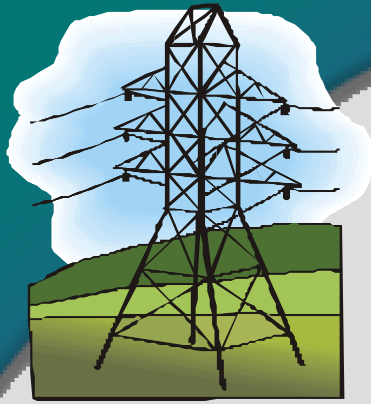
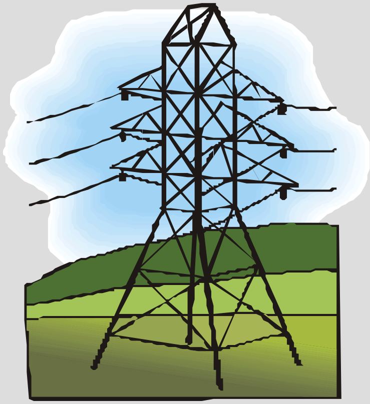




Modeling the Distribution Utility as an Agent in the Wholesale Market

Joseph M. Roop
Eihab Fathelrahman
Pacific Northwest National Laboratory

IAEE/USAEE Meeting, July 2004

Battelle

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

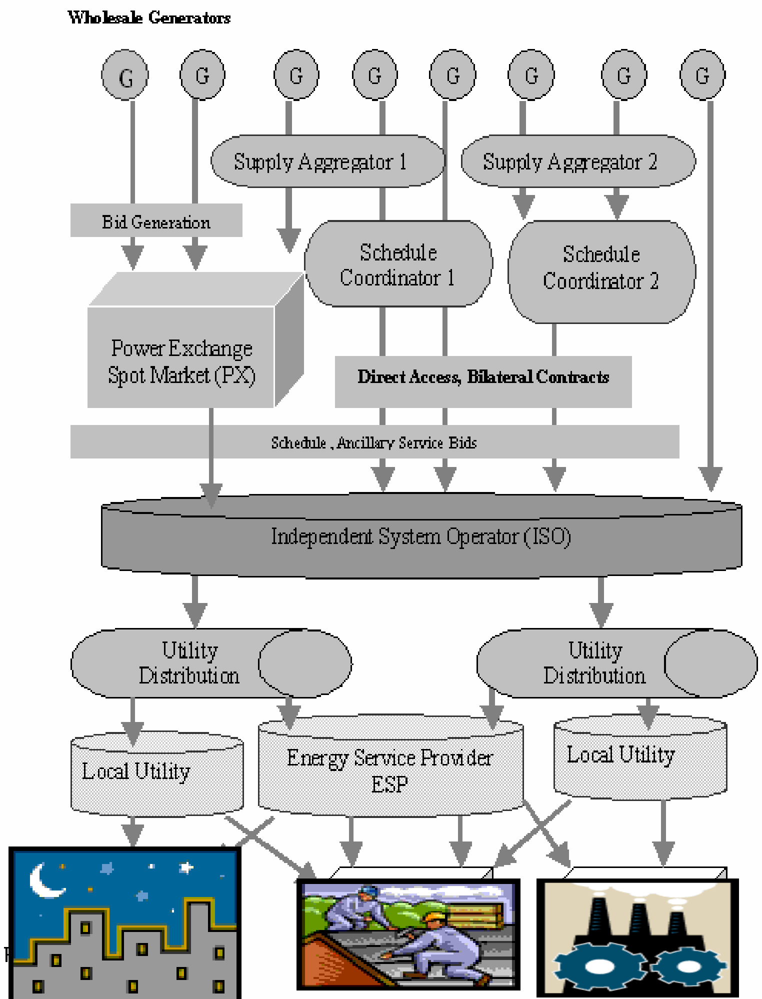
Overview

- Reflects two strategies for modeling agents as part of the grid
  - The power engineering approach
  - The network modeling approach
- Initial modeling was of customers within a distribution utility or load serving entity (LSE)
- Current extension is to create LSE agents that bid for power in a wholesale market
- Credits: Steve, Ross, Henry, Dave, Janet, Joe and Dean

Outline

- After a "big picture" view of the system, will explain the difference in approaches
- Then the similarities in economic behavior of the agents in the two systems
- Results of simulation of the two systems
- The mechanism for creating the LSE agent is then explained for each of the different approaches
- Status of these two current modeling approaches concludes the presentation

The Big Picture



Electricity Market Structure

Generators (Genco)

- Bid into the spot market with PX or
- Bid ancillary services into ISO or
- Schedule power delivery with ISO

Power Exchange (PX)

- Non-profit entity provide energy markets (Day-Ahead-Hourly, and Spot)

Independent System Operator (ISO)

- Maintain secure and reliable power supply Submit balanced schedules
- Provide settlements and info to PX
- Coordinate DAH, and spot balancing

Load Serving Entity (LSE)

- Demand aggregator for retail loads
- Purchase and market power to retail consumers
- Work with SC or PX

Customers (C) : End-users of energy who want to participate in the market

Battelle

Source Adopted from Gibson, Gerlad. Intelligent Software Agents for Control and scheduling of distributed generation. 1999

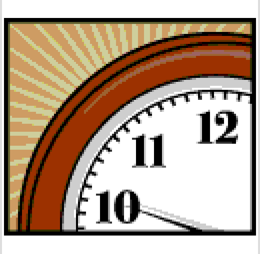
Differences in Approaches

- Power Engineering Approach
  - Model thermal loads for major appliances
  - Model other loads statistically
  - Modeling is done at the household level because this is the least price responsive
  - Currently neither commercial nor industrial sectors
- Network Modeling Approach
  - Models all loads statistically
  - Includes all three sectors
  - Includes behavioral characteristics as a way of balancing loads

Agent Logic

- In both approaches, the logic is the same for residential customers
- A bill is received each month; this triggers a response, depending on whether or not the bill is within expectations; the outcome may change the current contract
- Customers start with fixed rate contracts; can move to Time of Use (TOU) or real-time contracts
- Price sensitivity assures that power use is lowered during peak price periods

