Self-Healing Smart Grids

Vamsi Paruchuri, Ph.D.,

Dept. of Computer Science
University of Central Arkansas
Conway, AR 72035
vparuchuri@uca.edu

Founding Director
Unified Gateways Inc.
Bangalore, India
vamsip@unifiedgateways.com

Overview

- Smart Grids
- Self-Healing - What is it?
- Ongoing Efforts
- Our Efforts
- Smart Grids – India
- Conclusions

What is Smart Grid

Smart Grid is simply a communications system overlay on the existing electrical grid to make the electrical grid more controllable and much more efficient in the delivery of energy. The communications systems will be connected to strategically placed sensors throughout all four segments of the electrical grid: Generation, Transmission, Distribution and Consumers

- Eric Lightner, Director, Smart Grid Task Force

Key defining Functions

- Enable Active Participation by Customers
- Accommodate All Generation and Storage Options
- Enable New Products, Services, and Markets
- Provide Power Quality for the Digital Economy
- Optimize Asset Utilization and Operate Efficiently
- Anticipate and Respond to System Disturbances
- Operate Resiliently Against Attacks and Natural Disasters

- Eric Lightner, Director, Smart Grid Task Force

Self-Healing - What is it?

Self-healability is the property that enables a system to perceive that it is not operating correctly and, without human intervention, make the necessary adjustments to restore itself to normality

- Ghosh, et. al., 2007

Self-Healing - What is it? (2)

- *Dependable systems:* Systems that are globally trustworthy with respect to their ability to always deliver its service.
- *Fault-tolerant systems:* Systems in which faults may occur but do not affect the performance of the system.
- *Resilient systems:* Systems that could reconfigure to harness disturbances.
- As oppose to these three definitions that specify the *goals but not the means, self-healability* aims at correcting or put right undesirable system situations. That is an *active approach that operationalize the definitions stated above*

Self-Healing Grid - Vision

A self-healing grid is expected to respond to threats, material failures, and other destabilizing influences by preventing or containing the spread of disturbances. This requires the following capabilities:

- Timely recognition of impending problems
- Redeployment of resources to minimize adverse impacts
- A fast and coordinated response to evolving disturbances
- Minimization of loss of service under any circumstances
- Minimization of time to reconfigure and restore service

Amin, S. & Wollenberg, B. (2005) Toward a Smart Grid, IEEE Power & Energy Magazine.

Cascading Failures: An example

Consider a power outage that cascaded across the western United States and Canada on 10 August 1996.

- Began with two relatively minor transmission-line faults in Oregon.
- Ripple effects tripped generators at McNary dam
- Caused separation of the primary West Coast transmission circuit, the Pacific Intertie, at the California-Oregon border.
- The result: blackouts in 13 states and provinces costing some US$1.5 billion in damages and lost productivity.
- Analysis suggests that shedding (dropping) some 0.4% of the total load on the grid for just 30 minutes would have prevented the cascading effects and prevented large-scale regional outages

Note that load shedding is not typically a first option for power grid operators faced with problems.

Source: Amin S, "For the Good of the Grid", IEEE Power and Energy Magazine, Nov 2008

