Layered Dependability Modeling of an Air Traffic Control System

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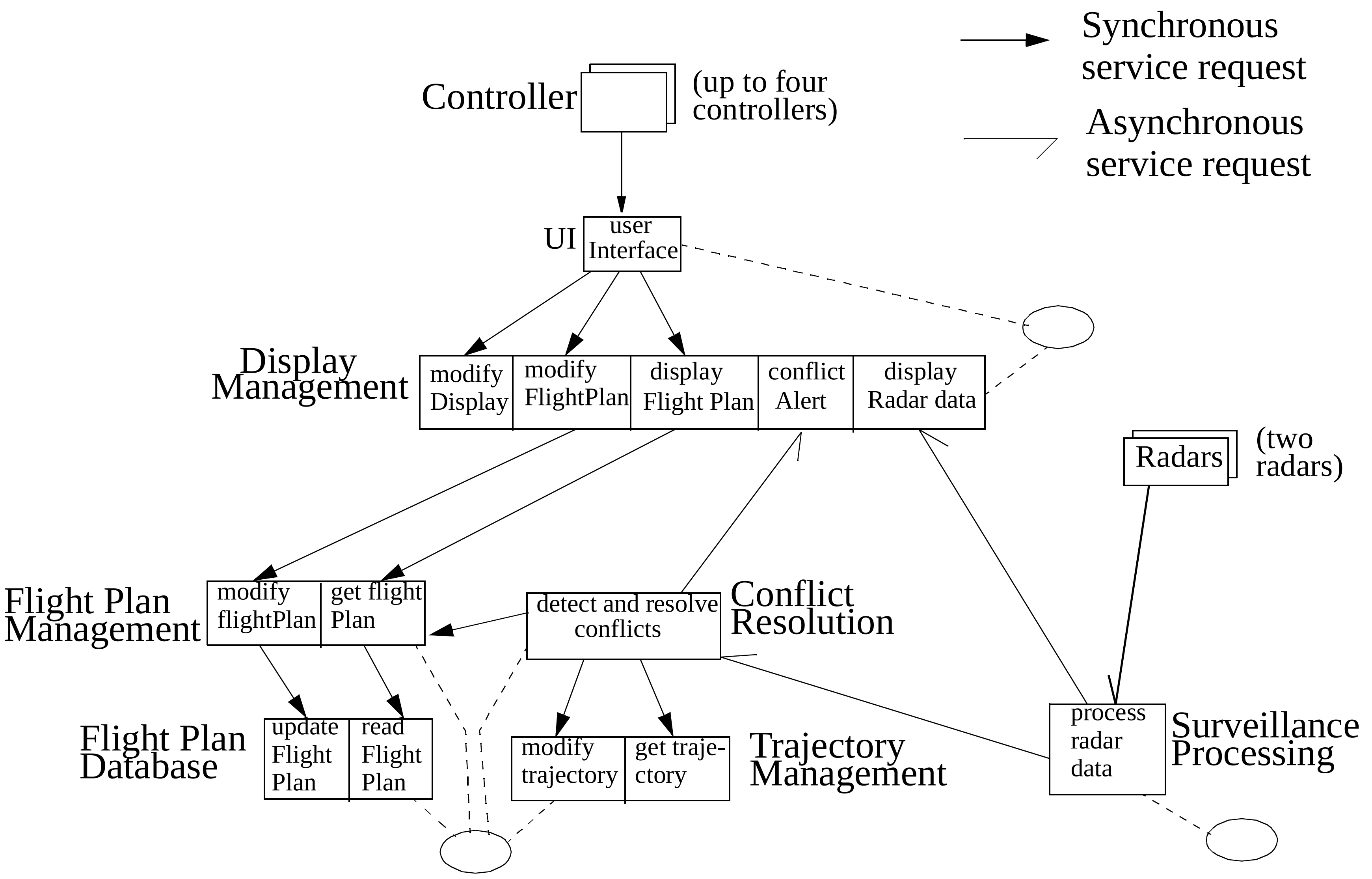
Overview

- dependability of complex systems
- dependability for systems with layered software architecture
- effect on coverage due to management subsystem failures
- performability measures

