EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: GREEN COMMUNICATIONS ON WIRELESS NETWORKS

Green communications, focusing on energy efficiency, is a hot topic in both academic and industry communities since they can significantly improve sustainability concerning power resources and environmental conditions. Later, with much focus on this area, several green communication methods started enrolling into a more thoughtful phase, with compelling applications in several networks. For instance, a simple and effective green communication solution is to arrange a sleep mode device incorporated by several MAC protocols with broad wireless network applications. However, it is required to examine the trade-off between green communications' energy efficiency and network requirements. In addition, it is crucial to appraise the performance concerning the energy consumption, the throughput, and the response time, regarding green communications under different wireless network conditions (e.g., different traffic and different channels).

With this motivation, this Special Section in IEEE ACCESS solicited the submissions of high-quality articles that addressed the open technical problems and challenges concerning green communications, taking into account the constraints of wireless networks. In particular, submissions were sought that efficiently integrate novel approaches, focusing on the network performance evaluation and comparison with existing green communication solutions.

The "Call for Papers" aroused great enthusiasm in the scientific community and received 141 submissions. Out of these, 47 articles were accepted for inclusion in the Special Section after a thorough review process by at least two independent referees. An analysis of the accepted articles, in chronological order, is carried out in the following, highlighting the authors' various research fields.

The article "Efficiency optimization for communication service based on QoS technology," by Li, proposes a novel algorithm, coupling security computing and Quality of Service (QoS), to enhance security credibility and communication service efficiency. The experimental results prove that the proposed solution can not only meet the quality requirements of users but also solve the security and credibility problems, and enhance the accuracy of semantic matching and the efficiency communication service.

The article "An energy-efficient scheduling approach for flexible job shop problem in an Internet of manufacturing Things environment," by Tian *et al.*, focused on the energy-efficient scheduling and real-time control of flexible job shop, which demands rescheduling affected operations and updating the scheduling. The authors suggest negotiation- and cooperation-based information interaction and process control method, which combines the Internet of Things (IoT) and energy-efficient scheduling method. The tests reveal that the proposed approach achieves a good effect in engineering applications, while optimization's efficacy is also proven.

The article "Toward energy efficiency aware renewable energy management in green cellular networks with joint coordination," by Jahid *et al.*, examines energy efficiency performance with a hybrid-powered off-grid LTE-A macro-cell base station striving maximum usage of renewable energy. The solution introduced by the authors is validated, and the obtained results confirm that a dual-axis tracking mode photovoltaic array with a high nominal battery bank capacity shows superior system performance compared to others.

The article "To reduce delay, energy consumption and collision through optimization duty-cycle and size of forwarding node set in WSNs," by Wang *et al.*, presents an investigation converged on comparing several approaches for the best duty cycle in Wireless Sensor Networks (WSNs). The analysis highlights that using a proper approach can lessen the end-to-end delay by 20.52%-79.96%, and, consequently, enhance energy efficiency.

The article "Long-term routing stability of wireless sensor networks in a real-world environment," by Lim *et al.*, appraises real-world WSN routing stability employing historical routing paths generated from ZigBee PRO nodes. The obtained results prove that routing stability is subjected to a link's quality, the implemented routing protocols, and the available routing options.

The article "Study on energy consumption optimization scheduling for Internet of Things," by Ding and Wu, introduces an energy-loss optimization scheduling modeling method based on a multi-objective fuzzy algorithm. The experimental results determine that the proposed solution has

the characteristics of high precision and considerable energy saving.

The article "Mobile multi-sink nodes path planning algorithm concerned with energy balance in wireless sensor networks," by Sun *et al*., proposes a mobile multi-sink nodes path planning algorithm with energy balance. The experimental results show that the proposed algorithm solves the "empty hole" problem effectively, balances the energy consumption of nodes, extends the network lifetime, and minimizes network latency.

