# Design of an Agile and Smart Manufacturing Exchange: Enabling Small Businesses through Standardized Protocols and Distributed Optimization

Challenge:

- Enable low-sot manufacture of small batches of complex devices

Solution:

- Agile *manufacturing exchange* (ME): Suppliers, assemblers, transporters, etc., participate through standardized protocols to fulfill orders
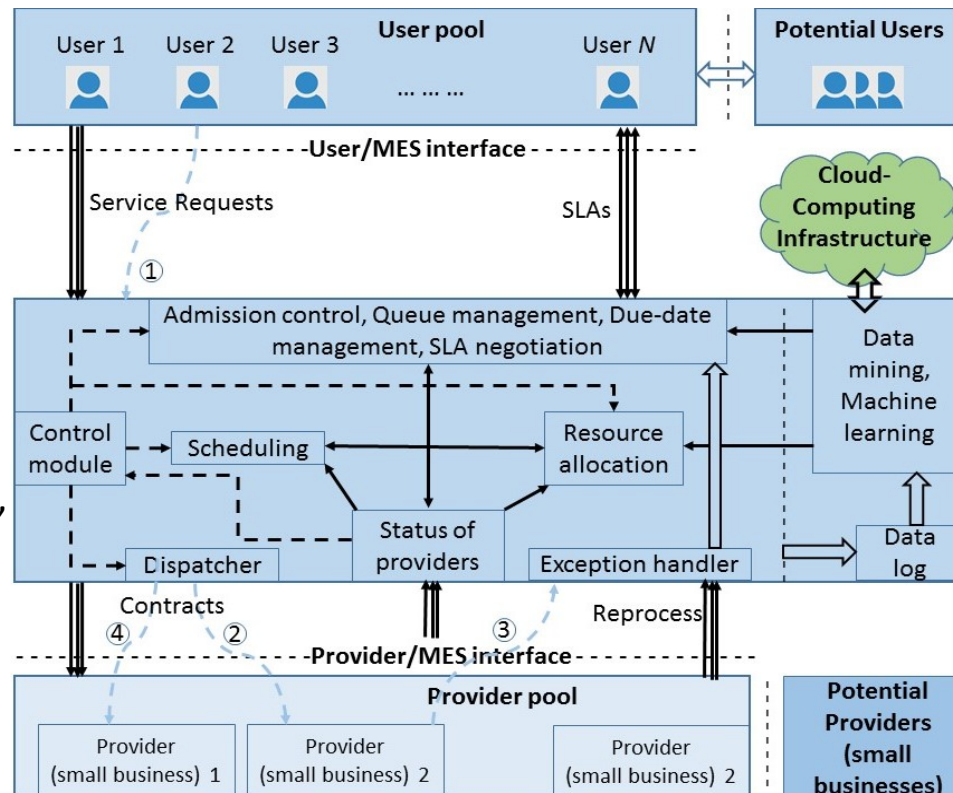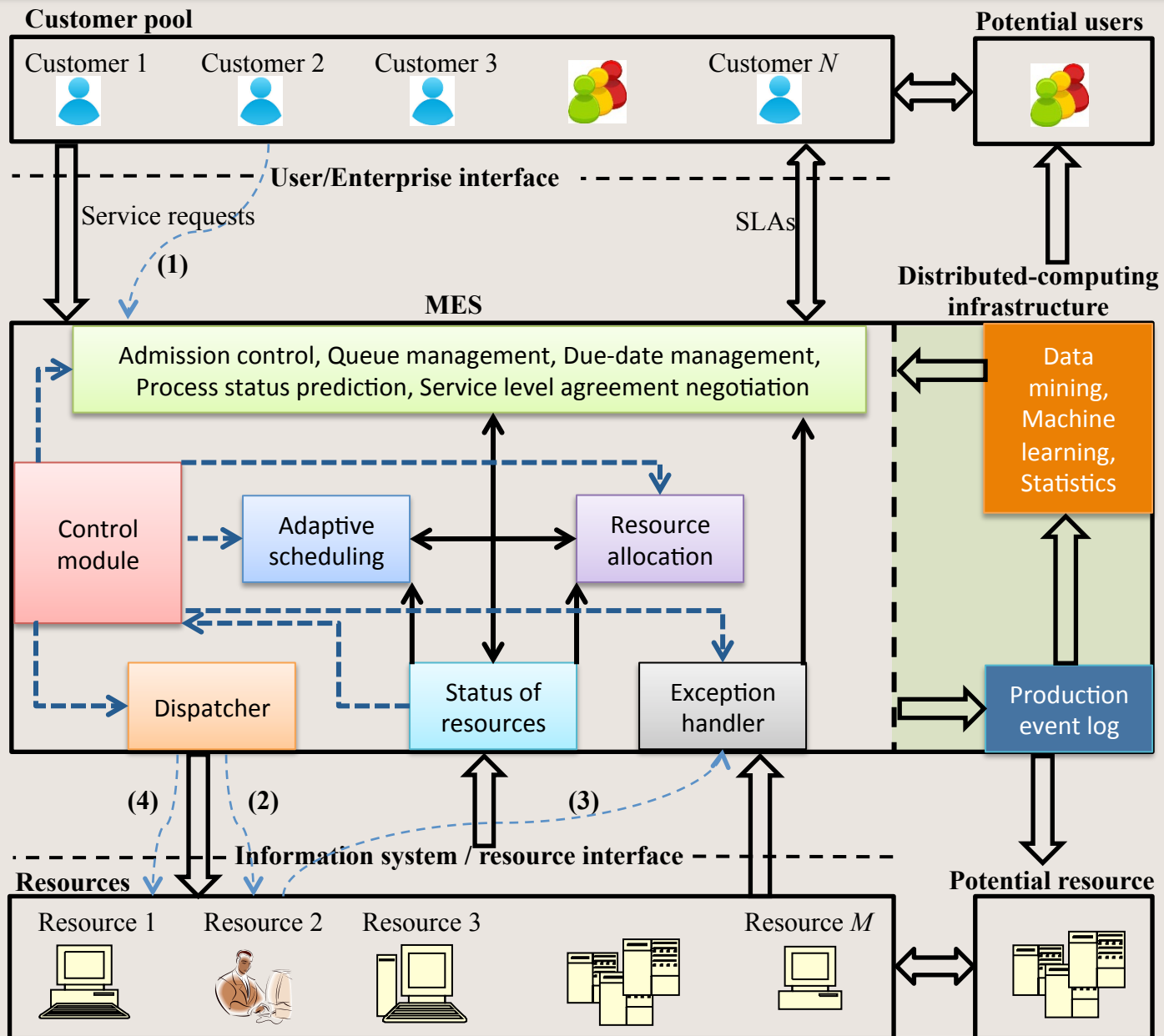

