# Special Issue on Communications and Networking for the Smart Grid

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The next generation electric grid, also known as the smart grid, is expected to be scalable, reliable, efficient, and secure, and facilitate deployment of renewable and distributed energy generation. The modern communications and networking technologies will play a vital role in the smart grid by supporting two-way energy and information flow and enabling more efficient monitoring, control, and optimization of different grid functionalities and smart power devices. The emerging field of smart grid has introduced new challenges for the communications and networking research communities. It has also created new multi-disciplinary research opportunities and potentials for collaborations among researchers in the communications, networks, signal processing, security, and power engineering areas.

This special issue of JCN puts together nine research articles related to smart grid communications and networking. In particular, these research articles cover issues related to using cognitive radio, cooperative and relay communications in the smart grid, demand side management in the smart grid, and security and authentication in the smart grid systems. A brief account for each of the articles is provided below.

## Security in the Smart Grid

The supervisory control and data acquisition (SCADA) systems work as the "brain" in a traditional power grid. As the traditional power grid evolves towards the smart grid, the conventional SCADA systems should be designed to work in a more distributed manner and provide new services in a secured fashion in a wide-area communication environment. The article titled "Wide-area SCADA system with distributed security framework" by Y. Zhang and J.-L. Chen presents an architecture and a security framework for such a distributed SCADA system based on the concept of distributed event-based systems (DEBS). In this SCADA service communication architecture, publisher and subscriber nodes are connected to a set of broker nodes, which form an overlay network on top of the physical network. These broker nodes enforce security control policies for end-to-end access protection with confidentiality. An implementation scheme based on homomorphic key switching is proposed for this security control.

The advanced metering infrastructure (AMI) is a core component in the smart grid which consists of meter data management servers (MDMS), data control units (DCUs), and smart meters (SMs). These components communicate with each other over an IP-based network for efficient usage and control of power. In order to have secured communication and prevent data manipulation (e.g., through impersonation attack), mutual authentication among the devices would be required. The article titled "Device authentication protocol for smart grid systems using homomorphic hash" by Y.-S. Kim and J. Heo develops two mutual authentication protocols between an SM and an MDMS so that they can authenticate one another and establish a secure communication channel. The proposed protocols use a matrix-based homomorphic hash to reduce the computations in a resource-constrained smart meter.

## Cognitive Communications

The utilization of radio spectrum for wireless communications in the smart grid environment can be improved by using the cognitive radio techniques. In the article titled "Biform game based cognitive radio scheme for smart grid communications" by S. Kim, the author proposes a spectrum management approach for cognitive wireless communications in a smart grid environment. The spectrum management approach uses a biform game, which is a hybrid noncooperative-cooperative game model that can be used for two-stage decision problems. In the first phase of the proposed model, the secondary user entities adaptively form clusters for cooperative spectrum sensing based on a cooperative game model. In the second phase, the detected spectrum opportunities are shared among the secondary users based on a cooperative bargaining game model. The performance of the proposed spectrum sensing and allocation method is evaluated by simulations.

ZigBee technology for short-range and low-power wireless communications will be used for smart metering in a home area network which is inter-networked with the smart grid communications network infrastructure. However, since ZigBee uses the same spectrum band (e.g., license-exempt 2.4 GHz band) as the IEEE 802.11-based wireless LAN technology, ZigBee networks could be vulnerable to interference from WLANs. Therefore, efficient techniques will be required for their coexistence with the WLANs. In the article titled "Cognitive beamforming based smart metering for coexistence with wireless local area networks" by K. Lee, C.-B. Chae, T.-K. Sung, and J. Kang, the authors propose a beamforming technique for the ZigBee network such that the required data rate for smart metering can be achieved and the transmit power can be minimized while causing no harmful interference to WLAN nodes (i.e., satisfying an interference power constraint). Also, to reduce the transmission energy even further, the authors propose an idea of dividing the metering data into multiple frames.

## Cooperative & Relay Communications

Wireless technologies including the IEEE 802.11-based WLANs and IEEE 802.15.4-based WPANs will be key technologies for smart grid communications networks. In particular, the IEEE 802.11sbased wireless mesh networking technology is promising to build the neighborhood area network (NAN) infrastructure for reliable and high-speed data communication in a smart grid environment. The IEEE 802.11s uses the enhanced distributed channel access (EDCA) method at the medium access control layer and the hybrid wireless mesh protocol (HWMP) at the routing layer. However, the traditional HWMP protocol may not work well in a smart grid communication environment, for example, due to inaccurate link cost metric calculation and mishandling of quality of service (QoS)-sensitive smart grid data. The article titled "Improving the reliability of IEEE 802.11s based wireless mesh networks for smart grid systems" by J. Kim, D. Kim, K.-W. Lim, Y.-B. Ko, and S.-Y. Lee proposes a reliability enhanced architecture for HWMP (namely, HWMP-RE) in an IEEE 802.11s-based wireless mesh network. The proposed architecture provides a route recovery mechanism, reduces route fluctuations, and considers the requirements for the smart grid data. The performance of the proposed HWMP-RE architecture is evaluated by NS-3 simulations.

