A Conceptual Framework of a Hierarchically Networked Agent-based Microgrid Architecture

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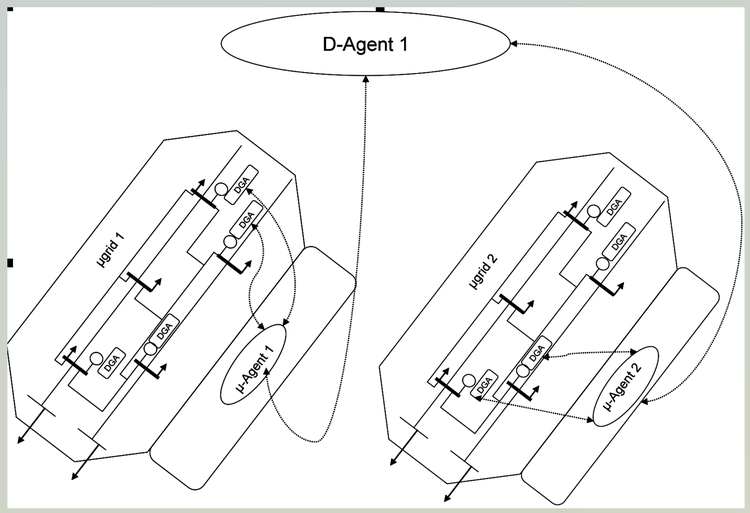
Electric power microgrids

- An emerging frontier under the Smart Grid Initiative
- **Microgrid**: a self contained subset with indigenous generation, distribution system assets, protection and control capabilities and loads that may be operated in either grid-connected mode or isolated mode
- **Advantages**: higher reliability, ancillary services, on-demand power quality, avenue for integration of renewables, energy storage, etc.
- Intrinsically distributive in nature; opportunity for distributed/coordinated control – Agent technology

Hierarchical agents-based microgrid architecture

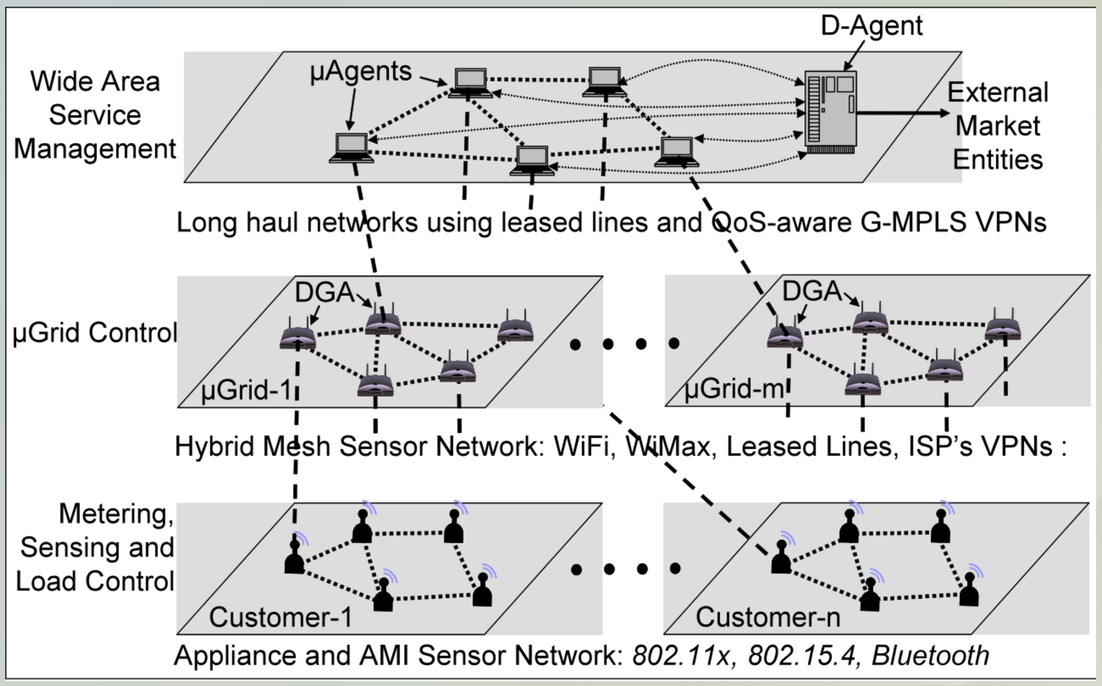
- *Customer*: an electrical power client with controllable loads and deemed the lowest common element in a *minimal microgrid*. *Minimal microgrid*: the lowest common self-sustaining subset of the electrical grid capable of communication with DISCOs and constituents through *agents*.
- *Agent*: an intelligent software and/or hardware entity capable of proactively interacting with other agents to attain a certain global objective.
- Types of agents:
  - *DG-Agent*: associated with customers and capable of independent control based on demand and economics. Performs function of *sensory mote* and communicates with other DG-Agents. Some may provide communication gateways to agents at next higher level, the *minimal microgrid*
  - *µ-Agents: associated with minimal microgrid and capable of cooperative control of customers. In a hierarchical architecture, µ-Agents can morph and transform responsibilities to a unique µ-Agent, when several minimal microgrids combine to form a new minimal microgrid to meet certain demand and economic functions.]. Some µ-Agents may provide gateways to communicate with the next level of agents, the D-Agent.*
  - *D-Agent: highest level in hierarchical agents-based microgrid and is in communication with the µ-Agents as well as other market entities that facilitate the economic sustainability of microgrids within a DISCO. There may be several D-Agents corresponding to multiple DISCOs within a subset of electric grid that may participate in a market scenario under the grid connected or collectively isolated mode.*



Microgrid Architecture

- Architecture deals with optimum placement and operation of assets
- Also dictates operation at point of common coupling (PCC), ability to seamlessly switch between modes, and services portfolio
- May be based on ownership, applications, and types of loads served
- May possess centralized or decentralized supervisory controls
- IEEE 1547.4 being developed to address architectural topics of microgrids
- Important examples: CERTS, NEDO, microgrids in Canada, and Europe

Sensor network for hierarchical agents-based microgrid



Customer premise wireless network

- Used for autonomous communication among emerging AMI
- Each node is a sensor or appliance control module
  - Load sensor, AMI based sensor, appliance control actuator, etc.
- Wireless nodes may form ad hoc mesh sensor network for information exchange
- Candidate technologies include: 802.11n ad hoc mode, 802.15.4, and Bluetooth
- Design requirements:
  - Short range in-building operation
  - Self-healing via topological reconfigurations

Microgrid control network

- Hybrid wireless and wired network
- Candidate technologies: 802.11n (WiFi), 802.16 (WiMax) may link DGAs
- Dedicated leased lines and ISP, VPN over cable, DSL may be used in forming mesh network
- Design requirements:
  - Support of multi-point to multi-point data
  - Fault tolerance for reliability
  - Seamless transfer between wired and wireless parts

Wide area service management

- Unlikely to be ad hoc
- Expected to be completely managed through D-Agent
- Networking done primarily using traditional long-haul links, packet based VPNs provided by ISP
- Other options: Emerging QoS aware VPNs such as G-MPLS over optical and WDM backbones
- Communication security envisioned at application layer
- Existing Secure Socket Layer (SSL) abstractions may serve purpose of secured end-to-end communication

Future work

- Expanded architecture for energy delivery and communication layers
- Include reliability, economics, interoperability, and security considerations
- Include adaptive controls and protection strategies

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