Energy and Utilities industry

Future Intelligent Utility Network

Fourth Annual Carnegie Mellon Conference on the Electricity Industry

FUTURE ENERGY SYSTEMS: EFFICIENCY, SECURITY, CONTROL

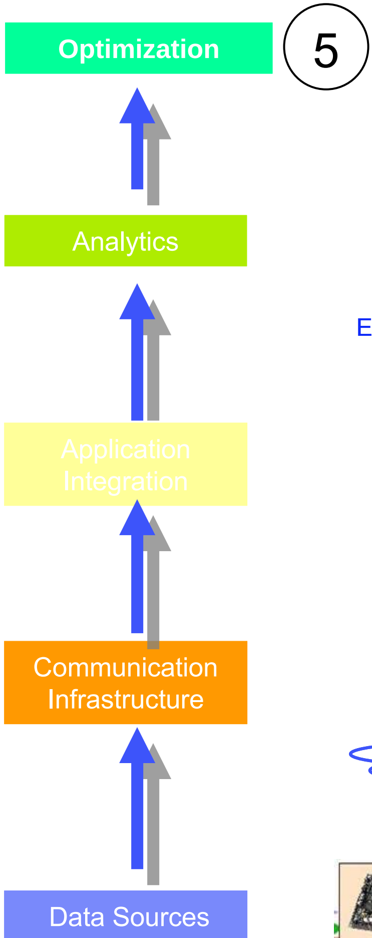
Session Five: Future Electric Energy Systems –Defining the Vision

