A Discrete Event Systems Approach to Failure Diagnosis: Theory & Applications

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Diagnostics in the Industrial World

- The Three C's:

  Cost, Computation, and Customer Satisfaction

  - Downtime is unproductive and undesirable.
  - Service is costly and competitive.

- Safety
- Health Regulations

Requirements for Industrial Systems

Diagnostic engine must be easy to develop.

Diagnostic engine must be simple to implement.

Diagnosis must be achieved with minimal, cost-effective set of sensors.

Diagnosis may need to be achieved with decentralized information

The “DES” Diagnostic Methodology

DES: Discrete-Event Systems

Modeling: languages and automata

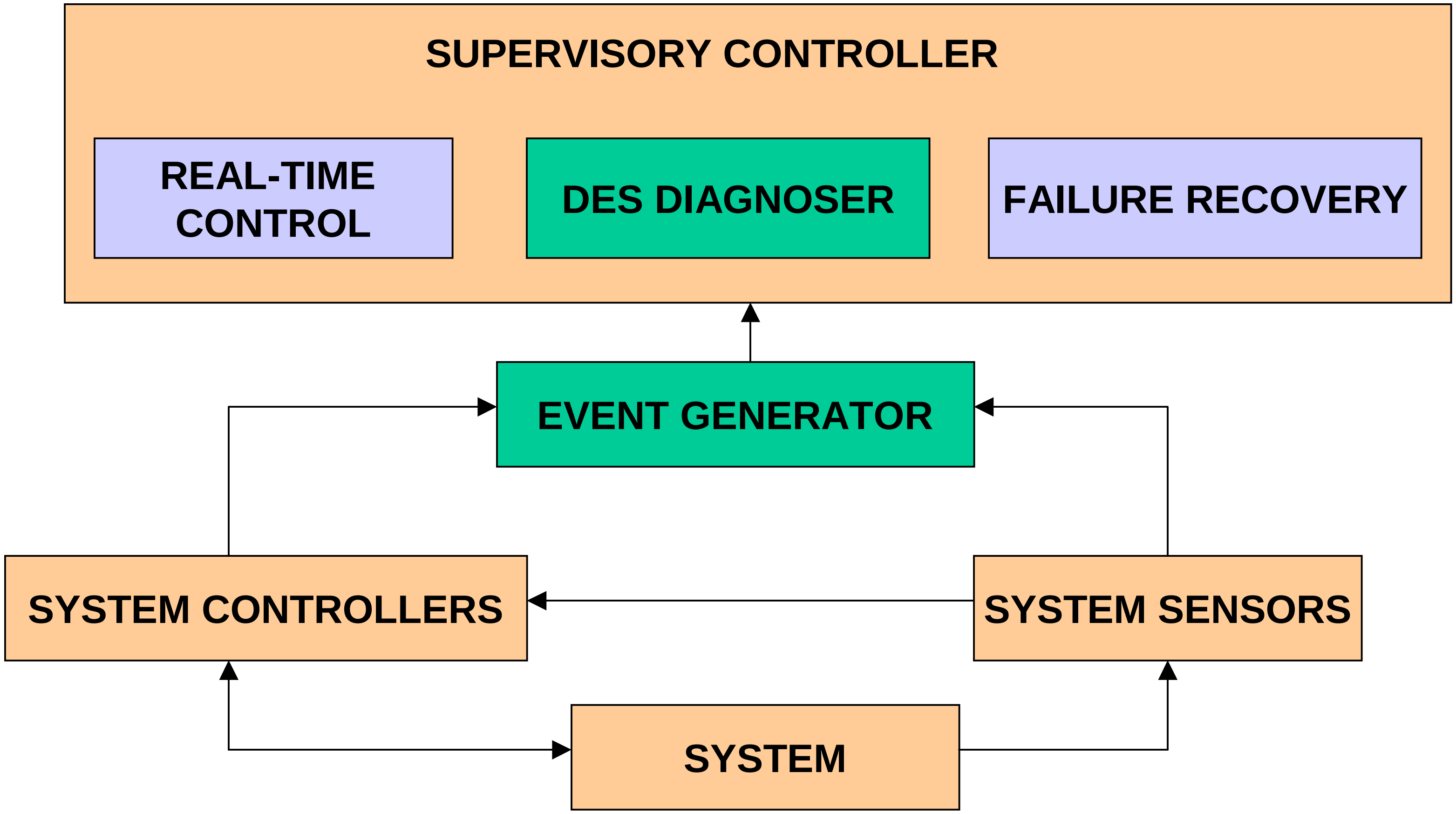
Dynamic tracking and state-based inferencing: Diagnosers

