Duke Energy

Controlling the Smart Grid

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Control Systems

Federated control is analogous to the command/control structure of the military

- Generals are responsible for the war but too far from it to direct battlefield level tactics
- Intermediate leaders (Colonels, Major, Captains, Lieutenants) are responsible for executing the war on the battlefield
- Privates are responsible for firing the weapons
- Command and control is executed through the command and control network
  - Control down
  - Report up

Militaries enable units to operate autonomously but cooperatively and collectively

Federated control has evolved as the leading model for distributed control systems

- Data is reported upward
- Control is executed at the lowest level possible
- Control within a layer is autonomous
- Only data used for control is reported
- Historical detail is stored within the layer where control is executed

Controlling the Smart Grid

Smart Grid Analysis

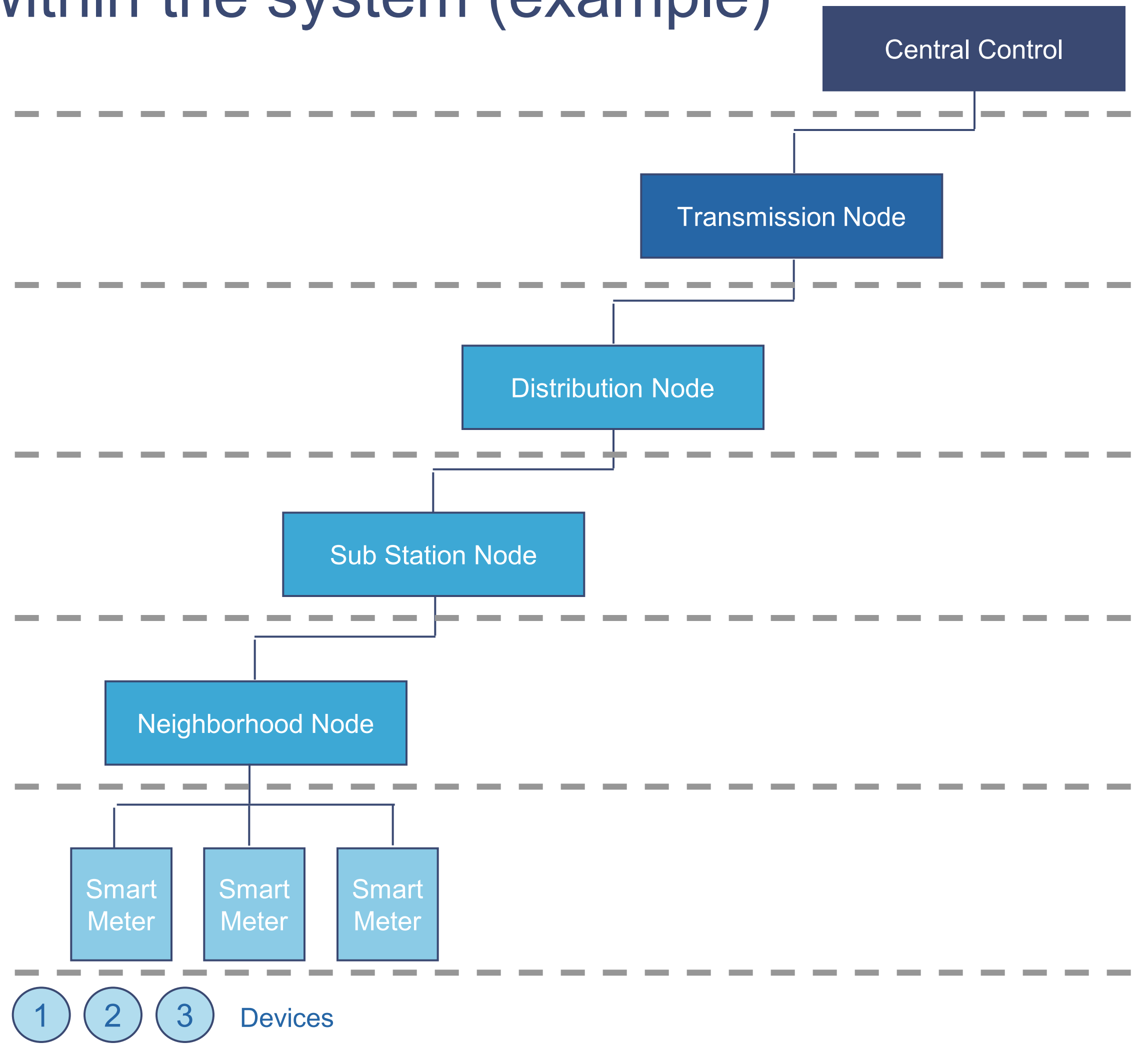
First we define the desired capabilities of the smart grid (example)

