Delivering Your Future
How to Build a Smart Grid Communications Network
from Concept to Reality

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Director
Telecommunications Services
CenterPoint Energy (CNP)

- Headquartered in Houston, TX
- Serving 5.5 million electric & gas customers
- $22.8 billion in assets
- $7.5 billion in revenue
- More than 8,700 employees
- Over 135 years of service to our communities
- Electric transmission and distribution
  - Over 2.2 million customers in Houston area
  - 17.3 GW peak demand
  - 80 GW hours delivered annually
  - 232 substations
  - 3,742 miles of transmission
  - 48,733 miles of distribution
Components of our Advanced Metering System (AMS)

Combined with back office computer systems and integration, our AMS provides:

- Daily register reads
- Daily 15 minute interval reads
- Remote connect / disconnect / on-demand reads
- Consumer access to their data via consumer portal
Smart Grid Communications Deployment

Purpose:
- Architect and build an end-to-end communications network to support the Advanced Metering System and Intelligent Grid.

Timeframe: 42 months

Objectives / Scope:
- Provide communications coverage to CNP’s entire 5,000 sq. mile electric service area
- Deploy approximately 5,500 cell relays (meter data collectors) and 140 WiMAX tower sites that communicate with 2,300,000 meters.
- Provide redundant two-way communications to end points, i.e., meters, grid devices.
- Utilize a dual communication (active-active) path architecture that is scalable to meet Smart Grid communication needs
- Provide required data throughput capacity
- Perform reliably, i.e., storm conditions
- Comply with cyber security standards
Project Organization

CenterPoint Energy established a Project Management Office

Provides project management expertise and governance to deployment of Smart Grid systems.

Specific work teams were established and stayed in close coordination throughout the project due to integrated nature of system.
Project Organization:
Communications Program Work Stream

Team Organizational Strategy: Based on “Design, Build, Operate, and Maintain” Model

Program Work Streams
- Metering
- Communications
- AMS Systems
- Integrated Services
- Retail Market
- IG Systems
- IG Systems Development
- IG Infrastructure

Functions Integrated across all Teams
- Lead
- Plan
- Design
- Build / Test
- Accept / Operate

Communications Infrastructure Teams
- End Device (Cell Relay / Grid Device)
- WiMAX Remote Radios
- WiMAX Aggregation Tower Site
- Fiber / Microwave Backhaul
- Project Support
# Communications Technology Direction

## Communication Components Considered

<table>
<thead>
<tr>
<th>Technology</th>
<th>Benefits</th>
<th>Challenges</th>
</tr>
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<tbody>
<tr>
<td><strong>Cellular</strong></td>
<td>• Most Geographic Coverage (typically)&lt;br&gt;• No additional infrastructure for backhaul&lt;br&gt;• Broadband coverage&lt;br&gt;• Rapid deployment</td>
<td>• High variable expense cost for data usage&lt;br&gt;• Reliance on cellular infrastructure&lt;br&gt;• Rapidly changing environment and technologies</td>
</tr>
<tr>
<td><strong>WiMAX</strong></td>
<td>• Engineer according to requirements&lt;br&gt;• Build for the future (higher bandwidth)&lt;br&gt;• Potential for synergies within field network&lt;br&gt;• Rapid deployment (once in place)</td>
<td>• Infrastructure cost&lt;br&gt;• Achieving coverage, i.e., geographies, meter density in certain areas&lt;br&gt;• Permitting</td>
</tr>
<tr>
<td><strong>Hardline</strong></td>
<td>• Proven technology&lt;br&gt;• Able to configure/size accordingly</td>
<td>• High fixed expense cost&lt;br&gt;• Difficult to manage individual circuits&lt;br&gt;• Reliance on carrier infrastructure&lt;br&gt;• Long Installation timeframes</td>
</tr>
<tr>
<td><strong>BPL/PLC</strong></td>
<td>• Utilize existing infrastructure&lt;br&gt;• The “Broadband” promise&lt;br&gt;• Large “theoretical” geographic coverage</td>
<td>• Frequency interference&lt;br&gt;• High price point&lt;br&gt;• Limited success in field trials</td>
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</table>

Most deployments rely on multiple technologies to achieve a full coverage cost effective solution.
Communications Technology Direction

Result: Hybrid Solution

- Private network
- Build to company specifications
- Rapid deployment
- Control
- Broadband speeds
- Geographic coverage

**Primary Communication Path**
- 2 Communication paths (active-active)
- 2 independent communication architectures
- High availability
- Scalable
- Automatic fail-over
- Ease of maintenance (manual fail-over)

**Secondary Communication Path**

**Hybrid (Private & Commercial)**
Communications Technology
Overview of Dual-Path Smart Grid Communications Network

- Primary communication: WiMAX tower based Access Points communicate with Cell Relays/ meter data collectors
- Secondary Communications (Redundancy): Cell Relays and IG devices can fail over to secondary network in the event of loss of WiMAX connectivity or WiMAX maintenance.

