# An Architecture to Enable Mega-Scale Transactive Energy Systems

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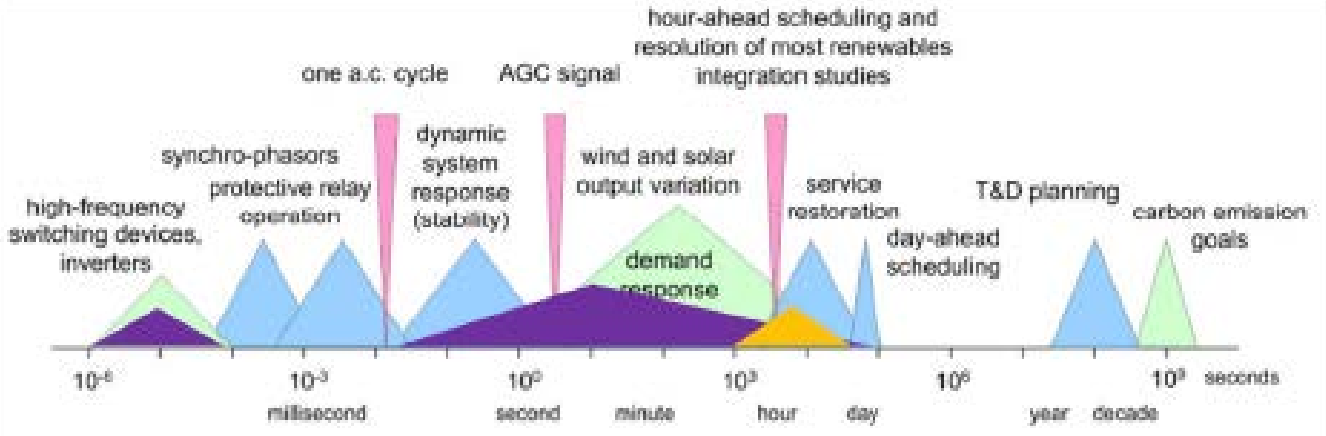
# Overview

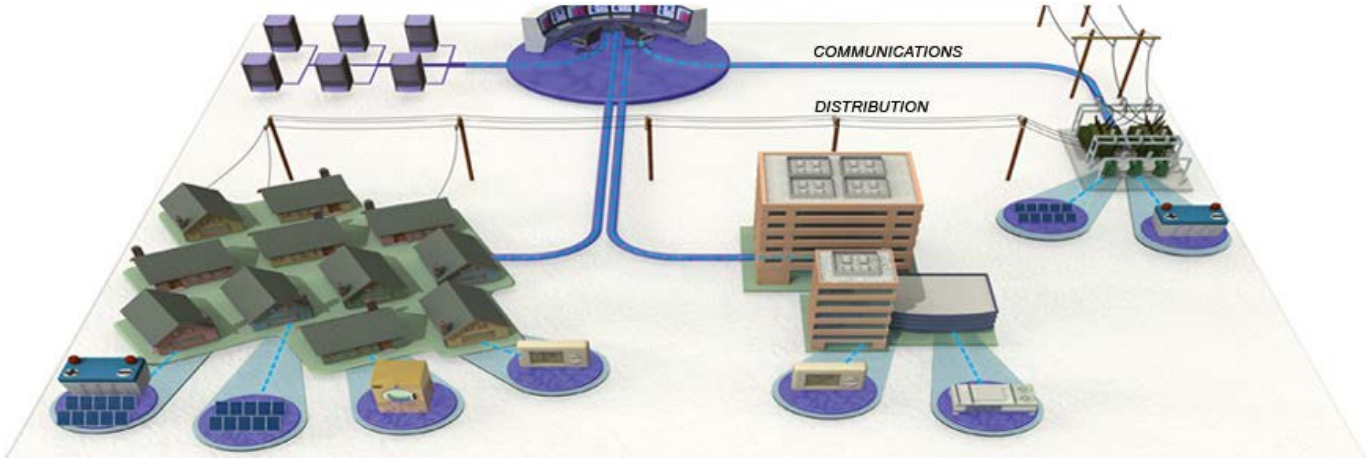
- The Challenges of Smart Grid Control
- Architectures for Transactive Energy
- When do Transactions Make Sense?
- Where Does the Intelligence Go?