Grid Components







Generation

Transmission

Distribution

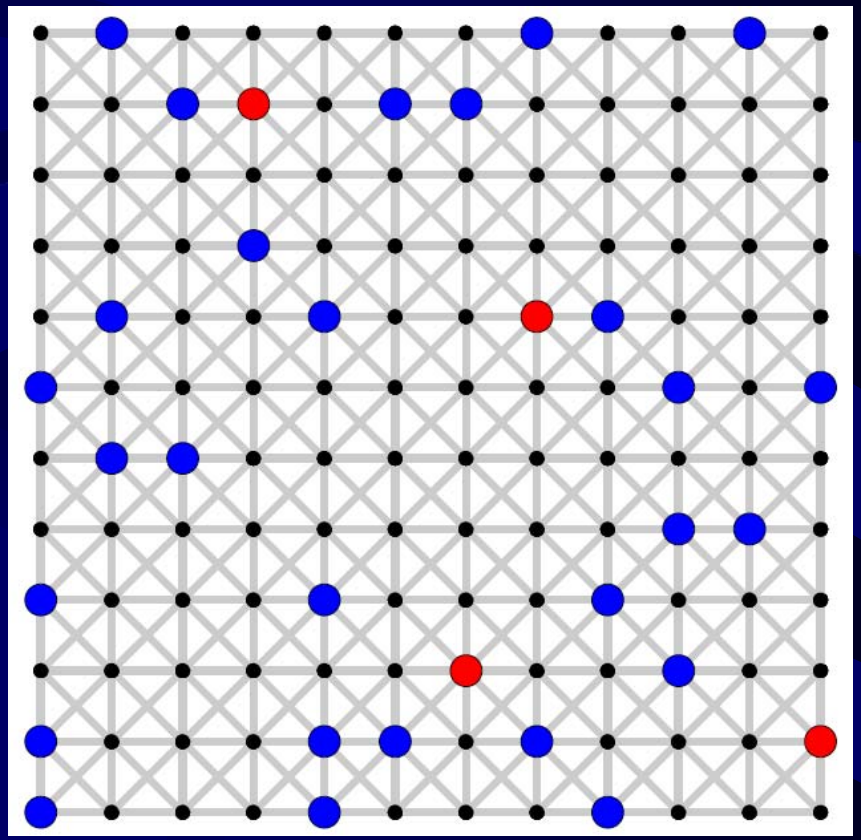
Focus areas

Transmission – Approaches

- Optimal Routing/Rerouting
- Multiple transmission lines - balanced routing
- Adaptive active islanding
- Priority of Loads (Hospitals Vs. Houses)

Graph theoretical approach

- The grid is represented as a directional weighted graph.
- The nodes of the graph are generators, storage, interconnects or demand units.
- The edges of the graph, namely the connections between the nodes, are transmission lines.



Graph theoretical approach (2)

The Grid can be represented as a multi-weighted directed graph G = (N, L, C, D) consisting of N ={n_1, n_2, … , n_N} nodes, L={l_1, l_2, … , l_N} links of lengths D={d_1,d_2,…, n_N} and capacities C={c_1 , c_2 , … , c_N }