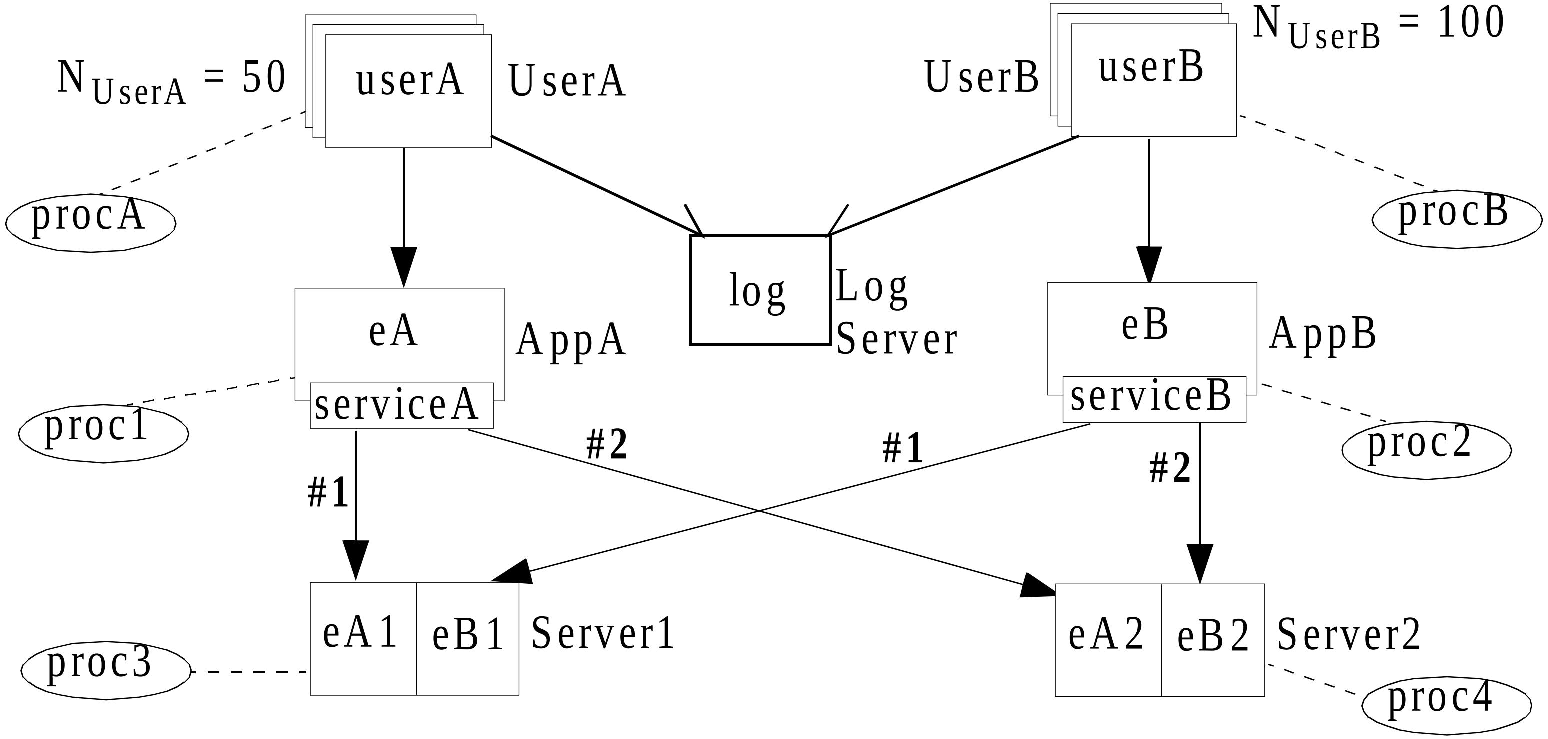
Layered Application Model

Tasks, Interactions and Dependencies, and Processors



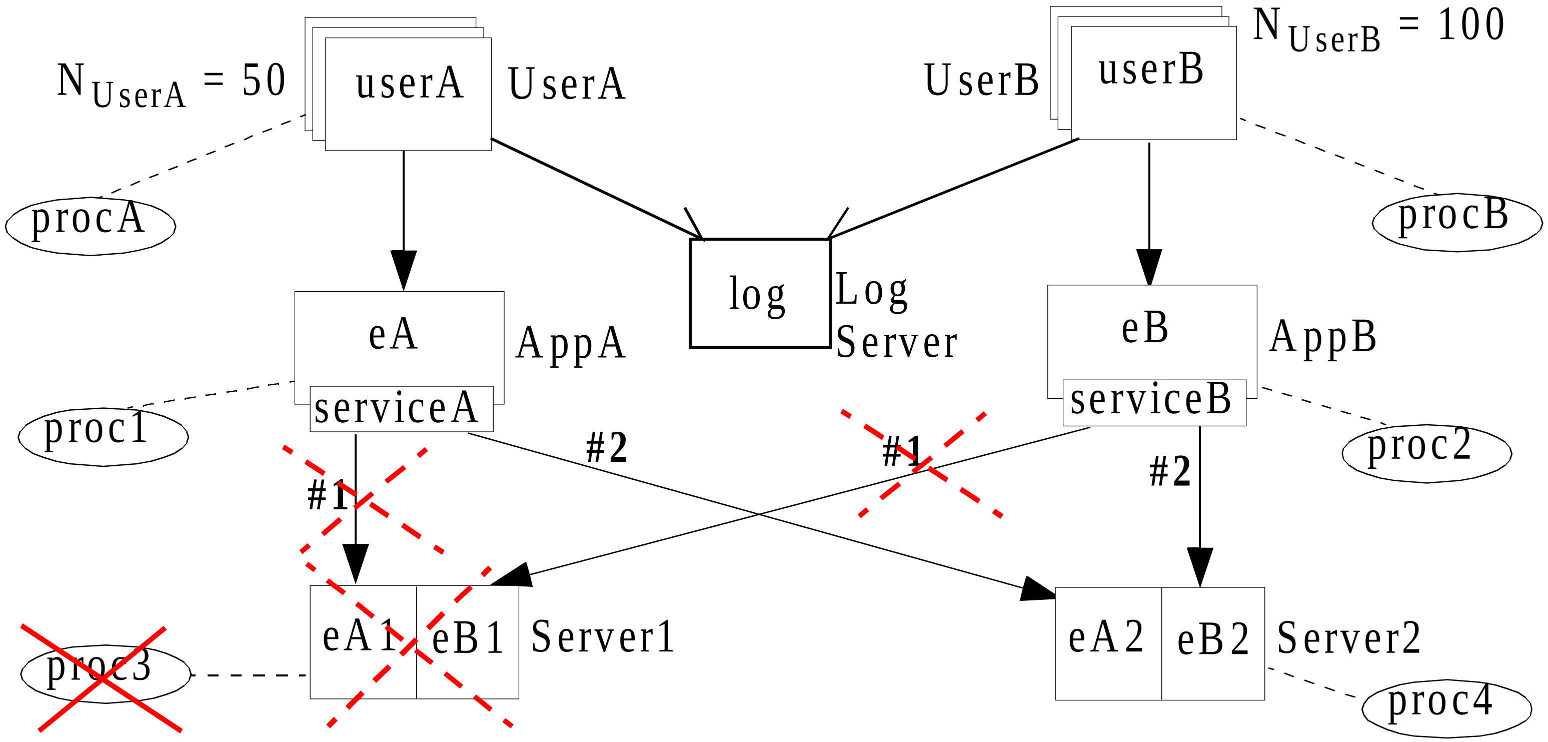
Replication Mechanisms

P**rimary-standby**, load-balancing, active, primary-standby-active



Example Configuration (1)