- Practical Implementation Experience

# Challenges of Smart Grid Control

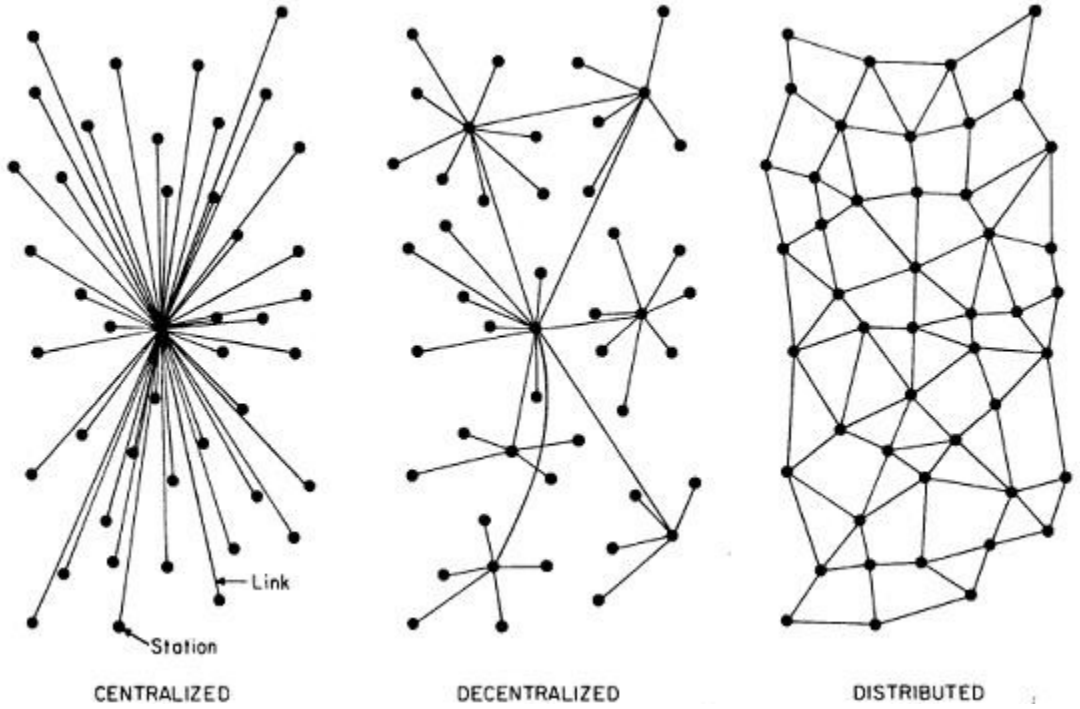
- Customer engagement
- Wide range of time scales
- Geographical distribution of assets
- Dynamic system state
- Failure is normal
- Number of nodes
- Security



