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EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: THE INTERNET OF ENERGY: ARCHITECTURES, CYBER SECURITY, AND APPLICATIONS—PART II

The energy crisis and carbon emissions have become two critical concerns globally. As a very promising solution, the concept of Internet of Energy has appeared to tackle these challenges. The Internet of Energy is a new power generation paradigm developing a revolutionary vision of smart grids into the Internet. The communication infrastructure is an essential component for implementing the Internet of Energy. A scalable and robust communication infrastructure is crucial in both operating and maintaining smart energy systems. The wide-scale implementation and development of Internet of Energy into industrial applications should take into account the following challenges:

- **Integrating highly scalable and distributed alternative energy generating sources with other available power grid systems:** To promote a green-energy-based industry and society and realize the optimization of energy utilization, the efficient gathering, transportation, and storage, and how to integrate these into the existing power grid are great challenges.
- **Advanced metering, monitoring and controlling systems:** Since the observability, controllability and predictability are three critical aspects in the Internet of Energy, real-time monitoring and controlling are faced with great challenges in order to collect precise energy consumption data, give deep analysis and provide rich user information. Thus, users can adjust their energy consumption intelligently with optimization as a main goal.
- **Cyber Security and Privacy-aware data management for Internet of Energy:** Among many applications in Internet of Energy, energy consumption data could be linked and mined to gain useful insights for optimization of energy utilization. At the same time, privacy and security concerns can prevent the information disclosure, energy waste and disaster. Further safeguards are needed to build trust in the data, which is instrumental for making critical decisions for the development of Internet of Energy.

While there are several well-established senior journals, such as the IEEE Transactions on Industrial Informatics, the IEEE Transactions on Smart Grid, and the IEEE Systems Journal, this Special Section in the IEEE Access focuses on the architectures, cyber security, and applications in the Internet of Energy. Eleven high-quality articles have been accepted from leading groups around the world after a rigorous peer-review process. IEEE journals are considered as the flagship journals in the engineering field. The IEEE Access is a new multidisciplinary, application-oriented, all-electronic archival journal which continuously presents the results of original research or development across all the IEEE's fields of interest. Because of its open access nature, this Special Section is freely accessible to all readers all around the world.

1) Because sensor nodes equipped with little batteries cause Wireless Sensor Networks to have a limited lifetime, the chargers are located on vehicles or mobile robots and all nodes can be recharged as the vehicles move around the WSN. In the article by Han *et al.* "MCRA: a multi-chargers cooperation recharging algorithm based on area division for wireless sensor networks," the authors propose Multi-Chargers Cooperation Recharging Algorithm (MCRA), analyzing the relationship of the movement energy consumption and energy transfer to the nodes, to prolong the lifetime of WSN. Then, the MCRA proves its practicability by theoretical derivation.
2) Having millions of sensors as the monitors can also consume huge amounts of energy in WSN. Quorum-based MAC protocol schedules nodes' wake-up times and decreases idle listening and collisions, increasing the network throughput and extending the network lifetime. However, how do you minimize delay while ensuring the network lifetime? Liu *et al.* in their article "QTSAC: a energy efficient mac protocol for delay minimized in wireless sensor networks," describe a novel Quorum time slot adaptive condensing (QTSAC)-based MAC protocol, achieving delay minimization and energy efficiency for the WSN.
3) One of the vital applications of the Internet of Energy (IoE) is to make full use of dynamic service combinations to meet the requirements of green energy management and match supply and demand. To achieve these objectives, in "Green energy management of the energy internet based on service composition quality," Qi *et al.* propose a service combination method for

quality-oriented green energy management, introduce the most economical control theory, and set the service quality as the most economical objective control function to realize a Pareto-efficient energy service management under quality of service demands. Then, a multi-objective algorithm is proposed to solve the above- using rapid convergence.

