

A Review of Joint Optimization of THz Communication and Edge Computing in 6G/7G Networks

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Abstract: The integration of Terahertz (THz) communication and edge computing is dignified to be a foundation of 6G and 7G networks, enabling ultra-high-speed data transmission, ultra-reliable low-latency communication (URLLC), and efficient resource utilization for diverse applications such as augmented reality, autonomous systems, and the Internet of Things (IoT). However, the associated challenges of THz communication, including high path loss, molecular absorption, and limited coverage, combined with the resource constraints and dynamic workloads in edge computing, necessitate innovative joint optimization strategies. This review provides a concise analysis of current methodologies for joint optimization of THz communication and edge computing, focusing on dynamic resource allocation, task offloading, load balancing, and scalability. Recent advancements, including artificial intelligence (AI)-driven and hybrid optimization techniques, are critically examined. By consolidating current knowledge, identifying research gaps, and highlighting emerging trends, this review aims to offer valuable insights into designing robust, efficient, and scalable frameworks for next-generation wireless networks.

Keywords: Terahertz Communication, Edge Computing, Joint Optimization, Ultra-Low Latency, Resource Allocation

1. Introduction

The advent of 6G and 7G networks is set to revolutionize industries and society by enabling unprecedented levels of connectivity, data rates, and intelligent automation. These next-generation networks promise to support transformative applications such as autonomous vehicles, smart cities, precision healthcare, and immersive experiences, driving advancements in various sectors. A pivotal enabler of these capabilities is THz communication, which operates in the frequency range of 0.1–10 THz. With its ability to provide ultra-high-speed data rates exceeding 100 Gbps and URLLC, THz communication addresses the demands of bandwidth-intensive and latency-sensitive applications [1-3]. Complementing this is edge computing, which decentralizes data processing by bringing computation and storage closer to the end-users.

By minimizing the need to transfer data to distant centralized data centers, edge computing significantly reduces latency, enhances real-time processing, and alleviates network congestion. The integration of THz communication and edge computing has become increasingly essential to support emerging applications such as augmented reality, holographic communication, and the Internet of Things (IoT), which require seamless coordination between ultra-fast data transmission and low-latency computation in highly dynamic and resource-constrained environments. While the integration of Terahertz communication and edge computing presents immense opportunities, several critical challenges must be addressed to



realize their full potential in 6G and 7G networks [4-7].

High path loss, molecular absorption, and interference in the THz frequency range limit signal propagation and complicate spectrum management in dynamic networks. Edge computing faces challenges like resource constraints, dynamic workloads, and latency variations, impacting scalability in ultra-dense environments. To address these challenges, the concept of joint optimization has emerged as a promising solution. By simultaneously considering the parameters of THz communication, such as spectrum allocation, interference management, and signal power control, alongside edge computing parameters like task offloading, resource allocation, and load balancing, joint optimization aims to achieve a synergistic balance between communication and computation [8-10]. The main contribution of this review paper are as follows;

- This review examines existing frameworks for the joint optimization of THz communication and edge computing in 6G/7G networks, focusing on resource allocation, task offloading, and load balancing.
- The paper identifies AI-based and hybrid optimization techniques, including machine learning and reinforcement learning, to address scalability, adaptability, and real-time decision-making challenges, offering insights for future unified frameworks.

2. Literature Survey

This section explores existing research efforts in the joint optimization of THz communication and edge computing, focusing on their methodologies, limitations, and applicability to 6G/7G networks and critically examines state-of-the-art approaches, highlighting the progress made and identifying key gaps that require further investigation.

The joint optimization of Terahertz (THz) communication and edge computing has been extensively explored in recent research to address the demands of next-generation 6G/7G networks. Shang et al. [11] proposed a joint deployment and wireless backhauling scheme for Robotic Aerial Base Stations (RABS) aimed at maximizing served traffic in dense and dynamic wireless networks experiencing significant data growth. Sub-Terahertz communication was leveraged to exploit its ultra-wide spectrum, while a multi-hop wireless scheme was introduced to extend coverage. The optimization of grasping locations, route flow control, and sub-band allocation was modeled as a robust optimization problem, solved using a column generation (CG)-based algorithm. Despite its advantages, the reliance on CG resulted in suboptimal solutions for large-scale networks due to incomplete exploration of candidate routes. Similarly, Hassan et al. [12] addressed the challenge of maximizing Low Earth Orbit (LEO) satellite coverage in 6G sub-THz networks using reconfigurable intelligent surfaces (RISs). A block coordinate descent (BCD) algorithm incorporating balanced K-means clustering, multi-agent proximal policy optimization (MAPPO), and whale optimization algorithms (WOA) was employed. However, the BCD framework faced convergence issues due to the non-convex and NP-hard nature of the optimization problem.