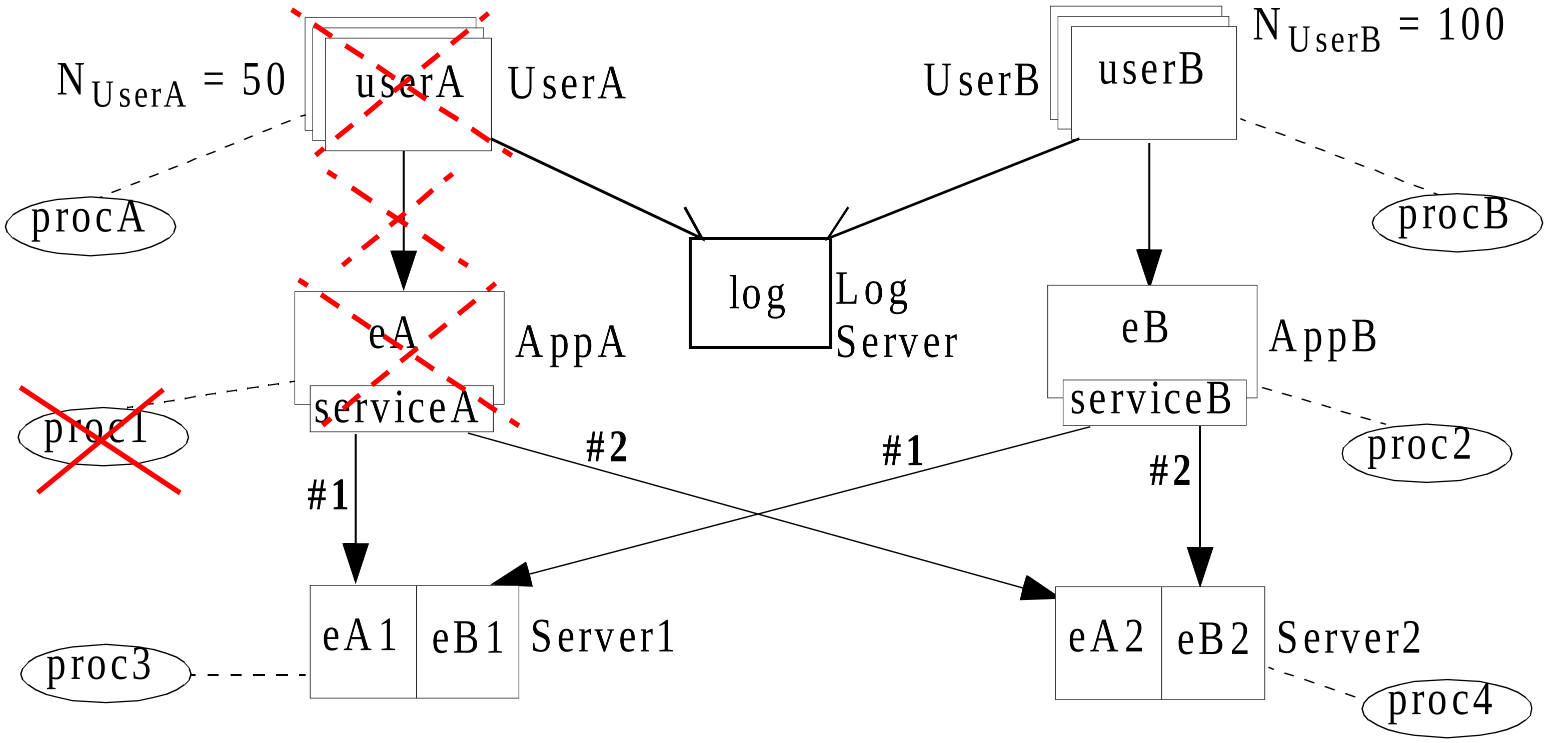
proc3 fails and causes Server1 failure...Server2 used instead