Ability to incorporate sensor information from multiple sources: real and *virtual* sensors

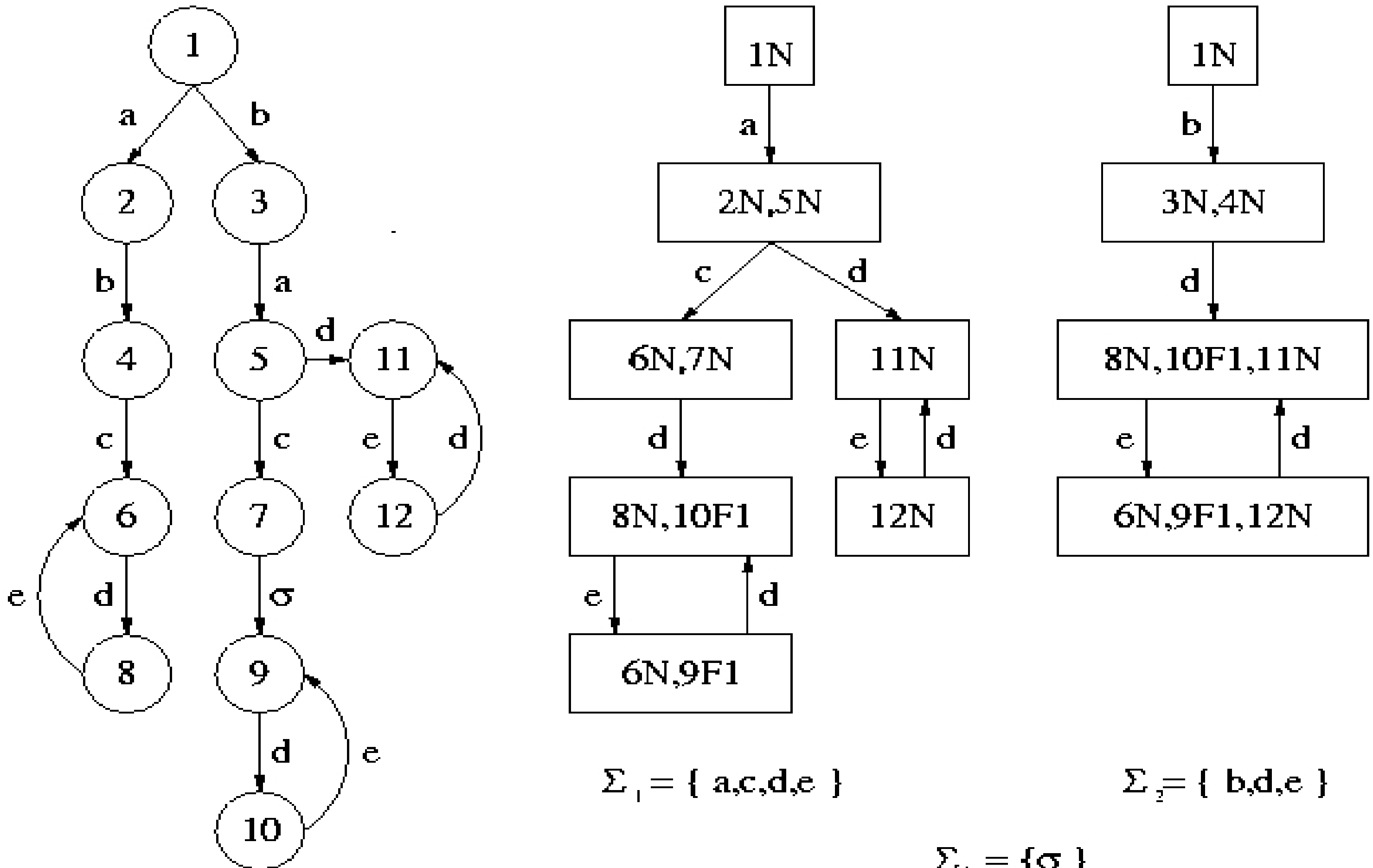
Automated design of diagnostic inference engine

Simple on-line implementation

Implementation



Example



$\Sigma_1 = \{ a,c,d,e \}$ $\Sigma_2 = \{ b,d,e \}$

$\Sigma_{f1} = \{\sigma_1\}$

Example 1:
Heating, Ventilation, and Air Conditioning Systems

Components hard to access, few sensors

Valve, pump, controller faults, etc.

Sinnamohideen, Sampath et al., JCI

Variable Air-Volume Controller

Courtesy, Johnson Controls, Inc.