The article titled “Smart grid cooperative communication with smart relay” by M. H. U. Ahmed, Md. G. R. Alam, R. Kamal, C. S. Hong, and S. Lee describes a wireless mesh architecture enhanced with relay nodes for smart grid communications. A relay selection method is proposed for cooperative communications in this architecture. The performance of the cooperative communication method is evaluated by simulations.

The Ethernet networks will be used extensively for data communication in a smart grid environment. The high-availability seamless redundancy (HSR) is a redundancy protocol at layer 2, which is used for fault tolerance in Ethernet networks. This HSR protocol transmits duplicate frames for each frame sent and thus doubles the traffic in the network. This may cause congestion and thus degrade the network performance. The article titled “Improvement of high-availability seamless redundancy (HSR) traffic performance for smart grid communications” by S. A. Nasif and J. M. Rhee proposes two approaches, namely, the quick removing (QR) and the virtual ring (VRing) approaches, to mitigate this problem. The first approach removes the duplicate frame from the network when all nodes have received one copy of the frame. The second approach divides any closed-loop HSR network into several virtual rings each of which will circulate the traffic of a corresponding group of nodes within it.

## Demand-Side Management

Plug-in hybrid electric vehicles (PHEV), which will be used widely in future generation transportation systems, will significantly increase the demand for electric power. The integration of these PHEVs into the smart grid will require intelligent methods for their charging and discharging so that the energy consumption profile for the PHEV owners is optimized and supply and demand in the power grid can be balanced. The article titled “Optimal charging and discharging for multiple PHEVs with demand side management in vehicle-to-building” by H. K. Nguyen and J. B. Song deals with the problem of designing optimal charging and discharging schedules for PHEVs in a vehicle-to-building (V2B) system. First, a centralized optimization problem is formulated as a convex program with an objective to minimizing the difference between the instantaneous energy demand and the average energy demand. Second, a noncooperative energy charging and discharging scheduling game is formulated. Based on this game model, the authors present a distributed algorithm in which each PHEV independently selects its best battery charging and discharging schedule to minimize its energy charging cost. The algorithm converges to the Nash equilibrium of the non-cooperative game.

In a similar spirit, the next article titled “Comparison of intelligent charging algorithms for electric vehicles to reduce peak load and demand variability in a distribution grid” by K. Mets, R. D’hulst, and C. Develder introduces two approaches to schedule charging of PHEVs in order to avoid the negative effects that the additional load due to the PHEVs may have on the power distribution grid. The first approach uses quadratic programming and discusses three algorithms. The second approach is based on a single-shot multi-unit auction market mechanism where the power distribution grid is organized as a commodity market and agents (i.e., sellers and buyers) act on behalf of the transformer and the households. The goal of both approaches is to minimize the peak load and load profile variability resulting from charging the PHEVs. The performance evaluation results show that the approaches based on quadratic programming perform better than the multi-agent system approach in terms of peak load and load profile variance reduction. However, the market-based approach is more flexible, requires less stringent knowledge of the load profiles, and also involves very limited information exchange when compared to the quadratic programming-based approaches.

We hope that you will enjoy reading this issue and find the articles useful. We would like to thank all the reviewers for their time in reviewing the articles submitted to this special issue. Our special thanks to Yumin who has constantly monitored the status of the progress of the review process and guided us throughout the process.

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In the framework of the mobile VCE, he has pioneered research on distributed cooperative space-time encoded communication systems, dating back to December 1999. He has published more than 150 technical journal and conference papers at a citation h-index of 30 and citation g-index of 64, holds a dozen patents, authored, co-edited, and contributed to 19 books, has given more than 30 international short-courses, and participated in ETSI, IETF, and other standardisation activities. He has been TPC Member and Co-Chair of various conferences, such as Technical Chair of IEEE PIMRC 2008 held in Cannes, France. He is Editor-in-Chief of ETT and is/has been holding various editorial positions for numerous IEEE and non-IEEE journals. He is Senior Member of the IEEE and Distinguished Lecturer of IEEE ComSoc. He had press coverage by BBC, Wall Street Journal, among others. He is fluent in 6 languages.

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