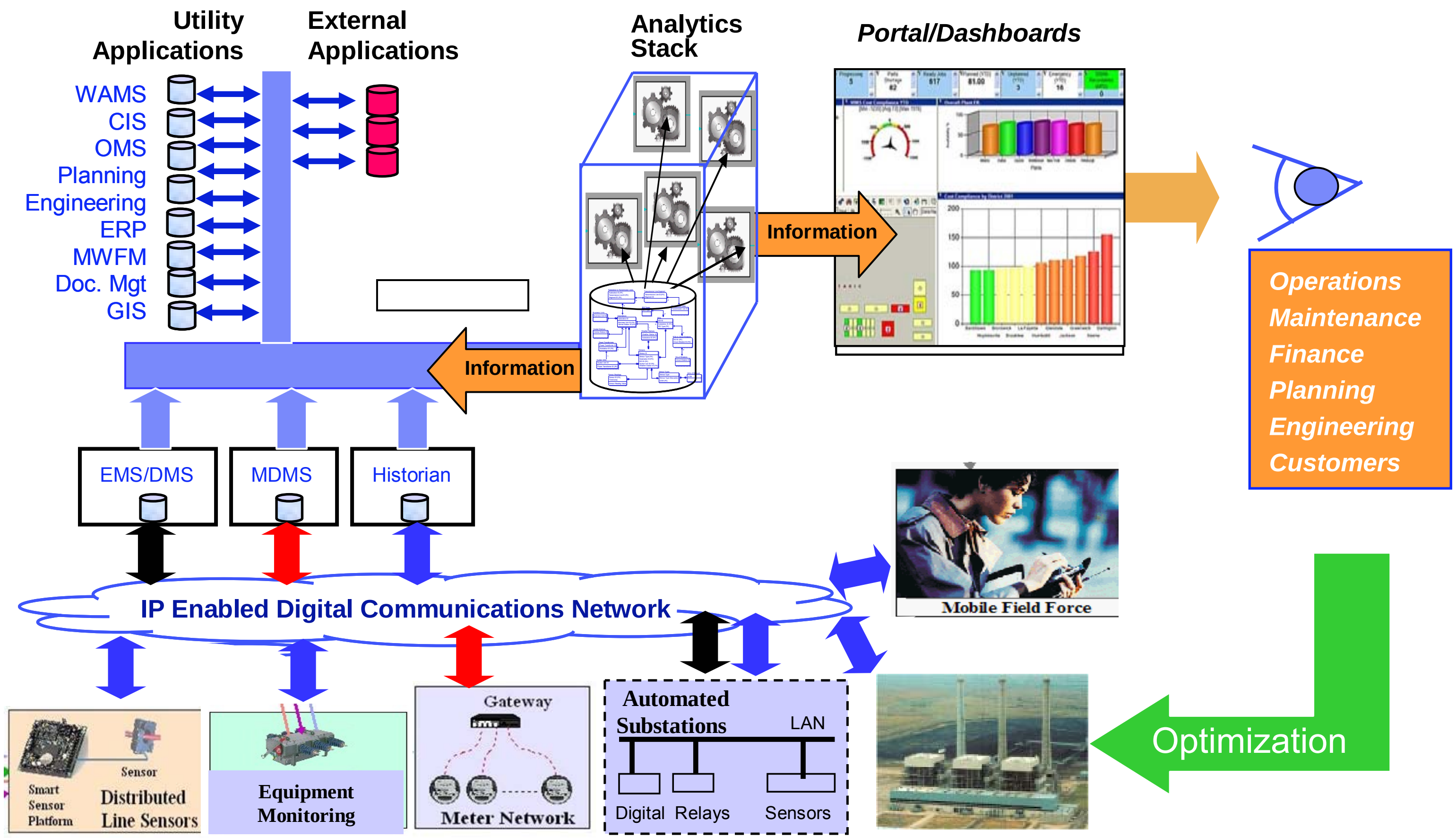
March 11, 2008

Five Major Components of an Utility Intelligent Network

5

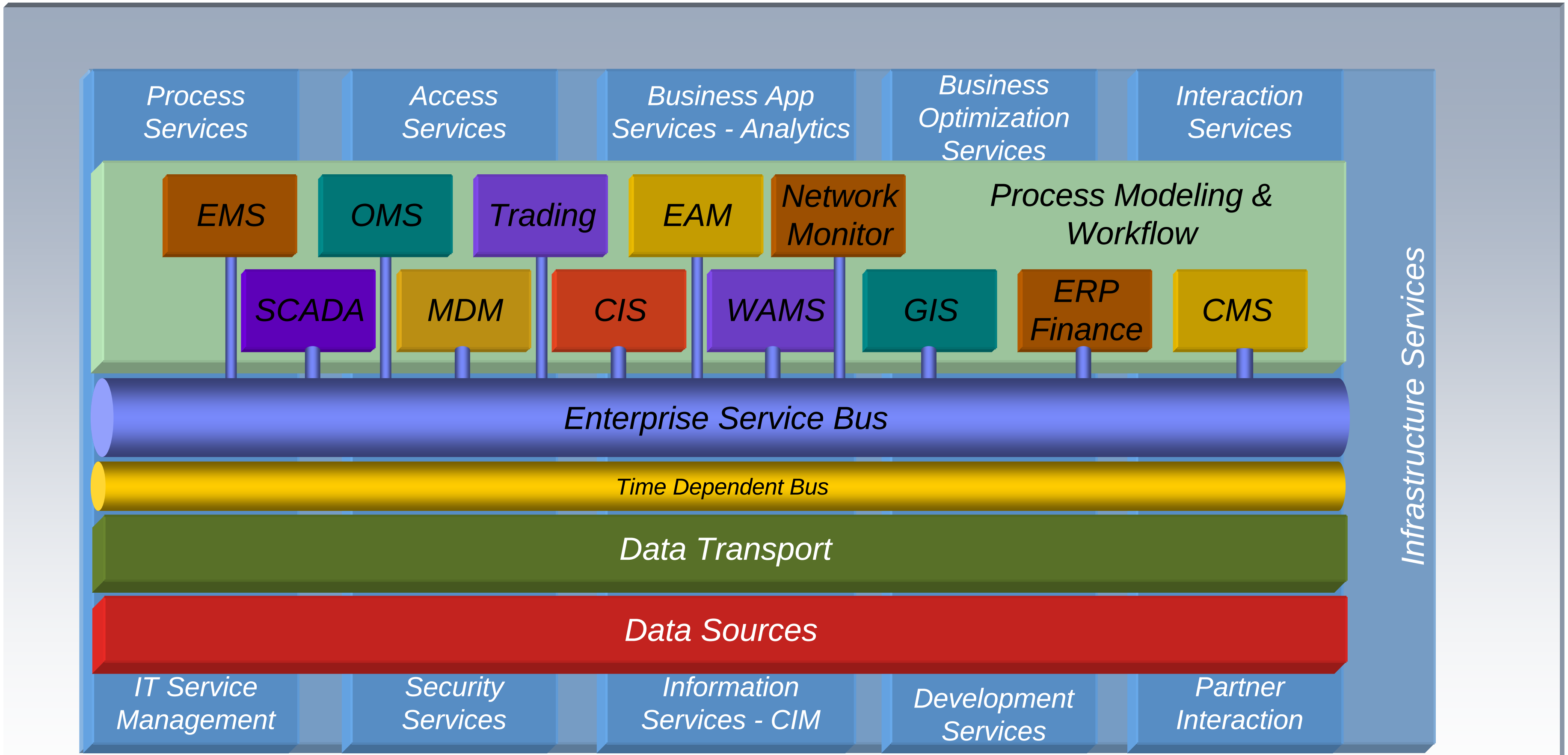
- *Information is presented to Users via customized portal dashboards for decision support*
- *Information available to Utility applications for automatic processing*





IBM

Solution Framework for Energy (SAFE)
Intelligent Infrastructure for Utilities



***An architectural blueprint** to support the integration of applications and new services for a utility company*

Requirements of network analytics lead to expand the capabilities of SOA

- Electric utilities have unique needs, especially for intelligent grids
  - Real-time data handling requirements on widely varying time scales (msec to months)
  - Separation of operational and enterprise data and systems as mandated by NERC CIP 002-009 and other security practices
  - Need to separate time critical data traffic from general enterprise data traffic for performance reasons
  - Need to support real time distributed analytics and data management for operational systems
- Extended SOA (XSOA) addresses intelligent grid solutions via
  - A two bus architecture: standard enterprise bus and new event processing bus
  - A set of bridge service classes that connect the real time operational systems and the back office enterprise systems
  - A CIM-based approach to the integration of utility data sources and databases, including real time grid operational data, historians, etc., without loading or compromising real time systems
  - Support for distributed intelligence for technical analytics

Applications and Integration

Intelligent Utility Network Architecture bus layers

Local Device Layer

Data Capture & Control
- Move data intelligently
- Execute local commands
- Run distributed operational logic
- Integrate wide range of device

Manage Distributed Device Infrastructure
- Discovery of devices and sensors
- Remote configuration, updating, "no touch"
- Monitoring

***New Data* drives…**

Time-Dependent Layer

Event Processing & Services
- Complex event processing
- Services such as: Data Aggregation, Geographic information, Identification and Association, Condition, Monitoring, Command and Permission, Persistence

Data Modeling & Integration
- Domain specific information models
- Interoperable information framework
- Integration with legacy data
- Federated data management

Analytics
- Domain specific analytic applications
- Apply and develop mathematical models
- Provide performance dashboards

***New Insight* enabling…**

Enterprise Service Layer

Business Optimization
- Model business processes for optimization
- Apply mathematical optimization techniques
- Optimize assets and processes