4) A case of load fluctuations occurs at the demand side, and hence previous works focused on elastic energy distribution to mitigate distribution level load fluctuations. Ma *et al.* in their article, "Elastic energy distribution of local area packetized power networks to mitigate distribution level load fluctuation," develop a cross-time hierarchical energy distribution scheme to coordinate energy distribution of dc sector and ac sector and exploit the elasticity of dc sector loads on both day-ahead basis and real-time basis, leading to a mitigation of distribution load fluctuation. Then, power distributions are optimized separately for different procedures of the scheme.
5) Another case of optimization happens in energy delivery. However, few of these works took the IoE architecture into account. In the article by Du *et al.* "Efficient forecasting scheme and optimal delivery approach of energy for the energy Internet," the authors design the architecture of the IoE under the backdrop of large-scale RES grid connection and the efficient forecasting and optimal utilization of energy.
6) Considering the optimal management in the IoE, such as energy utilization, etc., there is little consideration for the profit optimization in the IoE. The existing auction mechanisms can provide benefits for both primary users and secondary users. However, the economic efficiency of the auction is usually neglected. Zhai *et al.* in the article, "Truthful double auction for joint Internet of Energy and profit optimization in cognitive radio networks," model a profit maximization double auction mechanism to improve the benefit of networks with low energy. At the same time, security concerns are considered because buyers and sellers make their true critical decision.
7) How to preserve IoE's security is an important issue. However, most of the existing security works consider less about the Power cyber-physical systems (PCPSs) of IoE. In the article by Ge *et al.* "Security analysis of energy Internet with robust control approaches and defense design," the authors consider the unsafe uncertainties, construct a general cyber-attack model, and design a double-loop architecture for security defense. Then, security control scenarios are obtained from the character of each kind of cyber-attack according to this architecture.
8) Demand response (DR) management in IoE faces a number of unique cyber-physical security challenges. However, optimizing the security of demand response (DR) management with given energy states under IoE circumstance is rarely studied. Li *et al.* in their article "Fog computing-enabled secure demand response for Internet of Energy against collusion attacks using consensus and ACE," propose a fog computing enabled secure demand response (FSDR) scheme for IoE against collusion attacks using consensus and access control encryption.
9) The new-generation IoE endpoint devices face several challenges of software cryptography performance cost. However, few people have analyzed the performance cost of software encryption. Ledwaba *et al.* in the article "Performance costs of software cryptography in securing new-generation internet of energy endpoint devices," analyze whether endpoint nodes should still be considered capable of only supporting the most lightweight of cryptographic mechanisms, and evaluate whether or not microcontroller units are easily capable of running standard cryptographic algorithms.
10) With the research of blockchain in IoE, quantum computing attack seriously threatens the security of blockchain. To solve this problem, in "A secure cryptocurrency scheme based on post-quantum blockchain," Gao *et al.* present the definition of post-quantum blockchain (PQB) and propose a secure cryptocurrency scheme based on PQB, which can resist quantum computing attacks.
11) As an important part of the IoE, electric vehicles (EVs), and charging pile management are of great significance to the development of the IoE industry. However, few studies have considered the security of the management between EVs and charging piles. In "LNSC: a security model for electric vehicle and charging pile management based on blockchain ecosystem," Huang *et al.* model the lightning network and smart contract (LNSC) based blackchain. The proposed security model can be easily integrated with current scheduling mechanisms to enhance the security of trading between EVs and charging piles.

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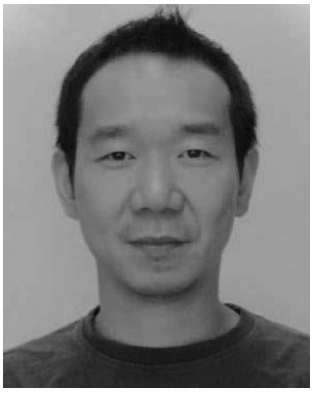

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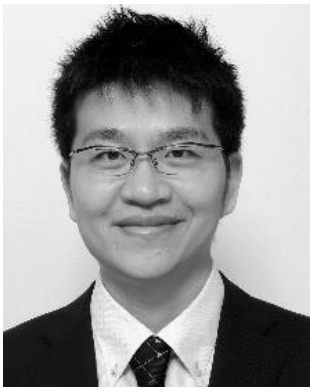

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