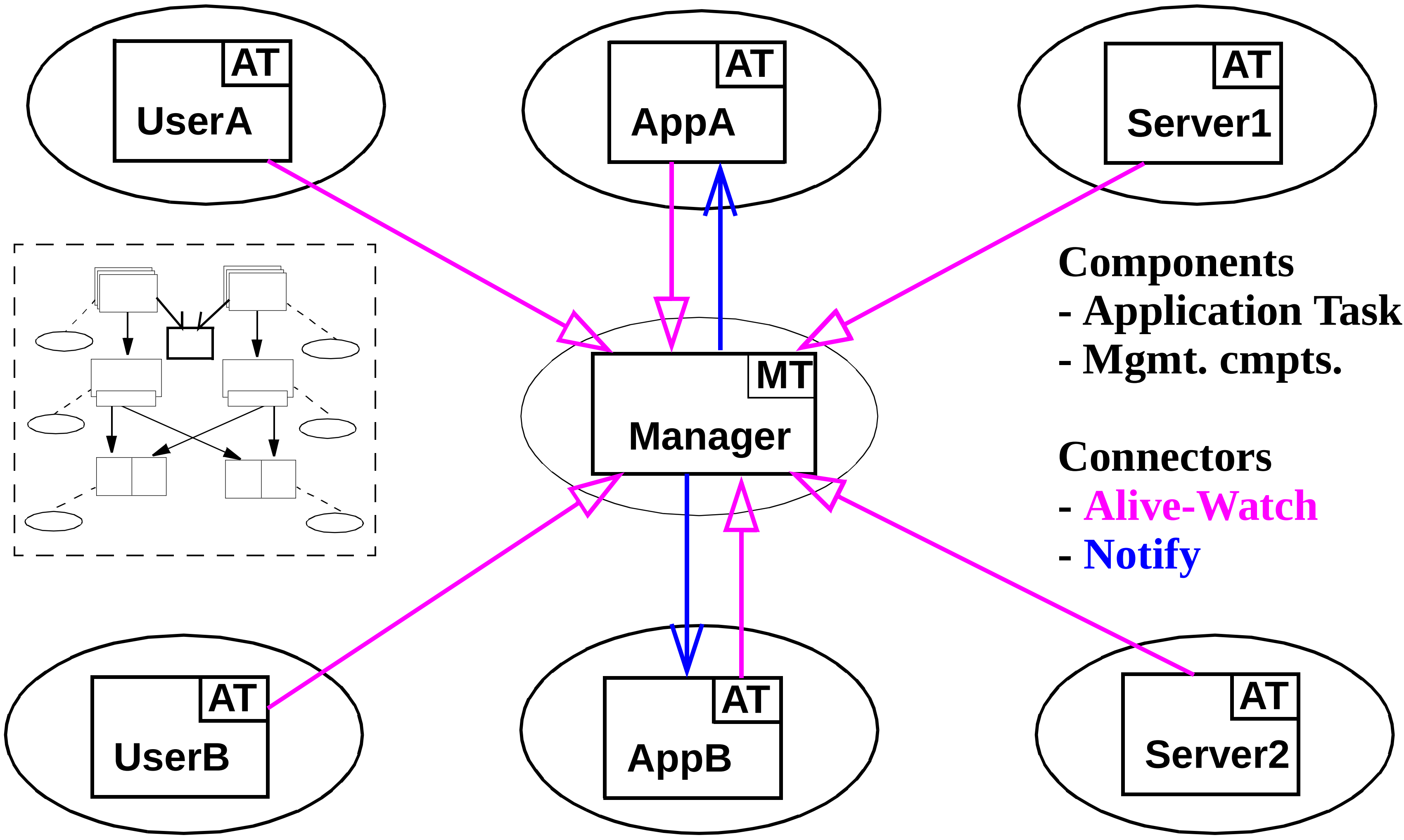
Example Configuration (2)

proc1 fails and puts AppA out.. Group UserA fails..

Here, failure cannot be compensated by standby servers



Centralized Fault Management Model



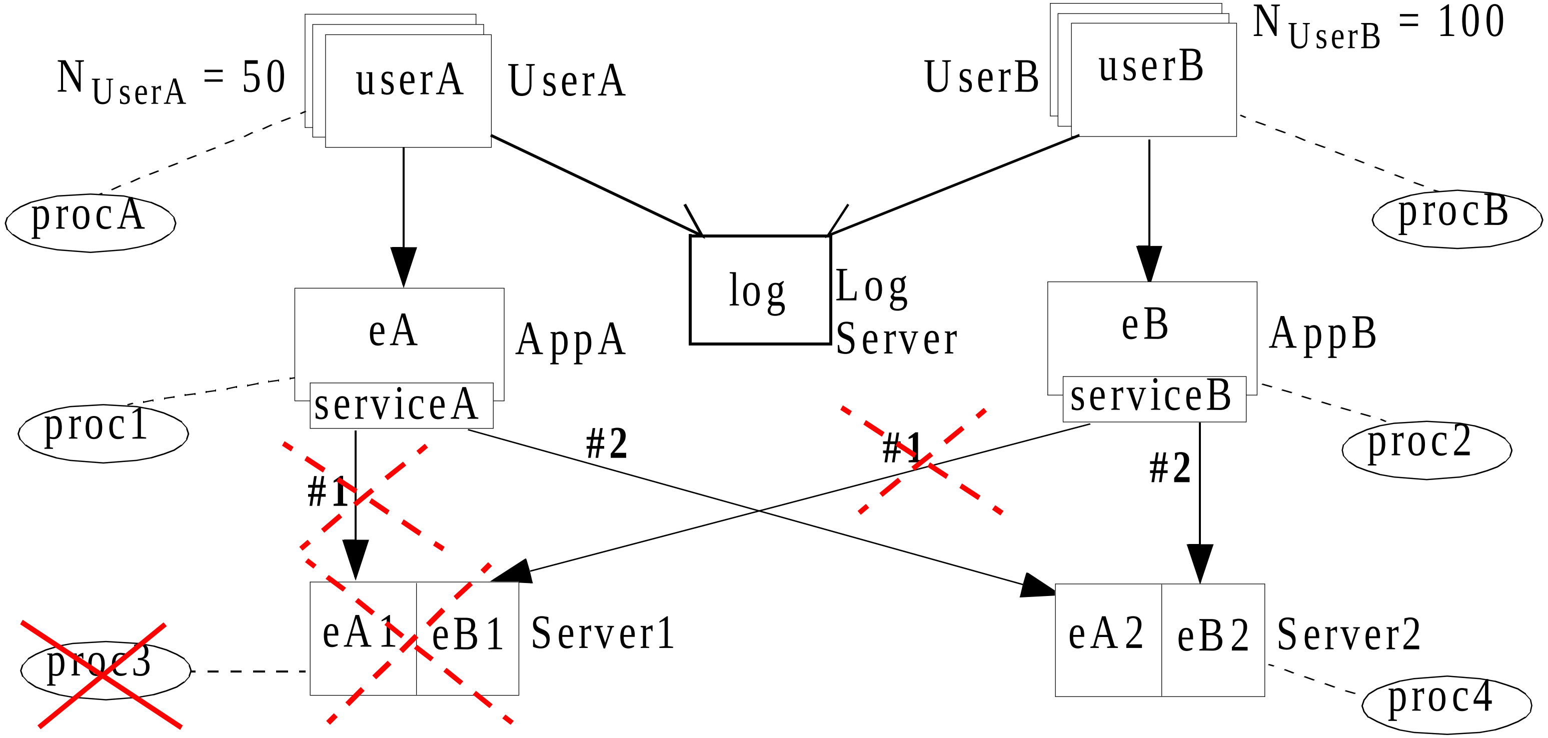
Components
- **Application Tasks**
- **Mgmt. cmpts.**

