Evolution Toward Decentralized Management and Coupled Systems

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IBM has invested over $50B in R&D during the last decade
IBM Research has ~3,000 researchers across 12 laboratories
Continuing trend to take advantage of distributed resources

- Integrating the management of distributed resources is a significant challenge
  - Many are customer owned, with evolving communication and control protocols
  - There are multiple parties that can benefit from their responsiveness
    - System operators
    - Distribution operators
    - The resource owners themselves
  - Each of these has different business and operational objectives and constraints
    - A decentralized, but coupled, management approach would could allow optimal use of these resources across this set of interested parties

- New approaches are needed to address the loosely-coupled nature of such systems
  - Coupled-system modeling
  - Emergent phenomena detection and management
Eras of Computing

- Tabulating Systems Era
- Programmable Systems Era
- Cognitive Systems Era
Big Data, Analytics & Value Creation

Degree of Complexity

Competitive Advantage

- Standard Reporting
- Ad hoc reporting
- Query/drill down
- Alerts
- Simulation
- Forecasting
- Predictive modeling
- Optimization
- Stochastic Optimization

- Linear/Integer Programming
- Nonlinear Programming
- Physical Modeling
- Data Mining
- Machine Learning
- Statistical Analysis
- Prescriptive
- Predictive
- Descriptive

- What exactly is the problem?
- What will happen next if?
- What if these trends continue?
- What could happen?
- What actions are needed?
- What happened?
- How many, how often, where?
- How can we achieve the best outcome?
- How can we achieve the best outcome including the effects of variability?

Based on: Competing on Analytics, Davenport and Harris, 2007 © 2010 IBM Corporation
Smarter Cities topics depend directly or indirectly on energy.

Models, Data and Analytics

City Operations and Planning

Urban Planning & Development

Government and Agency Administration

Environment

Sustainable

Urban Water Management

Building Energy Management

Other

Energy

Water

Public Safety and Surveillance

Public Safety

Citizen Engagement

Social Programs

Health

Infrastructure

Human

Transportation

Education

Social Programs

Transportation

Emergency Mgmt and Environment

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Coupled Systems

Atmosphere
Hydrosphere
Biosphere
Geosphere

Electricity Grid
Water Management

Interdependent Systems

Buildings
Transportation
Reservoirs
Wires & Pipes
Power Plants

Electricity Demand Management
Electricity Supply Management
Water Demand Management
Water Supply Management
Flood Impact Management
Storm Water Management

Electricity Consumption Behavior
Electricity Business Objectives
Water Consumption Behavior
Water Business Objectives
Flood Impact Behavior
Water Drainage Objectives

Coupled Earth Systems (Natural World)
Man-made World

Resource Management Modeling and Optimization

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Energy Cost Minimization in Water Systems

Description

- The solution minimizes the energy cost associated with pumping water through a treatment and distribution network, while meeting customer requirements and hedging against energy price uncertainty.

Significance

- Demonstrates significant cost savings by using mathematical optimization models to schedule pumps.
- Demonstrates how to best leverage lower (but uncertain) dynamic prices by hedging against uncertainty.
- Targets some of the major segments/pain points, namely energy cost reduction and leveraging renewable energy.
Transportation systems are also coupled to energy

CiM
urban commuter mobility analytics

TOPS
Transit passenger demand analytics, network optimization & multimodal simulator

PTA
Transit service awareness & bus arrival prediction service

TPT/DSSO
Real time prediction & control optimization

DOCIT
Dynamic optimization of intermodal transport

MegaTraffic Simulator
Large scale traffic flow simulator

Analytics, Optimization & Simulation
empowered by transportation domain models
Techniques like Transactive Control show promise

- The use of an economic value signal as a control signal can enable interoperability and the exchange of objectives and constraints between highly heterogeneous systems

- It can be overlaid on any type of system – not just energy systems
  - So it can provide a well-defined method of coupling the management of dissimilar systems
Transactive Control Definition

A distributed overlay approach utilizing a cost-based economic signal as a distributed control system signal

- All business and operational objectives and constraints can be assigned a value, and thereby incorporated into the signal

Transactive Incentive Signal (TIS): reflects true cost of electricity at any given point

Transactive Feedback Signal (TFS): reflects anticipated consumption in time
Challenges that must be addressed

- Management across highly heterogeneous, loosely-coupled Systems
- Dealing with emergent phenomena as an integral part of overall system management
- The challenges of modeling and optimizing these complex systems – Faster than real-time, so those models can be part of the operational system
- Working with the policy and regulatory communities to evolve in a way that enables such approaches – Across multiple industries, if we are to take full advantage of the coupled nature of our energy-dependent society