The article "Assessing the energy consumption of proactive mobile edge caching in wireless networks," by Yan *et al*., proposes a predictive caching algorithm that employs big data analytics to foretell user content requests and ascertain what content items need to be cached to deliver a more reliable quality of experience (QoE). The simulation results produce practical shrewdness for mobile operators to appraise the trade-off between cache energy consumption and transport energy, and the trade-off between refresh cycles and the total energy consumption of multiaccess edge computing and caching (MEC).

The article "A comprehensive study on enterprise Wi-Fi access points power consumption," by Silva *et al*., provides a thorough review of the power consumption and energy efficiency per bit of enterprise Wi-Fi access points (APs). The authors ascertain that the standby state discloses the least amount of power usage, and TX mode employs more power than RX mode, the same way that single-band uses scarcer power than dual-band devices, with the 5-GHz radio interface utilizing more power than the 2.4-GHz radio interface.

The article "Accelerating content delivery via efficient resource allocation for network coding aided D2D communications," by Xiao *et al*., investigates the resource allocation problem for network coding-assisted device-to-device (D2D) communications underlay cellular network. Simulation results show that the random linear network coding aided cooperative scheme achieved system sum-rate improvement of about 12% compared to the decode-and-forward cooperative scheme.

The article "Numerical optimization of the energy consumption for wireless sensor networks based on an improved ant colony algorithm," by Chu *et al*., introduces an optimization algorithm for WSN data collection based on an artificial bee colony method. The obtained results confirm that the proposed solution is more diminutive than other algorithms concerning energy consumption, which significantly increases the reliability and promotion of mobile wireless networks' reliable and orderly development.

The article "An efficient target tracking approach through mobile crowdsensing," by Luan *et al*., proposes an efficient target tracking approach to solve the target tracking problem. The experimental results demonstrate that the proposed solution can effectively track the target movement.

The article "Testing dynamic composition of semantic Internet of Things services based on QoS," by He *et al*., embellishes the research background and theoretical support of the QoS-based service composition method in semantic IoT and designs a composition framework and related codes. The evaluation of the proposed algorithm confirms its polynomial-level time complexity, stable performance in a massive service environment, and provides a basis for any time return to the optimal service composition method.

The article "Hybrid energy ratio allocation algorithm in a multi-base-station collaboration system," by Han *et al*., acquaints a multi-base station (BS) collaborative energy allocation algorithm, called hybrid energy ratio allocation (HERA), under renewable energy (RE) generation uncertainty, which is able to balance the time-of-use (TOU) power price of a smart power grid and the energy storage of a BS. The simulation results indicate that the HERA algorithm can maintain more REs under low power prices while employing more REs under high power prices.

The article "Offloading design for energy and spectral efficiencies tradeoff in massive MIMO enabled heterogeneous cellular networks," by Zhou *et al*., introduces two types of offloading mechanisms to achieve a tradeoff between energy-efficiency and spectral-efficiency experiences for massive multiple-input-multiple-out put enabled heterogeneous cellular networks. The simulation results determine that the designed mechanisms can achieve a trade-off between energy efficiency and spectral efficiency experiences by properly adjusting users' weighting parameters.

The article "An energy-efficient collaborative caching scheme for 5G wireless network," by Furqan *et al*., presents an energy efficiency based in-network caching scheme to ensure the energy efficiency and high cache performance of a content-centric network caching system. Simulation results show that the proposed scheme can outperform the existing scheme concerning content popularity, placement, and local hit rate, significantly improving energy efficiency in the 5G network hotspot.

The article "Energy aware resource allocation in multi-hop multimedia routing via the smart edge device," by Al-Turjman *et al*., introduces a novel multi-hop routing approach to increase the energy efficiency of device-to-device communication systems. The result shows that the proposed heuristic routing achieves better performance than the other existing techniques.