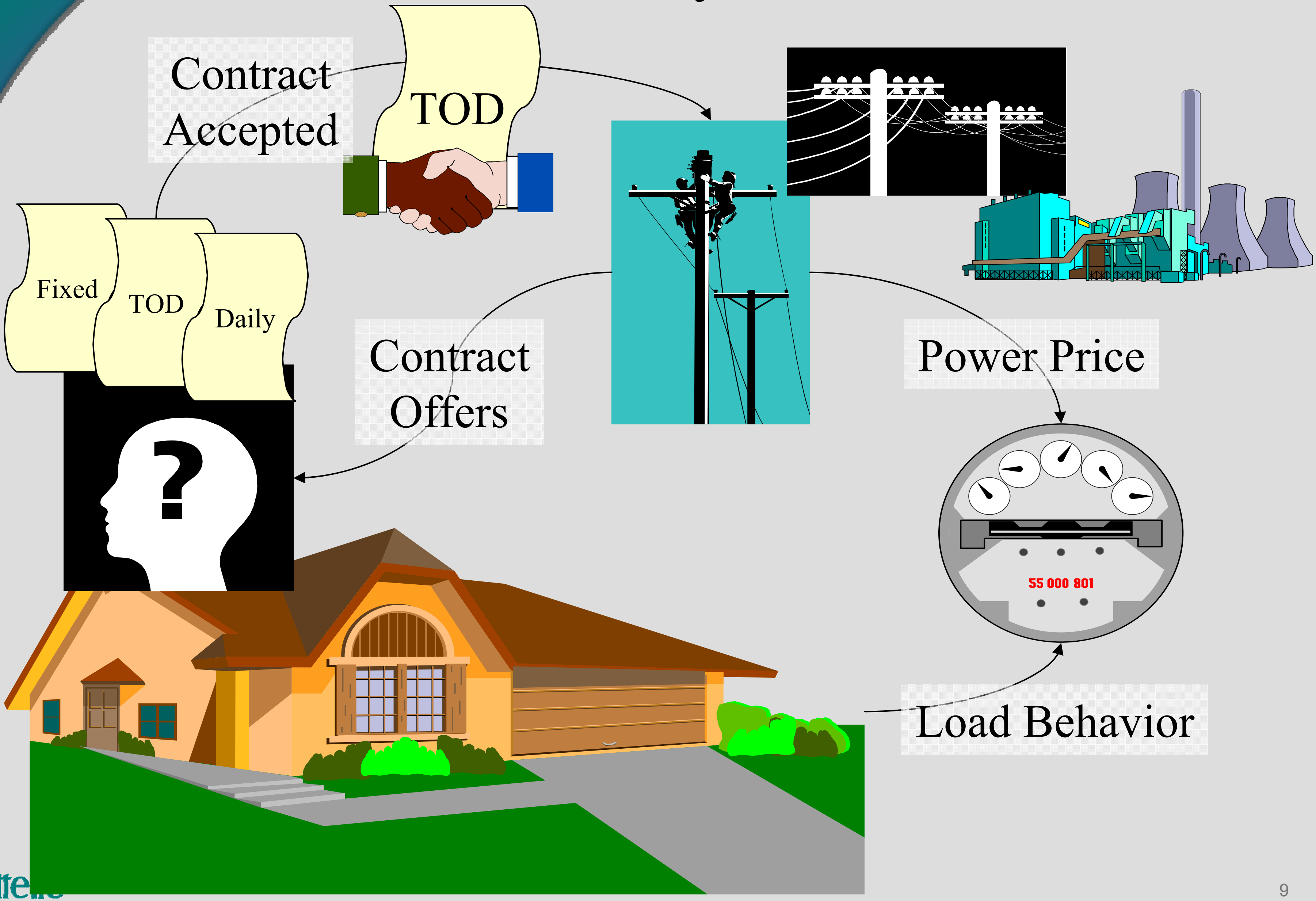
Three Basic Contract Types



- Fixed Rate (FR) is a guaranteed fixed price that is announced well in advance and applies to all units of consumptions.
- Time-Of-Use (TOU): rate schedules are published where prices differentiate between off-peak, shoulder, and on-peak time-of-day price.
- Real Time Price (RTP): Consumers have the opportunity to see electricity prices that vary from hour to hour, reflecting wholesale market price variation.
- ***Under any contract*** *we do not expect the customer to make active decisions based on price*

Model Structure

Customer/Utility Interaction



Define Customer Contract Decision Process

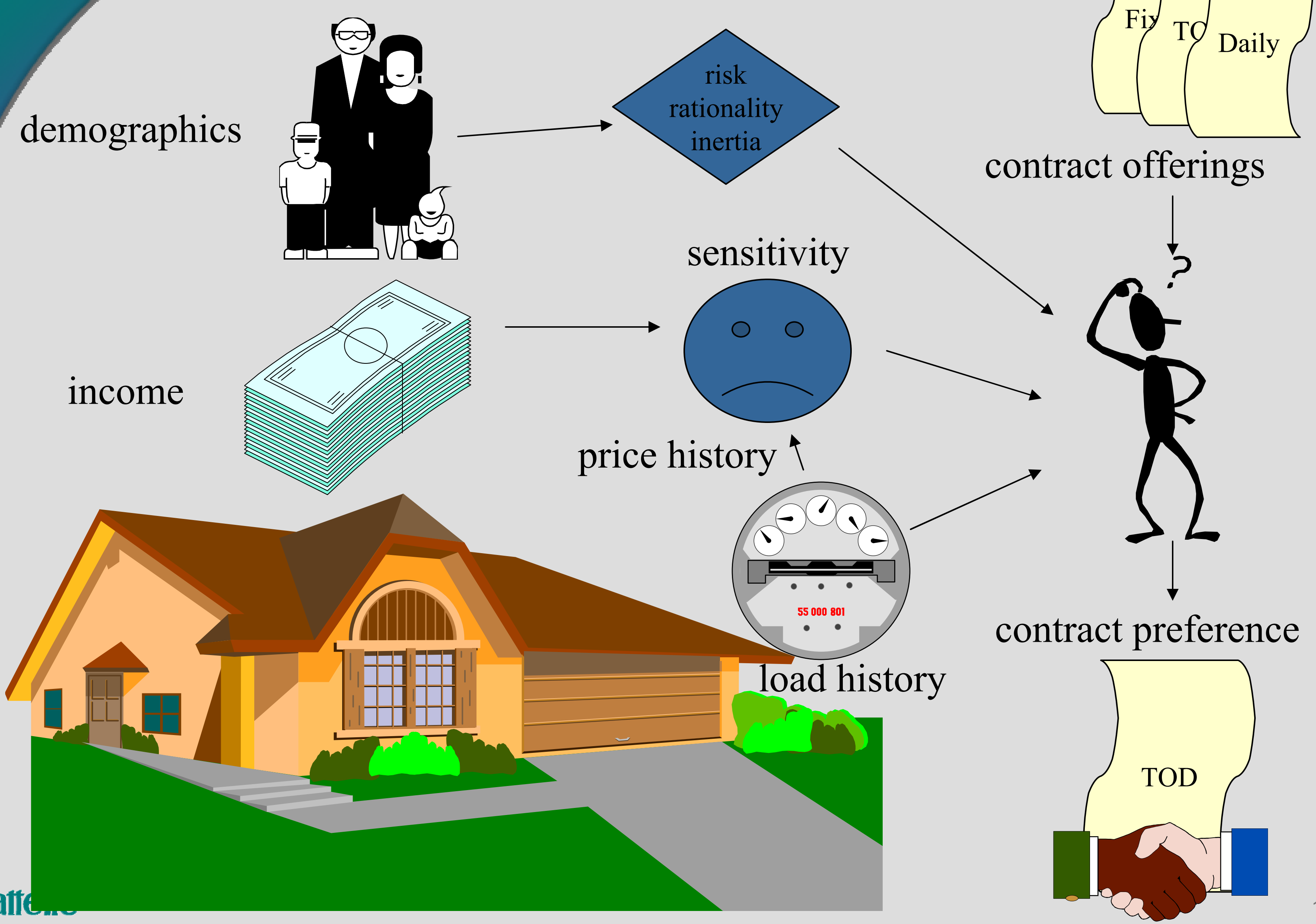
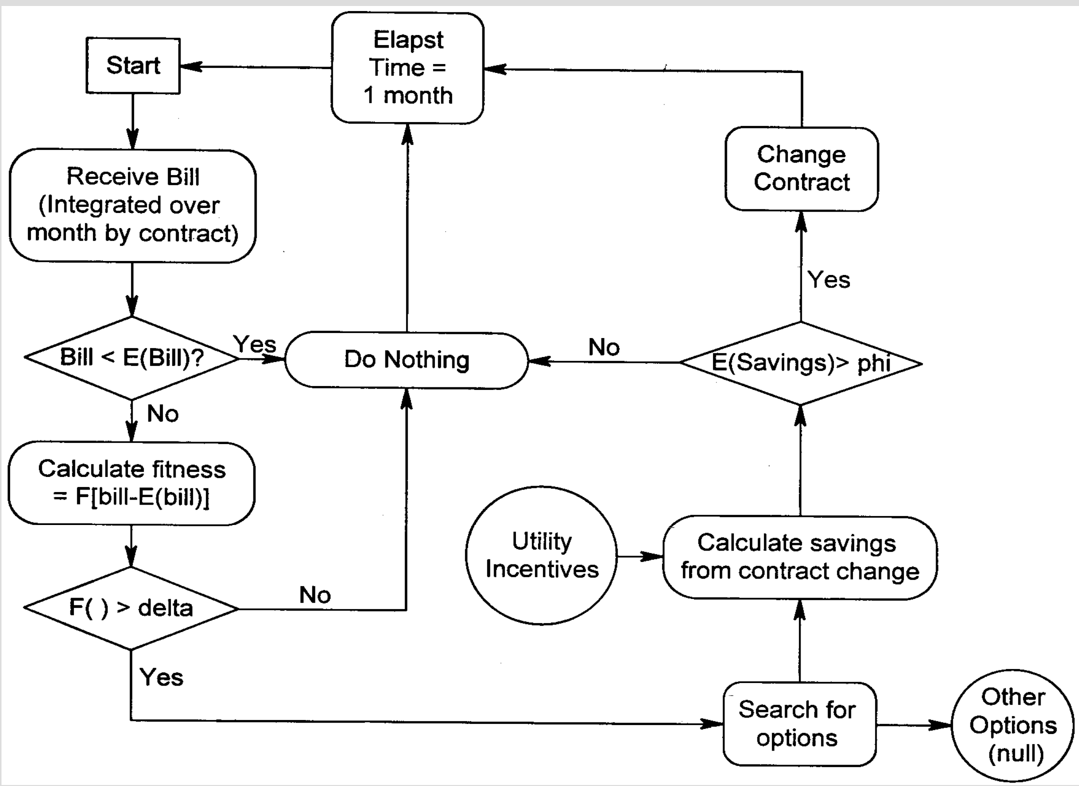


