# Overview of the EESG Research and Education; Vision for Dynamic Monitoring and Decision Systems (DYMONDS)

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March 11,2009

# Outline

- About EESG
- Drivers of Change
- New Requirements for System Operations and Planning
- Getting Started
- DYMONDS Vision
- DYMONDS-Related Work in EESG

# Electric Energy Systems Group (EESG)
## http://www.eesg.ece.cmu.edu

- A multi-disciplinary group of researchers from across Carnegie Mellon with common interest in electric energy.
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- Interests range across technical, policy, sensing, communications, computing and much more; emphasis on systems aspects of the changing industry, model-based simulations and decision making/control for predictable performance.

Electric Energy EESG Systems Group

# A sample of subjects currently offered in ECE

- 18-418 Electric Energy Processing: Fundamentals and Applications
- 18-875/19-633/45-855/45-856 Engineering and Economics Problems in Future Electric Energy Systems
- 18-618 Smart Grids and Future Electric Energy Systems
- 18-777 Large-scale Dynamic Systems
- Courses taught with an eye on regulatory, technological changes, and the implications of these on problem posing and possible solutions.
- Courses emphasize commonalities across different electric energy systems (power systems-power distribution to homes; shipboards, aircrafts and cars.
- In house software development to support the curriculum – (Graphical) Interactive Power Systems Simulator ((G)IPSYS).

# Summary of active research areas

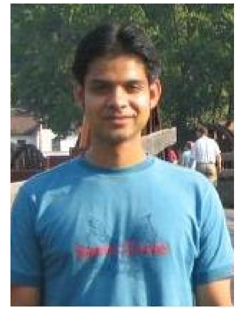
- NEXT GENERATION SCADA (DYMONDS) FOR IMPLEMENTING ENERGY AND ENVIRONMENT DREAM —THE ROLE OF SYSTEMS
- THE RENEWED ROLE OF STORAGE IN FUTURE ELECTRIC ENERGY SYSTEMS: CHALLENGES AND OPPORTUNITIES
- INTEGRATING DISTRIBUTED ENERGY RESOURCES (DERs) AND DEMAND SIDE MANAGEMENT
- MANAGING INTERMITTENT RESOURCES—WIND GENERATION

Noha Abdel-Karim

Prof. Greg Ganger

Prof. Marija Ilic

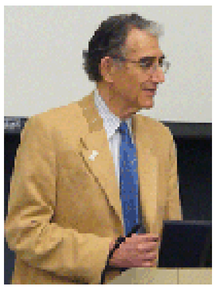
Jhi-Young Joo



Soummy Kar

Prof. Bruce Krogh

Ryan Kurlinski

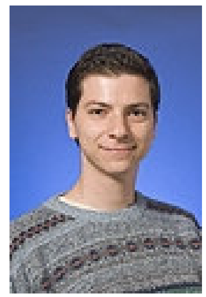


Prof. Lester Lave

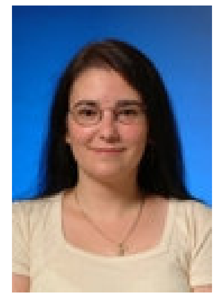
Juhua Liu

Prof. Jose' Moura

Masoud Nazari



Luca Parolini



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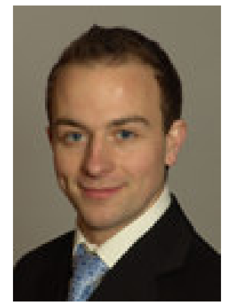


Niklas Rotering

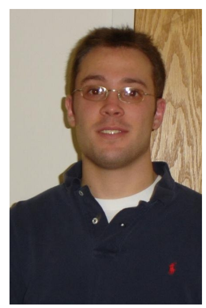
Prof. Bruno Sinopoli

Nermeen Talaat

Anupam Thatte

Prof. Ozan Tonguz

Usman Khan



Charlie Wesley

Richard Wu

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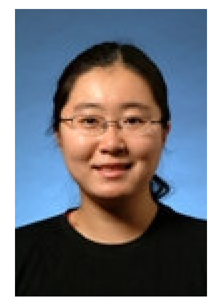


Yi Zhang


NOT PICTURED: Marcelo Elizondo, Jovan Ilic, Michael Kowalski, Nipun Popli

# DRIVERS OF CHANGE

- Organizational/regulatory
- Technological
- Environmenal
- National security

- These lead to major challenges to the operating and planning of today's electric power systems.