The article "Clustering routing algorithm and simulation of Internet of Things perception layer based on energy balance," by Xu *et al*., presents an algorithm that considers the residual energy of the node and the distance between the cluster head and the sink, which reduces the possibility that the node energy is still selected as the cluster head, and the cluster head is consumed by the single-hop transmission data due to the distance from the sink. Simulation results show that the proposed method achieves more reliable results, more balanced network energy consumption, lowest energy consumption of cluster head nodes, better network connectivity, and reliability, thus proving that the algorithm can effectively extend the network's life.

The article "Energy-efficient switching on/off strategies analysis for dense cellular networks with partial conventional base-stations," by Jian *et al.*, introduces an approach that jointly optimizes the switching on/off strategy and user association policy taking into account the QoS. Simulation results show that the proposed solution outperforms other proposed solution strategies in energy efficiency, improving and energy saving, and can significantly improve energy efficiency and reduce switching cost when the switching cost occupies a considerable proportion in the total energy consumption.

The article "Heterogeneous energy and traffic aware sleep-awake cluster-based routing protocol for wireless sensor network," by Shagari *et al.*, investigates energy efficiency and load balancing issues in a heterogeneous WSN scenario. The approach proposed by the authors is evaluated and compared against other solutions in terms of network lifetime, remaining energy, and throughput, and the obtained results prove its efficacy.

The article "Energy-saving algorithm and simulation of wireless sensor networks based on clustering routing protocol," by He, presents an efficient and energy-saving algorithm to solve node energy constraints, short network cycle, and low throughput in current WSNs. The simulation results determine that the proposed protocol can effectively reduce energy consumption, the energy consumption difference between nodes, and prolong the network life cycle.

The article "Energy efficiency analysis in cache-enabled D2D-aided heterogeneous cellular networks," by Panahi *et al.*, aims to rely on both device-to-device communications and small cells with power control/adjustment strategy to offload traffic from the main powered macrocell base stations, leading to energy saving in the network. Experimental results confirm that there indeed exists an optimal transmission power coefficient for the femto-base station to maximize the energy efficiency in the device-to-device-enabled heterogeneous network.

The article "iSEC: An optimized deep learning model for image classification on edge computing," by Kristiani *et al.*, demonstrates an optimized cloud and edge computing environment for in-depth learning, training, and inference. Simulation results show that the proposed solution obtains good performance concerning loss and accuracy.

The article "A localization based on unscented Kalman filter and particle filter localization algorithms," by Ullah *et al.*, evaluates the performance of Unscented Kalman Filter and Particle Filter-based localization algorithms. The simulation results show that the proposed localization algorithms can be used for different purposes, such as target tracking and robot localization, and can improve localization performance.

The article "Packet dropping minimization in energy harvesting-based wireless sensor network with linear topology," by Khoshabi Nobar *et al.*, proposes an optimization framework to minimize the summation of packet dropping probability subject to the data queue stability and quality of monitoring constraints of the network nodes. The achieved results show that, for any given constraint inside the net-

work's stability region, it is possible to accomplish almost the same value for the objective function at the cost of larger queue size if the energy harvesting rate is high enough.

The article "Techno-economic and energy efficiency analysis of optimal power supply solutions for green cellular base stations," by Jahid *et al.*, examines the plausibility of optimal power supply solutions such as standalone solar photovoltaic (PV) systems, hybrid PV/wind turbine (PV/WT), hybrid PV/diesel generator (DG), and hybrid PV/electric grid (PV/EG) to feed Long-Term Evolution (LTE) base stations about technical, economic, and environmental aspects in Bangladesh. The simulation results reveal that the cell zooming technique attained energy savings yielding up to 36%.

The article "Grid quality of service trustworthiness evaluation based on Bayesian network," by Huang, expounds the development background, current situation, and future challenges of Bayesian network technology. The authors present the studying status and existing problems of grid QoS trustworthiness evaluation, and introduce a network optimization analysis method and QoS trustworthiness evaluation algorithm. The simulation results show that the proposed method can enhance service information's trustworthiness and improve the rationality of service matching in a dynamic service grid environment.