Example 2:
Document Processing Systems

Complex processes, few sensors

Electro-mechanical and image quality faults

Sampath et al., Xerox Corp.

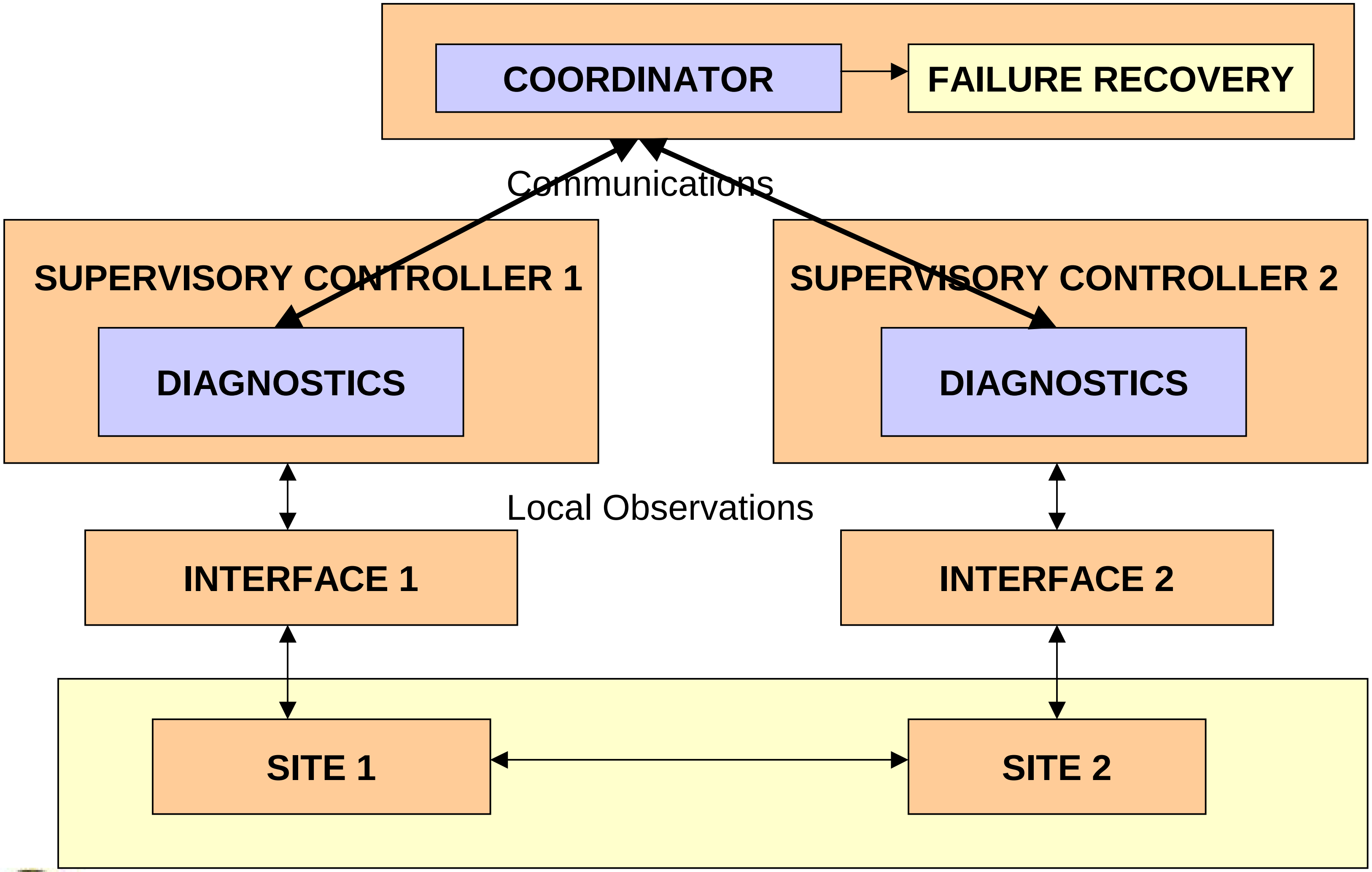
Example 3:
Automated Highway Systems (AHS)

Platoons of vehicles
Transmitter and receiver faults
Sengupta et al., PATH, UC-Berkeley

In general:

- Many systems are informationally decentralized
  - Computer and Communication Networks
  - Manufacturing Systems
  - Power Systems
- Need to develop methodologies to diagnose these systems

Decentralized Diagnosis with Coordinator



Key Ingredients

Local processing for diagnostics
Communication rule
Decision rule at coordinator

We call these a PROTOCOL

Objective

- Design a set of protocols and analyze their "complexity – performance" tradeoff
- Compare their performance to the centralized diagnoser

