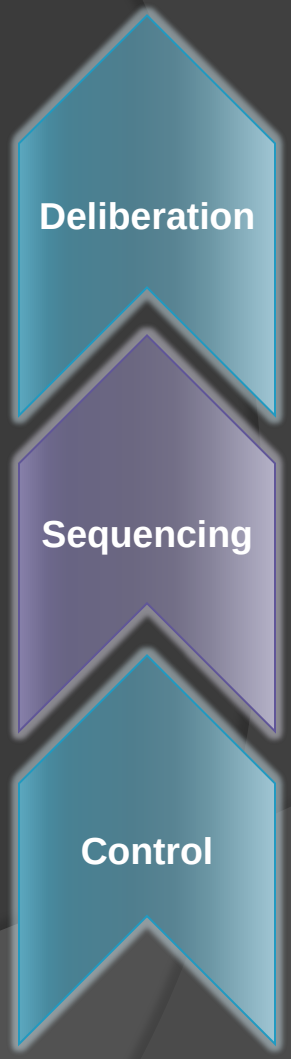




- The architecture was a fully decentralized architecture that reliably executed change in the presence of arbitrary failure. It was not a scalable architecture.
- i.e. systems that can accommodate partial inconsistent views and a relax the need for totally ordered broadcast communication
- Finding change management algorithm that can tolerate inconsistency and will eventually terminate in a system that satisfy constraints.
- The system should not violate safety constraints while it is converging on a stable state
- Self stabilizing algorithms have specific configuration and application

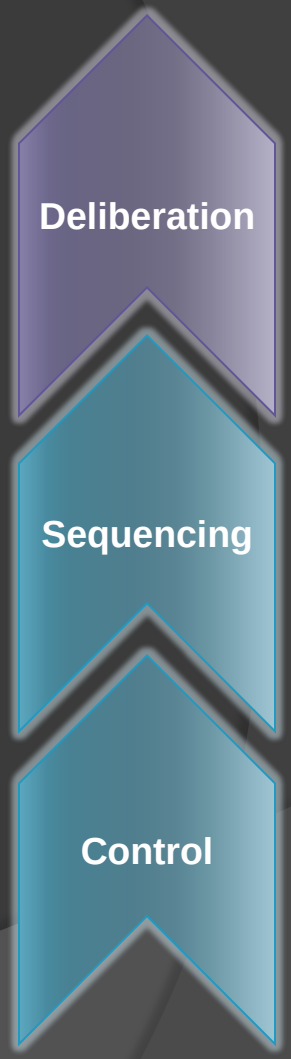


- Since we wanted to preserve the global structural constraints, a consistent view of system architecture was necessary.
- A more behavioral view of the system constraints will provide opportunity for relaxing the consistency requirement.
- If we are not interested in architecture, components can bind to any service that satisfies the local requirement. Failure of the remote service can trigger a search for replacement service



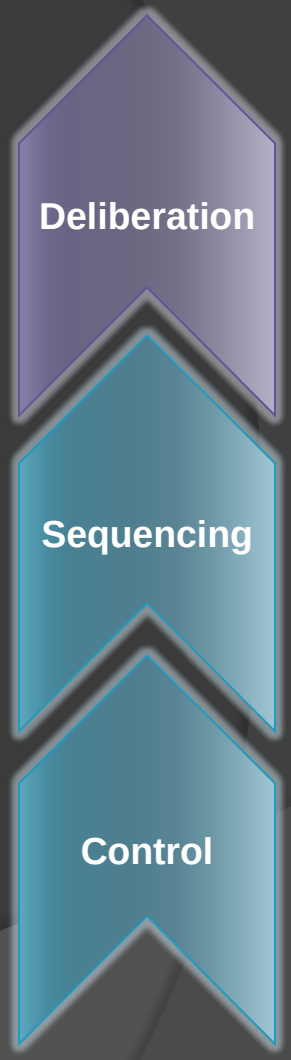
Goal Management Layer

- Precise specification of both application goals and system goals
- Refinement from high-level goals to specified goals (processable by machines) with human assistance