Connectors
- **Alive-Watch**
- **Notify**

Perfect detection and reconfiguration

proc3 fails and causes Server1 failure...

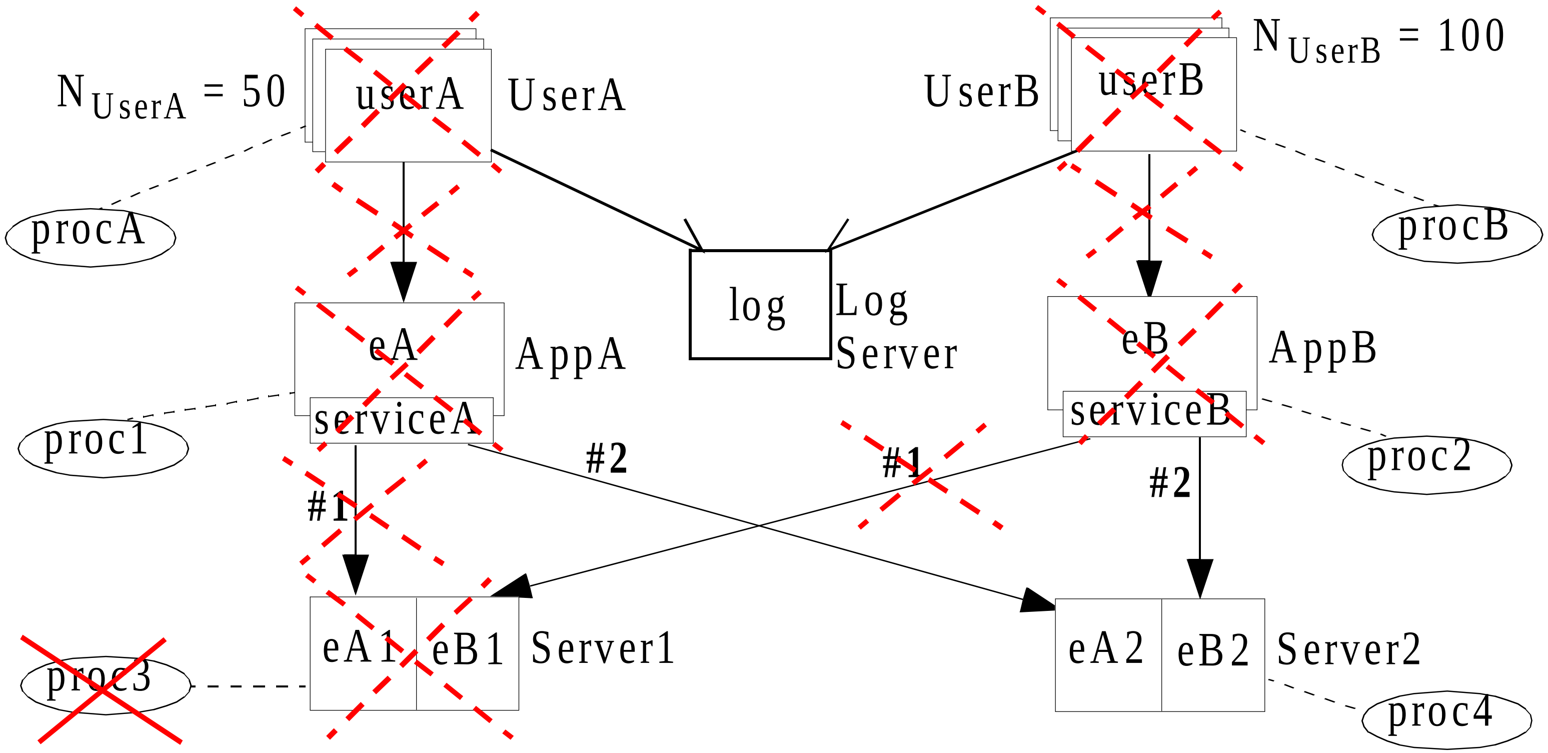
Full coverage: Server2 used instead



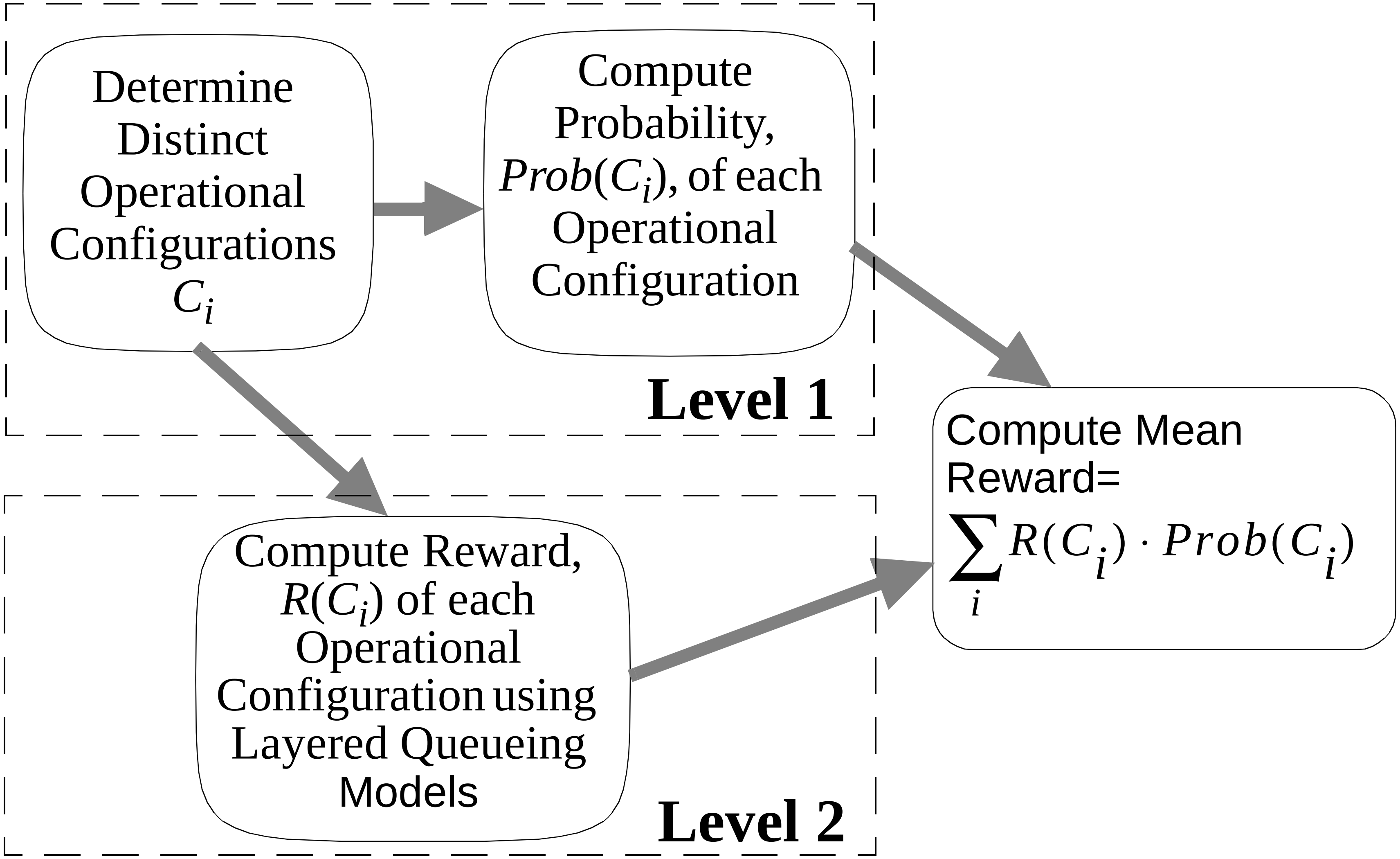
Partial coverage for centralized mgmt.

proc3 fails and causes Server1 failure...