# NEW REQUIREMENTS FOR OPERATIONS AND PLANNING

- Major departures from today's methods.
- Difficult challenges and opportunities.
- Transform the existing electric power grid into the key enabler of
  - integration of existing and disruptive technologies to meet customers' needs
  - implementation of distributed sub-objectives (contextual, spatial, temporal)
  - coordinated system-wide tradeoffs (social welfare; QoS; emission; security)
  - distributed risk management at value

# Single optimization subject to constraints (old) vs. Reconciling multi-dimensional tradeoffs (new)

| Single optimization subject to constraints | Reconciling tradeoffs |
|---|---|
| Schedule supply to meet given demand | Schedule supply to meet demand (both supply and demand have costs assigned) |
| Provide electricity at a predefined tariff | Provide electricity at QoS determined by the customers willingness to pay |
| Produce energy subject to a predefined $CO_2$ constraint | Produce amount of energy determined by the willingness to pay for $CO_2$ effects |
| Schedule supply and demand subject to transmission congestion | Schedule supply, demand and transmission capacity (supply, demand and transmission costs assigned) |
| Build storage to balance supply and demand | Build storage according to customers willingness to pay for being connected to a stable grid |
| Build specific type of primary energy source to meet long-term customer needs | Build specific type of energy source for well-defined long-term customer needs, including their willingness to pay for long-term service, and its attributes |
| Build new transmission lines for forecast demand | Build new transmission lines to serve customers according to their ex ante (longer-term) contracts for service |

# GETTING STARTED

- Must recognize that one size does not fit all.
- Must observe initial operating and planning practices and build on it.
- View as a constantly evolving path dependent process.
- Understand industry state and performance as a function of initial system, expected performances and candidate technologies.

# GETTING STARTED

- Understand that solutions are non-unique
- Instead, provide an industry environment in which
  - Choice (technical/organizational objectives; tradeoffs) is enabled by embedding intelligence at different industry layers
  - Interactions across industry layers are multi-directional and IT-enabled (bottom-up – communicating choice; top/down-coordinating)
  - Depending on the type of information exchanged convergence of multiple tradeoffs and system-wide objectives is approached