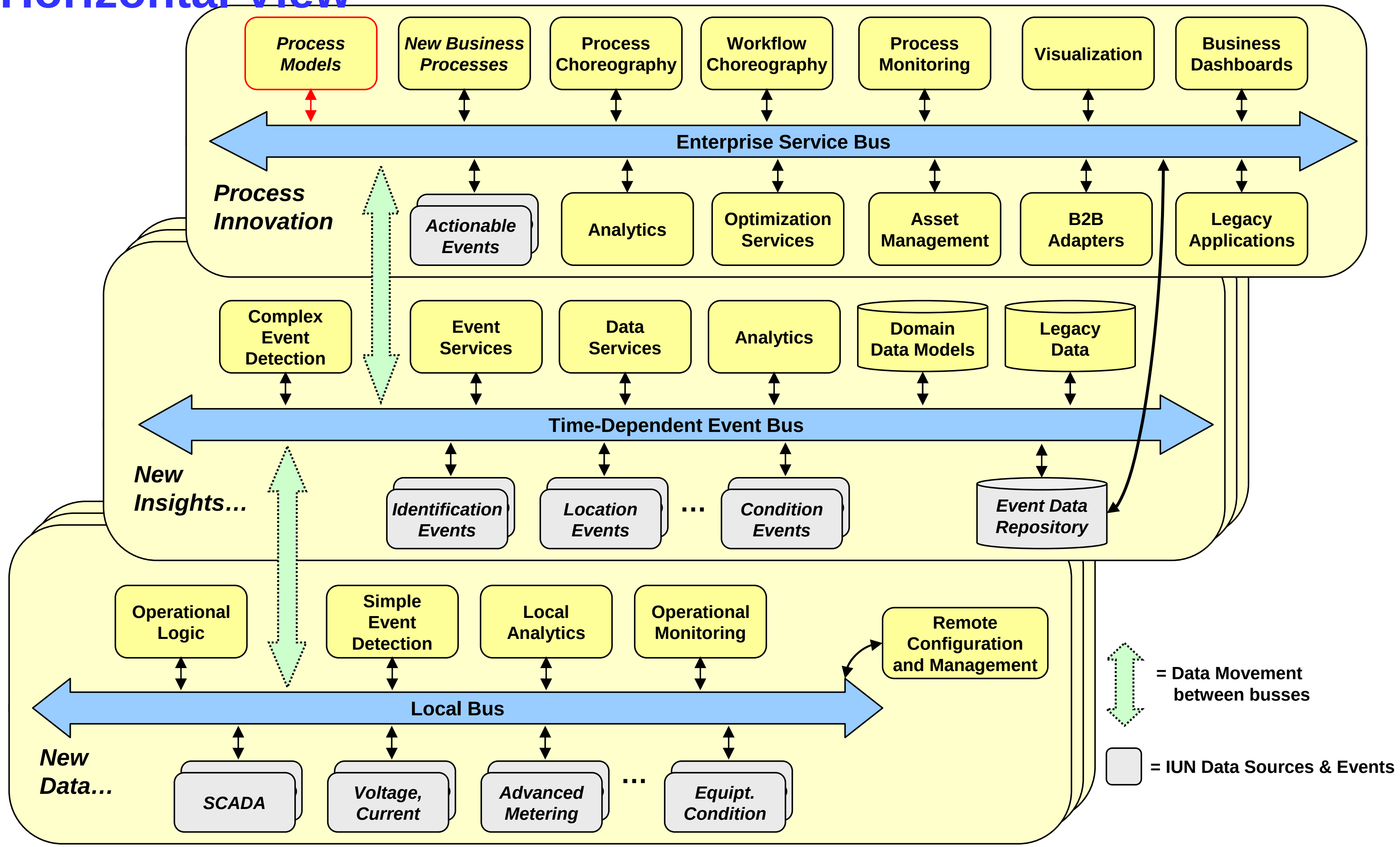
Business Process Services
- Event driven SOA processes (i.e. traceability)
- Sense & respond dynamics
- Enterprise application integration
- Align with business strategy
- Link with Websphere Business Process Modeler

Process Integration
- Extend legacy and enable new business processes
- Monitor business processes
- Provide information to people
- Improve operational logic and business rules