Diagram of Decision Logic
Monthly Household Contract Selection



ϕ = Actual bill - bill if used the same power but had the other contract in place

$\psi \equiv 0.3$ = propensity trigger value

Model Parameters

- n = customer number
- t = time in hours
- $\rho \in [0,1]$ = recency = willingness to let the contract remain unchanged
- $p_n(t) \in [0,1]$ = propensity to switch contracts for customer n in period t

  $p_n(t+1) = (1-\rho)^t p_n(t) - F_n(\varepsilon, \Delta f)$ such that $p \downarrow$ likelihood to change $\uparrow$
- δ = dollar savings threshold for wanting to make a change
- $\varepsilon(\delta) \in [0,1]$ = acceleration of willingness to change if reward is high
- Δf = fitness = [Actual bill - Expected bill]
- The Modified Fitness Measure is computed as

  where $f_n(t)$ = fitness measure

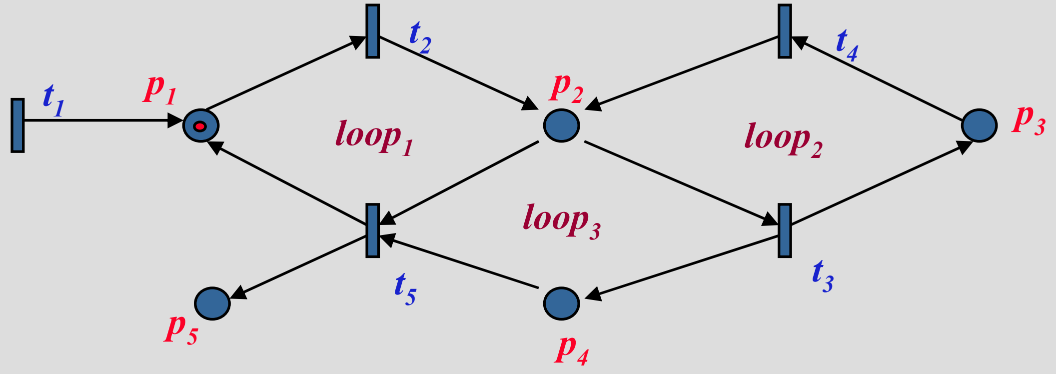
$$F_n(\varepsilon, \Delta f) = \begin{cases} 0 & \text{if } \Delta f \leq \delta \\ f_n(t) & \text{if } \Delta f > \delta \end{cases}$$