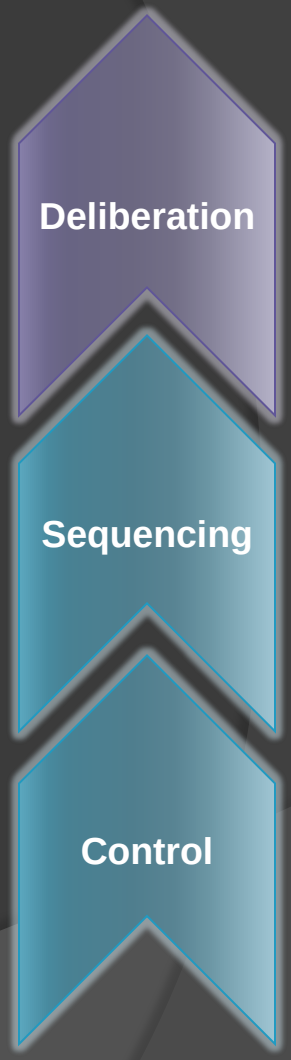
Challenge

- Goal specification that it is both comprehensive by human users and machine readable.
- Producing a change plan based on system goals and current state of the system
- May be intractable problem
- If tractable, response time may be an issue



Solutions

- Design a set of plans offline
- Try them
- Will the change plans satisfy any possible system states?)
  - used in active-standby server pairs
- Challenge:provide online planner, when change management layer figure out non of the current plans apply to observed system state
- In decomposition of goals, operational plan from the goals, constraining the problem domain helps.



Conclusion

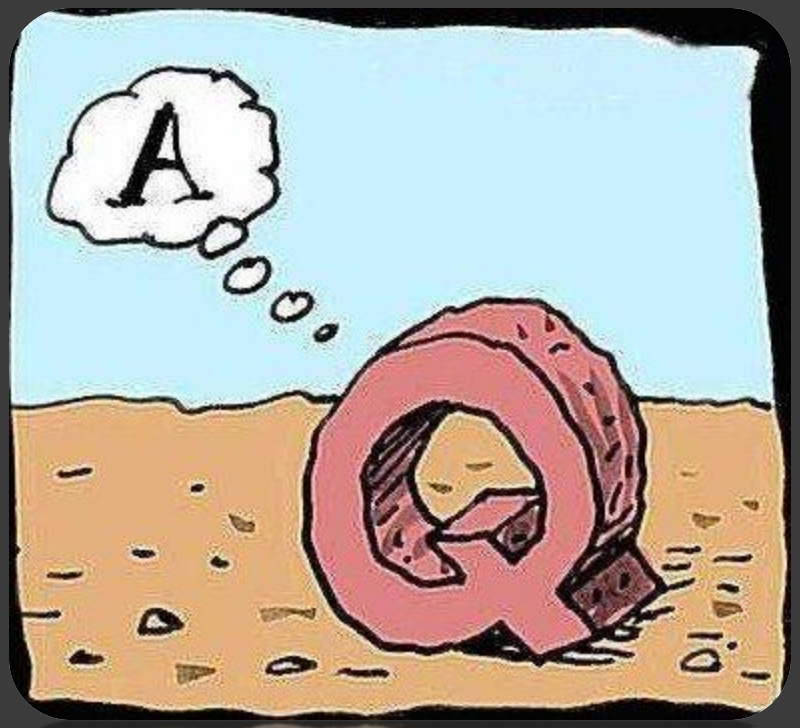
- Self management at the architectural level.
- In self-managed SW architecture, components automatically configure their interaction in a way that is compatible with an overall architecture specification and achieves the goals of the system.

Conclusion

- Component Layer:
  - Provide change management that:
    - reconfigures the software components
    - ensures application consistency
    - avoids undesirable transient behavior.
- Change Management Layer,
  - Decentralized configuration management
    - Can tolerate inconsistent views of the system state
    - Converge to a satisfactory stable state.
- Goal Planning Layer:
  - On-line (perhaps constraint based) planning

Overall Challenge

- A comprehensive solution based on integrated solutions to the challenges supported by an appropriate infrastructure.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