Process Innovation…

… within a framework of Scalability, Security, Privacy & Standards

Intelligent Utility Network Reference Architecture – Horizontal View



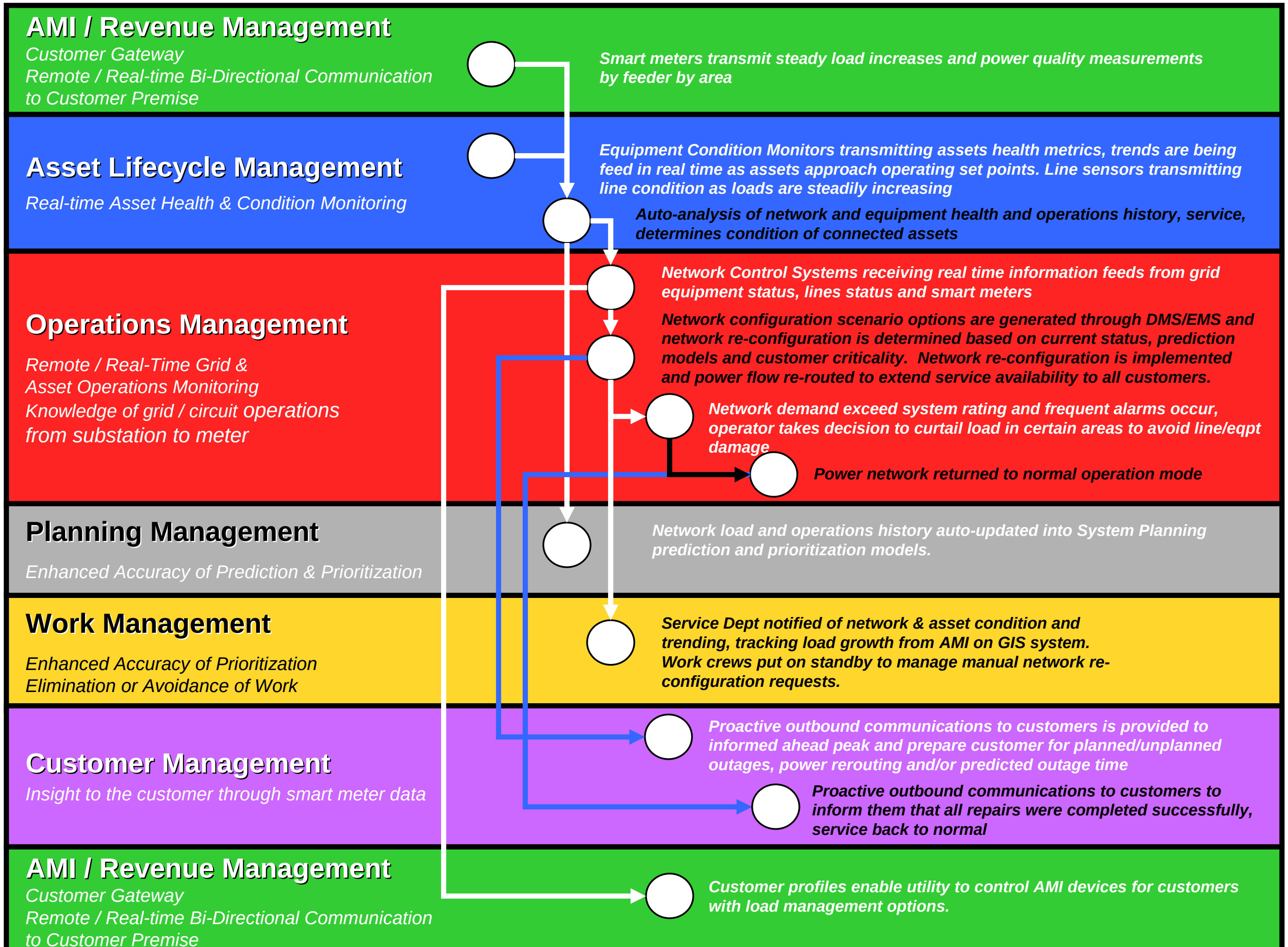
Applications and Integration

Benefits of the dual bus structure

- Provides a clean separation of operational data flow and enterprise data traffic, allowing both to proceed efficiently
- Facilitates data security measures consistent with best cyber security practices
- Enables high-reliability, priority data transfer among grid control, geospatial, and fault analytics services
- Supports multi-party real time analytics applications integration in same manner as enterprise applications can be integrated on an enterprise integration bus
- Simplifies the problem of filtering real time grid message floods
- Forms the basis for an analytics platform that supports both distributed and centralized high performance analytics computing simultaneously

Management of Peaks and Load Control

AMI in place allowing for load curtailment to consumers, electricity demand is peaking past operating parameters of grid, utility has to effect load control of some consumers in order to remain within grid system rating



WHAT DECREASES

- *# Planned Manual Inspections*
- *Manpower Requirements*
- *# Asset failure outages*
- *# Customer complaints*
- *Loss of Revenue*
- *Equipment Replacement Volume Over Time*
- *Wear and Tear on P&C Equipment*
- *Call Center Call Volume*

WHAT INCREASES

- *Network Availability & Reliability*
- *Life Cycle of Assets*
- *Utilization of Asset*
- *Asset Knowledge Base*
- *Operator Ability to Manage Risk*
- *Work Mgt Accuracy & Prioritization*
- *Productivity of Work Crews*
- *Customer Satisfaction*

A well designed Intelligent Utility Network will produce a broad range of benefits for the utility and its customers

Asset Management

Equipment Condition Monitoring

- Real time knowledge of asset health, 'sweat the assets' whilst controlling operating risks
- Increased asset life thru better management & maintenance
- Optimize Capital and O&M spending
- Remote management of Sensors/IEDs

Workforce Management

- Reduce frequency and duration of site visits through remote monitoring and configuration
- Accurate response to outage location & cause
- Better prepared & informed crews
- Captures the knowledge of staff

Information Management

- Provides a common infrastructure for Utility applications & communications
- Access and re-use of common services
- Data inputted one time, re-used many times
- Reduced system integration costs
- Reduced operating costs
- Reduced system maintenance costs

Utility Business Functions

Operations Management

Intelligent devices, sensors & meters to eliminate system "blind spots"

- Faster detection and localization of outages
- Better load balancing & maintaining stability
- Locate power quality, reliability & fault issues before they impact customers

Customer Experience

- Meet Regulator expectations
- More choices about price and service
- Less intrusion
- More information with which to manage consumption, cost, and other decisions.

Planning Management

Access to accurate historical operations & asset data improves grid planning

- Optimize CAPEX across grid, defer capital investments
- Accurate design & sizing of new/ replacement equipment to meet demand / growth
- Investment decisions based on customer profile

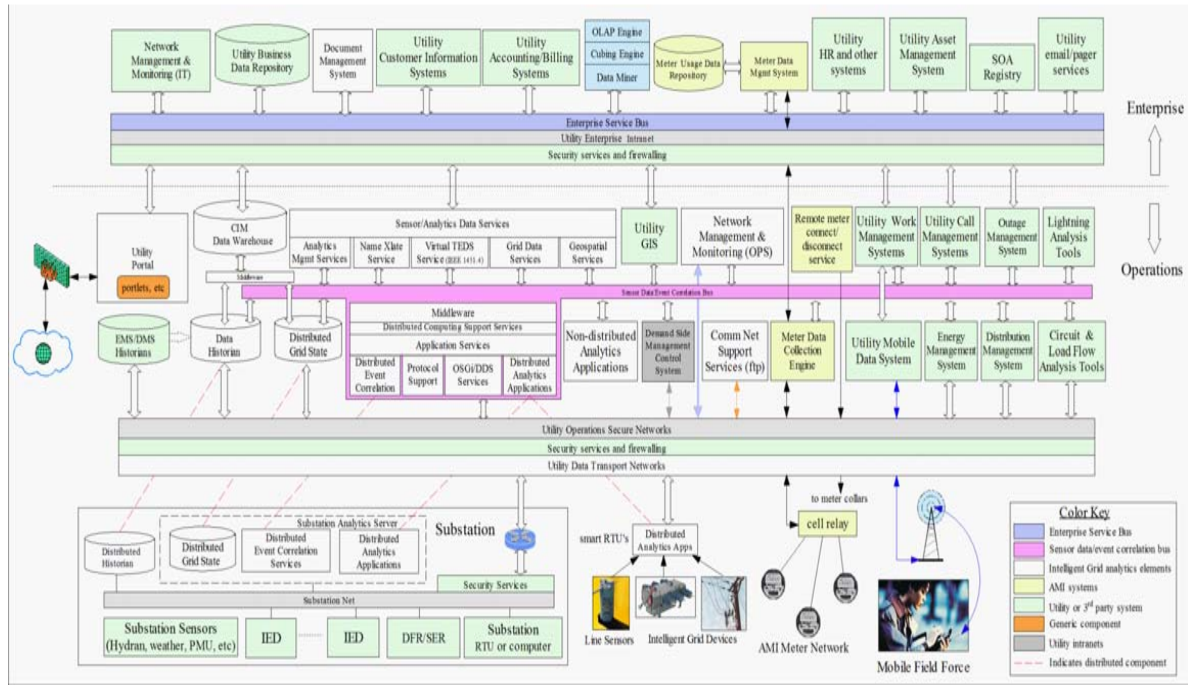
Revenue Management

Intelligent meter a portal to the consumer

- Profile of customer usage
- Remote connect/disconnect, load control
- Assurance of billing/revenues
- Customer participation in time based rates
- An intelligent sensor on the grid