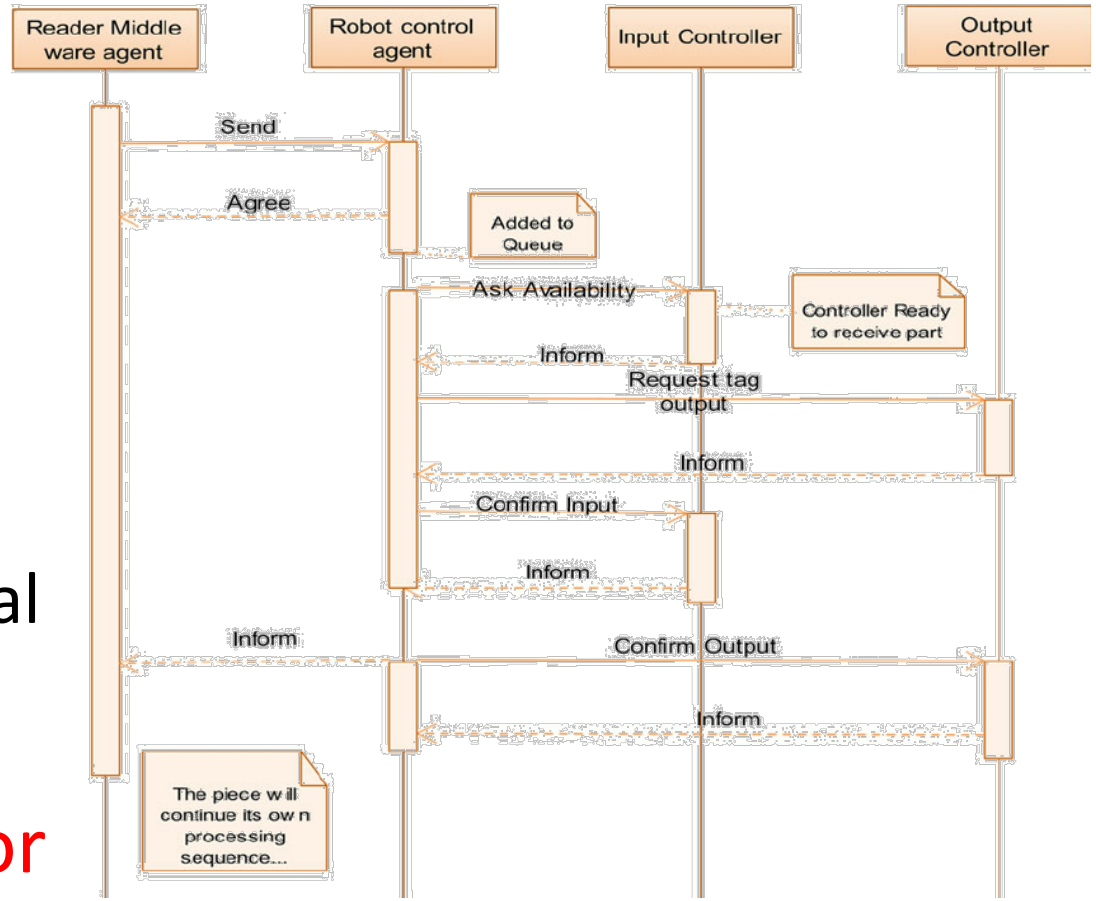
# Architectures for Transactive Energy

- TE does not imply an architecture
- Decentralized vs Distributed
- Clear Hierarchical Distinctions:
  - GWAC: Regional, Control Area, Distribution, Market Participation, Supply, Building
- Functional layout is not the same as the physical layout



# When do Transactions Make Sense?

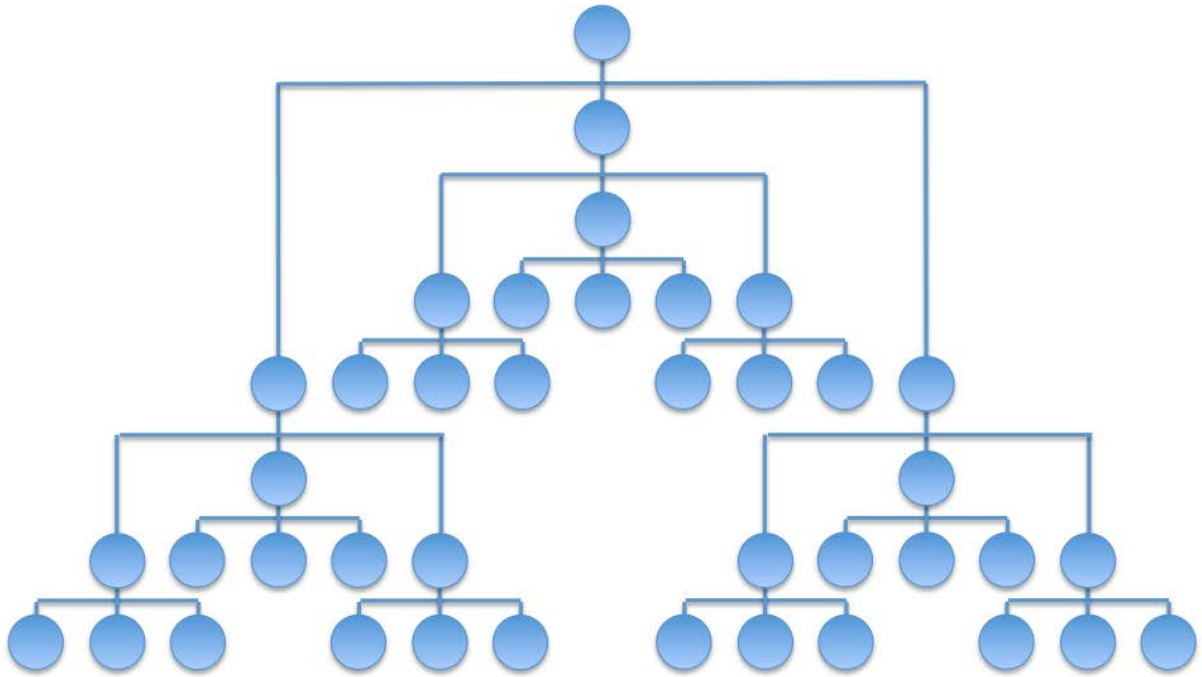
- Transactions require:
  - Sensing
  - Communication
  - Processing
  - Action
- Transactions for CPS:
  - Must respond to needs of physical system given cyber constraints
- Current definition of TE is not for short-time scale tasks!