Node strength: $$s_i = \sum_{j \in N} c_{ij}$$

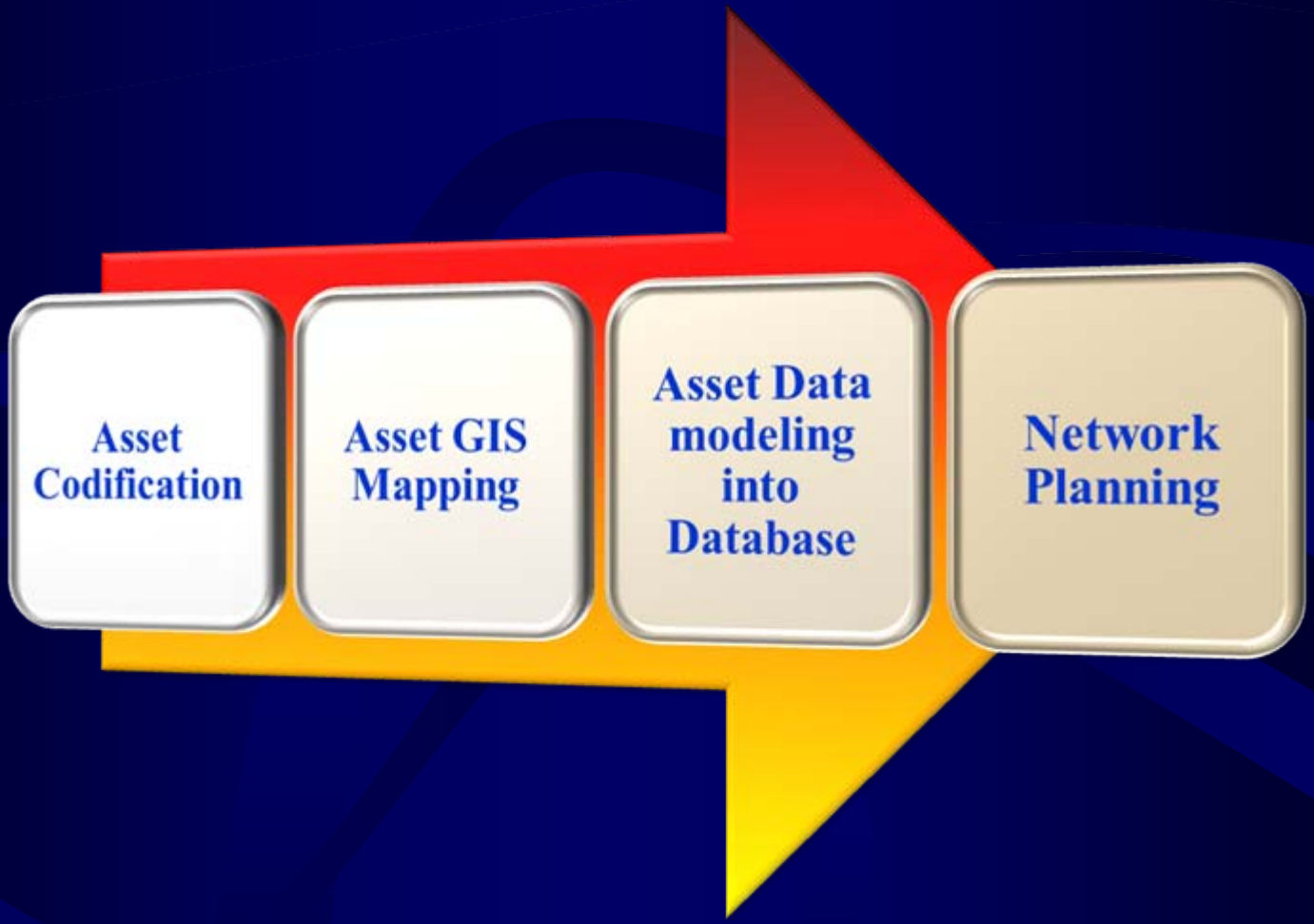
Impedance: $$Y_i = \sum_{j \in N} \left[\frac{w_{ij}}{s_i} \right]^2$$