Scientific Impact:

- Production planning and performance prediction
- Distributed optimization under uncertainty
- Distributed online optimization and scheduling

Broader Impacts:

- Intelligent mass customization systems for manufacturing
- Dynamic resource deployment, graceful recovery from failures, scalability

# Manufacturing Enterprise System (MES)
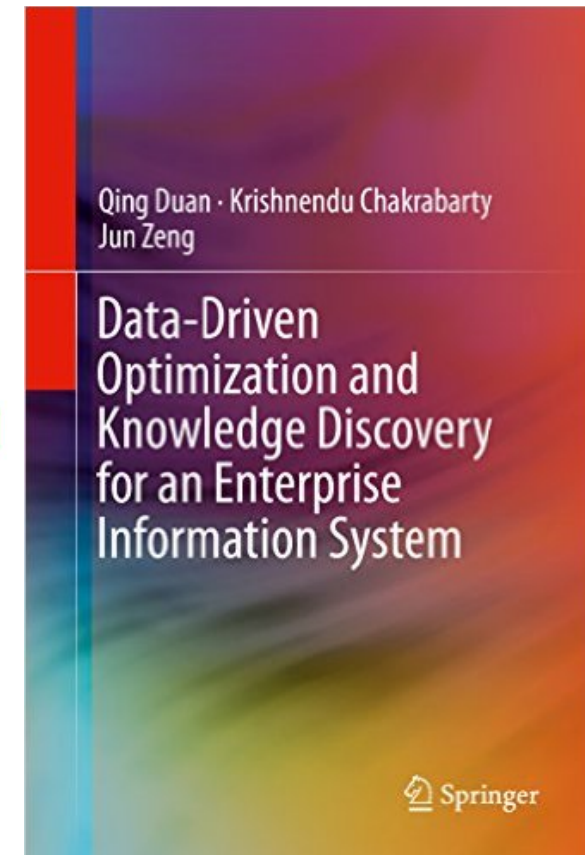
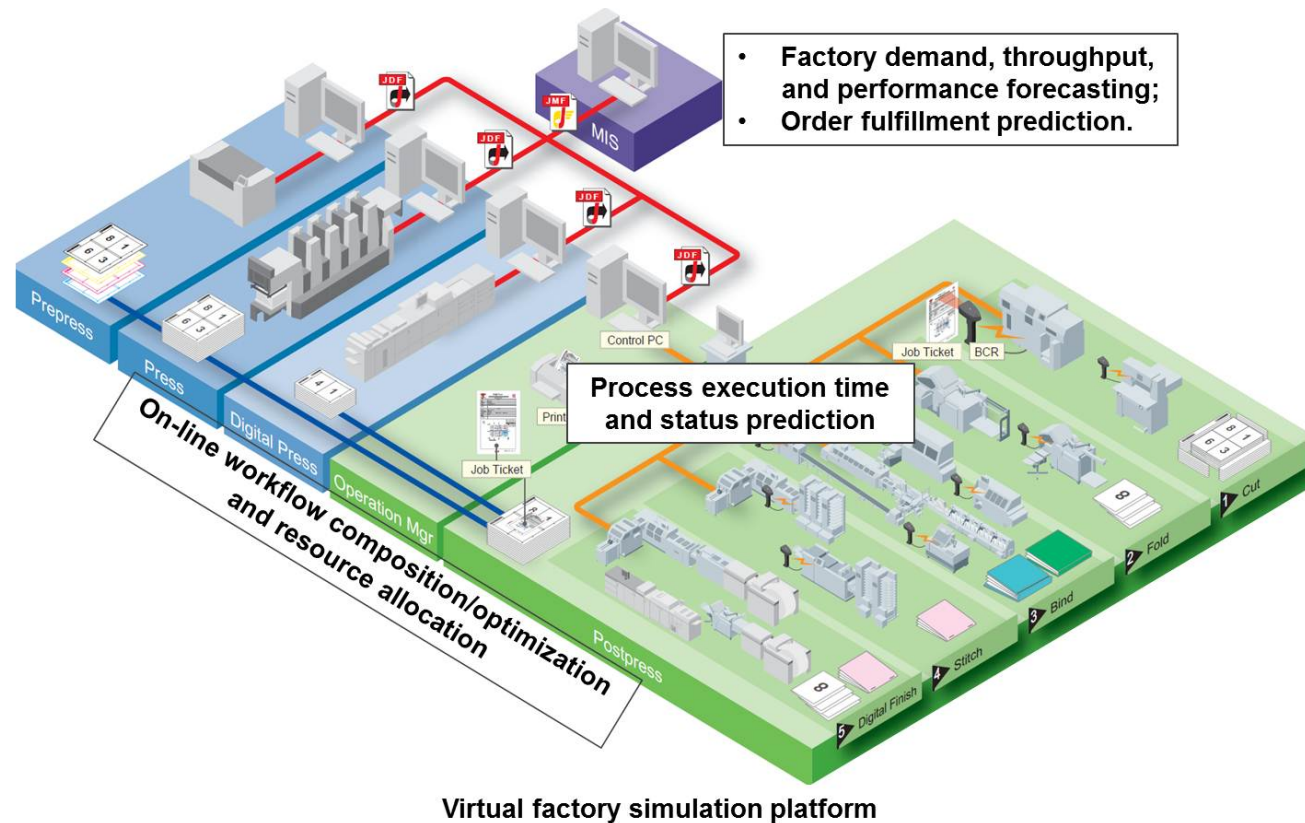# Smart Manufacturing Network

1. Users: Generate product requests
2. Product requests translated to job sequences by MES based on provider status
3. Providers: Bid for jobs, process jobs, route for further processing
4. Last provider in the sequence delivers final product