# Where Does the Intelligence Go?

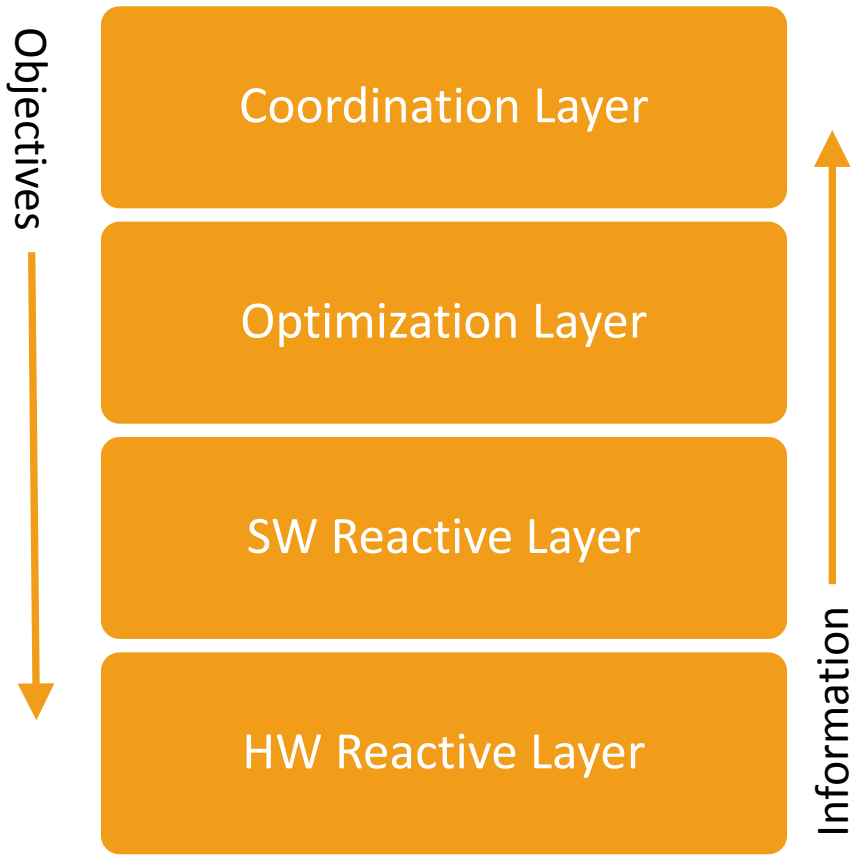
- Where it makes sense!

- Put things in the right place to optimize:
  - Performance
  - Use of domain knowledge
  - Time to respond
  - Bandwidth consumed
  - Processing requirements
  - Privacy / Data security