The article "Analysis of network coverage optimization based on feedback K-means clustering and artificial fish swarm algorithm," by Feng *et al.*, introduces a clustering process based on the K-means algorithm and a scoring function to dynamically adjust the system to obtain stable operation of the system and transmit information while reducing system energy consumption. The experimental results highlight that the proposed algorithm has specific practical effects, and it can be applied to subsequent WSN coverage optimization.

The article "Power allocation for downlink hybrid power line and visible light communication system," by Liu *et al.*, presents an optimal power allocation algorithm that finds an optimal solution by transforming the non-convexity of the original formulated model into the convex programming. The simulation results show that the proposed solution can maximize the sum rate compared to other approaches while considering users' fairness.

The article "Solar PV and biomass resources-based sustainable energy supply for off-grid cellular base stations," by Hossain *et al.*, investigates the feasibility of solar photovoltaic and biomass resources based hybrid supply systems for powering the off-grid Long-Term Evolution (LTE) cellular macrocell base stations in Bangladesh, focusing on the technical, economic, and environmental issues. The simulation results reveal that the proposed system is eco-friendly and technically feasible, and can also satisfy the base station energy demand independently without the support from the battery bank.

The article "A performance-to-cost analysis of IEEE 802.15.4 MAC with 802.15.4e MAC modes," by Choudhury *et al.*, performs a performance-to-cost analysis

of Deterministic and Synchronous Multi-Channel Extension (DSME) and Time-Slotted Channel Hopping (TSCH) MAC modes of IEEE 802.15.4e with 802.15.4 MAC protocol to analyze the trade-off of choosing a particular MAC mode over others. In the evaluation, the parameters considered for performance are throughput, latency, and energy consumption, and the results highlight the applicability of different MAC modes to different application scenarios.

The article "Green elevator scheduling based on IoT communications," by Van *et al.*, proposes an energy-saving elevator scheduling algorithm to diminish the energy waste in an elevator system with IoT communications. The evaluation of communication transmissions reveals that the energy-saving elevator scheduling algorithm could achieve green communications.

The article "Energy-efficient cooperative routing scheme for heterogeneous wireless sensor networks," by Hung *et al.*, proposes an energy-saving routing mechanism in which several WSNs deployed in the same geographical environment form a heterogeneous sensor network and sensor relay packets for its WSN and also for other WSNs. The obtained results show that the proposed solution prolongs the lifetime of sensors and makes more flexible relaying chances in a heterogeneous WSN.

The article "Energy-saving technology of 5G base station based on Internet of Things collaborative control," by Chang *et al.*, analyzes the principle and performance of a distributed and centralized algorithm in the base station sleep scheme, and proposes a centralized dynamic cluster sleep strategy based on genetic algorithm. The simulation results reveal that the proposed 5G base station sleep scheme has a specific energy reduction effect and can enhance the system energy efficiency.

The article "Blockchain-based distributed firmware update architecture for IoT devices," by Choi and Lee, introduces a decentralized firmware update architecture based on blockchain, which is able to distribute network load and guarantee the integrity of firmware images. The performed analysis reveals that the proposed update architecture can meet blockchain's characteristics, such as decentralization, transparency, and irreversibility.

The article "Queuing model based edge placement for work offloading in mobile cloud networks," by Chin *et al.*, investigates the problem of green communications for work offloading in mobile cloud networks by proposing two specific algorithms. Simulation results show that the proposed approach definitely lessens the traffic load generated by work offloading.

The article "FFRP: Dynamic firefly mating optimization inspired energy efficient routing protocol for Internet of underwater wireless sensor networks," by Faheem *et al.*, presents a novel dynamic firefly mating inspired routing scheme for wireless sensor networks-based time-critical marine-monitoring applications. The simulation results verify the proposed scheme's best performance against all other routing schemes, whether the values are promising.

