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Message from the Review Board Directors

Welcome to the December 2020 issue of the IEEE ComSoc MMTC Communications – Review.

This issue comprises four reviews that cover multiple facets of multimedia communication research including multi-view clustering, radio frequency energy harvesting communications, spectrum trading, and 360-degree video streaming. These reviews are briefly introduced below.

The first paper, published in IEEE Transactions on Multimedia and edited by Dr. Tiesong Zhao, proposes a novel graph completion-based method for multi-view clustering with missing views.

The second paper is published in IEEE Transactions on Wireless Communications and edited by Dr. Ye Liu. It proposes a new non-linear recursive energy harvesting model and new transmission scheduling strategies using the model.

The third paper, published in IEEE Internet of Things Journal and edited by Dr. Qin Wang, proposes a blockchain-based secure spectrum trading and sharing system for unmanned aerial vehicles (UAV)-assisted cellular networks.

The fourth paper, published in IEEE INFOCOM 2020 and edited by Dr. Mengbai Xiao, proposes a 360-degree video streaming system that uses super-resolution for reducing the bandwidth requirement.

All the authors, reviewers, editors, and others who contribute to the release of this issue deserve appreciation with thanks.

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Graph Completion-Based Method for Incomplete Multi-View Clustering

A short review for "Adaptive Graph Completion Based Incomplete Multi-View Clustering"
Edited by Tiesong Zhao

Jie Wen, Ke Yan, Zheng Zhang, Yong Xu, Junqian Wang, Lunke Fei, Bob Zhang, "Adaptive Graph Completion Based Incomplete Multi-View Clustering," IEEE Transactions on Multimedia, Early Access Article, 2020.

Multi-view clustering aims at grouping data samples by exploiting compatible and complementary information from multi-view data. It is a highly useful technique in computer vision tasks [1]. In this problem, a common assumption is the complete existence of all views in each sample. However, this may not be guaranteed in real-world applications, which brings challenges to explore underlying clustering structure of incomplete multi-view datasets.

Many research works have been conducted to the incomplete multi-view clustering problem, such as kernel canonical correlation analysis (KCCA) based [2], non-negative matrix factorization based and multi-modality grouping [3] methods. However, these methods are inapplicable to the data with multiple incomplete views. To this end, some weighted matrix factorization based [4], graph based [5] and deep learning based [6-7] incomplete multi-view clustering methods have also been proposed. These methods aim to obtain a common representation while ignoring the information of missing views and the information imbalance factor of these incomplete views, thereby resulting in limited performances.

The traditional multi-view spectral clustering was utilized to process incomplete multi-view data; however, it is not able to construct a complete similarity graph for clustering. To this end, this paper proposes an adaptive graph completion-based method. It integrates the interactions of within-view preservation, between-view inferring, consensus representation learning and adaptive weight assignment in a joint framework for graph completion and consensus representation learning. Simultaneously, adaptive weights are learned to highlight the crucial components and reduce the negative effects of redundant factors, leading to a more discriminative consensus representation.

By employing an alternative iterative optimization approach in objective function, this framework recovers complete similarity graphs of different views with the optimal underlying clustering structure and then aggregates them to obtain more discriminative consensus representation for spectral clustering, thereby achieving good clustering performances.

Experimental results on both text documents and images indicate the following findings:

1) The multi-view clustering methods show superior performance to that of the best single view, which suggests a powerful potential for multi-view learning;
2) In multi-view clustering methods, this work outperforms several state-of-the-arts in terms of clustering performances, evaluated by six evaluation metrics;
3) The performance of this work is believed to be benefitted from its exploration of more complementary and consistency information of incomplete multi-view data.

In summary, this paper handles the incomplete multi-view data clustering problem and provides a new perspective to exploit hidden rewarding patterns from multi-view or multi-modal data. Two beneficial defined measures, including within-view preservation and between-view inferring, are available to evaluate the quality of multi-view heterogeneous data sources. As a result, encouraging clustering performance is achieved on five well-known real-world datasets. This may also facilitate to explore several potential interesting integrations with other fields, such as low-rank recovery, signal random sampling and reconstruction.