# DYMONDS VISION

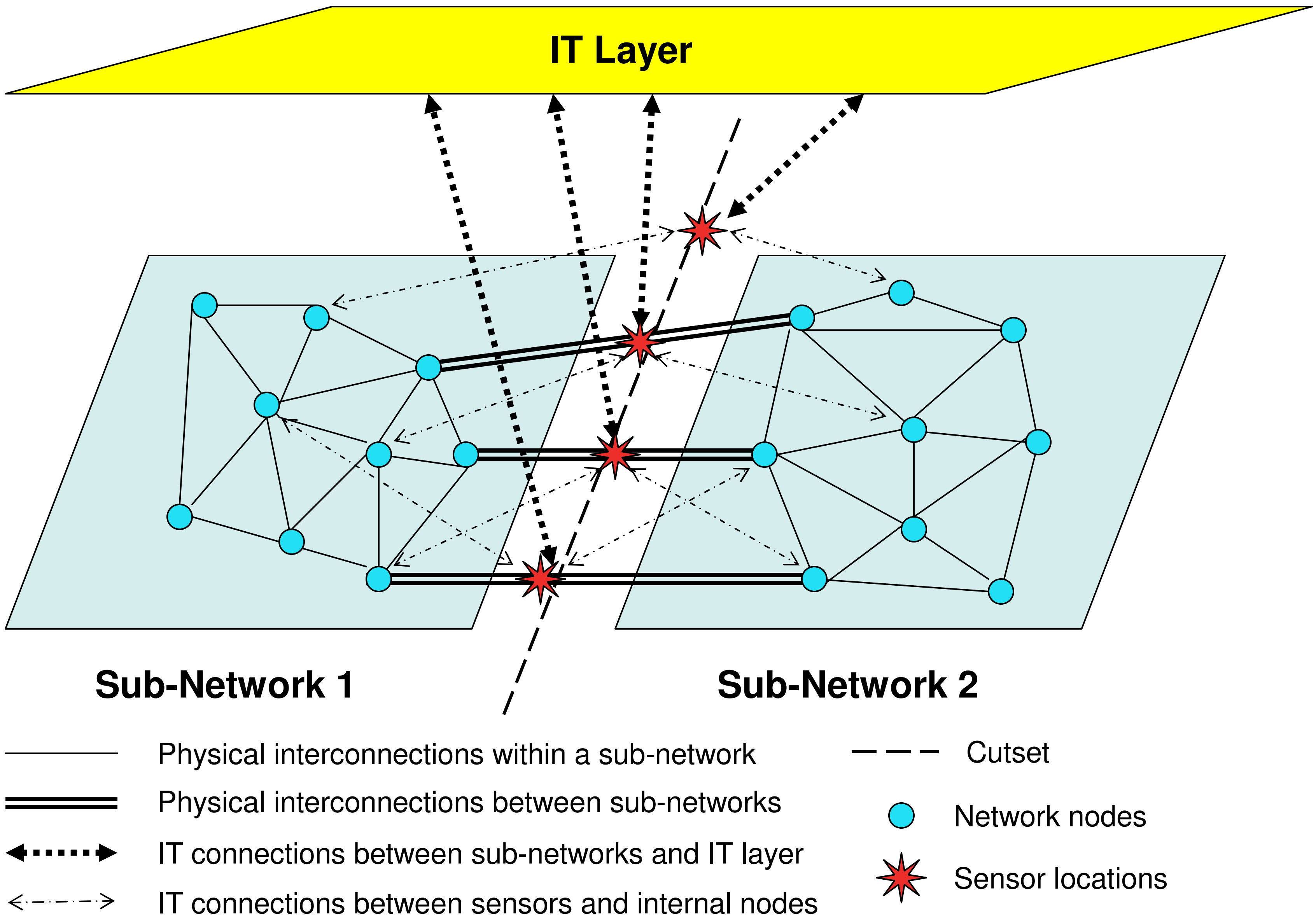
- IT-based means of catalyzing orderly industry evolution by
  - Deploying model-based sensors, actuation, intelligence into various industry layers
  - Deploying model-based interactive communications/learning/adaptation across industry layers to coordinate sub-objectives of different layers (temporally, spatially, contextually)

# IT-ENABLED ECONOMIES OF SCOPE

- Distributed objectives could be made to converge to system-wide objectives by inducing unconventional gains through economies of scope (value of prediction; value of look-ahead decision making; value of learning;  value of IT-enabled cooperation through aggregation; value of transparency; value of liquidity)