Issues to Consider

- System Architecture (legacy and new systems, integration)
- Data architecture (CIM, telemetry, grid state, connectivity, models)
- Analytics architecture (management, integration)
- T&D Vendor perspective of IUN
- Data transport performance
- Standards
- Meta-data management (network addresses, point lists, naming, sensor calibration data, connectivity…)
- Security
- Communications



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High-Impendence Fault Detection based on Real-time Event-driven Modeling, Analytics, and Optimization

Current state / What we would like to accomplish

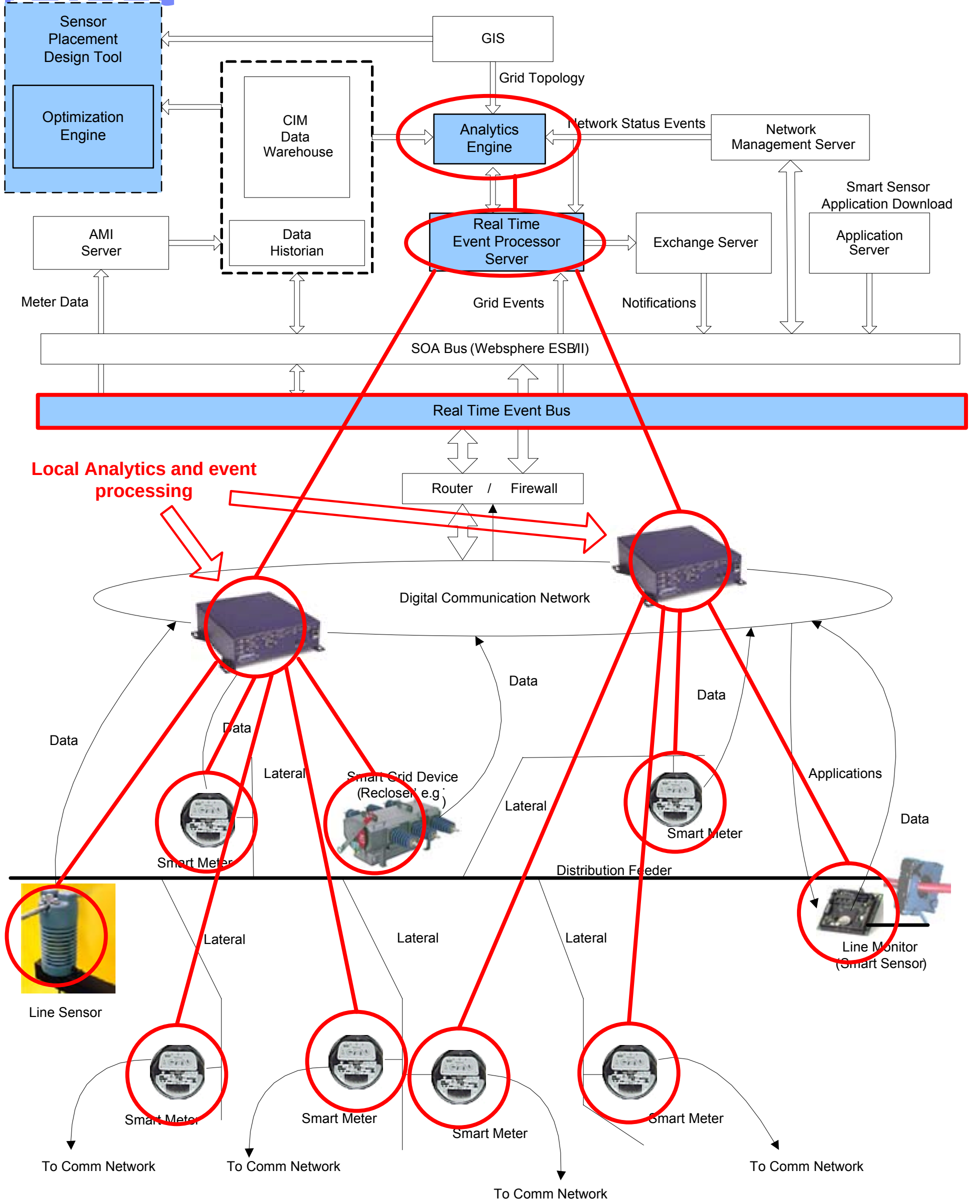
- Current methods of detection
  - Breakers tripping
  - Limited waveform data from some types of reclosers
  - Readout from meters at the substation (human)
  - Phone call from someone who noticed a fault (most common)

- What we would like to accomplish
  - Automatic detection and localization
  - High accuracy (within 3 spans)
  - Fast response
  - Tools for optimal sensor placement
  - Adaptability