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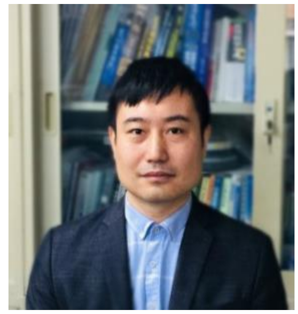

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Practical Transmission Scheduling in Energy Harvesting Wireless Communication Systems

A short review for "A Nonlinear Recursive Model Based Optimal Transmission Scheduling in RF Energy Harvesting Wireless Communications"

Edited by Ye Liu

Y. Luo. L. Pu, Y. Zhao, W. Wang and Q. Yang, "A Nonlinear Recursive Model Based Optimal Transmission Scheduling in RF Energy Harvesting Wireless Communications," IEEE Transactions on Wireless Communications, vol. 19, no. 5, May 2020.

Sustainability is an ever-increasing demand for the Internet of Things (IoT) [1], as numerous embedded smart devices are required to sense, compute, and communicate with each other frequently, but the energy is limited. Benefit from the energy harvesting techniques [2] [3], it is possible for the IoT devices to achieve energy-neutral operation through obtaining ambient energy from radio-frequency signal, solar energy, vibration and other renewable energy sources. However, a critical issue faced is how to efficiently use the harvested energy because of the dynamic characteristics of ambient energy sources in terms of power density, duration, location, etc. Thus, optimal transmission scheduling is one fundamental problem in energy harvesting communication systems [4].

During the past decade, many transmission scheduling approaches [5] have been proposed to improve network performance under certain energy collected. However, most of them are designed based on the conventional energy harvesting model and leads to the inaccurate energy calculation because the harvested energy is modeled as random process with predetermined values. In fact, other factors, such as data transmission and nonlinear charging characteristics, also affects the amount of energy can be harvested. Therefore, more accurate and realistic energy harvesting models are crucial. To fill this gap, this paper makes threefold contributions, which are summarized as follows.

First, the nonlinear charging characteristic of batteries and impact of transmission scheduling strategies on the harvested energy are discussed in an in-depth way. Circuit non-linearity leads to nonlinear power conversion efficiency, as matching circuit, rectifier, voltage multiplier, and other circuit components all exhibit nonlinear characteristic. In addition, battery charging process is also nonlinear, so the instantaneous harvested energy is hard to estimate accurately. Furthermore, the batteries, such as super-capacitor and lithium cell, are usually imperfect because of energy leakage, capacity degradation, and imperfect knowledge of battery status. Finally, the relationship between transmission power and circuit power consumption is not linear and causes the circuit power non-linearity. Therefore, it is really difficult to describe energy harvesting process perfectly.

Second, the nonlinear energy harvesting process is illustrated through in-depth theoretical and experimental analysis to prove the limitations of transmission scheduling based on conventional energy harvesting model. Especially, the energy-voltage function of energy storage, energy level function, and the maximum residual energy function are given to model the charge characteristic of energy harvesting devices. For experimental measurements, the Powercast P2110 development kit, Micro850 controller, and PannelView800 display are used to generate ambient energy, control the charging time, and results demonstration, respectively. Based on these efforts, the relationship between normalized residual energy and harvested energy is obtained, and an interesting/crucial finding is that a global optimal point for the maximum energy harvesting efficiency is exist. Moreover, the novelty of the above nonlinear energy harvesting model lies in a feedback loop from data transmission to energy harvesting module is added to represent the nonlinear charging process.

Third, although a more realistic energy harvesting model is obtained, it is still challenging to design practical transmission scheduling in energy harvesting communication systems, as the correct connection between the harvested energy and the transmission strategy is hard to establish. To solve this problem, recursive algorithm is exploited to design optimal offline transmission scheduling. Extensive evaluations show that the proposed approach improves network throughput and increases the energy that can be harvested compared with conventional strategies. In addition, the feasibility of online transmission scheduling and corresponding policy is discussed for a comprehensive consideration.