# DYMONDS-NEXT GENERATION SCADA

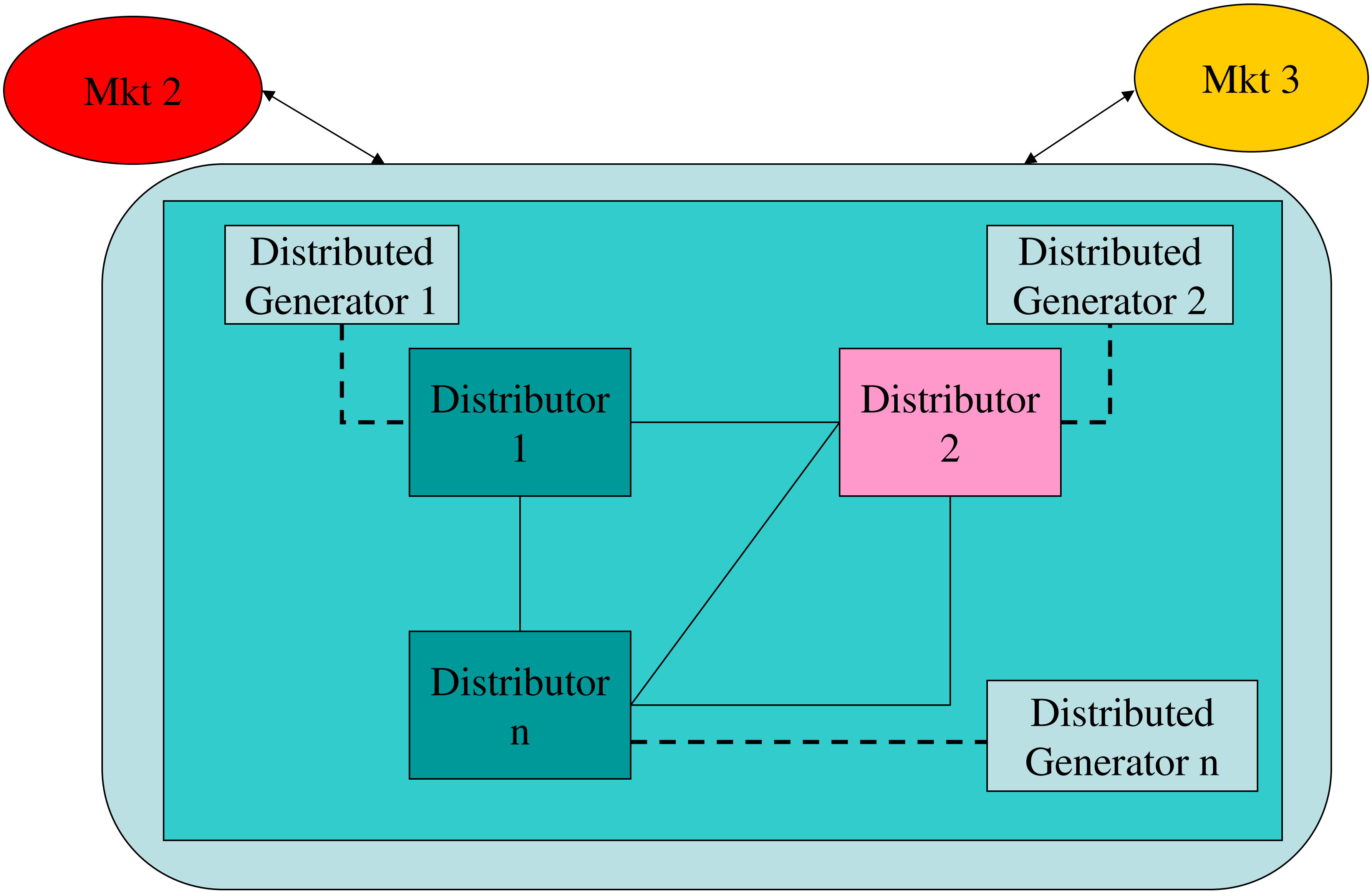
- Today's SCADA –hierarchical (top-down)
- Next generation SCADA—interactive multi-directional (top/down-coarse; bottom-up/detailed and then aggregated at several layers)
- Uncertainties managed at value by assigning risk at each layer and the corresponding value
- Much information unique and known only at lower layers  communicated in a bottom-up way to the higher layers; higher layers coordinating system-wide effects using the information provided to them in order to facilitate system-wide performance


IT Layer
Sub-Network 1
Sub-Network 2
Physical interconnections within a sub-network
Physical interconnections between sub-networks
IT connections between sub-networks and IT layer
IT connections between sensors and internal nodes
Cutset
Network nodes
Sensor locations