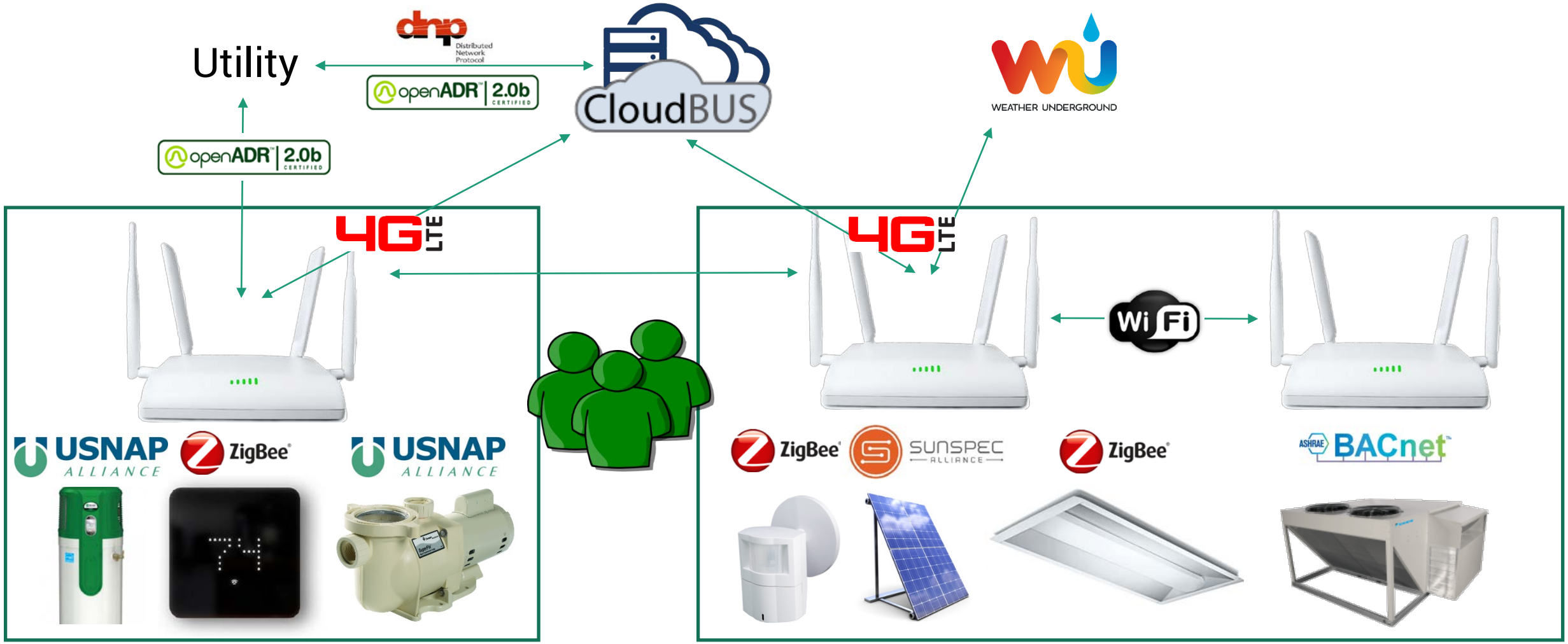


# Practical Experience

- Intwine and CWRU have been involved in many TE projects:
  - NASA Deep-Space Hab, NREL HEMS, CA Neighborhood PV controller, SMBC Automation, Campus Building Automation
- Key Lessons
  - Security, security, security
  - Connectivity is key – High availability
  - Multi-Protocol edge computing platform
  - Interoperability is difficult – follow existing standards
- Primary functional decomposition based on time-to-respond