In summary, the proposed new nonlinear recursive energy harvesting model and practical offline/online transmission scheduling strategies are big steps forward for the sustainable wireless communication systems [6] and the Internet of Things.

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Blockchain Enabled Spectrum Trading for UAV-Assisted Cellular Network

A short review for "Blockchain-Based Secure Spectrum Trading for Unmanned-Aerial-Vehicle-Assisted Cellular Networks: An Operator's Perspective"

Edited by Qin Wang

J. Qiu, D. Grace, G. Ding, J. Yao and Q. Wu, "Blockchain-Based Secure Spectrum Trading for Unmanned-Aerial-Vehicle-Assisted Cellular Networks: An Operator's Perspective," IEEE Internet of Things Journal, vol. 7, no. 1, Jan 2020.

In recent years, unmanned aerial vehicles (UAVs) have attracted increasing interest and are expected to be an important complementary part of future wireless communication networks due to their remarkable advantages of low cost, high mobility, and deployment flexibility [1]–[3]. To fully reap the benefits of deploying UAVs for communication purposes, some core technical challenges still need to be faced with. On the one hand, most UAVs in the market basically operate on the unlicensed spectrum, which is usually of limited data rate, unreliable, and vulnerable to interference, thus severely restricting the potential performance of UAVs [4]. On the other hand, there always exist significant security and privacy threats for UAV-assisted wireless communications due to the untrusted broadcast features and wireless transmission of UAV networks.

In fact, UAVs and ground base stations often belong to multiple different operators, each selfishly seeking to maximize their individual benefit. In general, the cellular network operators will be not willing to share their own spectrum to the UAV networks, since the total usable bandwidth of the cellular networks is limited and sharing part of the total bandwidth with UAVs may harm the capacity of the cellular base stations. Thus, to promote the adoption of spectrum sharing, some incentive mechanisms should be developed to motivate the mutual cooperation between the operators. However, there are significant security and privacy challenges for such peer-to-peer (P2P) spectrum trading in UAV-assisted cellular networks. Blockchain technology may provide possible solutions addressing the security and privacy challenges because of its advantages of decentralization, anonymity, and trust.

In this paper, the consortium blockchain technology is exploited to develop a secure spectrum trading system named spectrum blockchain for UAV-assisted cellular networks. Besides, to deal with the computation-intensive blockchain creation and verification process, mobile edge computing is applied to help to offload the computation task to proximate authorized edge computing nodes. Under the mobile edge computing aided consortium blockchain framework, secure spectrum trading between the mobile network operator (MNO) and the UAV operators with privacy protection can be achieved in a distributed manner, which is more suitable for energy-constraint UAV networks. Moreover, since spectrum pricing along with the amount of traded spectrum need to be optimized in the spectrum blockchain, a Stackelberg game is formulated to jointly maximize the profits of the MNO and the UAV operators.

Thus, the authors' major contribution is to propose a pricing-based incentive mechanism to motivate the MNO to open its owned spectrum for UAV networks. A Stackelberg game is formulated to obtain the optimal spectrum pricing and purchasing strategies, which can jointly maximize the revenues of the MNO and the UAV operators. A spectrum blockchain framework is proposed to illustrate the detailed operations to address the potential security and privacy issues caused by malicious attacks in the spectrum trading process. A consortium blockchain is presented in which the consensus process is executed on preselected nodes with moderate cost.

In the Stackelberg game, there are two kinds of participates, i.e., the MNO and the UAV operators. The interactions between them aim to find the optimal unit price and the optimal amount of spectrum each UAV should buy. The MNO's objective is to maximize its revenue obtained from selling the spectrum to the UAV operators. Mathematically, the utility function of the MNO is decided by the unit price and the amount of spectrum vector bought by all UAVs. From the spectrum purchaser's perspective, the utility function of an arbitrary UAV operator is defined as the payoff/benefit grained from allocated spectrum minus the cost incurred due to buying the spectrum. The payoff/benefit function is usually called as the spectrum obtainment gain, which is an increasing function of the amount of bought spectrum. A log function is used to model the spectrum obtainment gain in this paper. The cost function is decided by the cost incurred when the UAV operator purchases spectrum from MNO. In general, the cost increases with the increasing of the amount of obtained spectrum. It is modeled as the product of the unit price and the amount of obtained spectrum bought by a UAV.