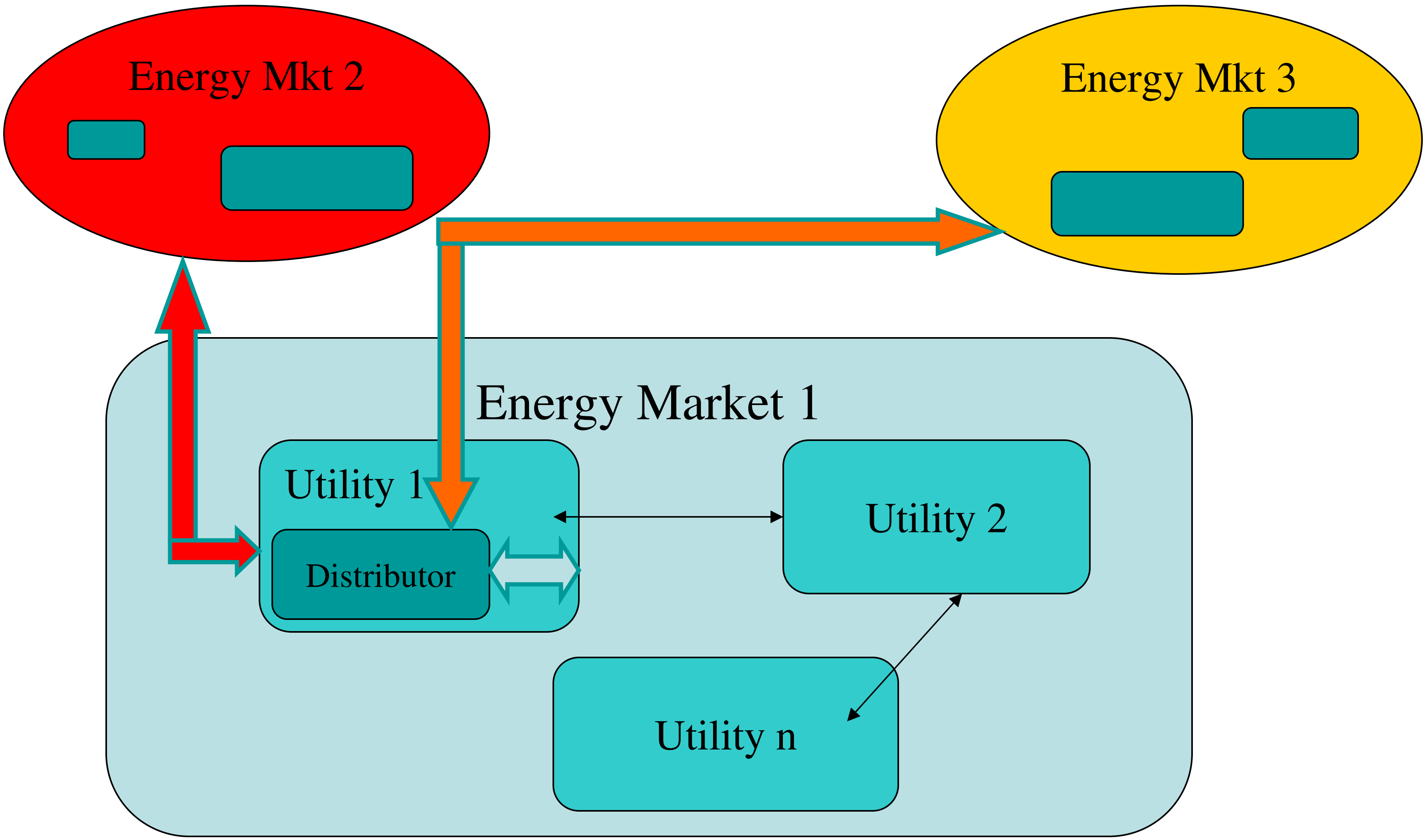
# DYMONDS-RELATED WORK IN EESG

- Each subject of posters is an example of either
  - Designing models and model-based intelligence (sensing, control, decision making methods) to be embedded at the specific industry layers (demand, aggregate demand, generation, transmission distribution, etc), or
  - Designing models and model-based intelligence for the type of information to be exchanged interactively in order to approach system-wide performance