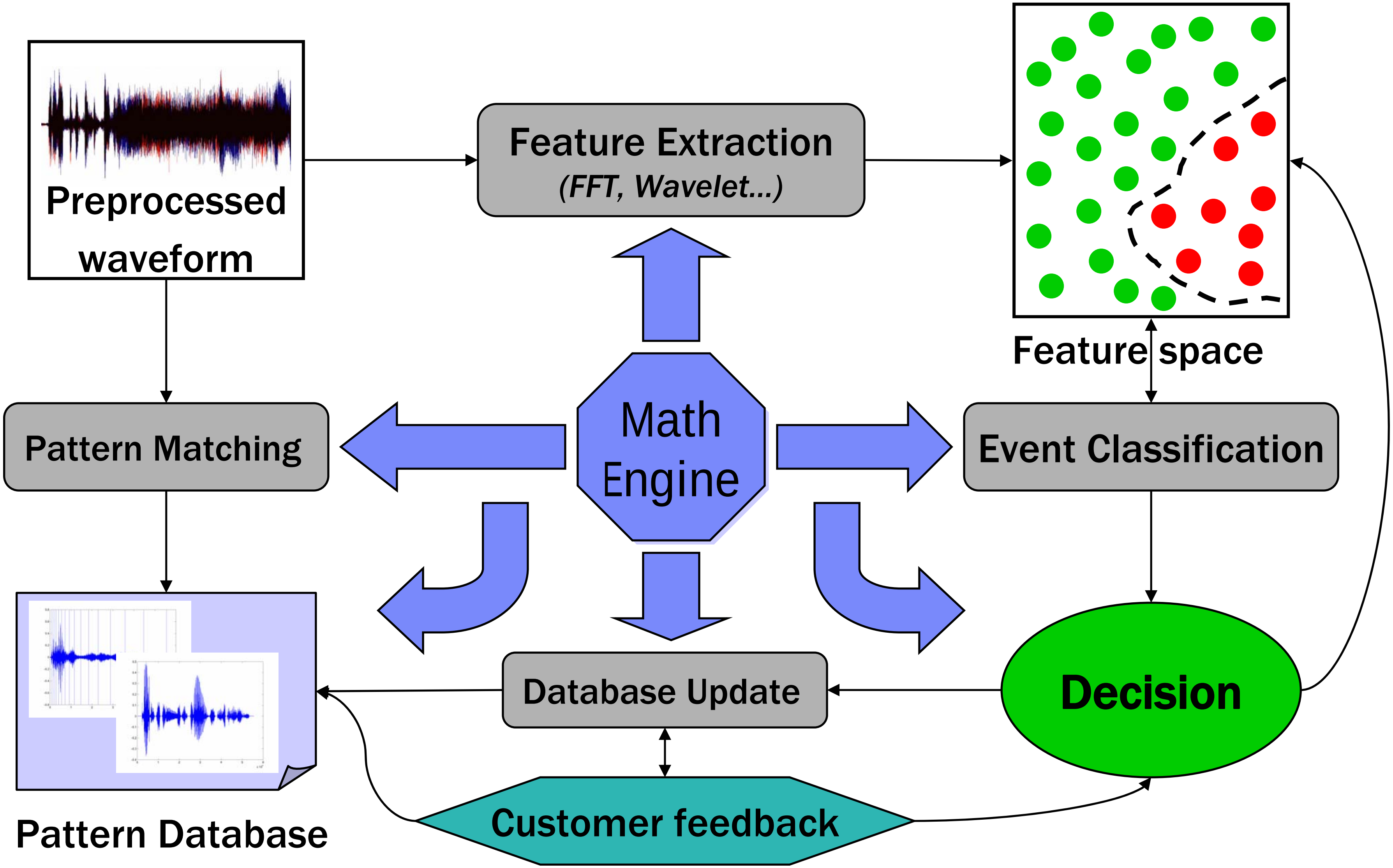
Event-driven Grid Analytics Project

Using or developing technology elements at IBM Research that support the emerging Intelligent Utility Network architecture:

- Event bus and event-based programming framework
  - Schema models and event programming framework
  - Real-time messaging
- High-Z fault analytics
  - New real-time event-driven fault characterization analytics
- Sensor placement optimization tool
  - Design-time tool to determine optimal number and placement of grid sensors

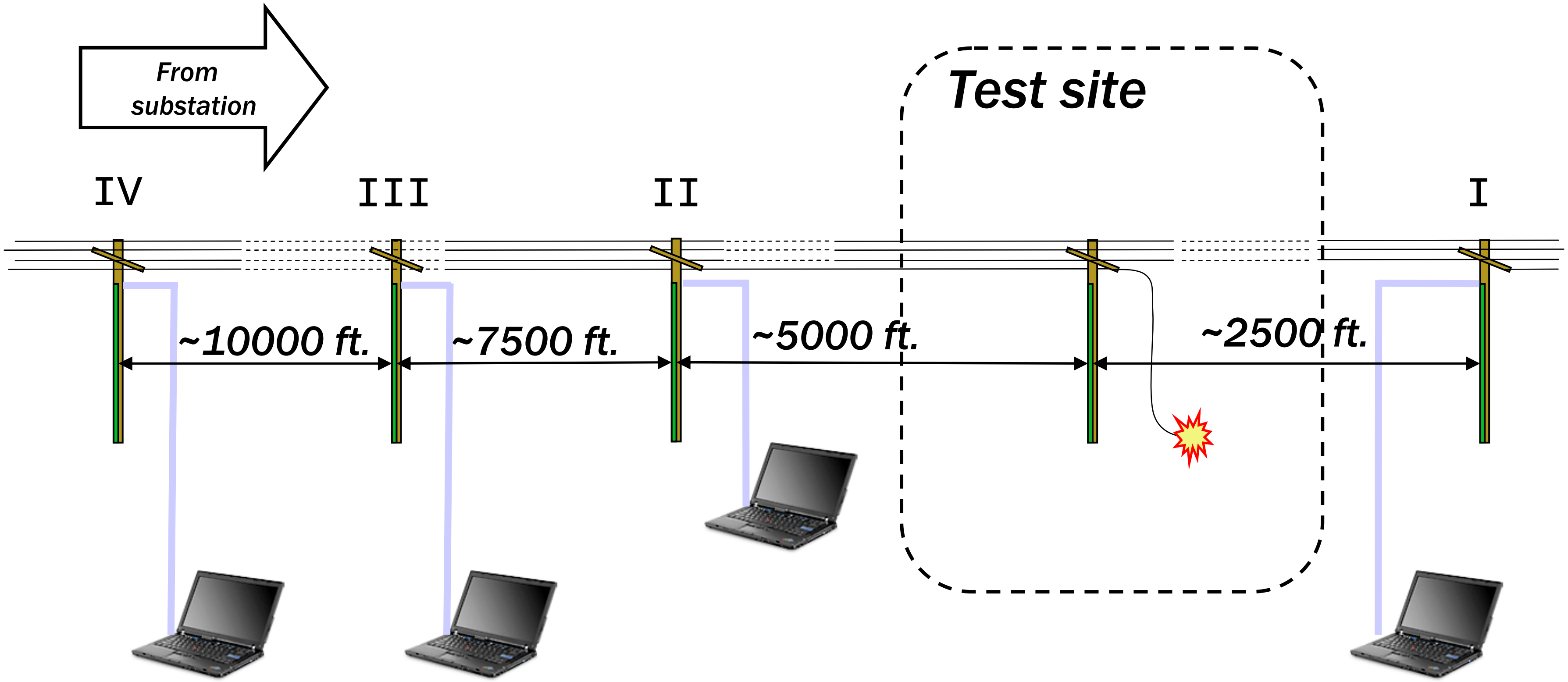


Detection



Preprocessed waveform
Feature Extraction
(FFT, Wavelet...)
Feature space
Pattern Matching
Math Engine
Event Classification
Pattern Database
Database Update
Decision
Customer feedback