$$f_n(t) = \left[\frac{bill - \delta}{Expected\ bill} \right]^2$$

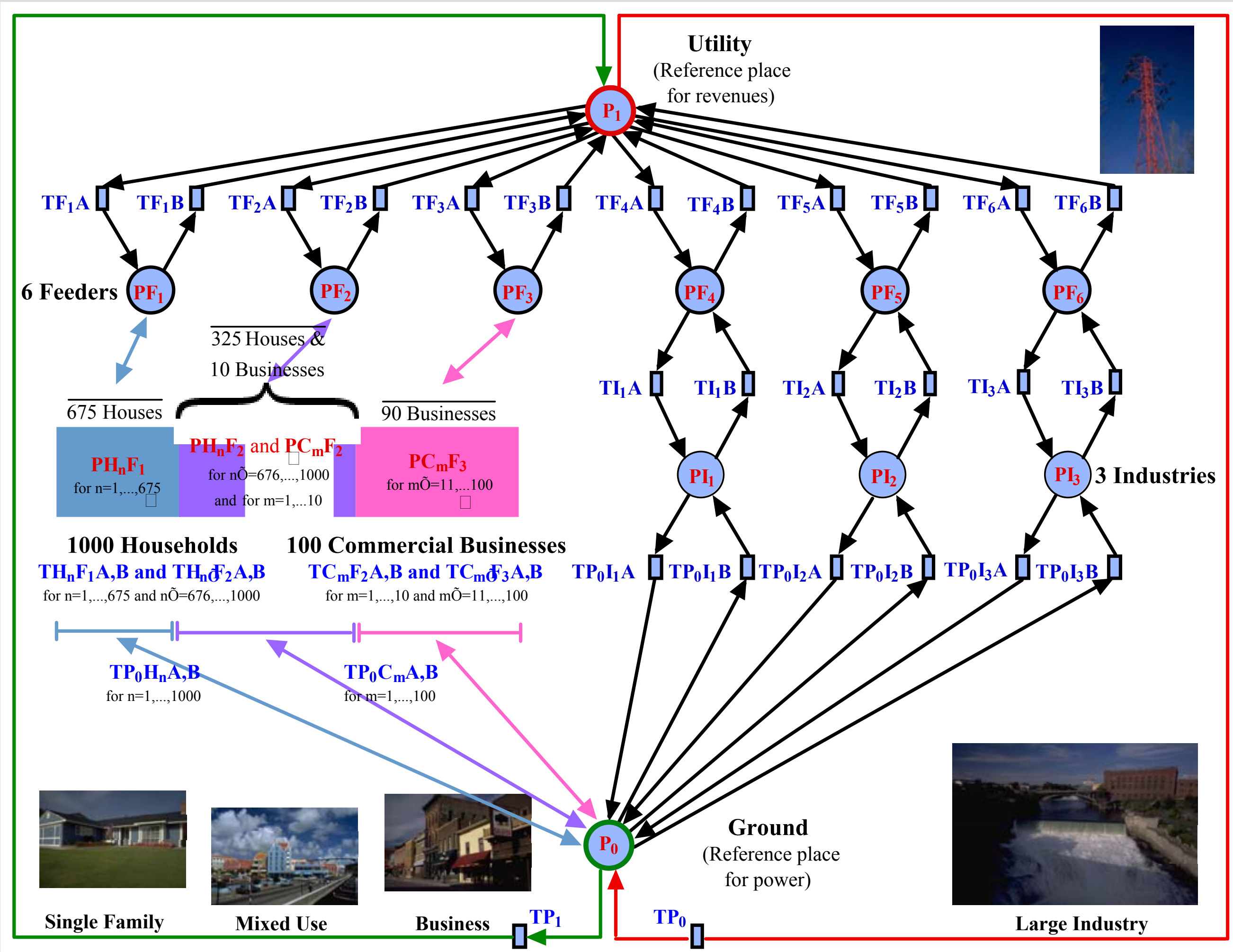
Battelle

The Hybrid Petri Net Approach

- Infrastructure is modeled as a network-of-networks (places and transitions)
- Network captures place (nodes), transitions (rules governing token movement including direction) and time
- Execution of transition can be conditionally or probabilistically dependent on other variables
- Network is subject to conservation laws (equivalent to Kirchhoff's laws of current & voltage)