Partial coverage: Manager failed, so system failed



Analysis - currently



Determine Distinct Operational Configurations C_i

Compute Probability, $Prob(C_i)$, of each Operational Configuration

Level 1

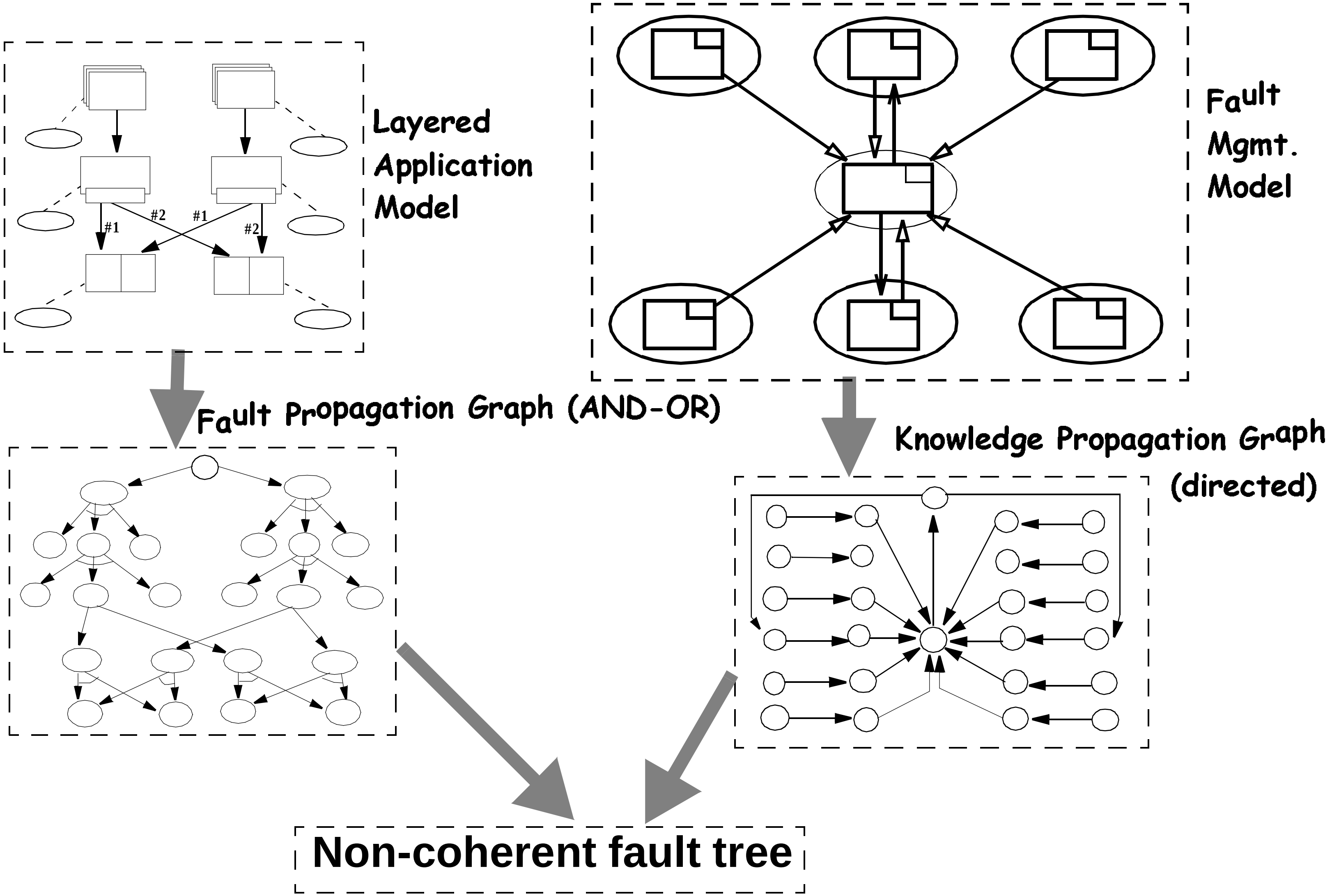