Clustering co-efficient, community structures, cascading models, resiliency

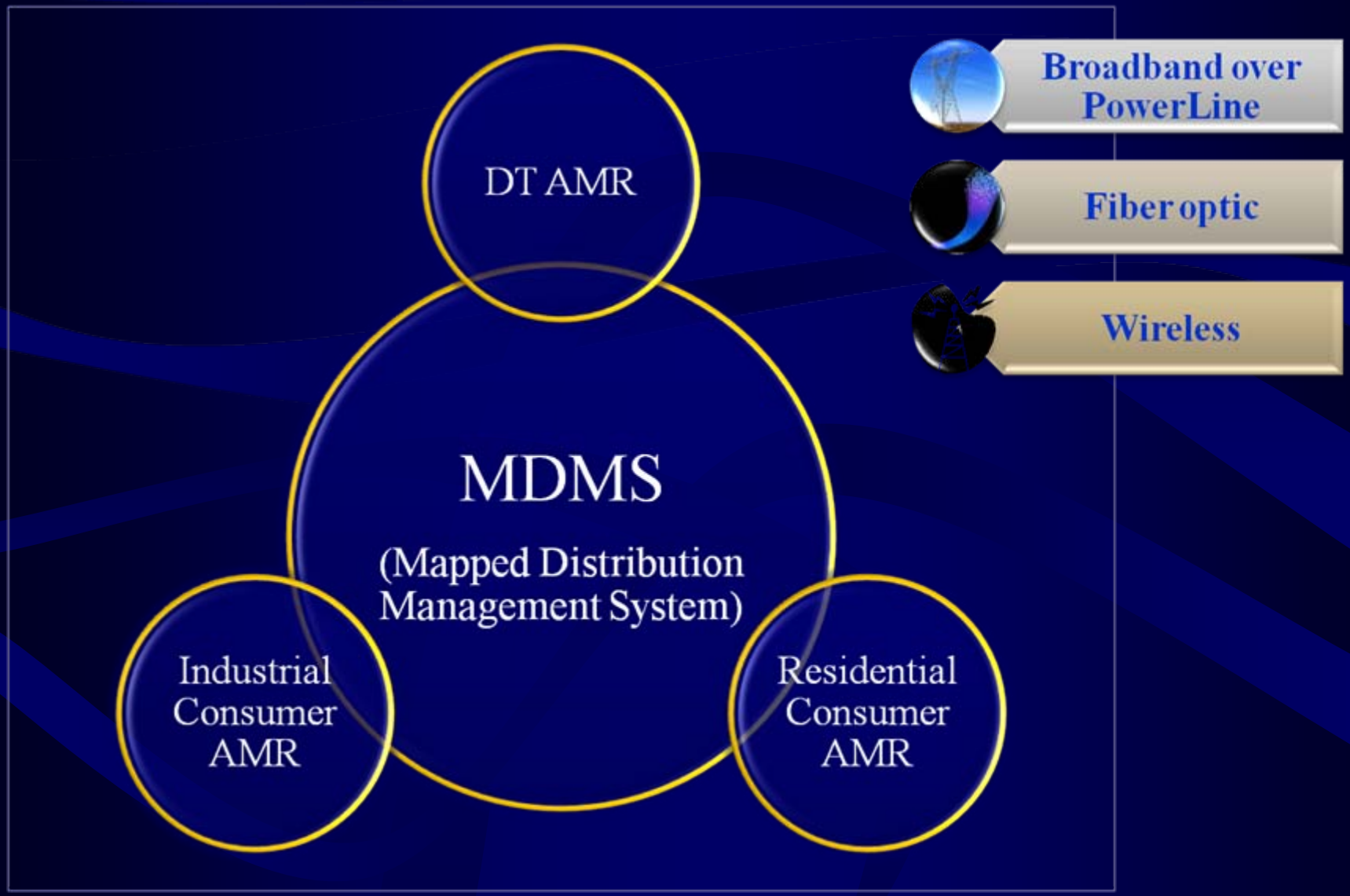
Distribution – Approaches

- Automatic Meter Reading
- Shedding with priorities
  - Consumer based; e.g., Hospitals / Offices Vs. Houses
  - Service based; e.g., lights Vs. Air Conditioning
- Dynamic Pricing