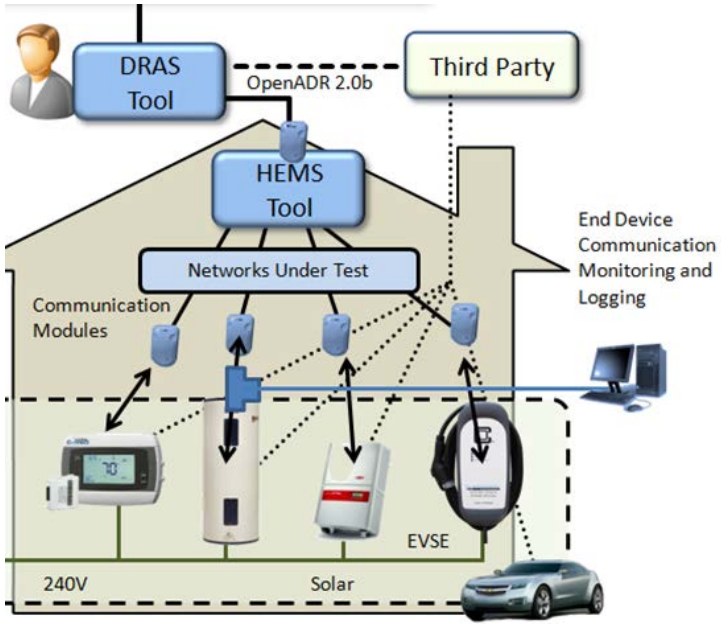


# Practical Experience



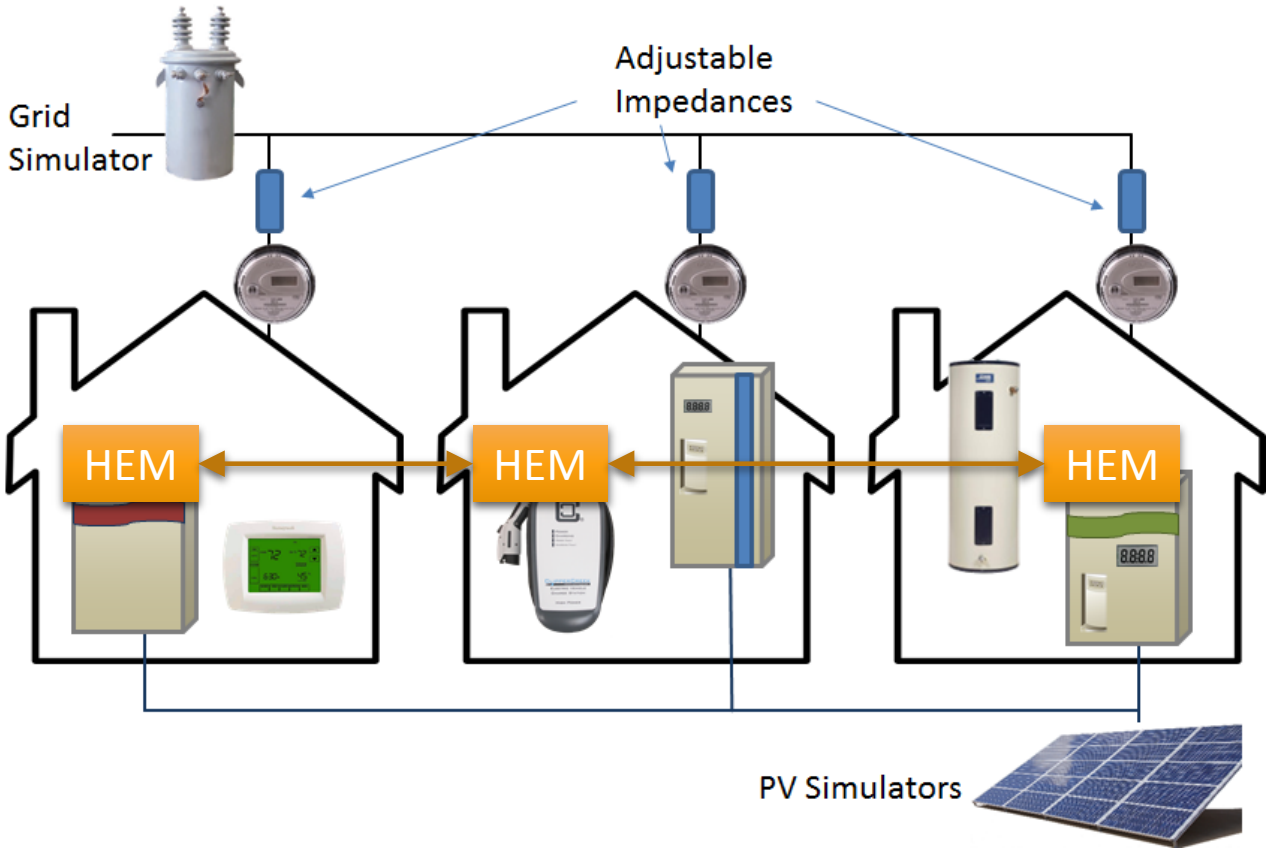
# HEMS for National Labs

- HEMS = Home Energy Management System
- Grant from DOE in coordination with EPRI
- Used ICG to coordinate loads in a home in response to OpenADR signals constrained by homeowner's preferences
- Developed CTA-2045 modules with open APIs
- Used VOLTTRON multi-agent framework