Compute Reward, $R(C_i)$ of each Operational Configuration using Layered Queueing Models

Level 2

Compute Mean Reward=

$$\sum_i R(C_i) \cdot Prob(C_i)$$

Probabilities of Operational Configurations



Layered Application Model

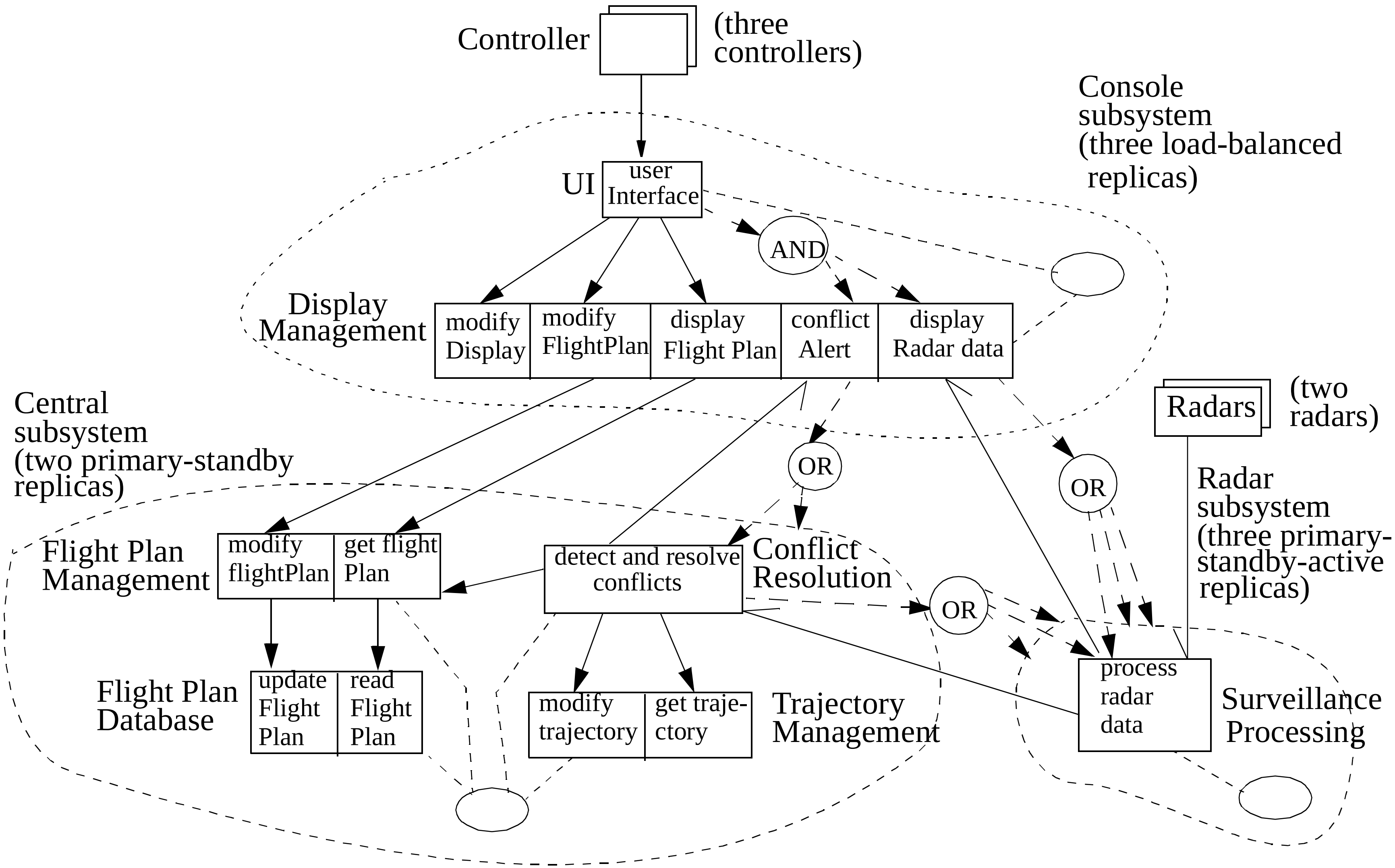
Fault Mgmt. Model

Fault Propagation Graph (AND-OR)