Goals:
- Learn from data
- Accommodate multiple product flows
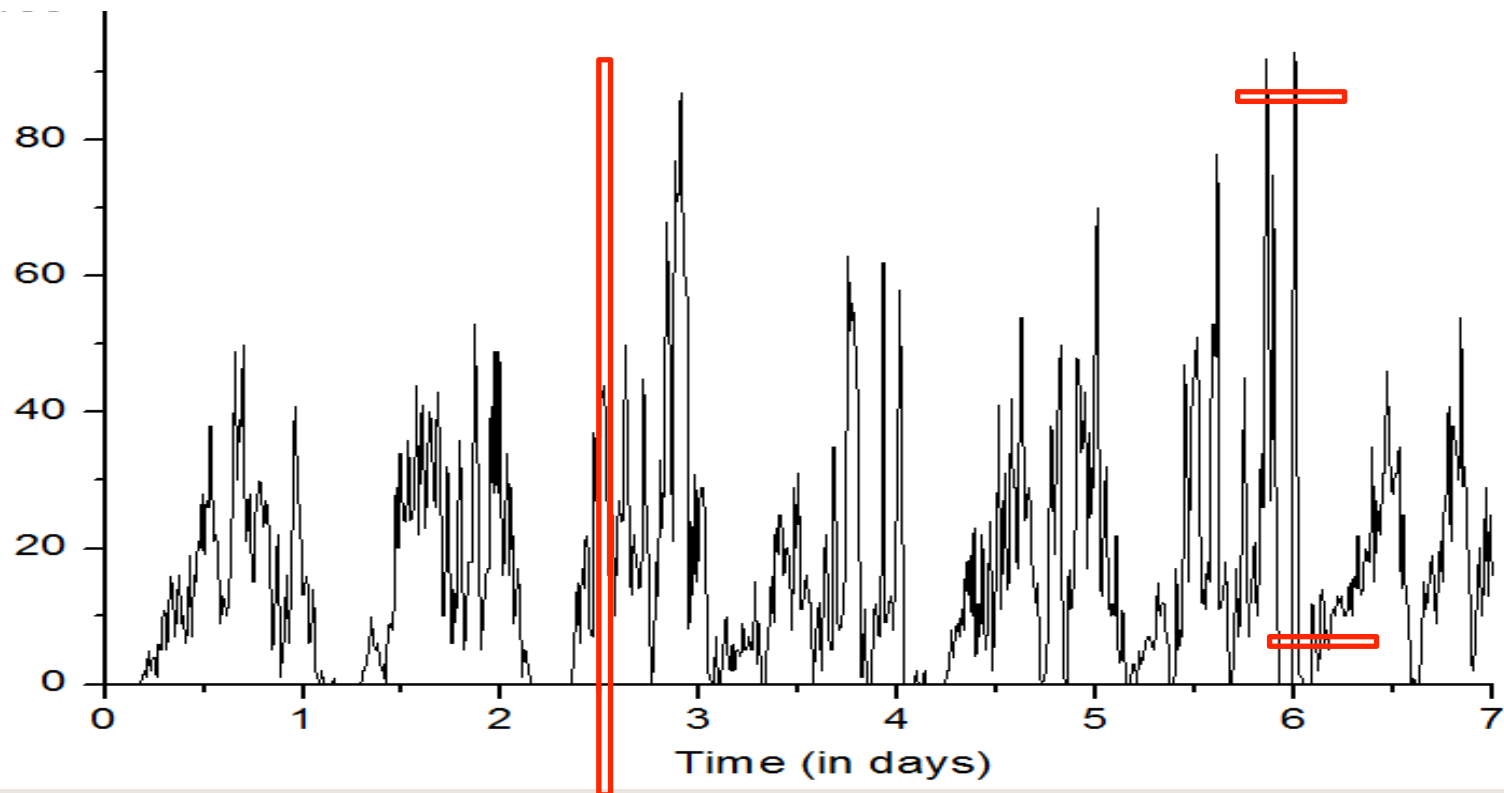- Dynamic and uncertain user demands
- Uncertain network components