- Depending on location and criticality, IG device may have different secondary communication solution.

Meters form a mesh network and communicate with Cell Relays (collectors) at a designed ratio of approximately 400:1.
Deployment Considerations...

Close coordination with the meter deployment

Network communications in place three months ahead of meter deployment

Smart Grid PROGRAM
CenterPoint Energy Proprietary and Confidential Information
Deployment Considerations...
Address coverage for remote and low meter density areas

- The last 1% of meter coverage requirement
- Tools in the bag – communication solutions
  - RFLAN range extenders - meter collector mesh network extensions
  - 900MHz systems – provide extended coverage areas
  - WiMAX Repeaters – provide additional WiMAX coverage
- Solution and combination of solutions are selected for application based on network availability, environmental and meter density
Deployment Considerations...
Be prepared to meet aggressive time lines

Cell Relay site selection process in the absence of a permanent TOP

WiMAX antennae were placed on top of a 150’ crane to test signal strength at planned cell relay sites
Deployment Considerations...

Prototype solutions, test, complete construction standards, and validate installation procedures via testing/training

1. Prototype: test fit, constructability, parts list.
3. Cell Relay Site Assemblies
4. Installed Cell Relay Site
Deployment Considerations...
Manage suppliers, field coordination, construction and performance acceptance/testing

Major equipment and long lead items such as cell relays, radios, network electronics, towers and buildings need to be specified, bid and ordered.
Deployment Considerations...

Leverage a common communications infrastructure. The IG Network is built on the AMS Communications Infrastructure.

<table>
<thead>
<tr>
<th></th>
<th>AMS</th>
<th>IG</th>
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<tbody>
<tr>
<td>Fiber backhaul</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Microwave backhaul</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>WiMAX (primary)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>GSM (back-up)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Satellite (back-up)</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>
Deployment & Operational Considerations...

Analyze, select, implement network management tools early since they are used for both construction and operations.
Deployment & Operational Considerations...
Engage Network Operations at the project onset

- Establish an operational strategy that parallels deployment; operations input in the network design is critical to an effective operation.
- Establish Network Control Center that enables complete end-to-end network visualization and management
- Fully leverage data analytics as part of the monitoring and management; it is a valuable tool in the alerting of potential network issues
- Establish a solid acceptance process for the handoff to production
Deployment & Operational Considerations...

Implement dashboards and data analytics into day-to-day network operations

CNP has moved to a greater utilization of and reliance on automation technology and data analytics; a premium has been placed on network uptime, resiliency and reliability.
Keys to our Communications Network Success

- Strong governance processes - including risk management, change management, financial management, project planning/scheduling, metrics/benefits reporting, technical architecture, etc.
- Integration and close alignment of project team, vendors and support functions
- Sound materials management was key to maintaining adequate inventories
- Efficient design & installation standards / procedures
- Solid deployment strategy kept teams aligned
- Effective deployment exception management strategy
- Early implementation of operational strategy
- Effective change management and business process change strategy
Delivering Your Future
The Future of Managing the Smart Grid Communications Network
Utilizing Data Analytics

William Bell
Director Analytics & Data Services
The Challenge: Big Data is a Reality
Business Challenges
“all fueled by data”

- **Innovation for Growth**
  - Intelligent Meters
  - Smart Grid

- **Business Transformation**
  - Information Technology
  - Operations Technology

- **Consumer Evolution**
  - Access
  - Expectation
  - Preferences
Basis for Data Innovation & Data Management

Complex Data Management

- Technologies, processes, resources and interoperability to support Dark Data

Dark Data

- Stored Objects
- Structured & Unstructured
- No Residual meaning or Value
Transformation From Data Driven to Intelligence Driven

Strategic shifts require changes in constructs, methods, and speed in Data innovation

- Operation → Innovation
- Independent → Co-dependent
- Internal Centricity → External Centricity
- Customer Driven → Consumer Driven
- Data Driven → Intelligence Driven
- Architectures → Architecture
- Divergence → Convergence
- IT/OT → CT (CenterPoint Energy Technology)