- Manage consumption at the house for optimal performance
- Manage load at the neighborhood level
- Resolve demand by shifting availability within transmission & distribution
- Trigger on-demand power generation as last resort when transmission & distribution system cannot meet demand

Next we define business scenarios which the control model must incorporate (example)

1. Reduce consumption: execute home behaviors to reduce consumption by category to meet neighborhood level load target. When all available behaviors are exhausted generate request for more power.
2. Shift generation: shift consumption from power lines to power storage within home such as electric car or other battery storage.
3. Balance consumption: notify neighborhood nodes to execute home behaviors by category to reduce unbalanced consumption
4. Generation outage: notify neighborhood nodes to execute all applicable home behaviors to reduce consumption
5. Local outage: send message when anticipate load of sub-level drops by greater than x%

We apply a federated control model and identify control points within the system (example)



Make decisions on generation capacity

Make decisions on transmission destination

Make decisions on sub-stations delivery

Make decisions on neighborhood delivery

Make decisions on home delivery based on defined target

Make decisions on individual device consumption

Control individual device consumption

Finally we define the data elements required to deliver the capabilities for each control point (example)

Central Control

- Load
- Available on demand generation
- Demand trajectory
- Conservation criteria by date & time
- Date & time

Neighborhood Node

- Load
- Load per house
- Load target by date & time
- Date & time

Transmission Node

- Load
- Load per distribution node
- Power availability in generation

Smart Meter

- Load
- Load per device category
- Inside & Outside Temperature
- Inside & Outside Humidity
- History (house, per device)
- Category targets by date & time
- Date & time

Distribution Node

- Load
- Load per sub-station
- Load target by date & time (roll-up)
- Date & time