Advancements in hybrid communication systems and resource allocation methods were also proposed. Gurinder Singh et al. [13] explored hybrid Visible Light Communication (VLC) and Radio Frequency (RF)-based Vehicle-to-Everything (V2X) systems, demonstrating high reliability under diverse meteorological conditions. However, severe weather such as heavy snow or dense fog significantly degraded VLC performance, necessitating additional mechanisms for reliability. Liu et al. [14] reported a 0.22 THz communication system achieving an 84 Gbps air interface rate over 1.26 kilometers, supported by innovations in integrating THz systems, redesigning baseband signal processing, and optimizing radio frequency components. Nevertheless, the lack of joint optimization between communication and computation limited its

adaptability in integrated edge computing scenarios. Song et al. [15] proposed a multi-UAV-aided Mobile Edge Computing (MEC) system operating at THz frequencies, optimizing relay selection, power control, positioning, and user-resource association for minimizing service delays. An iterative penalty dual decomposition (PDD) algorithm was employed to approximate solutions, yet subproblem decomposition introduced inefficiencies in dynamic edge computation environments with rapidly changing workloads.

Further developments integrated advanced optimization frameworks and security mechanisms. Syed et al. [16] proposed an edge computing-enabled e-URLLC framework (ECCE) for next-generation consumer electronics, employing a Services Classifier to divert traffic to appropriate platforms while ensuring performance. However, challenges in dynamic and heterogeneous environments could lead to inefficiencies in resource allocation. Hu et al. [17] introduced Tera-SpaceCom, a GNN and DRL-based algorithm for joint resource allocation and task offloading, targeting long-term resource efficiency. Despite its potential, scalability issues and prolonged convergence times were observed in large-scale satellite networks. Wu et al. [18] developed the Iterative Order-Preserving Policy Optimization (IOPO) framework for energy-efficient task offloading, achieving rapid convergence by avoiding exhaustive search. However, iterative updates struggled to maintain performance in highly dynamic environments. Zhao et al. [19] focused on integrating THz communication and MEC with reinforcement learning for augmented reality (AR) in the Internet of Vehicles (IoV). A static data-driven AR task offloading framework and a distance-aware bandwidth allocation algorithm were proposed, yet offline reinforcement learning hindered adaptability in dynamic resource scenarios. Kamruzzaman[20] introduced a 6G security management framework (WC-SM-AI) leveraging artificial intelligence to optimize network lifespan, spectral efficiency, and data integrity. Nonetheless, the high computational complexity of the deep neural network module presented scalability challenges in resource-constrained environments.

3. Future Scope

The reviewed studies highlight significant advancements in the joint optimization of Terahertz communication and edge computing for next-generation networks. However, several challenges remain unaddressed, offering opportunities for future research.

Enhanced THz Signal Propagation and Spectrum Management: To address the issues of high path loss, molecular absorption, and interference in the THz frequency range, advanced beamforming techniques and reconfigurable intelligent surfaces (RIS) can be explored to improve signal strength and extend propagation distances. Dynamic spectrum management algorithms, leveraging real-time network analytics and AI-driven interference mitigation, are essential to enhance spectrum efficiency in ultra-dense networks.

Scalable and Adaptive Edge Computing Solutions: Resource constraints and dynamic workloads at edge nodes necessitate hybrid computation models integrating edge and cloud resources for scalability. Multi-agent reinforcement learning (MARL) frameworks can be designed for real-time task offloading and resource allocation in heterogeneous environments. Additionally, edge caching and proactive resource prediction techniques, supported by AI, can alleviate latency variations and improve overall efficiency.

Joint Optimization Frameworks for Integrated Networks: Future research should focus on unified frameworks that jointly optimize communication and computation in highly dynamic scenarios. Techniques such as graph neural networks (GNNs) and deep reinforcement learning (DRL) can be extended to address large-scale optimization problems, ensuring adaptability and scalability in environments with rapid changes in resource demands and network topologies.

Energy-Efficient and Low-Complexity Solutions: Energy efficiency is critical in THz-enabled and edge computing systems. Lightweight deep learning models, combined with energy-aware task scheduling, can reduce computational complexity. Decentralized optimization algorithms, such as federated learning, can also minimize the reliance on centralized processing, enabling efficient operation in resource-constrained networks.

Hybrid and Adaptive Resource Allocation Mechanisms: Future frameworks should incorporate hybrid resource allocation mechanisms that integrate offline and online learning techniques. Offline learning can optimize general system behaviour, while online adaptation allows real-time adjustments to handle dynamic workloads and resource variability, addressing the limitations of static algorithms.