Network for Contract Choice

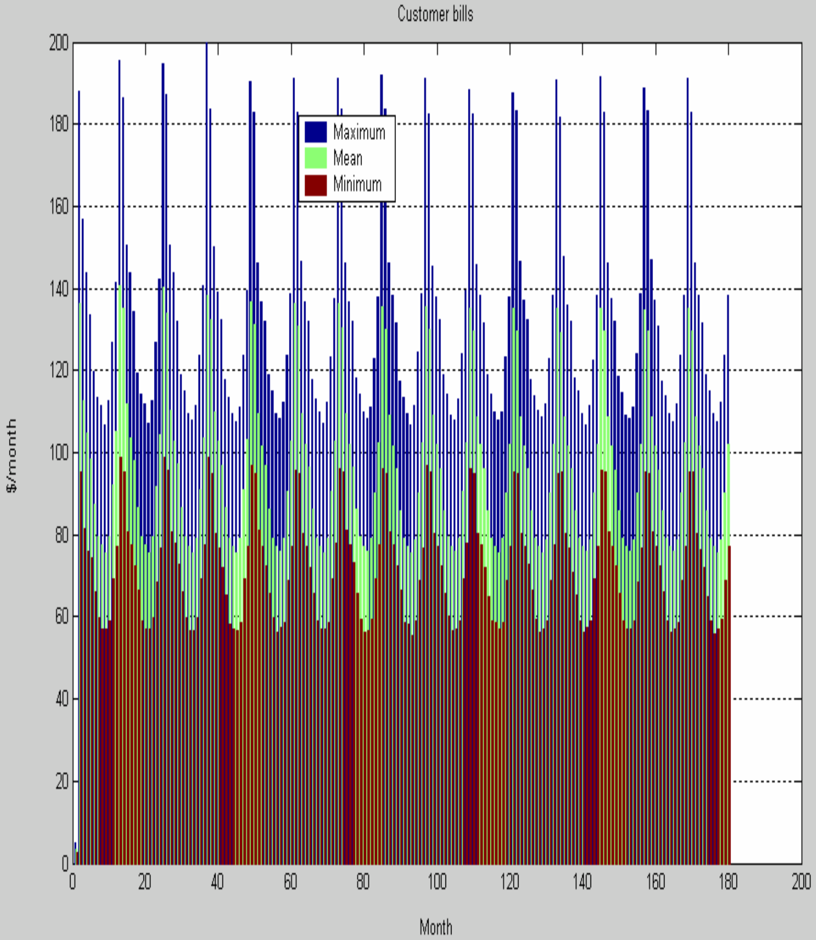


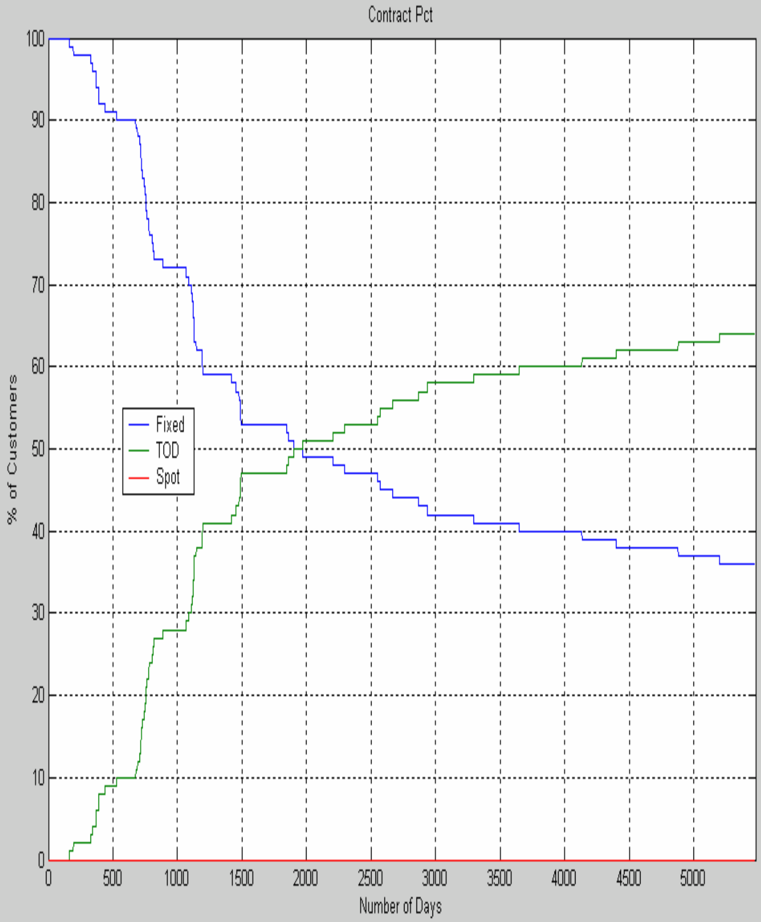
Model Results

Battelle

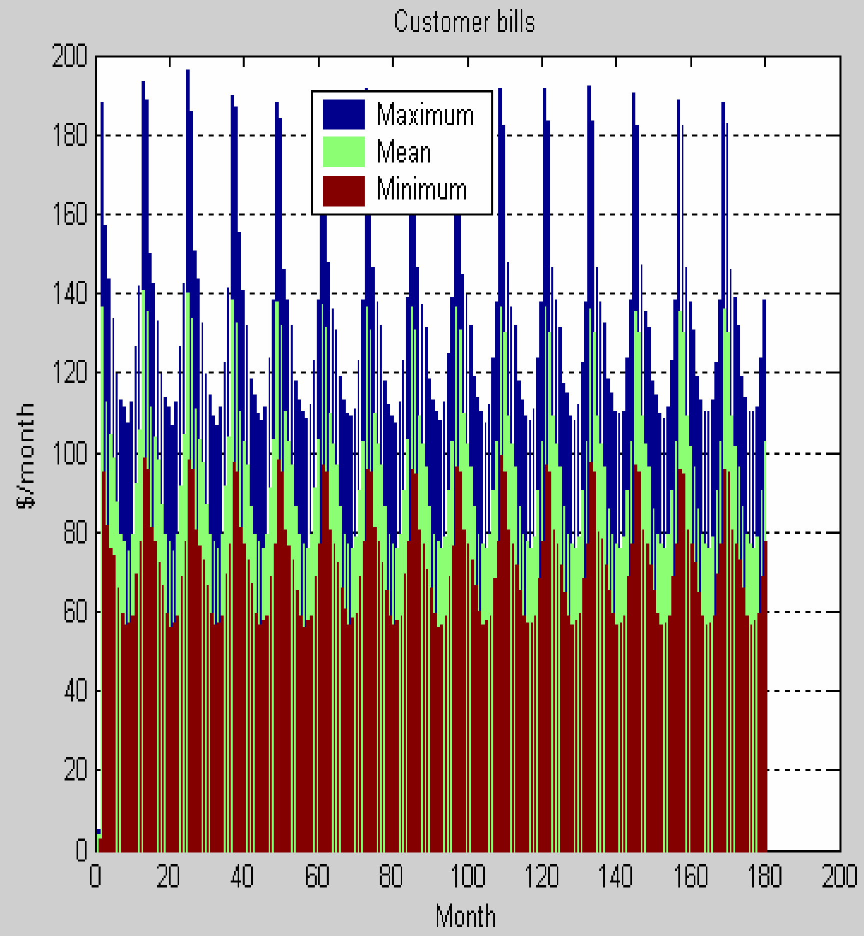
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

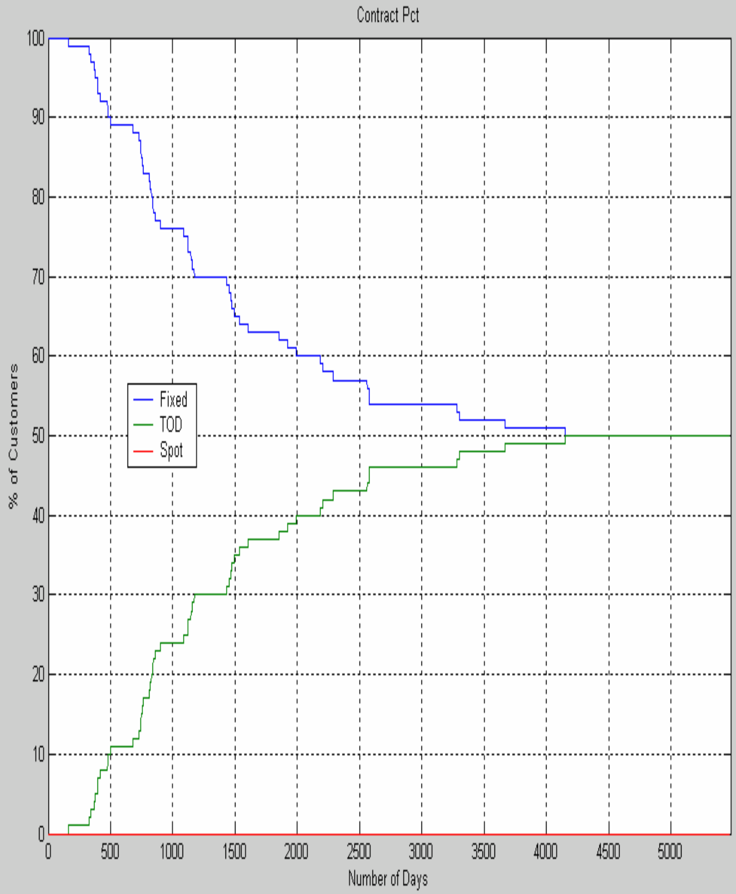
Contract Selection Percentages for Experiments – Power Engineering





