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Message from the Review Board Directors

Welcome to the August 2024 issue of the IEEE ComSoc MMTC Communications – Review.

This issue comprises three reviews that cover multiple facets of multimedia communication research including risks concerns of generative AI in the IoT, UAV-assisted edge computing with altitude-dependent computing power, and universal boosting architecture for neural representations for videos. These reviews are briefly introduced below.

The first paper, published in IEEE Internet of Things Magazine and edited by Dr. Ye Liu, offers a thorough examination of the security challenges posed by the convergence of Generative Artificial Intelligence (AI) and the Internet of Things (IoT). The paper delves into the multifaceted risks associated with this integration, emphasizing the urgent need for robust security measures in an increasingly interconnected world.

The second paper, edited by Dr. Qin Wang, was published in IEEE Transactions on Wireless Communications. This paper establishes an analytical framework for UAV-assisted MEC systems with altitude-dependent computing power.

The third paper, edited by Dr. Takuya Fujihashi, was published in IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR). This paper introduces a universal boosting framework for current implicit video representation approaches.

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

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Risks Concerns of Generative AI in the IoT

A short review for "Security Risks Concerns of Generative AI in the IoT"

Edited by Ye Liu

H. Xu, Y. Li, O. Balogun, S. Wu, Y. Wang, and Z. Cai, " Security Risks Concerns of Generative AI in the IoT," in IEEE Internet of Things Magazine, vol. 7, no. 3, pp. 62-67, May 2024.

Generative AI [1], which involves algorithms capable of creating synthetic data that mimics real-world patterns, is revolutionizing IoT applications across various sectors. The authors illustrate this with examples from smart cities, healthcare, and industrial IoT, where generative AI is enhancing efficiency, optimizing processes, and generating synthetic data for training machine learning models. However, while these applications demonstrate the significant benefits of generative AI, the authors caution that they also introduce critical security vulnerabilities that must not be overlooked.

One of the primary concerns discussed in the paper is the risk to data privacy and integrity [2]. Generative AI's ability to create and manipulate vast amounts of data can lead to significant breaches in privacy if not properly safeguarded. In IoT environments, where data is continuously collected and transmitted, any vulnerability can result in widespread data leakage, compromising the privacy of individuals and the integrity of entire systems. The authors underscore the importance of implementing robust safeguards to protect against these risks, particularly as IoT devices become more ubiquitous in sensitive areas like healthcare and finance.

Another critical security risk identified by the authors is the vulnerability of AI models themselves [3]. Generative AI models, which are central to AI-driven IoT systems, are susceptible to various forms of attack, including model theft and poisoning. For instance, cybercriminals could steal AI models to understand their structure and devise more effective attacks or inject malicious data into training sets, leading to compromised decision-making in IoT applications. These risks highlight the need for securing AI models against unauthorized access and manipulation, ensuring that they remain reliable and effective in real-world applications.

The paper also addresses the broader security challenges within IoT networks, which are exacerbated by the interconnected nature of IoT devices. A breach in a single device can potentially compromise the entire network, leading to cascading failures. The heterogeneity of IoT devices, each with varying capabilities and security protocols, adds another layer of complexity, making it difficult to implement consistent and robust security measures across the network. The authors argue that this interconnectedness demands a comprehensive security strategy that extends beyond individual devices to encompass the entire IoT ecosystem.

In response to these security risks, the authors propose several strategies to enhance the security of generative AI in IoT. One key approach is enhancing data privacy and integrity through encryption, anonymization, and stringent access control. By encrypting data during transmission and implementing multi-factor authentication and regular audits, organizations can significantly reduce the risk of unauthorized access and data breaches. Additionally, the authors advocate for the continuous monitoring and updating of security measures to adapt to the evolving threat landscape.

Developing robust security protocols is another critical strategy highlighted in the paper. The authors emphasize the importance of implementing security measures throughout the lifecycle of IoT devices and generative AI models, from the development phase to deployment and maintenance. This includes secure coding practices, automated update mechanisms, and regular security audits to ensure that systems remain protected against emerging threats.

The paper also discusses the benefits of adopting a multi-layered security approach, often referred to as defense-in-depth. This strategy involves implementing multiple layers of security measures, such as firewalls, intrusion detection systems, and regular vulnerability assessments, to create a more resilient security framework. By combining technical measures with administrative controls and physical security, organizations can better protect their IoT ecosystems from sophisticated cyberattacks.

Furthermore, the authors suggest leveraging AI itself as a tool for enhancing security. Machine learning algorithms can be used to detect unusual patterns or anomalies in network traffic, providing real-time threat detection and mitigation. AI systems can also simulate various cyberattack scenarios, allowing organizations to identify potential vulnerabilities and strengthen their defenses before they are exploited.