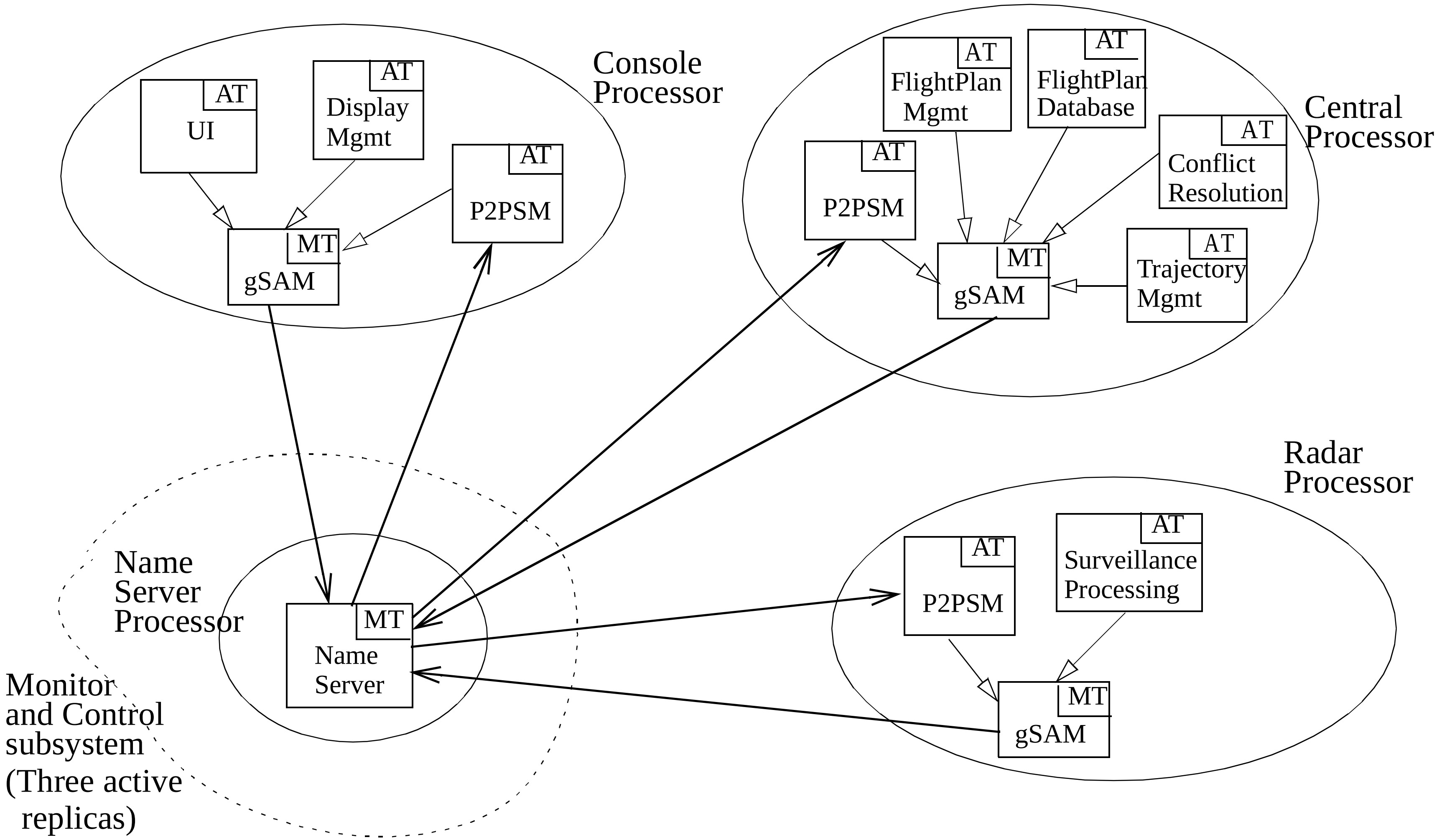
Knowledge Propagation Graph (directed)

Non-coherent fault tree

Layered Model of ATC En Route System



Fault Mgmt. Model of ATC En Route System



Results

Number of components (tasks and processors): 51

Number of connectors in fault management model: 118

Failure probability of all processors: 0.05

Failure probability of all tasks (including management tasks): 0.1

Total number of nodes in the graph that combines information from both the fault propagation graph and the Knowledge Propagation graph: 715

Number of operational configurations: 14

Time to generate and compute probabilities of configurations: 277 secs

Probability of system being in working state: 0.33

Average throughput for Controller task: 0.067 requests/sec

If failure probability of management tasks decreased to 0.05, then

Probability of system being in working state: 0.45 and average throughput for Controller task increases to 0.093 requests/sec.

Conclusions

- Dependability evaluation for layered software architectures
- Scalable technique
  - separation of performance analysis from failure-repair
  - much smaller set of configurations because of layered architecture than of failure states
- Operational configurations takes into account:
  - layered dependencies
  - "Knowledge failure" effects that depends on the status of the Management system which limits the reconfiguration capability
- Explosion of configuration is a limitation