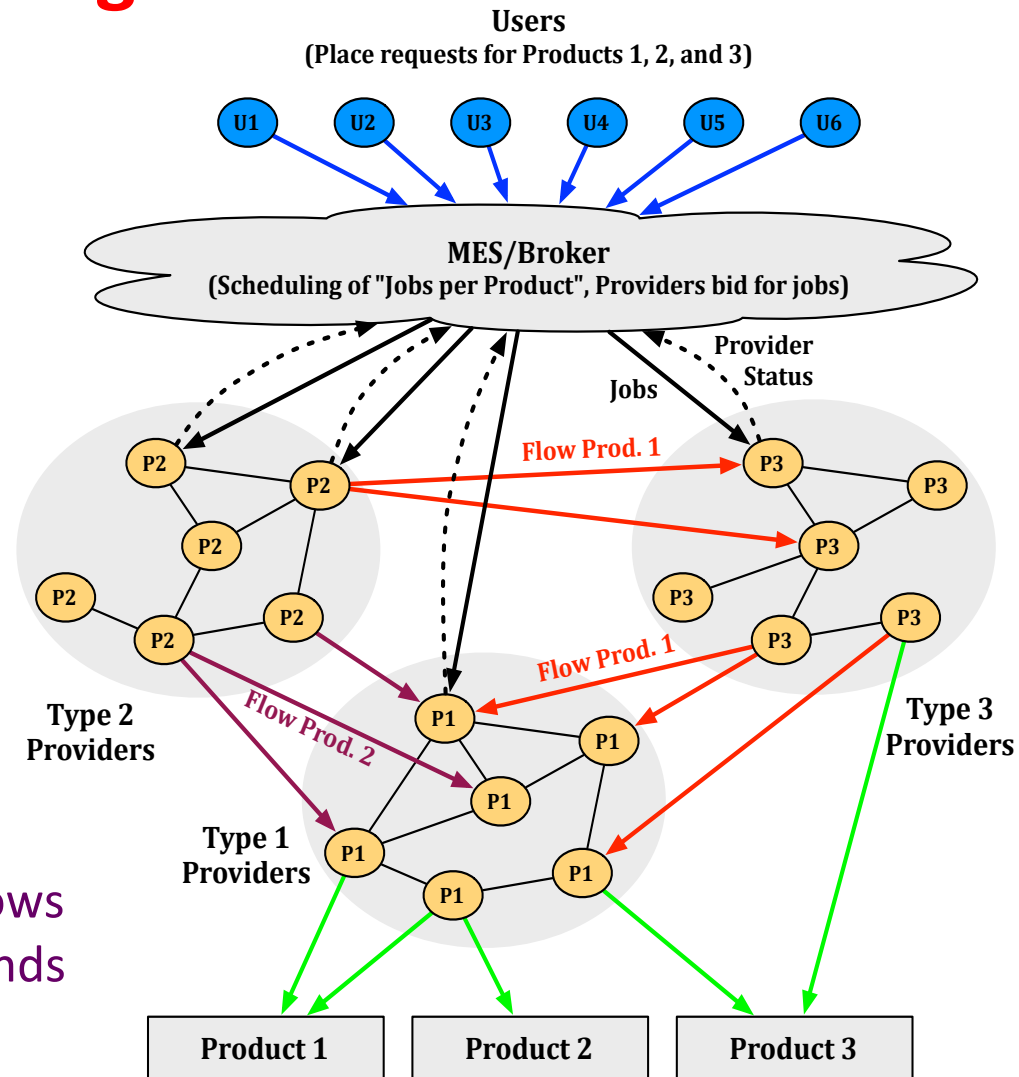
Background: Collaboration with HP Labs Open Innovation Office on Digital Print Factory Optimization (2010-2014)