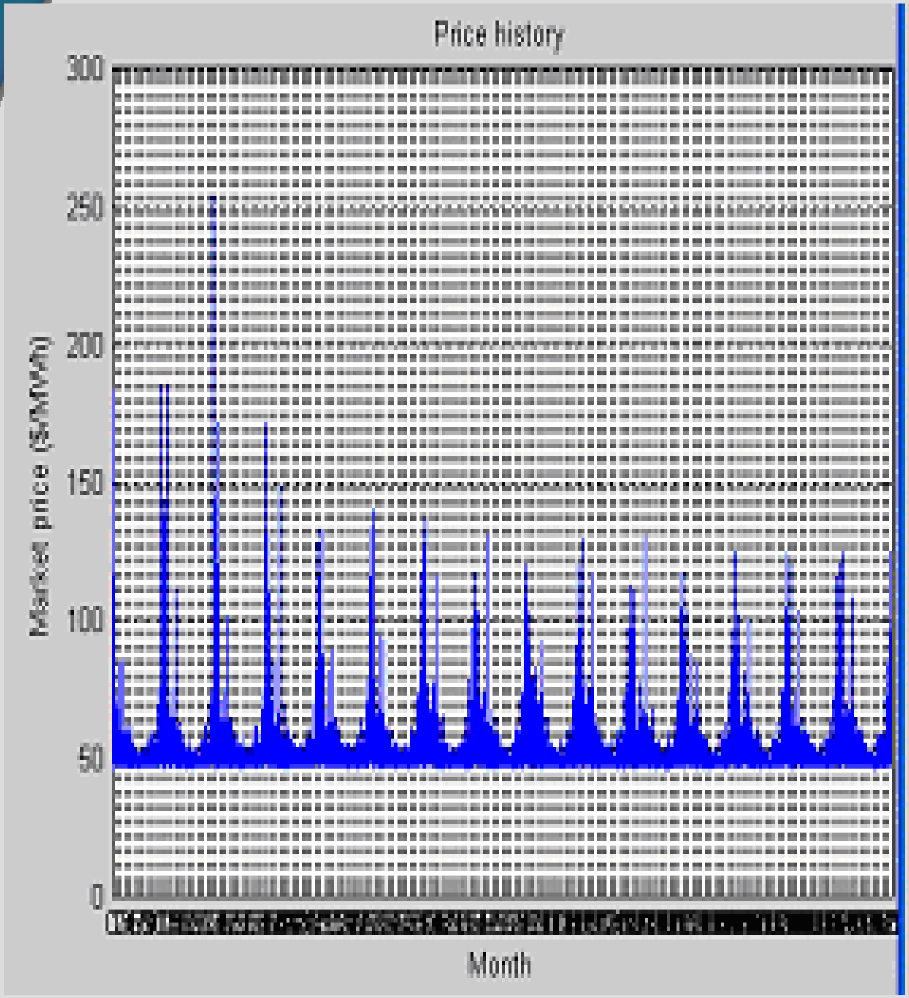
Balance between FR and TOU

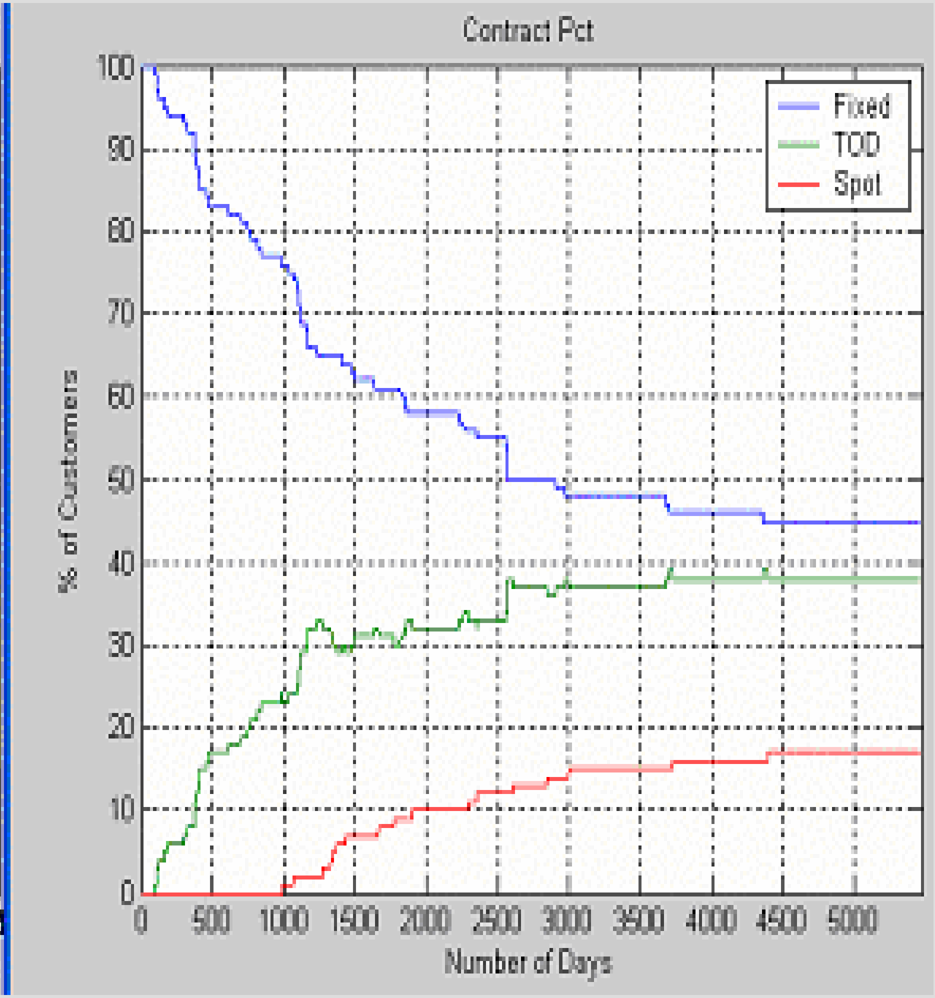




Battelle

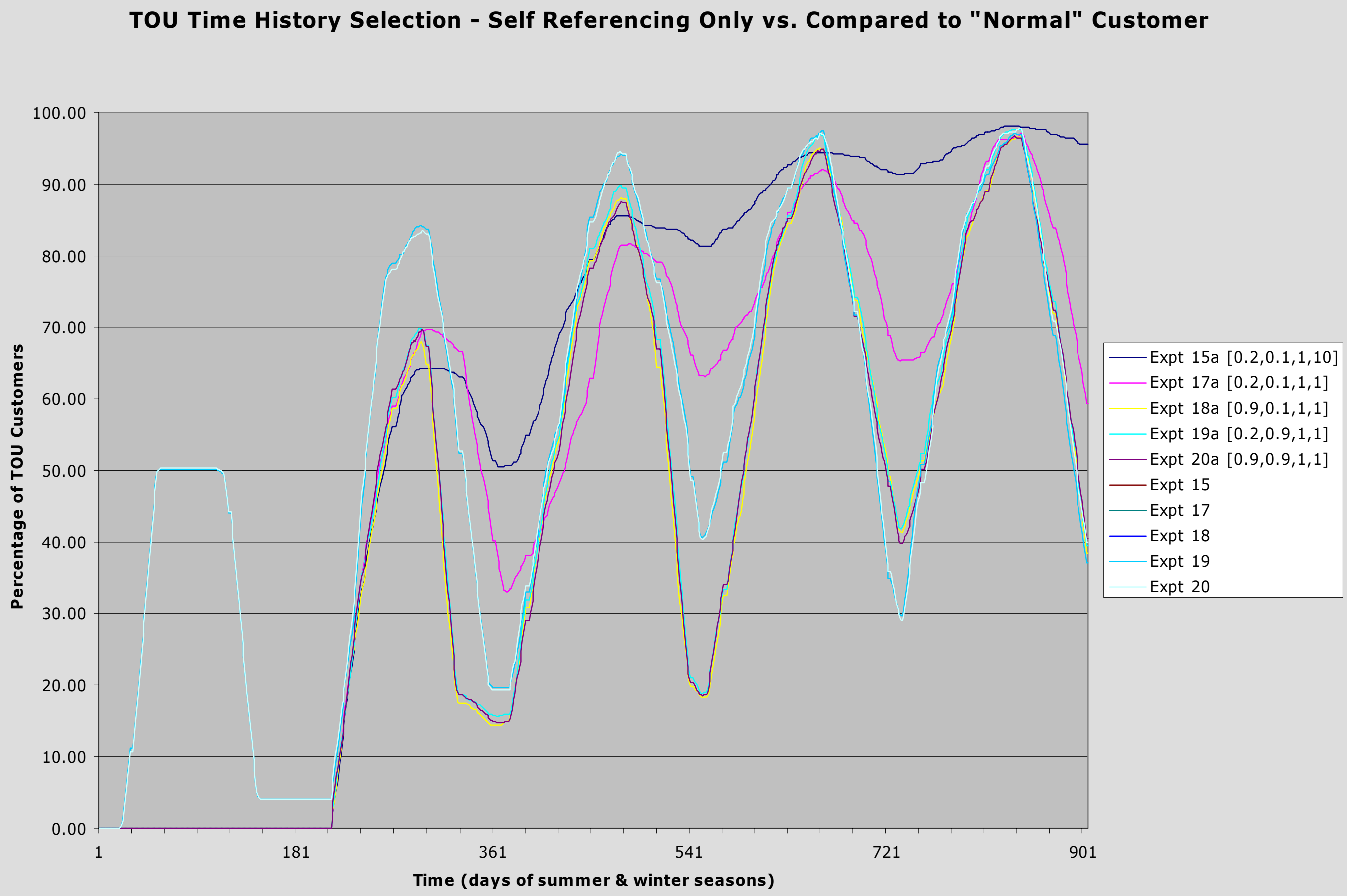
Lower Bulk Electricity Price





Contract Selection Percentages, Petri Net Approach

More Petri Net Results



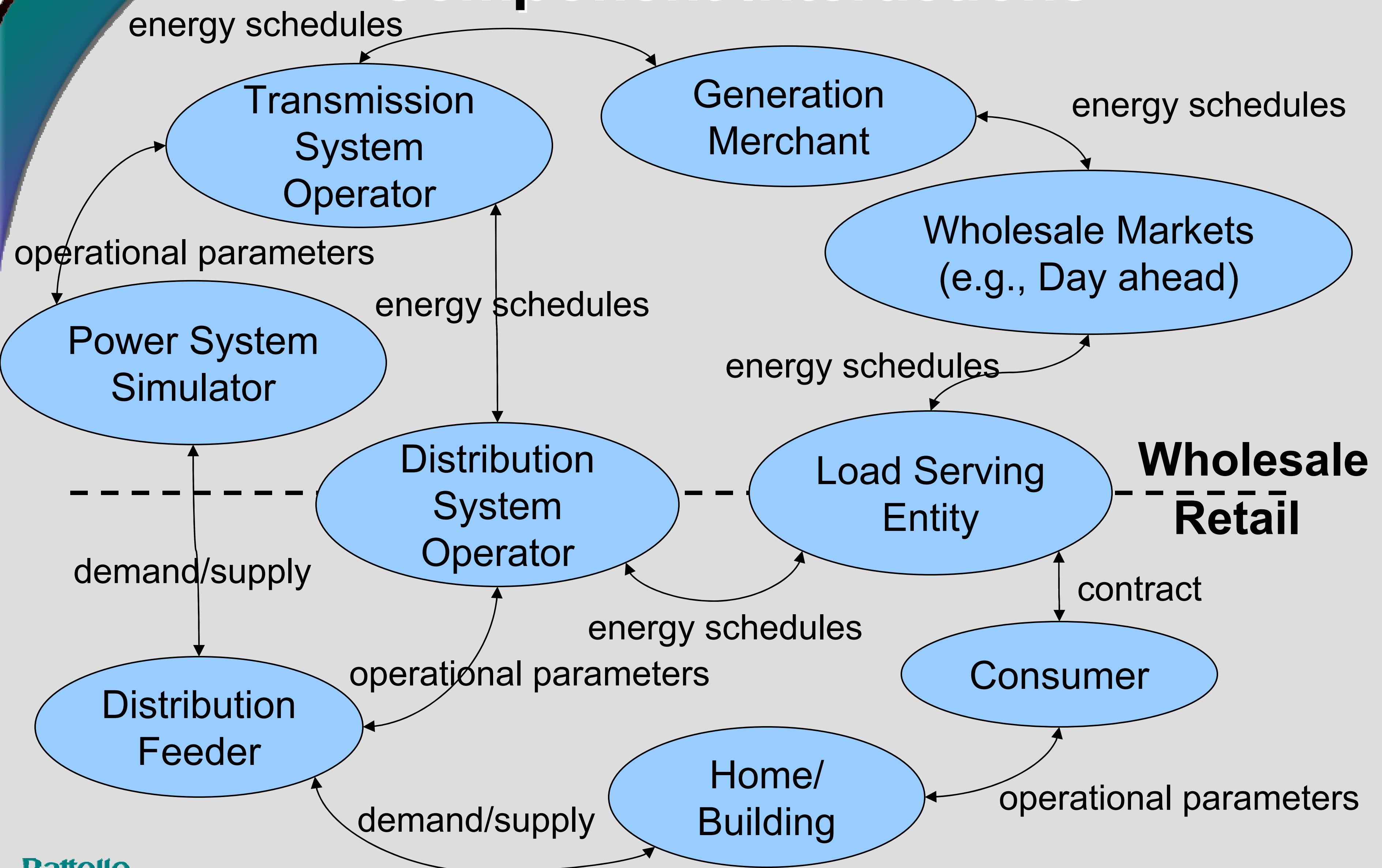
Battelle

Creating the LSE Agent

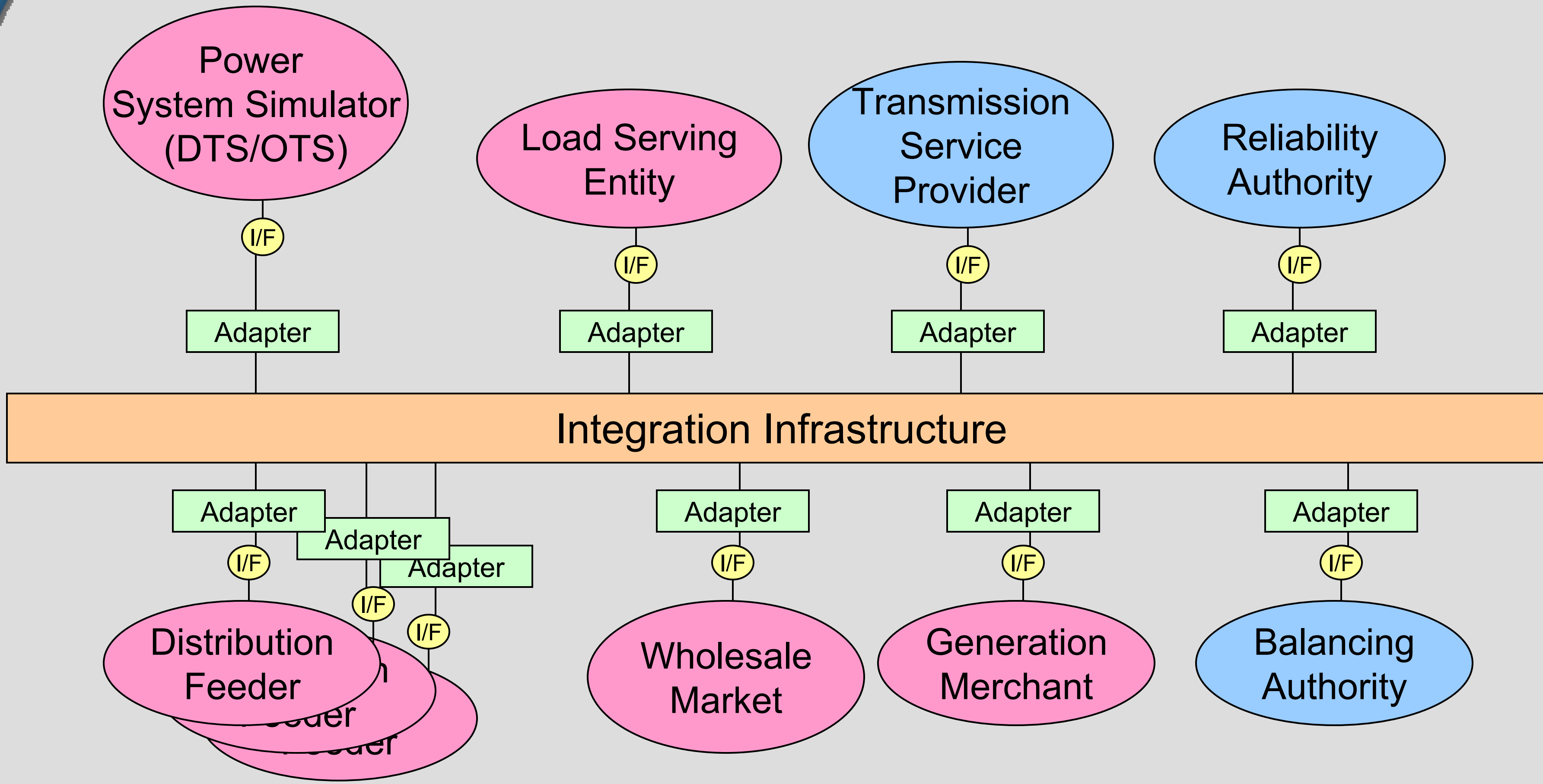
Objectives of LSE Agent

- Provide service to customers
- Cover costs – power, O&M, return on equity
- Key performance metric that regulates reward is how well the LSE provides power to customers at "least cost"