Looking ahead, the authors discuss the potential for generative AI to continue driving innovation in IoT, while also acknowledging the need for ongoing research and development in security technologies. They predict that as generative AI becomes more powerful, the security risks it poses will evolve and become more sophisticated. To address these challenges, the authors call for a balance between embracing the innovative capabilities of generative AI and ensuring that robust security measures are in place.

In conclusion, this paper provides a comprehensive and insightful analysis of the security challenges associated with the integration of generative AI and IoT. The authors effectively balance the discussion of generative AI's potential benefits with a critical examination of the security risks it introduces. Their proposed strategies for mitigating these risks are practical and emphasize the need for a proactive and comprehensive approach to security. This paper is a valuable contribution to the ongoing discourse on the safe deployment of AI-driven technologies in IoT ecosystems, offering essential insights for researchers, policymakers, and technology developers alike.

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UAV-Assisted Edge Computing with Altitude-Dependent Computing Power

A short review for "UAV-Assisted Multi-Access Edge Computing with Altitude-Dependent Computing Power"

Edited by Qin Wang

Y. Deng, H. Zhang, X. Chen and Y. Fang, "UAV-Assisted Multi-Access Edge Computing with Altitude-Dependent Computing Power," in IEEE Transactions on Wireless Communications, vol. 23, no. 8, pp. 9404-9418, Aug. 2024.

With the rapid development of Internet of Things (IoT) technology and edge intelligence (e.g., the explosive growth in the number of mobile in IoT devices such as smartphones, tablets, and wearable devices), emerging diverse intelligent applications on these devices, such as facial recognition and augmented reality, have provided mobile users with high-quality experiences [1]. Leveraging mobile edge computing (MEC) technology, IoT mobile devices can offload part of the complex computation-intensive tasks to edge servers (ESs) with strong computing capabilities, thereby significantly reducing the energy consumption of the devices. However, traditional ESs are usually installed in fixed-position cellular base stations, making them unable to effectively provide computation offloading services for IoT mobile devices when damaged by natural disasters or during large unexpected outdoor events.

With continuous advancements in unmanned aerial vehicle (UAV), equipping UAV with edge servers has become a promising approach. Compared with traditional architectures, UAV equipped with edge servers can efficiently provide computation offloading tasks for IoT mobile devices due to their fast deployment, strong scalability, and flexible maneuverability [2].

Compared to ordinary edge computing, edge intelligence computing can utilize intelligent methods to address issues like connection strategies and resource management in UAV-based MEC, while also providing computation services for intelligent applications running on ground users (GUs) or UAV users. UAV-based MEC involves equipping UAV with high-performance chips and deep reinforcement learning algorithms, giving them the ability to make optimal decisions based on current channel states, ground node distribution, and their own positions. This enables UAV to leverage their strong maneuverability to quickly and flexibly provide computation offloading tasks to multiple user devices within an area [3].

In UAV-assisted MEC systems, determining the altitudes of the UAV is a key design consideration. This decision not only affects the communication link quality between GUs/ESs and the UAV but also impacts the available computing resources for computation offloading. Therefore, system performance and UAV altitude deployment strategy are intricately linked. In previous works, UAV altitude deployment strategies generally assume a fixed computing resource pool [4]. In such cases, fixed computing resource pools may lead to suboptimal network resource allocation and increase the possibility of bottlenecks in computing capacity at edge servers, thereby reducing task computation performance.

To address this, the authors have established an analytical framework for UAV-assisted MEC systems with altitude-dependent computing power. This framework incorporates key elements such as the random distribution of GUs and ESs, dynamic computation task generation, and signal-to-noise ratio-based coverage probability. The authors investigated the interdependence between communication link quality and computing capacity concerning UAV altitude deployment in UAV-assisted MEC systems with highly dependent computing abilities, as opposed to previous works that typically assume computing capacity is independent of UAV altitude.

First, in the research model, the authors used a dual-state approximate channel model (line-of-sight and non-line-of-sight) to derive the coverage probability of GUs and ESs based on the signal-to-noise ratio. These foundational results successfully captured the impact of network parameters, particularly the effects of UAV altitude on wireless communication link quality and computing capacity. By considering the computing capacity of a single ES and the average number of ESs covered by a UAV, the authors established a communication-aware, altitude-dependent computing capacity model.

Secondly, given that each computation task undergoes three consecutive processing stages: uploading from the GU to the UAV, relaying from the UAV to the ES, and computation at the ES, the authors constructed a three-stage tandem queueing model to illustrate the interrelationships among these stages. By combining the results from the computing capacity and transmission models, the authors determined the task arrival rate and service rate, approximating the tandem queue to an M/D/1 → D/1 → D/1 model. Subsequently, they used queuing theory to analyze end-to-end service delay, including transmission delay, computation delay, and potential waiting time.

