WIRELESS COMMUNICATION AND NETWORKING TECHNOLOGIES FOR SMART GRID: PARADIGMS AND CHALLENGES

Xi Fang, Dejun Yang, and Guoliang Xue
Dec. 2011
Outline

1. Introduction
2. Overview of Smart Grid
3. Wireless Communication and Networking Paradigms in Smart Grid
4. Challenges for the Research on Wireless Technologies in Smart Grid
5. Conclusions
1. Introduction

2. Overview of Smart Grid

3. Wireless Communication and Networking Paradigms in Smart Grid

4. Challenges for the Research on Wireless Technologies in Smart Grid

5. Conclusions
1. Introduction

**Electrical Grid:**

Electricity delivery system that may support all or some of the following operations:

1. Electricity generation
2. Electricity Transmission
3. Electricity Distribution
4. Electricity Control
1. Introduction Cont.

Smart Grid:

Using two-way flows of electricity and information is expected to provide:

1. Distributed power generation
2. Self-monitoring
3. Self-healing
4. Adaptive and islanding micro-grid
5. Various customer choices

Advanced information and communication system is required
Examples:

1. Real time pricing: to reduce users power demands at peak periods

2. Monitoring system for grid self-healing: detect failure events and act accordingly
In This Presentation:

We present four wireless communication and networking paradigms for smart grid:

1. Smart Home
2. Micro-grid
3. Electric Vehicle System
4. Monitoring System

And present the associated research challenges
Outline

1. Introduction

2. Overview of Smart Grid

3. Wireless Communication and Networking Paradigms in Smart Grid

4. Challenges for the Research on Wireless Technologies in Smart Grid

5. Conclusions
2. Overview of Smart Grid

Traditional Power Grid:

Unidirectional flow of electricity and information

Located away from heavily populated areas

Stepped down again from distribution voltage level to service voltage level

Unidirectional flow of electricity and information
2. Overview of Smart Grid

**Smart Grid:**

- **Disconnected = Islanding mode**
- Distribution grid is capable of generating power

Bidirectional flow of electricity and information

**Micro-grid**

**Charging and discharging**
2. Overview of Smart Grid

By utilizing modern information technologies, the smart grid can:

1. Respond to events that occur anywhere in the grid, such as in power generation, transmission, and distribution

2. Adopt the corresponding strategies or behaviours
1. Introduction
2. Overview of Smart Grid
3. Wireless Communication and Networking Paradigms in Smart Grid
4. Challenges for the Research on Wireless Technologies in Smart Grid
5. Conclusions
3. Wireless Communication and Networking

**Four Scenarios:**

1. Smart Home
2. Micro-grid
3. Electric Vehicle System
4. Monitoring System

Applicable communication and networking technologies
3.1. Smart Home

1. Obtain info from end user’s devices and utilities
2. Control the behaviour of the devices
3.1. Smart Home Cont.

**Info Exchange**

Manage energy consumption to reduce bills

SM: 1. knows appliances energy consumption, 2. knows the real time pricing → control appliances operation to reduce energy consumption

ZigBee communications

Remote house owners control

SM: 1. knows house owner location through smart phone GPS, 2. house owner coming home → starts air conditioner and control home temperature

Cellular communications
3.2. Micro-Grid

1. Users need to decide when to operate in islanding mode?

2. How to optimize power usage and resource allocation if in islanding mode?

3. Users distributed generators can sell electricity to other users.


IEEE 802.11, 802.15, 802.16, cellular tech. or combinations.
3.3. Electric Vehicle System

Impact on the grid:

1. Significant new load (if uncoordinated charging this can lead to overloading)

2. New way to store and supply electric power ➔ peak shaving and valley filling
3.3. Electric Vehicle System Cont.

**Info Exchange**

- **Coordinated Charging**
  - Group of vehicles optimize their charging operations → Scheduling to guarantee no overload
  - Communication among: vehicles, utilities, and stations
  - *Cellular networks and VANETs*

- **Realizing V2G**
  - Sell electricity (in excess) to the grid at peak time
  - Communications between car owner and utility
  - *Use any available wireless network in vehicle location*
3.4. Monitoring System

To enable self-monitoring and self-healing:

1. Large number of sensors are deployed to detect failure events

2. BS reports periodically the grid status to the operator (through fibre optics backbone)

   Wireless Sensor Network for communication between sensors and the BS via one-hop or multi-hop communications
Outline

1. Introduction

2. Overview of Smart Grid

3. Wireless Communication and Networking Paradigms in Smart Grid

4. Challenges for the Research on Wireless Technologies in Smart Grid

5. Conclusions
4. Challenges

Four Issues:

1. QoS of Information Data
2. Wireless Communication Network Management and Control
3. Security and Privacy
4. Interoperability and Compatibility
4.1. QoS of Info Data

**Data Types**

- **Critical Data**
  - e.g. grid status info collected by monitoring system

- **Non-critical Data**
  - e.g. user energy consumption and billing info exchange

**Differentiated QoS:** guarantee that critical data are delivered in timely manner (unreliable wireless environment)
4.2. Wireless Network Management

1. Wireless network should be organized in centralized or distributed manner?

- On one hand: traditional utility will still play a dominant role in the foreseeable future ➔ info is still controlled and managed by one or more centralized electric utilities

- On the other hand: many distributed entities are introduced in the smart grid ➔ prefer distributed and self-organized communication network

- An open question
2. How to optimize the heterogeneous wireless communication system underlying the smart grid?

- Smart meter may exchange info with appliances using ZigBee, with utilities using WiMAX, and with the house owner using cellular network

- How to jointly optimize these networks to reduce cost and improve wireless resource utilization
4.3. Security and Privacy

**Malicious Attacks**

- **Network Availability**
  - Delay or block info transmission
  - Threat to real-time monitoring

- **Info Privacy**
  - Info stored at meters
  - Can reveal info on user habits and activities

- **Data Integrity**
  - Modify or corrupt data
  - False-data injection attack (grid status)
4.4. Interoperability and Compatibility

Smart grid = integration of complimentary components, functions, and subsystems → different wireless communication protocols are used:

1. How to take advantage of legacy infrastructure to reduce deployment and installation cost? Ex: using cellular networks and WiFis

2. We must consider that the current design of the wireless communication systems underlying the smart grid can be easily upgraded to support new features
5. Conclusion

1. Introduction
2. Overview of Smart Grid
3. Wireless Communication and Networking Paradigms in Smart Grid
4. Challenges for the Research on Wireless Technologies in Smart Grid