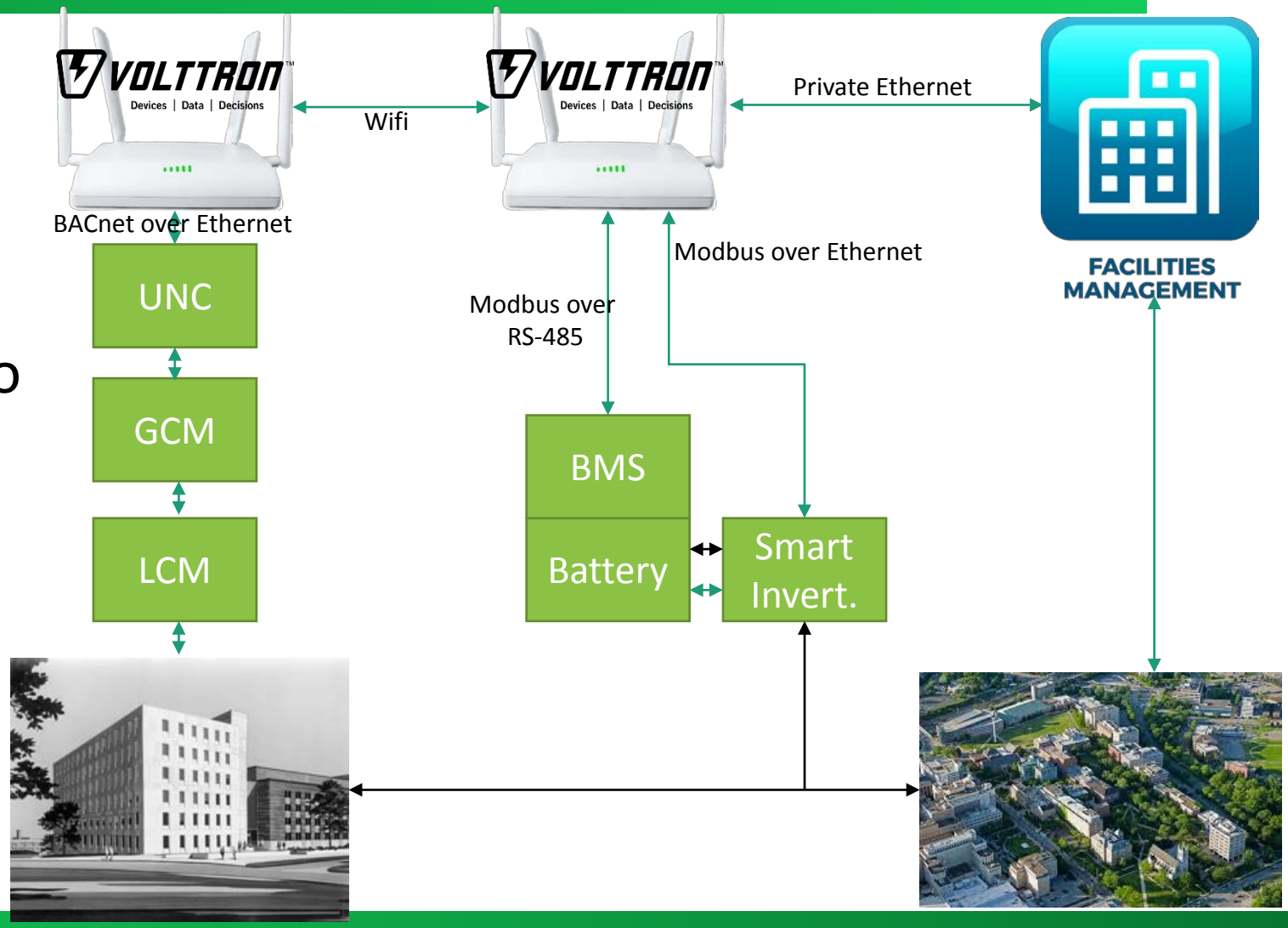
# Coordinated Control for Increased PV

- Grant from California Energy Commission with EPRI, PG&E, SCE, SMUD, UL & device manufacturers
- Objective is to use HEMS for scalable solution to mitigate impact of Solar PV on distribution system
- ICGs coordinate loads and PV within home and other ICGs in the neighborhood to minimize voltage droop at transformer



# Olin Building @ CWRU

- DoE/PNNL Demonstration Project
- Objective is to use the storage and load control to flatten load observed by campus
  - 40kW variation due to labs/HVAC



# Takeaways for Device Manufacturers

- Security
  - Encryption, Authentication, Updatable Firmware
  - Can’t be treated as an after thought
- Interoperability via Standards
  - Have local APIs
  - Direct-to-Cloud is NOT interoperable
- Use your expertise for on-board control (HW Reactive)
- Provide mechanism to enable setpoints to be changed (SW Reactive)