Sensor and Actuator Networks (SANET) for Smart Grid

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Outline

- Smart Grid
- SANET for Smart Grid
- Challenges in SANET for Smart Grid
- Research at HKU
  » Core technologies
  » Application: Home energy management system
Smart = Self-Adaptive
Smart Grid

- Transforms the electric grid into a “smart” grid by employing information technologies such as
  - Intelligent sensors
  - Advanced communications
  - System control and management
Benefits of Smart Grid

- Increased renewable energy usage $\Rightarrow$ reduced greenhouse gas emissions
- Increased energy efficiency via better balance of supply and demand
- Improved security and reliability via fast and effective response to energy generation and consumption fluctuations and catastrophic events
Smart Grid Architecture

- Application & Decision Support
- Distributed Sensing & Actuation
- Advanced Communications & Networking
Smart Grid Architecture

Focus of this talk =>

Application & Decision Support

Distributed Sensing & Actuation

Advanced Communications & Networking
Sensor

- Measures and converts physical properties into electrical signals and/or data
  - Energy flow: voltage, current, frequency, power factor …
  - Environment: temperature, humidity, luminance …
  - Working condition: temperature, pressure, speed, acceleration, vibration, position (sag) …
Sensor Examples

Temperature Sensor

Vibration Sensor

Ultrasonic Sensor

Position Sensor

Current Sensor

Motion Sensor
Actuator

- Execute control decisions
- Converts electrical signals into physical phenomena (e.g. displays) or actions (e.g. switches, breakers)
  - Energy flow: breaker, switch, dimmer …
  - Working condition: valve, brake, motor
  - User interface: light, speaker, display ...
Actuator Examples

Indoor Breaker

Outdoor Vacuum Breaker

Dimmer

Energy In-Home Display

Motor

Valve
Sensor and Actuator Network (SANET)

- Network of nodes that sense and potentially also control their environment
- Information communication through diverse kinds of methods and media to enable collaboration among nodes and interaction between nodes and the surrounding environment
Sensing in Smart Grid

The key is to balance supply and demand.

Power Supply Sensing
Transmission Capacity Sensing
Power Demand Sensing

Wind Turbine 65 kW - 1500 kW
Hydroelectric Power Plant 1 MW - 2000 kW
Nuclear Power Plant 1 MW
Coal/Natural Gas Power Plant 500 MW - 2000 MW
Step-up transformer Reduces voltage to transmission levels
Transmission Lines 115kV - 268kV
Electric Substation Reduces voltage from transmission to distribution levels
Distribution Lines 13kV
Business Customers
Residential Customers
Challenges

- Heterogeneous and distributed system
- System dynamics
- Scalability
- Autonomous management
- Flexibility
- Energy efficiency and cost efficiency
Research Topics

- Pervasive Service-Oriented Network (PERSON) model
- Context-aware intelligent control
- Compressive sensing
- Device technologies
PERSON Model

- **Objective**
  - Provides a general framework to seamlessly integrate diverse kinds of actors and networks into a unified service-oriented architecture

- **Principle**
  - Decomposes the complex system into different layers with loose coupling between them

- **Addresses**
  - Heterogeneous and distributed systems
  - System dynamics
  - Flexibility
Context-Aware Intelligent Control

- Addresses the dynamics in smart grid, to enhance
  » Service availability
  » Convenience
  » Efficiency
  » Security
Compressive Sensing

- **Objective**
  - Exploits data correlation in time and space domains to lower the costs of sensors and communications

- **Addresses**
  - Scalability
  - Energy efficiency
  - Cost efficiency

- **Methodology**
  - Complete continuous sampling to ensure reliability
  - Selective transmissions to ensure short delay & cost-effectiveness
  - Complete reconstruction based on sparse data
Compressive Sensing
- Wind Power Sensing

- Wind conditions in adjacent areas are similar.
- Exploits the data correlation in spatial domain.
Compressive Sensing - Residential Power Demand Sensing

- Power consumption does not change rapidly.
- Exploits the data correlation in time domain.
Device Technologies

- Low power consumption design
- Power-harvesting technologies
- Compact design
- Low-cost design
Prototype of HKU Home EMS

- In-Home Display & Power Meter
- ZigBee-enabled Devices
- Web-based Monitoring

GUI - Power Consumption
GUI - Power Consumption Comparison
Web-based Monitoring
http://icee.hku.hk/

Thank You