There are mainly three parts for the operation of the spectrum blockchain for secure spectrum trading. 1) Reputation-based miner selection. A secure and efficient reputation management scheme is designed for the edge computing nodes and the candidates with high reputation acting as active miners will be selected to ensure a reliable consensus process. 2) Block mining and generation. The selected edge computing nodes then act as miners to collect the transaction records from the MNO and the UAV operators and perform block generation. 3) Block verification with consensus process. A new generated block is audited by the miners via the consensus mechanism before storing it. As long as most miners agree on the block data, this block can be added into the spectrum blockchain.

The operations of the spectrum trading process include system initialization, reputation-based miner selection, trading spectrum between MNO and UAV operators, block mining and generation, and block verification with consensus process.

Numerical results demonstrate that the revenue of the MNO under the nonuniform pricing scheme is in general larger than that under the uniform pricing scheme. If a spectrum seller has a large amount of spectrum to sell, it would like to price lower to stimulate consumption. Besides, the UAV operators with more spectrum coins have a higher priority in bandwidth obtainment. When the available bandwidth is small, the MNO will reject the request from the operators with low spectrum coins, and provide the limited resource to the operators with high spectrum coins.

In summary, the proposed consortium blockchain based secure spectrum trading framework enables the MNO and UAV operators to trade spectrum in a credible environment without relying on a trusted third party.

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PARSEC: A 360-Degree Video Streaming System with Super-Resolution

A short review for "Streaming 360-Degree Videos Using Super-Resolution"

Edited by Mengbai Xiao

M. Dasari, A. Bhattacharya, S. Vargas, P. Sahu, A. Balasubramanian and S. Das, "Streaming 360-Degree Videos Using Super-Resolution," in IEEE International Conference on Computer Communications, Virtual Conference, 2020

The immersive experience brought by 360-degree videos is unprecedented and this novel type of panoramic content is increasingly popular on commercial streaming platforms. However, the prohibitively high bandwidth requirement is the main reason hindering its deployment. As a result, the tile-based solutions are being developed where the content downloaded is restricted to the user's predicted viewport [2], [3], [4]. Unfortunately, promising schemes towards long-term viewport prediction are still being explored. State-of-the-art viewport-adaptive streaming systems can only achieve 58-80% accuracy even for predicting 1 second in the future. The longer the prediction window is, the less accurate the prediction [1], [2].

In this paper, the authors suggest trading off the network bandwidth for computation capacity at the client side. Specifically, they develop PARSEC (PAnoRamic StrEaming with neural Coding), a 360-degree video streaming system that delivers tiles at low resolutions via network and reconstructs the high-resolution content at the client side with deep neural networks (DNN). Though the method is effective for regular videos [5], [6], several practical issues have to be tackled before adopting it in the 360-degree video streaming: 1) The mobile devices that are commonly used to watch 360-degree videos have limited computation capability. The inference speed of DNN models might be slow and can hardly catch up with the video playback. 2) The DNN models are large and consume network resources as well, which offsets the bandwidth savings achieved. 3) Since the DNN model generalizes over the entire video, the quality of reconstructed frames is unstable.

To overcome these challenges, PARSEC is implemented as a full-fledged 360-degree streaming system based on two core ideas. The first is to train individual DNN models that reconstruct super-resolution frames in a video segment. These so-called micro-models have three major benefits over the design choice that trains a large model for a video: 1) The models are much smaller so transferring them over network consumes less bandwidth, and the delivery is also more flexible that the system does not have to send all models if the user stops watching; 2) the models with smaller size have a much faster inference speed; 3) the frame reconstruction can align with the viewport adaptive streaming that only the tiles fall in the user's viewport are reconstructed. The second idea is to develop a neural-aware adaptive bitrate (ABR) algorithm, in which not only the network resources but also the computation capacity at the client side determines the streaming process.