- Factory demand, throughput, and performance forecasting;
- Order fulfillment prediction.

Process execution time and status prediction

On-line workflow composition/optimization and resource allocation

Virtual factory simulation platform

Qing Duan · Krishnendu Chakrabarty
Jun Zeng

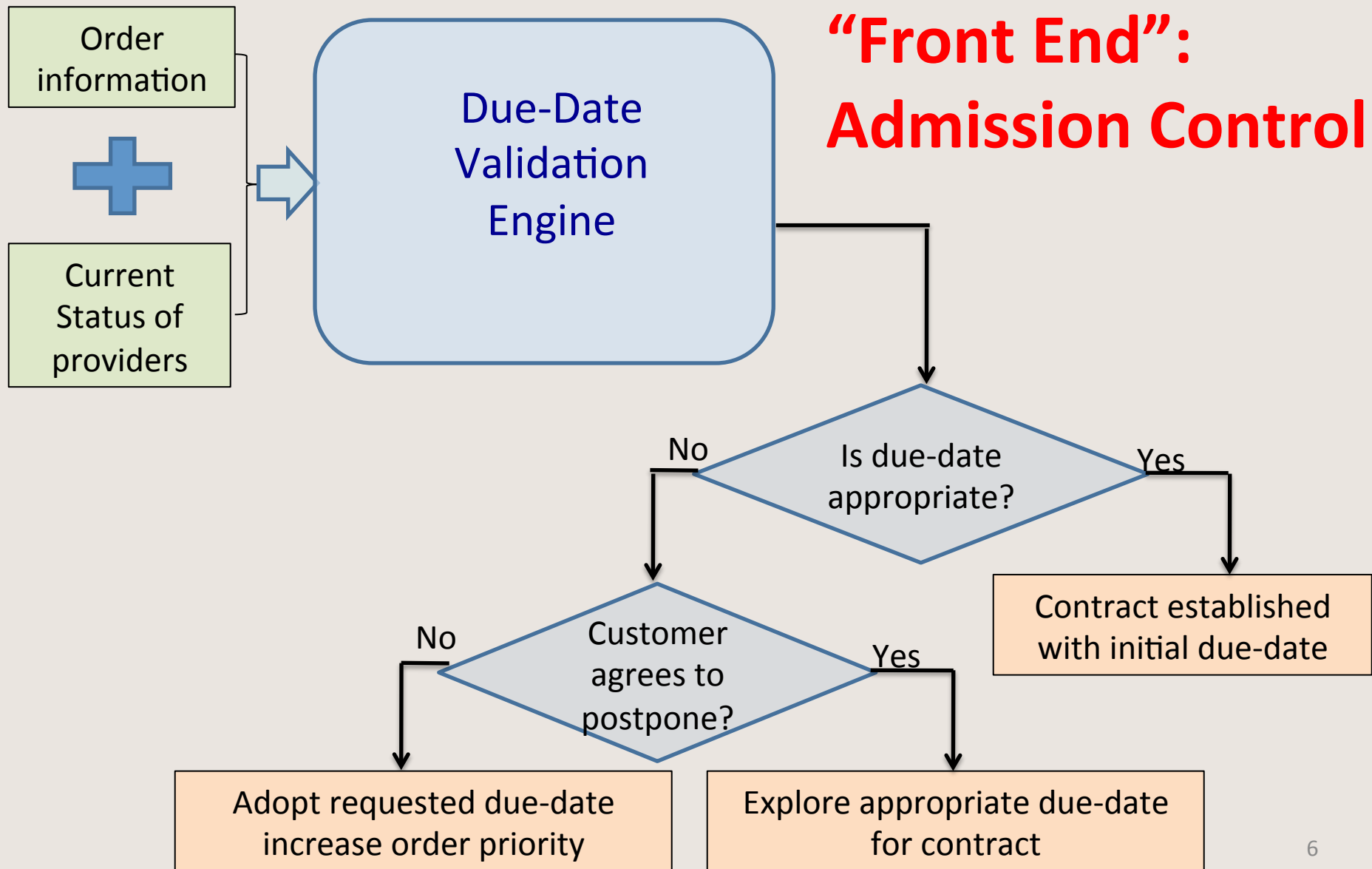Data-Driven Optimization and Knowledge Discovery for an Enterprise Information System

Springer

Address system complexity by studying the information system as a mass-customization enterprise