The article "An efficiency-improved clustering algorithm based on KNN under ultra-dense network," by Liang *et al.*, formulates a convex optimization problem in which the objective is to maximize the system throughput with overlapping virtual cells and propose a clustering method to solve this optimization issue. Numerical results show that the proposed method significantly outperforms other clustering algorithms in system throughput, indicating superior performance provisioning properties.

The article "Energy efficiency optimization and resource allocation of cross-layer broadband wireless communication system," by Dong *et al.*, studies the energy efficiency in resource allocation of multi-cell cooperative massive MIMO systems. The simulation results show that the authors' method has specific effects concerning the mutual influence of cell base stations and invalid base stations' operation caused by dense base stations.

The article "Study on network security based on PCA and BP neural network under green communication," by Liu *et al.*, proposes the security organization and data communication security between network subnets based on implicit certificates within ultra-dense networks. The evaluation shows that the lightweight secure data communication method proposed by the authors can secure internal communication at the built-in network level.

The article "Optimizing content placement and delivery in wireless distributed cache systems through belief propagation," by Chuan *et al.*, focuses on the content sharing problem to minimize the average energy consumption for content caching and delivering in device-to-device-enabled cellular networks. The solution introduced by the authors is evaluated, and the results show that it can not only achieve the right balance in accuracy and convergence but also outperform in terms of delivering delay and caching hit ratio in wireless-distributed cache systems.

The article "Practical sender authentication scheme for in-vehicle CAN with efficient key management," by Youn *et al.*, proposes a sender authentication and key management scheme considering the limitations of In-vehicle CAN. The authors develop a hardware and network simulator to evaluate the proposed scheme's performance and security, and the obtained results prove that it is suitable for solving the problem of in-vehicle CAN authentication.

The article "On modeling optimizations and enhancing routing protocols for wireless multihop networks," by Al-Zahrani, presents mathematical models for flooding techniques and studies the effects of these techniques on their respective protocols concerning energy and time consumption in wireless multihop networks. The results depict that the proposed method helps in reducing delay and overall overhead during data communication.

The article "A deep reinforcement learning based approach for energy-efficient channel allocation in satellite Internet of Things," by Zhao *et al.*, introduces a novel approach for dynamic channel allocation in Satellite IoT.

The simulation results determined that the suggested solution consistently outperforms traditional channel allocation algorithms.

The article ''Social interaction assisted resource sharing scheme for device-to-device communication toward green Internet of Things,'' by Yang *et al.*, proposes a social interaction-assisted resource-sharing scheme to further improve the utilization of spectrum resources and address the problem of interference coordination between device-to-device communication and cellular networks for green IoT. The simulation outcomes revealed that the proposed scheme could deliver improvements concerning the transmission success rate for green IoT.

The article ''Energy-efficient two-tier data dissemination based on Q-learning for wireless sensor networks,'' by Wang and Hsu, proposes two two-tier data dissemination schemes based on Q-learning for WSNs. The simulation results show that the proposed schemes can effectively reduce the sensor nodes' energy consumption compared with other approaches.

The article ''Indoor positioning system using artificial neural network with swarm intelligence,'' by Cheng *et al.*, introduces a hybrid algorithm that employs an artificial neural network to resolve indoor positioning problems using swarm-intelligence algorithm to perform the time-consuming task of adjusting parameters. Experiment results prove that the proposed hybrid algorithm's positioning accuracy is equivalent to the exhaustive method, but with far shorter search times.

In conclusion, the Guest Editors would like to thank all the authors who submitted their research articles to this Special Section. Moreover, the Guest Editors highly appreciate the contributions of the reviewers for their constructive comments and suggestions. They are also grateful to the Editor-in-Chief and the Editorial Staff of IEEE ACCESS for accepting their Special Section proposal, and for their kind cooperation, patience, and active engagement.

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