Overview of data collection test setup



Types of experiments conducted on February 2, 2007

- Several types of experiments performed (grayed out tests not performed)
  - Powered wire on
    - Concrete
    - Asphalt
    - Wet grass (caused Low Impedance Fault due to amount of recent rain)
    - Dry sod (not available)
    - Sand (both wet and dry)
    - Reinforced concrete if possible (depends on site issues)
  - Drilling a hole in a ceramic insulator and introducing water to the hole to simulate a "cracked insulator" type of fault.
  - Capacitor switching – this is an example of a typical "false positive", some legitimate behavior that might be easily be misclassified as a High Impedance Fault.
  - Touching the wires to tree branches
    - With a wet stick
    - Dry branches (winter meant there was little sap)
    - Placing a stick connecting two wires
  - Throwing a dead (already) squirrel on the powered wires (Customer decided against this test)
  - Dirty insulator
  - Insulator with radial crack

- ***Collected 12 GB of sensor data for analysis by Math Sciences teams***

Test Site Layout

Data Collection Systems and Sensors

Photos from the tests

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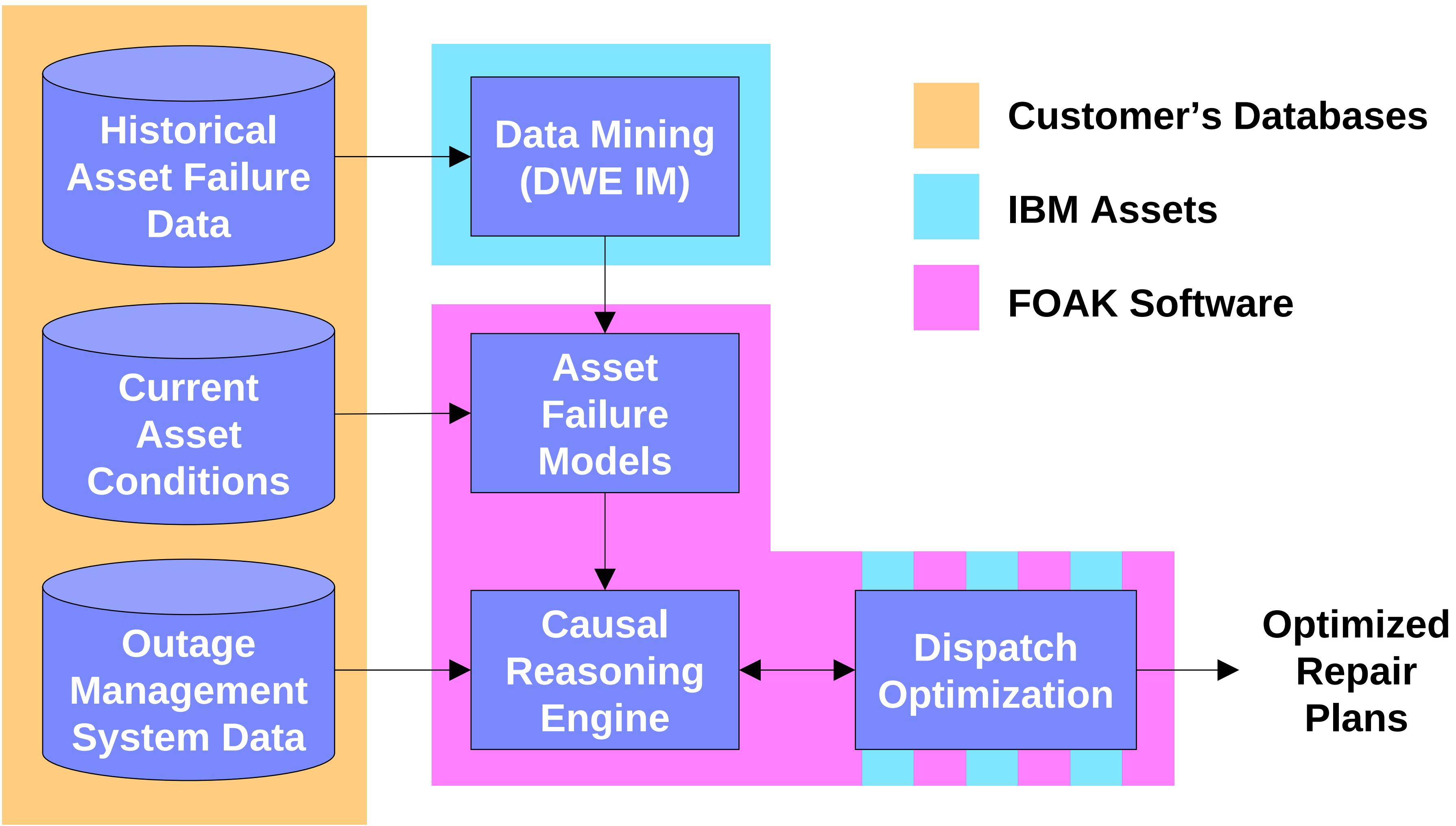
Outage Root Cause Analysis using Bayesian Networks and Data Mining

Customer Problem

- **Repair times for power outages is increasingly becoming a public-relations issue**
  - Society is increasingly dependent on electrical power to function
- **Penalties can be imposed by Public Utilities Commissions**
  - Can be substantial
- **Utilities incur direct financial loss from power outages**
  - Lost revenues (Energy Not Delivered)
- **Reducing repair times requires**
  - Better utilization of all available information (data analytics)
  - More effective dispatch of repair crews (optimization)