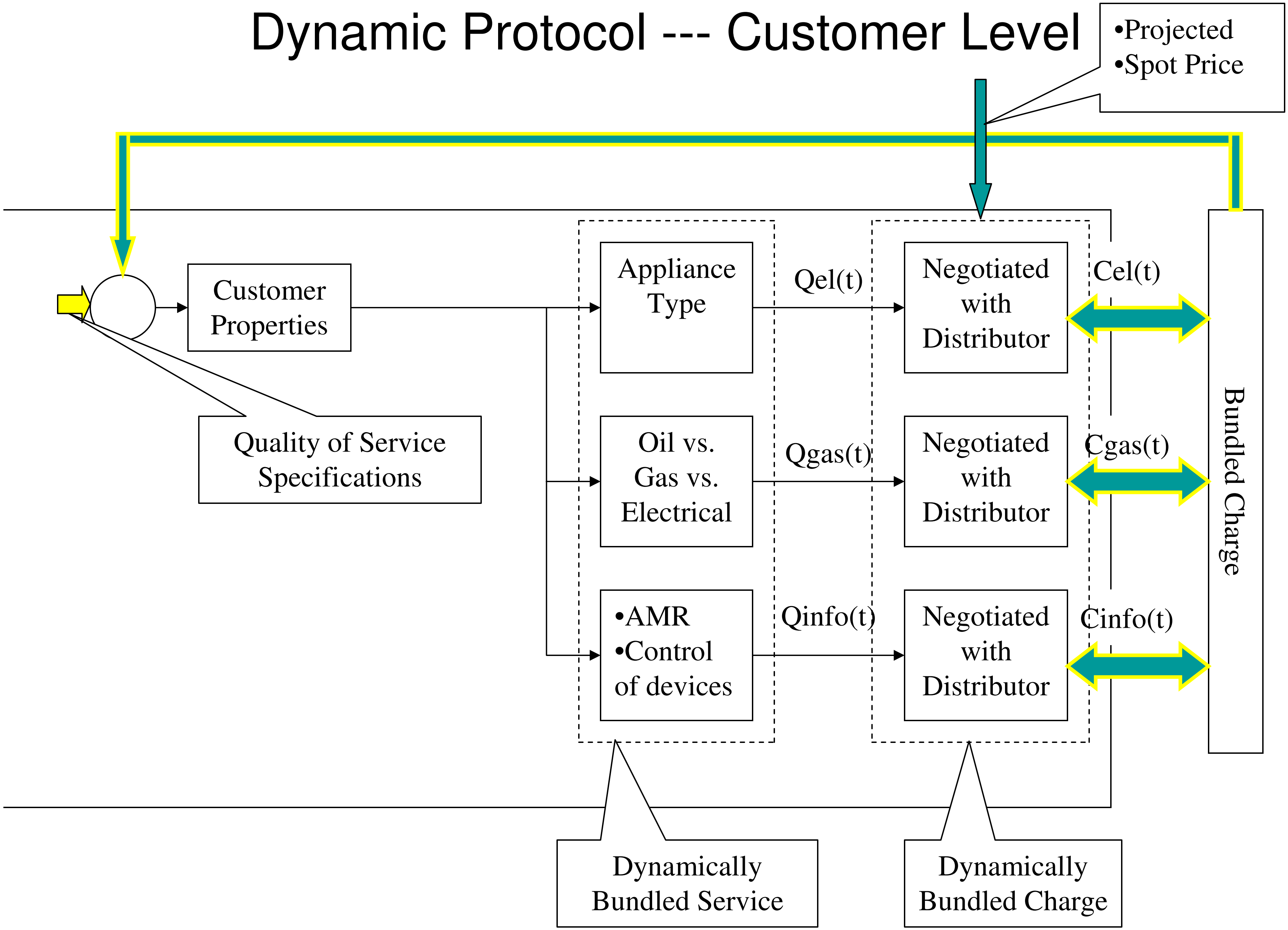
# Dynamic Protocol --- Utility Level



# Dynamic Protocol --- Energy Market Level



# Dynamic Protocol --- Customer Level



# Next Steps: Consider Joining CMU's DYMONDS Consortium

- Further develop together the DYMONDS framework and much of the new sensor/control-based modeling and decision making for embedding intelligence into different industry layers and across industry layers.

- Build a close working mode with the industry and government to further test implications of the concepts using real data. We are in the process of forming DYMONDS consortium—a place to work together, share pre-IP ideas and work toward transforming the industry together.