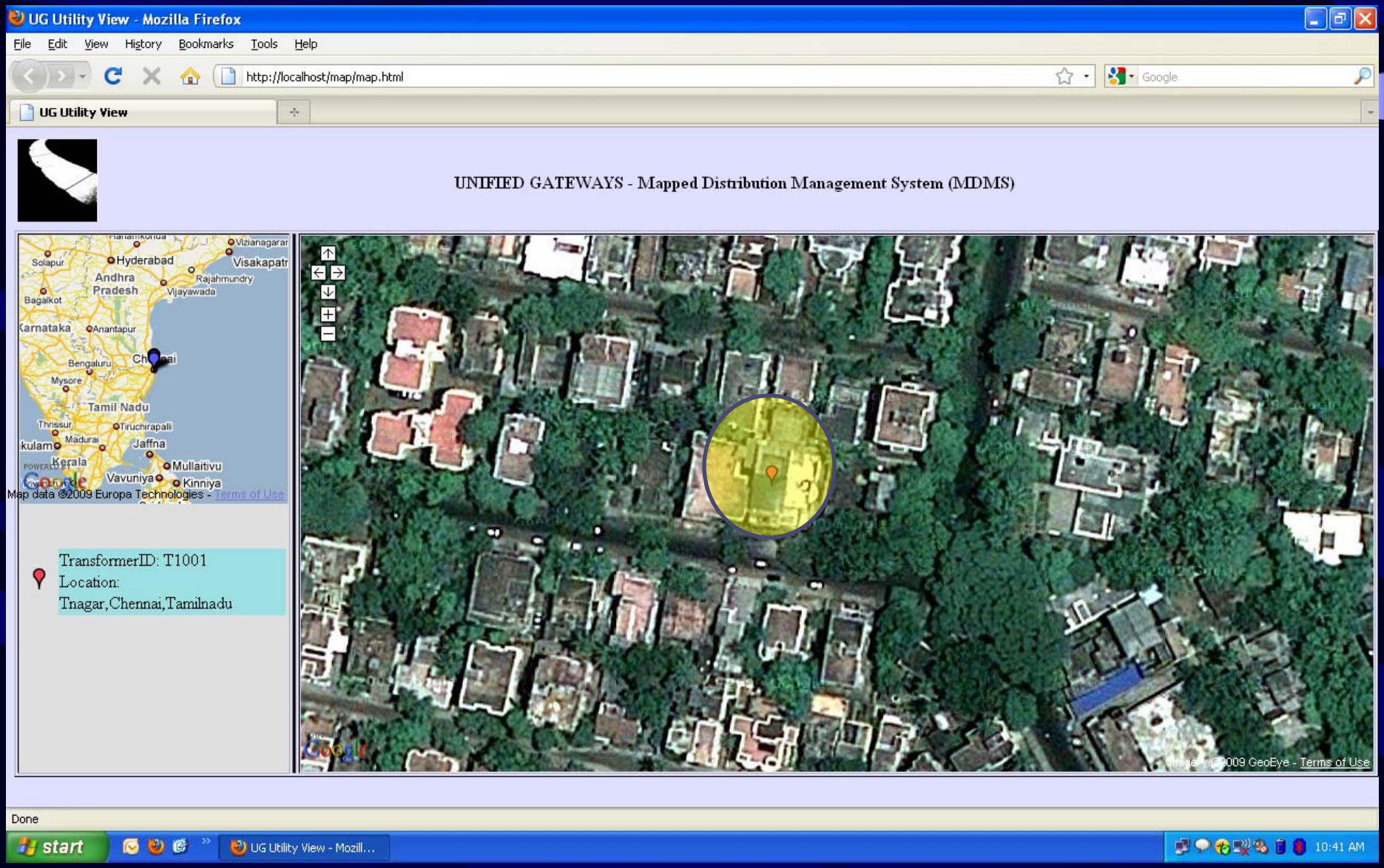
Automatic Meter Reading Process – Preparation Phase