Preliminary experiments show that a plain use of the super-resolution technique can hardly fit the 360-degree video streaming. The higher the video resolution is, the lower/larger the inference rate/the model size is. The inference rate cannot even match the playback speed. As a result, the authors choose to train individual micro-models for segments. The micro-models are deep convolutional neural networks (CNNs)-based, in which each convolutional layer is followed by a leaky rectified linear function (LReL). Batch normalization is adopted for faster learning. For each segment, the tiles at 192x192 and their down-sampled ones at 24x24, namely ultra-low resolution tiles (ULR tiles), are used to train the model offline. The loss function used in the training is the PSNR metric. When reconstructing the tiles, the client downloads the ULR tiles of a segment and the corresponding micro-model, inputs the ULR tiles to the micro-model, and eventually generates the tiles at high resolution.

Such a novel technique also introduces extra complexity into the streaming system. An ABR algorithm that takes computation resources on the client into account is desired. In PARSEC, the authors design the neural-aware ABR algorithm by formulating the streaming decisions as an Integer Linear Program (ILP) and solves it with a greedy algorithm. Within the ABR algorithm, a tile could be fetched over network, generated from the micro-model, or missed. No matter a tile is downloaded or is generated, it should be ready at the client side before its playback. A greedy heuristic is adopted to solve the ILP that aims at maximizing the QoE, which runs in less than 2 ms for 200 tiles and 5 quality levels.

In PARSEC, the content streaming is implemented on GPAC, which provides APIs for video coding, rendering and tile packaging in DASH. The DNN models are developed with Keras and Tensorflow.

Extensive experiments are carried out to evaluate PARSEC. The dataset used in the evaluation contains 10 videos as well as 50 user's watching traces. Three peer systems, i.e., Flare [2], Fan et al [1], and NAS [6], are compared to PANRSEC. PANRSEC outperforms all three alternative systems with respect to the QoE. When comparing to Flare, PANRSEC achieves 37-48% higher QoE as the bandwidth is set to follow the publicly available broadband network and 4G/LTE traces. The superiority reduces to 17-28% over the real WiFi networks. Under a poor network configuration of 1 Mbps, PARSEC outperforms peer systems by 1.8x. If the network is not the bottleneck, it is observed that PARSEC consumes 43% less bandwidth than Flare.

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Paper Nomination Policy

Following the direction of MMTC, the Communications – Review platform aims at providing research exchange, which includes examining systems, applications, services and techniques where multiple media are used to deliver results. Multimedia includes, but is not restricted to, voice, video, image, music, data and executable code. The scope covers not only the underlying networking systems, but also visual, gesture, signal and other aspects of communication. Any HIGH QUALITY paper published in Communications Society journals/magazine, MMTC sponsored conferences, IEEE proceedings, or other distinguished journals/conferences within the last two years is eligible for nomination.

Nomination Procedure

Paper nominations have to be emailed to Review Board Directors: Zhisheng Yan (zyan@gsu.edu), Yao Liu (yaoliu@binghamton.edu), Wenming Cao (wmcao@szu.edu.cn), and Phoenix Fang (dofang@calpoly.edu). The nomination should include the complete reference of the paper, author information, a brief supporting statement (maximum one page) highlighting the contribution, the nominator information, and an electronic copy of the paper, when possible.

Review Process

Members of the IEEE MMTC Review Board will review each nominated paper. In order to avoid potential conflict of interest, guest editors external to the Board will review nominated papers co-authored by a Review Board member. The reviewers' names will be kept confidential. If two reviewers agree that the paper is of Review quality, a board editor will be assigned to complete the review (partially based on the nomination supporting document) for publication. The review result will be final (no multiple nomination of the same paper). Nominators external to the board will be acknowledged in the review.

Best Paper Award

Accepted papers in the Communications – Review are eligible for the Best Paper Award competition if they meet the election criteria (set by the MMTC Award Board). For more details, please refer to http://mmc.committees.comsoc.org/.

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MMTC examines systems, applications, services and techniques in which two or more media are used in the same session. These media include, but are not restricted to, voice, video, image, music, data, and executable code. The scope of the committee includes conversational, presentational, and transactional applications and the underlying networking systems to support them.