- Information Centricity
- Data Compression
- Data Derivatives
- Complex Events
- Complex Analytics
- Dark Data
- Complex Data Management

CenterPoint Energy
New Business Requirements

Complex Data Management

>500,800,000 interacting operating systems

Millions of events recognized, analyzed and stored per day, Storage requirements up 200% per year

Data-in-memory, Complex Event Processing, Complex Analytics, decisions in real-time become the norm

Dark Data

From 88,000 meter reads a day to 220,800,000 a day

From 0 to as many as 23,000,000 Home Area Network Energy Devices

Security Costs doubled in last two years, support increased by 25%
Analytics & Data Services
Delivering Information You Can Trust
Enabling Efficient Data Driven Decision Making
How to Define, Validate and Deliver Analytics?

**Define**
- Phase One: Determine Level of Automation
- Determine Type of Analytics Required
- Business Process & Analytical Control Points
- Business Outcome Defined
- Start: Operational Need

**Validate**
- Phase Two: Confirm Business Outcome is met
- Start: Define Hypothesis
- Prototype &/or Test Hypothesis
- Determine Data Set Required
- Determine Conditions, Criteria and Scenarios

**Deliver**
- Phase Three: Learn, Improve & Optimize Analytics Process
- Start: Define Business Rules, Requirements & Technical Design
- Execute & Validate Analytics
- Build, Test, Implement & Deploy Industrial Solution
- Define Controls & Error Management
Analytics Initiatives

- Diversion Detection and Dispositioning (in pilot & PRD)
- Transformer Load Management, Connectivity and Predictive Loading (in Pilot)
- Financial and Regulatory Month End Revenue Estimation (in PRD)
- Outage Analysis and Correlations and moved daily reporting from OAS (in PRD)
- Provide real-time situational awareness and correlations for Comms, Outage & Distribution Dispatching
Develop Data Foundation – Improve Data Delivery – Learn from Results
Diversion Detection and Dispositioning
Transformer Load Management, Connectivity & Predictive Loading
Single Transformer Report with Actual & Predicted Load
Financial & Regulatory Month End Revenue Estimation/Calculation

Maximizing Smart Meter Technology
- Daily register readings from each meter
- 96 interval readings from each meter
- Moved from 90+% estimation to .01% estimation

Data-Driven Decision Making
- No longer dependent on monthly register reads
- Weather normalization can be more accurate, supported by timely and comprehensive interval data rather than traditional sampling methods
- Smart meter interval data will be required in future rate cases for cost allocation and weather normalization

Predictive Analytics Benefits Financial Forecasts
- Enhanced understanding by rate class of recent trends in consumption
- Enhanced ability to anticipate future loads
- Our New Automated calculation has replaced arduous manual efforts with more accurate results

This solution went into production effective July 1, 2012.
Smart Meter Infrastructure

Generating Station

Transmission and Substation System

High Voltage Lines

Step-down Substation

Distribution System

Commercial Customer

Internet Web Services

Fiber Link

Wireless Tower

Cell Relay

RF Wireless Repeater

Local Home Area Network

Residential Consumer

Smart Meter
Near-Real-Time View of AMS Comms Systems Status in Telecoms Control Room
Traditional View of the Storm with Lightning
Meter Outage Events with No Matching Restoration & Length of Outage
Meter Outage Events rolled up to Outage Cases
Real-Time Situational Awareness Dashboard in Use Today