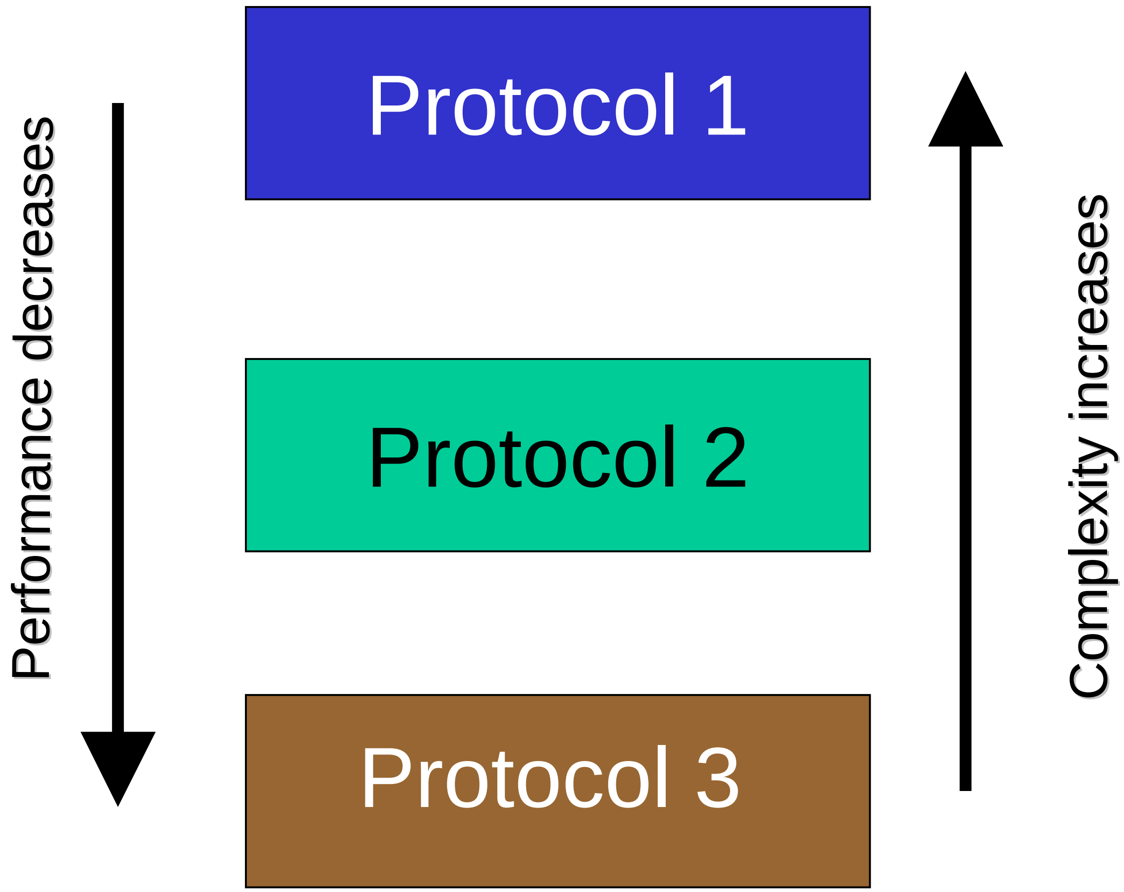
The centralized scheme is the "only" one available for comparison purposes…

Work Done So Far

Uses *extended* diagnosers and 1-step memory at coordinator

Diagnosers + state intersection

Diagnosers but trivial/no coordinator



Salient Features of Approach

- Formal: model-based, diagnosability
- Applicable to dynamic systems
- Analytical foundations:
  - diagnosers, indeterminate cycles, failure-ambiguous traces
- Amenable to design:
  - sensor selection, active diagnosis
- Easy of implementation
- Extensible, versatile

Other Extensions of "Basic" Theory

- Timed models of DES
  - *Chen & Provan,* Rockwell, ACC 97
  - Zad et al., Univ. of Toronto, CDC 99 (see also CDC 98)
- Decentralized DES
  - Sengupta et al., PATH–U.C. Berkeley,WODES 98
  - Rozé and Cordier, IRISA, WODES 98
  - Pencolé, IRISA, DX-00
- Modular DES
  - Ricker et al., IRISA

Challenges Ahead

- Large-scale systems:
  - Decoupling, modularity
- Decentralized-information systems
  - Novel architectures
- Imprecise information
  - Probabilistic extension
- More industrial applications