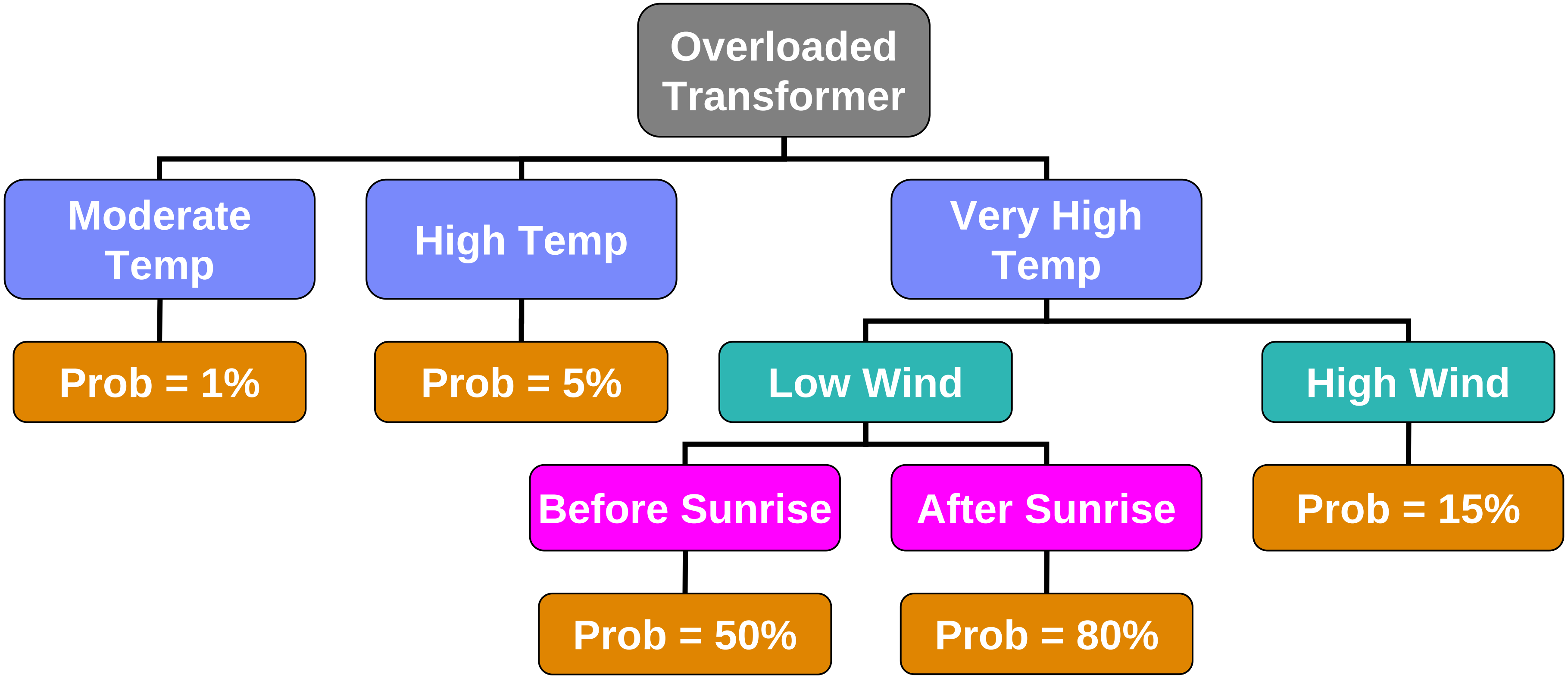
Solution Approach



Asset failure models take into account environmental factors that affect outages

- **Data-mining based predictive models provide probability estimates of network asset failures as functions of**
  - Weather conditions
  - Asset age, condition, repair history
  - Vegetation management status
  - Load levels
  - Overhead/underground
  - Third party activity (e.g., construction)
- **Data mining enables these models to be constructed for individual utilities based on their own data**

Example: Probability of an outage being caused by an overloaded transformer



Causal modeling enables customer calls, network sensor data, and diagnostics to be combined with environmental factors

- **Causal models would be used to**
  - Encode the topology of power distribution networks
  - Encode cause-and-effect relationships between asset failures and outages caused by those failures
  - Encode cause-and-effect relationships between asset failures and network sensor output
  - Encode cause-and-effect relationships between asset failures and outcomes of diagnostic tests on those assets
  - Encode cause-and-effect relationships between outages and customer complaints
  - Combine the above with the outputs of asset failure models to take into account environmental factors
  - Provide simultaneous probability of failure estimates for all assets as functions of incoming customer complaints, network sensor data, diagnostic tests by repair crews, and environmental factors

Because probabilities are updated for all variables in the model, causal models can be used for multiple purposes

- **Identify the most probable root causes**
  - The most probable root causes could change as probabilities are updated
- **Estimate number of customers without power**
  - An expected value calculation
  - Updates as probabilities are updated
- **Generate optimum diagnosis plans for difficult-to-isolate faults (e.g., for underground assets)**
  - Identify not only the first asset to diagnose and fix, but also subsequent assets in case the first ones turn out to be in working condition
  - Minimize mean time to repair
- **Perform simulations to identify weaknesses in the network**

Dispatch optimization can reduce mean time to repair through more effective dispatching based on causal modeling

- **Get the right materials on the right trucks**
  - More accurate identification of assets/components involved
  - Avoid return to Distribution Center for additional material
  - Reduce wait time for additional material
- **Dispatch the right crews and equipment**
  - Avoid re-dispatch of different crews
  - Reduce wait time for additional resources when multiple crews are required
- **Coordinate multi-crew repairs (e.g., underground cable failures that cannot be switched)**
  - Accelerate location of fault
  - Reduce crew wait times

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Data Center Thermal Management for Energy and Space Efficiency

Client Problem

Power / cooling constraints are #1 concern for IT managers*	▪ significant utility costs: today's IT hardware requires ~ 30-40% of additional power to cool the equipment ▪ growing environmental concern about energy efficiency ▪ existing infrastructures are experiencing "hot spots", architectural constraints & limitations to deliver required power/cooling capacities ▪ often, upgrade of IT hardware requires major capital investments ▪ construction costs are surging since they are proportional to the DC power density ▪ Gartner: 70 % of equipment fails due to environmental facility related problems ▪ insufficient cooling will be a major problem facing 43% of data centers within 2 years*
Holistic DC thermal management solutions are not available	▪ varying approaches presented from unproven "Equipment Manufacturers" or DC consultants are confusing to clients and often conflicting ▪ every data center is different (no fit all solutions) ▪ no standards yet (Watts / sq. ft, ceiling / floor height, etc.) ▪ educated scientific, quantitative "solutions" are rare or completely missing

Rapid Data Center Survey and Measurement tool

"cart" with sensors (thermal, humidity, flow, noise), which is mounted in a defined 3D pattern is rolled thru data center while data logging and tracking the position