Lastly, based on the end-to-end service delay results, the authors studied the problem of maximizing the number of tasks completed within a deadline, referred to as service throughput. This research provides valuable insights for ensuring QoS-aware service provisioning and network planning in UAV-assisted MEC systems with highly relevant computing capabilities. Since end-to-end delay and the number of completed tasks are affected by the UAV altitude and task admission ratio, service providers can strategically adjust UAV altitude deployment and task admission decisions to achieve target service throughput.

Simulation results indicate that, for given network parameters, the proposed scheme can achieve the optimal UAV altitude for maximum task computation throughput. Compared to traditional fixed-altitude UAV edge computing methods, the proposed altitude-dependent computing model and optimization algorithm significantly enhance system computing performance and resource utilization. This study not only offers a new perspective on the application of UAVs in multi-access edge computing but also demonstrates the significant potential of altitude-dependent computing models and optimization algorithms in dynamic resource optimization.

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A Universal Boosting Architecture for Neural Representations for Videos

A short review for "Boosting Neural Representations for Videos with a Conditional Decoder"

Edited by Takuya Fujihashi

X. Zhang, R. Yang, D. He, X. Ge, T. Xu, Y. Wang, H. Qin, J. Zhang, "Boosting Neural Representations for Videos with a Conditional Decoder," IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2024.

With increased demand for video streaming services, video compression has become a key technology for delivering high-quality video signals over band-limited wired and wireless networks. The typical video coding standards are H.264/Advanced Video Coding (AVC) [1], H.265/High-Efficiency Video Coding (HEVC) [2], and H.266/Versatile Video Coding (VVC) [3]. Such video coding standards exploit motion estimation, transform, quantization, and entropy coding to compress video signals into the bitstream.

Recent studies have designed learned video coding based on the advancement of deep learning techniques for further compression. Specifically, some studies replace each module (motion estimation, transform, quantization, and/or entropy coding) with a trainable architecture, which is trained to maximize the rate-distortion performance of the trainable encoder and decoder.

One of the issues in the learned video coding is considerable inference delay (decoding delay) when reconstructing the video frames from the received bitstream. To reduce the decoding delay, recent studies utilize the concept of implicit neural representation (INR) for multi-dimensional signal compression. The pioneering works on INR are SIREN [4] and Neural Radiance Fields (NeRF) [5], i.e., pixel-wise INR. For example, SIREN consists of simple multi-layer perceptron (MLP) layers with sinusoidal activation functions. It trains the relationship between the indices of each pixel and the corresponding pixel values. Compression with Implicit Neural Representations (COIN) [6] is the first study to introduce the concept of INR to compression. In contrast to traditional and learned video compression, COIN sends the trained weights to the receiver, and the receiver repeatedly feeds the indices of each pixel to reconstruct the pixel values of whole pixels. Some studies have designed Neural Representations for Videos (NeRV) [7], i.e., frame-wise INR. In contrast to the pixel-wise INR, NeRV outputs the corresponding video frame from the input time index. Extended works such as hybrid NeRV (HNeRV) [8] and Expedite NeRV (E-NeRV) [9] have been proposed to enhance the reconstruction quality under the same traffic.

This paper introduces a universal boosting framework for current implicit video representation approaches. A key innovation is the proposed conditional decoder, equipped with a temporal-aware affine transform module inspired by the Adaptive Instance Normalization layer (AdaIN) [10]. This module uses the frame index as a prior condition to effectively align intermediate features with target frames, thereby enhancing the frame-wise INR performance. The flexibility of the proposed conditional decoder allows it to be seamlessly integrated into the existing frame-wise INR decoder, further boosting its performance.

Another significant contribution of this study is the replacement of the Gaussian Error Linear Unit (GELU) layer with a SINE layer to generate more diverse features. The existing NeRV-like solutions used GELU-based frame reconstruction blocks, which limited the number of feature maps. By introducing SINE layers in later up-sampling stages, the research team achieved a more balanced parameter distribution across the network, thereby enhancing the model's capacity. In addition, the authors integrated L1, MS-SSIM, and frequency-domain losses for the loss function to overfit the model to the given video. Furthermore, a consistent entropy minimization (CEM) technique based on a network-free Gaussian entropy model was proposed to ensure the consistency of training and inference performance and capture the interrelationships between elements in each weight or embedding to accurately estimate the probability distribution.

Experiment results using the UVG dataset show that the proposed boosted frame-wise INR architectures achieved better rate-distortion performance than the existing frame-wise INR architectures, i.e., NeRV, HNeRV, and E-NeRV. In addition, the authors also demonstrated the performance gain in other tasks, such as regression, inpainting, and interpolation. Even in such tasks, the proposed boosted architecture yielded better reconstruction quality than the existing INR architectures with a slight increment in model size.

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