1 2 3

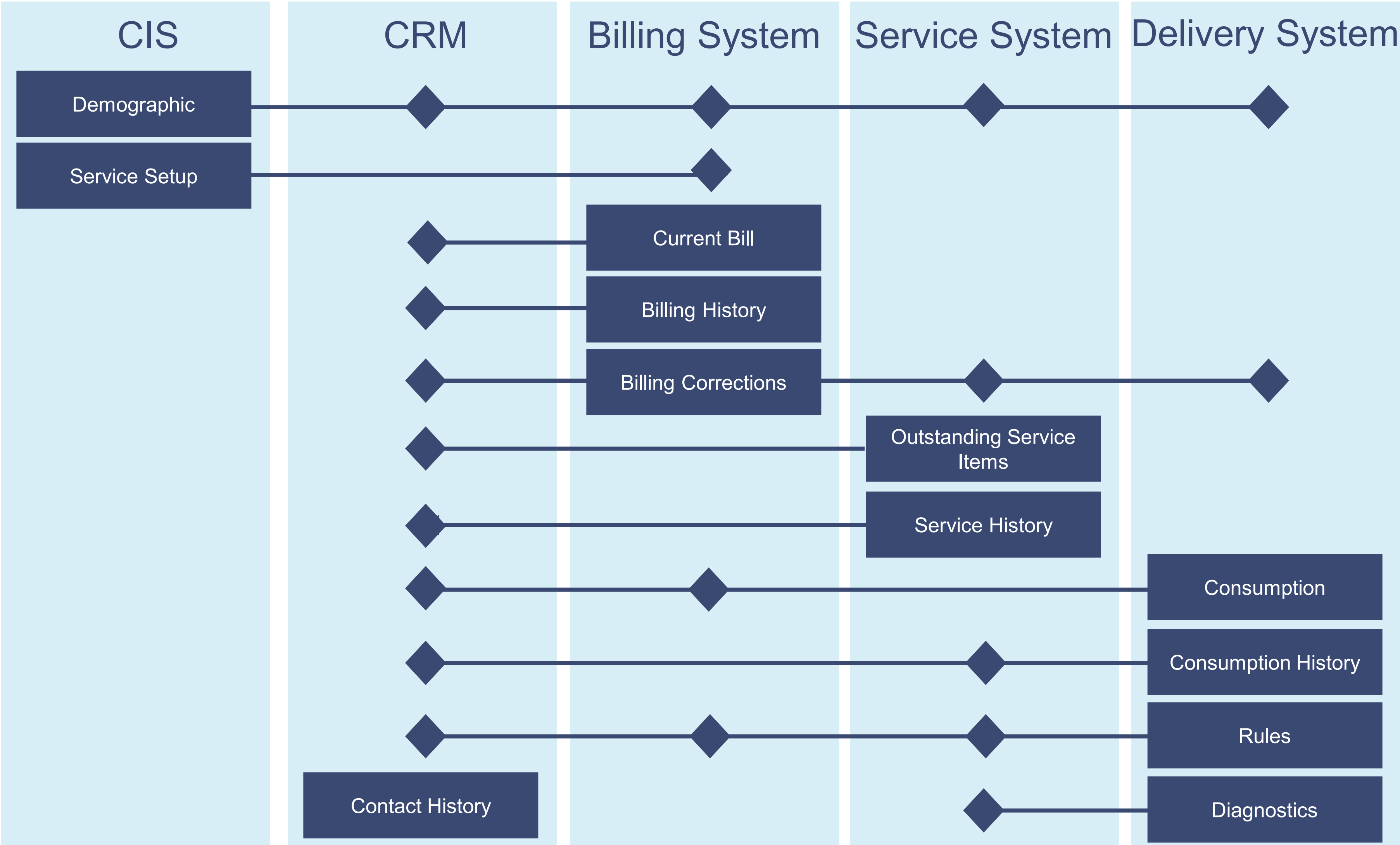
Devices

- Load per device
- Device category

Sub Station Node

- Load
- Load per neighborhood node
- Load target by date & time (roll-up)
- Date & time

Data Model - Customer



System of Record
Data Consumer

Controlling the Smart Grid

Lessons Learned

Lessons learned in other industries

1. Focus on architecture, not technology, as the technology will change and should be prescribed by the guiding principles, standards, and requirements reflected in the architecture
2. Vendors follow industry leaders, they don't lead them. Get out in front of the vendors with a vision and an architecture. This puts Duke into the proactive position managing the role of technology in smart grids
3. Focus on open systems which leverage existing, proven technologies. Trying to move into a new paradigm while proving new technologies stacks all the cards against success

Lessons learned in other industries

4. Determine the appropriate level of upgradeability within the control system required to meet the requirements of today and tomorrow at the right price
5. Use the vision to guide the requirements definition process; just because it can be done doesn’t mean it should be done

Controlling the Smart Grid

Futureproofing

Designing for the future

- Tremendous benefit of computer based systems is the ability to add functionality without upgrading hardware (technology footprint)
- Requires a certain amount of “headroom” which results in increased costs
- The best benefit/cost balance is obtained by focusing on requirements in complimentary technology footprint groups instead of functionality groups
- Technology footprint = processor, memory, persistent storage, network bandwidth

Method for defining technology footprint and cost

1. Prioritize requirements into categories (must have, want to have, nice to have, icing on the cake)
2. Prioritize requirements within each category
3. Define technology footprint for each must have requirement
4. Calculate cumulative baseline technology for must have requirements
5. Define growth increments and cost for each footprint component (next step up in processor, memory, etc.)
6. Rate footprint drivers for remaining requirements on a scale of 1 (low impact), 3 (medium impact), or 5 (high impact) (ex: analysis may be a 5 for processor, 3 for memory, 1 for storage and 0 for network)
7. Group remaining requirements by highest impact (nothing can be a high impact in every area since there are speed bottlenecks moving from fast processors towar slow networks)
8. Evaluate each group to determine incremental footprint growth and cost to implement
9. Prioritize functionality of groups vs. costs

Summary

- Distributed systems benefit from a federated control model
- A federated control model will deliver the required capabilities
- Other industries have resolved many of the issues being faced in the Smart Grid
- “Futureproof” today’s investments by investing in “headroom”

Smart Grid

Engaging your customers in the war for energy independence

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