Non-Uniform Order Arrivals

Orders accepted every 15 minutes

Digital Print Factory data, HP Labs

Order information

Current Status of providers

Due-Date Validation Engine

"Front End":
Admission Control

Is due-date appropriate?

No

Yes

Contract established with initial due-date

Customer agrees to postpone?

No

Yes

Adopt requested due-date increase order priority
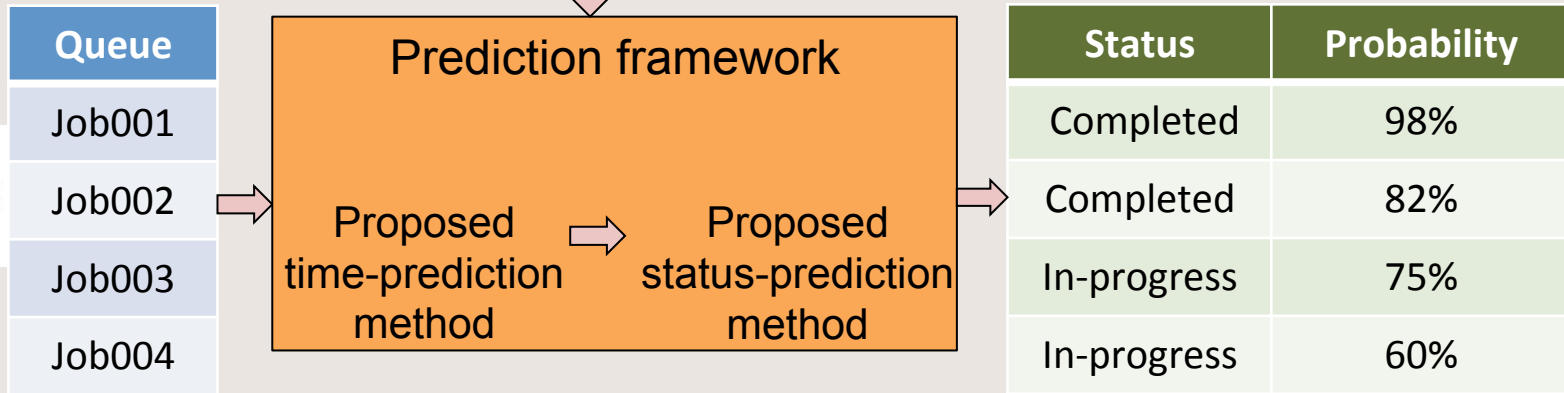
Explore appropriate due-date for contract