<table>
<thead>
<tr>
<th>Circuits</th>
<th>Outage Case Summary</th>
<th>Reliability Performance ( Forced &amp; Outside)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>0</td>
<td>57</td>
</tr>
<tr>
<td>EAV</td>
<td>0</td>
<td>0</td>
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<tr>
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<td>0</td>
</tr>
<tr>
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<tr>
<td>SPB</td>
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</tr>
</tbody>
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| SDIYTD: 15.59 (Goal: 17.55) | 0.00 Under | 0.08 Under | 0.09 Under | 0.10 Under | 0.11 Under | 0.12 Under | 0.13 Under | 0.14 Under | 0.15 Under | 0.16 Under | 0.17 Under | 0.18 Under | 0.19 Under | 0.20 Under | 0.21 Under | 0.22 Under | 0.23 Under | 0.24 Under | 0.25 Under | 0.26 Under | 0.27 Under | 0.28 Under | 0.29 Under | 0.30 Under | 0.31 Under | 0.32 Under | 0.33 Under | 0.34 Under | 0.35 Under | 0.36 Under | 0.37 Under | 0.38 Under | 0.39 Under | 0.40 Under | 0.41 Under | 0.42 Under | 0.43 Under | 0.44 Under | 0.45 Under | 0.46 Under | 0.47 Under | 0.48 Under | 0.49 Under | 0.50 Under | 0.51 Under | 0.52 Under | 0.53 Under | 0.54 Under | 0.55 Under | 0.56 Under | 0.57 Under | 0.58 Under | 0.59 Under | 0.60 Under | 0.61 Under | 0.62 Under | 0.63 Under | 0.64 Under | 0.65 Under | 0.66 Under | 0.67 Under | 0.68 Under | 0.69 Under | 0.70 Under | 0.71 Under | 0.72 Under | 0.73 Under | 0.74 Under | 0.75 Under | 0.76 Under | 0.77 Under | 0.78 Under | 0.79 Under | 0.80 Under | 0.81 Under | 0.82 Under | 0.83 Under | 0.84 Under | 0.85 Under | 0.86 Under | 0.87 Under | 0.88 Under | 0.89 Under | 0.90 Under | 0.91 Under | 0.92 Under | 0.93 Under | 0.94 Under | 0.95 Under | 0.96 Under | 0.97 Under | 0.98 Under | 0.99 Under | 1.00 Under |
Real-Time Comms Dashboard in Use Today (Supporting High Data Rate)
Real-Time Comms Dashboard in Use Today in Telecom Control Center
New Video Wall – Situational Awareness Coming Soon
Benefits of Advanced Analytics

What the analytics teams do is take mountains of data and provide business value by extracting meaningful information and generating actionable tasks that:

- Protect the grid
- Improve communications performance
- Reduce the back office cost of revenue collection with improved revenue estimations
- Meeting regulatory reporting requirements more efficiently and effectively
- Protect the company and the market from diversion
- Improve the quality of field work by issuing orders for the maintenance of equipment instead of rolling after outages
- Developing a way for CNP to provide aggregated Demand Response as a resource to ERCOT and the Texas deregulated market in the event generation capacity does not meet projected load
- and many others
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APPENDIX: Communication Technology Direction
Result: Hybrid Solution

Hybrid Backhaul Solution

- AMS Backhaul (Radio/Wireless) PRIMARY Communication Path
  - This portion of the communication network connects the “take-out” points to/from the cell relay devices in the field
  - Bandwidth – 128 Kbps (minimum requirement)
  - Utilizes a new “purpose-built” WiMAX infrastructure (GE MDS Mercury 3650 Radio System)
    - Operates in the lower 3.65 GHz Band
    - WiMax 802.16d Standard
    - Redundant configuration
    - Ethernet Interface, 10/100BaseT, RJ-45
    - Point to Multi-Point Design, Access Point to Remotes
    - 3 Sectors per Tower

- AMS Backhaul (Cellular) SECONDARY Communications Path
  - This portion of the communication network connects the cell relays to the data center via the AT&T cellular network
  - Bandwidth is adequate

Meter Communications

- Smart meters operate in a Mesh Network
- The Cell Relay is the Master Meter of the Mesh Network
APPENDIX: Communication Technology Direction

CenterPoint Energy Dual-Path Communication: Advanced Meter System

AMS Communications Network

- HAN Devices
- Electric Meters
- Level-1 Meter
- Level-X Meter
- Pole Mount Cell Relay
- Remote Radio
- Access Point Radios
- WiMAX Network
- Cellular Data Network (GSM/GPRS)

Existing Communications Network

- IT AMS Switches
- IT AMS Firewalls
- DCE Collection MDM Processing
- Data Base

- AMS Metering
- AMS Systems
- AMS Integrated Systems
- AMS Retail Markets

Transport Network and Cellular backhaul

- Internet
- IPSec Tunnel
- Cellular Backbone
- Atlanta Fire Wall

Mockup for Smart Grid PROGRAM
CenterPoint Energy Proprietary and Confidential Information
APPENDIX: Communication Technology Direction
CenterPoint Energy Dual-Path Communication: Grid Devices
APPENDIX: Analytics on the Horizon

- AMS Performance & Device Lifecycle Management
- Support for Demand Response
  - Customer targeting
  - Event dispatch and decision support
  - Event settlements & billing
  - Program effectiveness
- System Load and Asset Utilization
- Outage & Momentary analysis
  - Better outage scope determinations, more reliable outage status
  - Connectivity model validations
  - Power quality – catch it early
- Support for TDU rate design
- Market & Settlement Information Services
- Financials
  - Unbilled energy
  - Forecasting
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