- This metric requires that LSE learn how customers will respond to price signals that it creates
- Anticipate the influence of weather
- Use this information in the bidding for wholesale power

Component Interactions



Component/Agent Based Simulation Vision

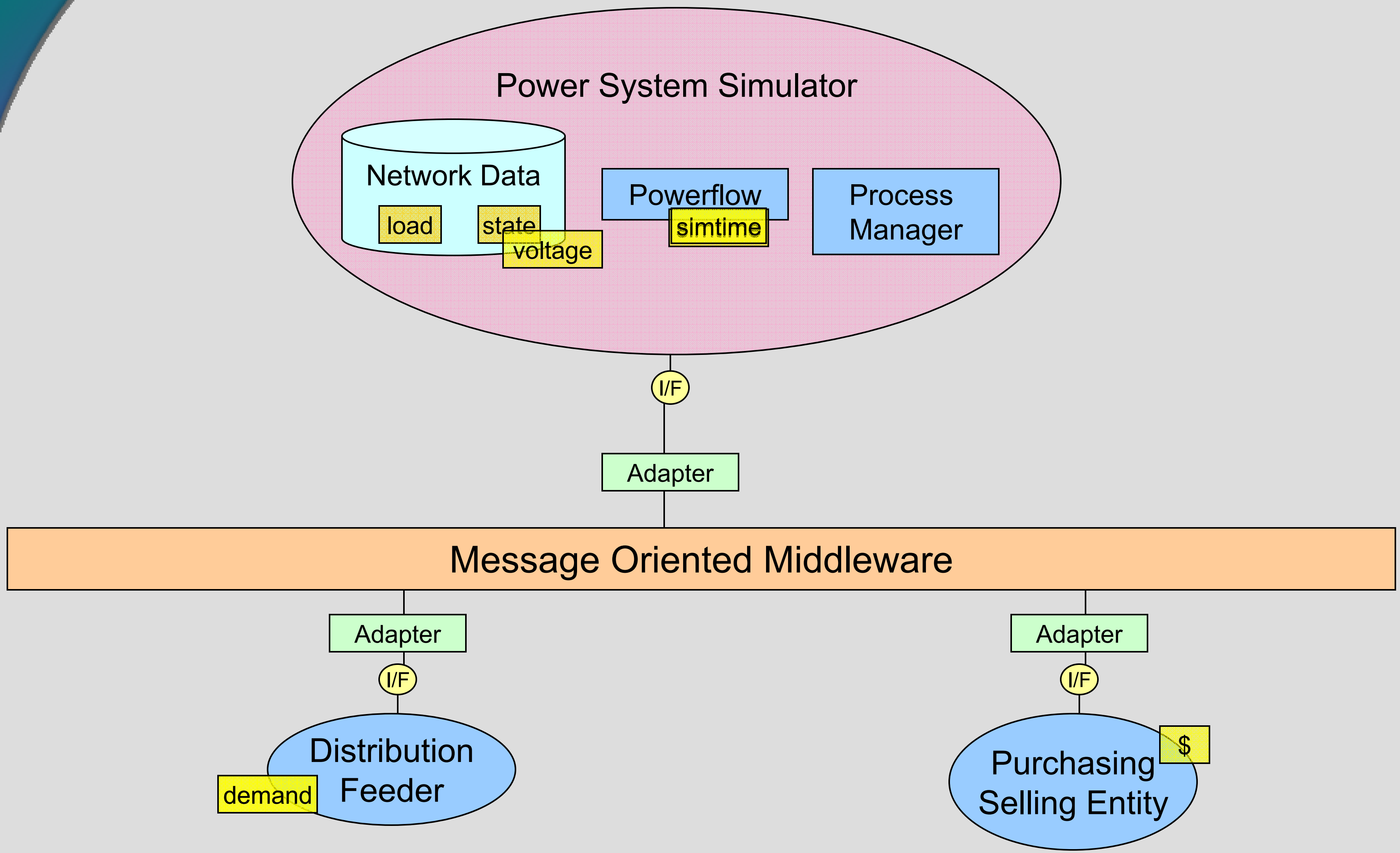


LSE as an Agent – Petri Net Approach

- Components are the same as with Power Engineering approach
- Key difference is that the behavioral rules that balanced loads are now errors that the LSE uses to learn how to better function in the wholesale market
- To succeed, the LSE has to cover costs, learn how price responsive customers are, and use this information to be effective in the wholesale market
- A key objective is to provide power at "least cost" to customers

Status

Prototype



Battelle

Petri Net Approach

- Dean is back on board and will begin programming the code to simulate the multiple LSE, multiple generator interaction in a wholesale market
- Since our focus is on the LSE, GenCos will simply bid their marginal cost into the market, LSEs will develop a strategy based on customer behavior, costs, etc.
- Will use a year’s run as basis for estimation of loads and price response
- We expect results by the end of the year.

Questions?