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"Front End": Manufacturing Apps

- Protocols for interoperability and resilience
- Manufacturing "apps": Open-source initiative for specifying, provisioning, and fulfilling orders
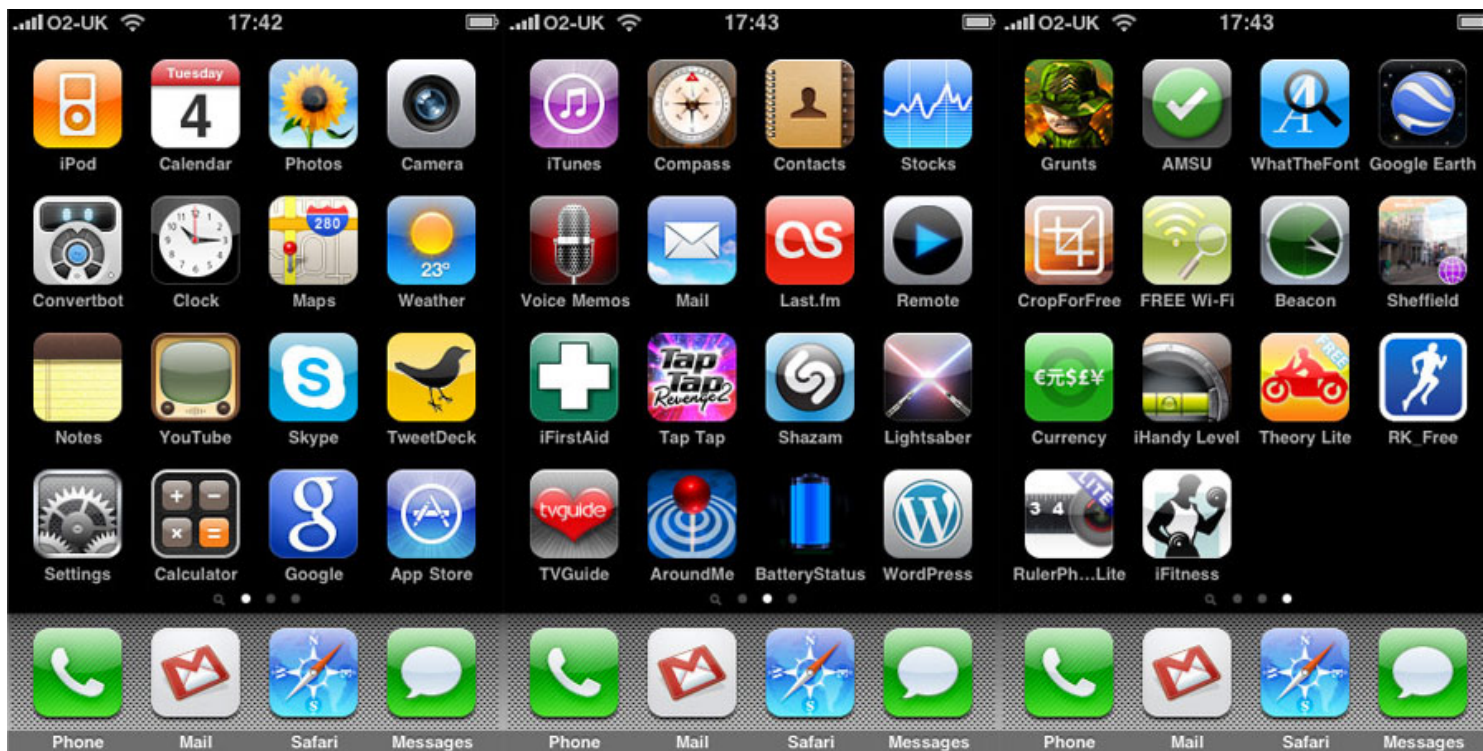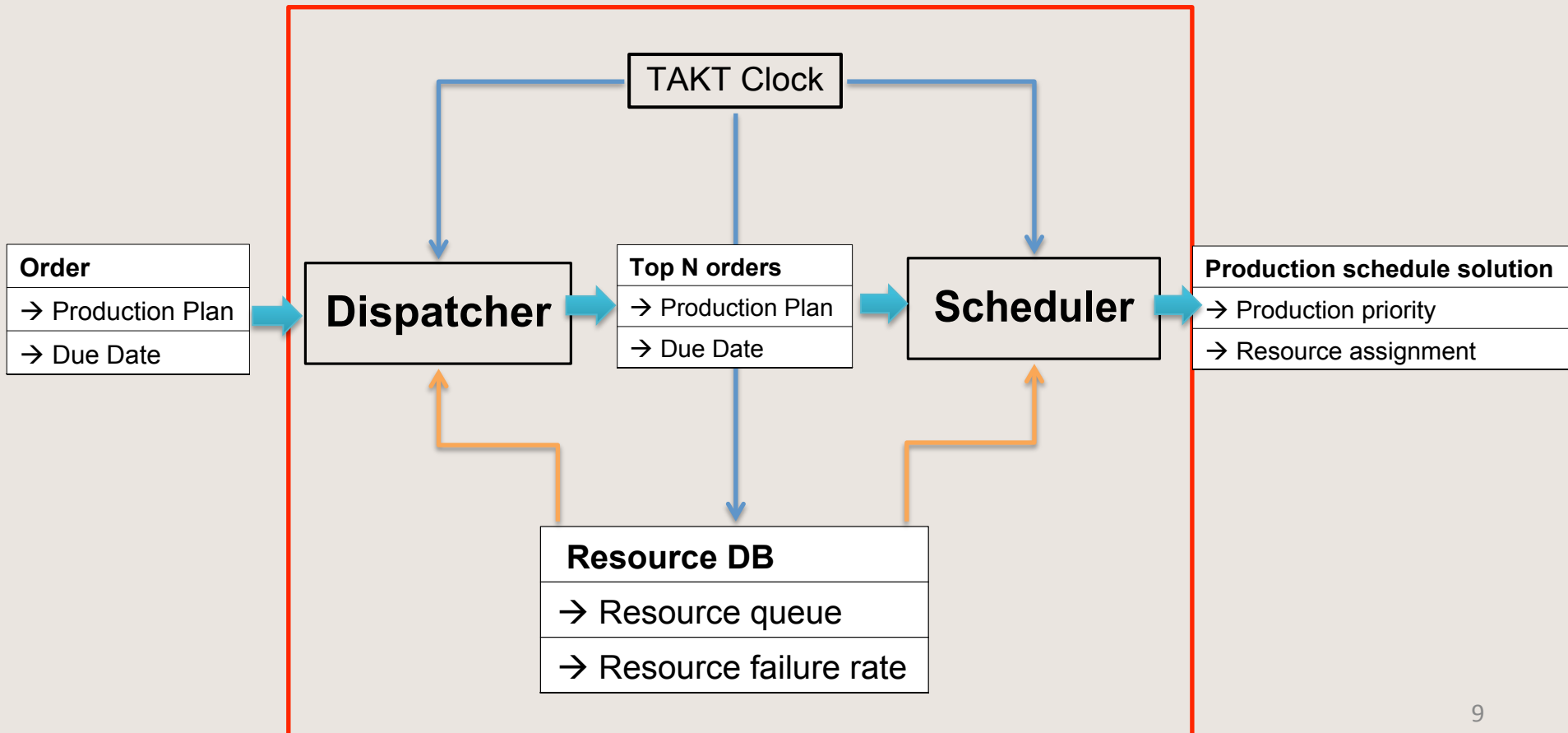
"Front End" Predictive Analysis

At the end of an arbitrary predictive horizon, e.g., one hour, one day

Queue
Job001
Job002
Job003
Job004

Prediction framework

Proposed time-prediction method → Proposed status-prediction method

Status	Probability
Completed	98%
Completed	82%
In-progress	75%
In-progress	60%

"Back End": Production Scheduler

Production Scheduler

"Back End": Distributed Optimization

Distributed, finite-horizon, optimization: Predictions about future state of the system

Distributed and robust optimization: Handle uncertainty in network parameters and user demands

Distributed online optimization: Utilities and constraints change with time and the decision makers rely on historical data

Distributed scheduling algorithms:
- Large-scale systems: Model products as flows manufacturing system (jobs per unit time)
- Smaller systems: Discrete formulations that schedule finite numbers of jobs over the available providers

Visual Analytics

SimCloud: Cloud-Computing Platform from HP Labs