Automatic Meter Reading Process – Network Rollout

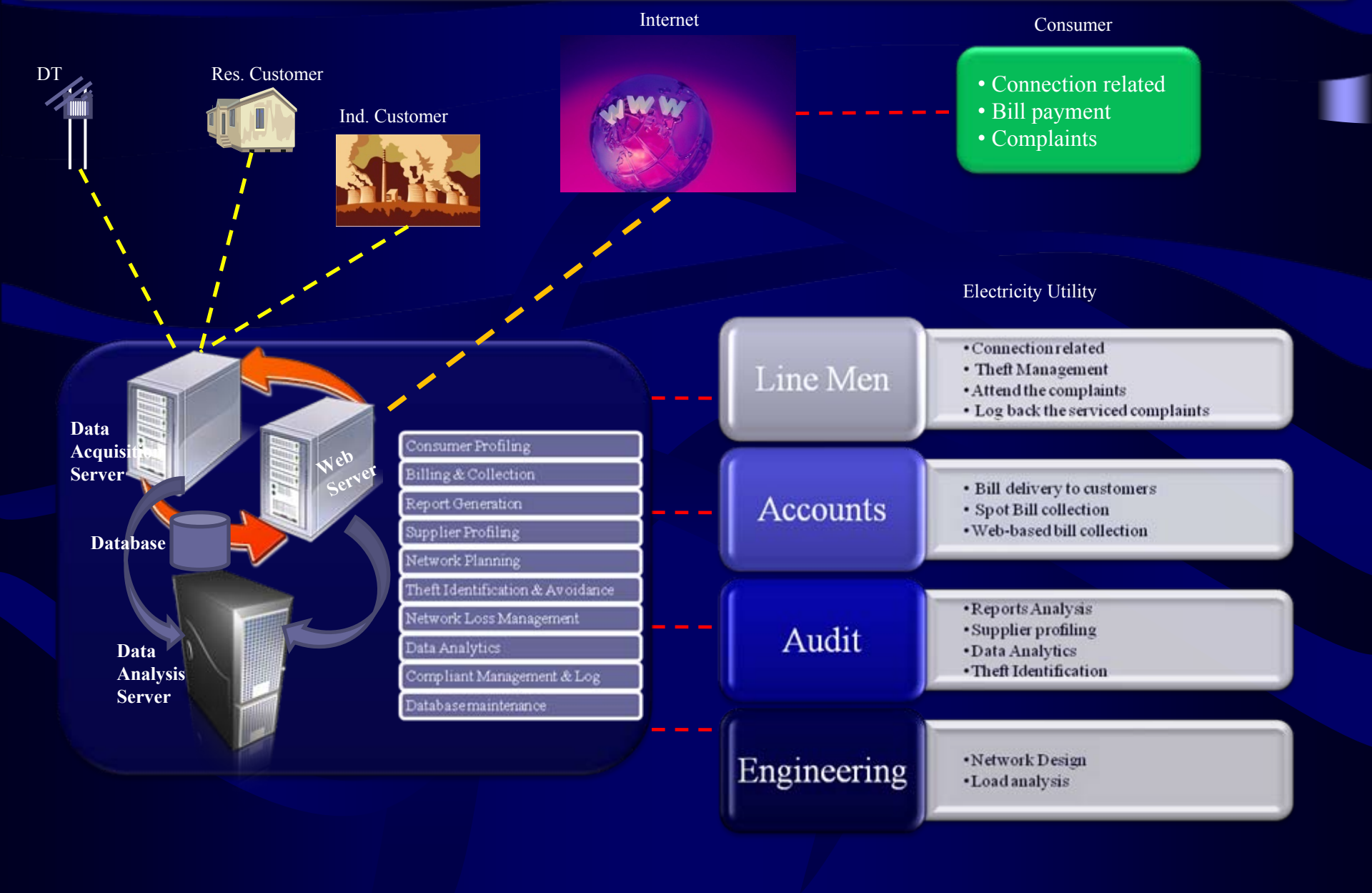


Automatic Meter Reading Process – MDMS Snapshots



Automatic Meter Reading Process – Network Analytics

Automatic Meter Reading – The whole process



Several Related on-going R&D

- Energy Bill passed in December 2007: Title XIII Smart Grid, Sections 1301 □1309
  - Establishes a statement of policy supporting modernization of the grid;
  - authorizes a biennial status report and survey of barriers to modernization
- Initiatives at several utilities, including Xcel, AEP, Austin Energy, ISOs, etc.
- EPRI: Intelligrid, Fast Simulation and Modeling
- US Department of Energy: Gridwise and Modern Grid Initiatives, Self-Heals (NETL)

Smart Grids - India

Sources:

- *Ministry of Power website*
- *Planning commission of India*
- *KPMG Analysis of Indian power sector*
- *Investment commission of India*

- Smart Grid efforts fall under R-APDRP (Restructured Accelerated Power Development and Reforms Program) http://pfc.gov.in/apdrp/apdrp2.html
- Wireless (WiMax/WiFi/VHF Radio) is seen as a major contributor for Smart Grid in India
- Government Investment size in Power Projects including T&D is USD 2 Trillion within next decade
- Private investments in Power Sector for reliable and economic energy supply to a tune of USD 120-150 Billion in next five years
- UG working with both Transmission State Government run Companies

Summary

- Self-healing has to be a critical characteristic of Smart Grid
- Has to be incorporated and supported by all components (Generation, Transmission, Distribution and Consumers)
- Several ongoing studies lead by EPRI