4. Conclusion

This review paper analyzed recent advancements in the joint optimization of THz communication and edge computing for 6G/7G networks. Existing studies demonstrated significant progress in improving network efficiency, resource allocation, and task offloading using advanced techniques such as reinforcement learning, graph neural networks, and multi-agent systems. However, challenges such as high path loss, molecular absorption, interference in THz frequencies, and edge computing constraints like scalability and dynamic workloads persist. Future research must address these limitations by developing adaptive, scalable, and energy-efficient frameworks. Emphasis on hybrid resource allocation, intelligent spectrum management, and low-complexity optimization can pave the way for robust solutions. Such advancements will ensure the seamless integration of THz communication and edge computing in next-generation networks.

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References

- [1] T. Kürner, D.M. Mittleman, and T. Nagatsuma, "THz communications," *Springer Series in Optical Sciences*, pp. 234, 2022.
- [2] M.L.R. Mehta, "Terahertz communication-Path towards beyond 5G: A Survey," *International Journal of Engineering Research and Applications*, vol.10, no.7, pp. 13-20, 2020.
- [3] L. Zhang, X. Pang, S. Jia, S. Wang and X. Yu, "Beyond 100 Gb/s optoelectronic terahertz communications: Key technologies and directions," *IEEE Communications Magazine*, vol. 58, no. 11, pp.34-40, 2020.
- [4] V.K. Quy, A.Chehri, N.M. Quy, N.D. Han and N.T. Ban, "Innovative trends in the 6G era: A comprehensive survey of architecture, applications, technologies, and challenges," *IEEE Access*, vol. 11, pp.39824-39844, 2023.
- [5] B. Li, D. Dupleich, G. Xia, H. Zhou, Y. Zhang, P. Xiao and L.L. Yang, "MDD-enabled two-tier terahertz fronthaul in indoor industrial cell-free massive MIMO," *IEEE transactions on communications*, vol.72, no.03, 2024.
- [6] Y. Zheng, Q. Liu, X. Du, O. Li, J. He, and G. Wang, "A Co-hardware and Co-waveform THz Integrated Sensing and Communication System for High-rate Communication and Millimeter-level Imaging." In *2023 IEEE International Conference on Communications Workshops (ICC Workshops)*, pp. 213-218, 2023.

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- [7] L. Mucchi, S. Shahabuddin, M.A. Albreem, S. Abdallah, S. Caputo, E. Panayirci and M. Juntti, "Signal processing techniques for 6G," *Journal of Signal Processing Systems*, vol. 95, no. 4, pp.435-457, 2023.
 - [8] V. Petrov, H. Guerboukha, D.M. Mittleman, and A. Singh, "Wavefront Hopping: An enabler for reliable and secure near field Terahertz communications in 6G and beyond," *IEEE Wireless Communications*, vol. 31, no. 1, pp.48-55, 2024.
 - [9] X. Liao, P. Zhou, Y. Wang and J. Zhang, "Path Loss Modeling and Environment Features Powered Prediction for Sub-THz Communication," *IEEE Open Journal of Antennas and Propagation*, vol.05, no.06, pp. 1734 – 1746, 2024.
 - [10] S. Xie, H. Li, L. Li, Z. Chen and S. Li, "Reliable and energy-aware job offloading at terahertz frequencies for mobile edge computing," *China Communications*, vol. 17, no. 12, pp.17-36, 2020.
 - [11] W. Shang, Y. Liao, V. Friderikos, and H. Yanikomeroglu, "Unlocking sub-THz by Robotic Aerial Base Stations: Joint Deployment and Wireless Backhaul Routing," *IEEE Open Journal of the Communications Society*, vol.05, pp. 7582 – 7597, 2024.
 - [12] S.S. Hassan, Y.M. Park, Y.K. Tun, W. Saad, Z. Han, and C.S. Hong, "SpaceRIS: LEO satellite coverage maximization in 6G sub-THz networks by MAPPO DRL and whale optimization," *IEEE Journal on Selected Areas in Communications*, vol.42, no.05, pp. 1262 – 1278, 2024.
 - [13] G. Singh, A. Srivastava, V.A. Bohara, Z. Liu, and D. Pesch, "Towards 6G-V2X: Aggregated RF-VLC for ultra-reliable and low-latency autonomous driving under meteorological impact," 2022.arXiv preprint arXiv:2208.06287.
 - [14] K. Liu, Y. Feng, C. Han, B. Chang, Z. Chen, Z. Xu, L. Li, B. Zhang, Y. Wang, and Q. Xu, "High-speed 0.22 THz communication system with 84 Gbps for real-time uncompressed 8K video transmission of live events," *Nature Communications*, vol. 15, no. 1, pp.8037, 2024.
 - [15] H. Song, H. Seo, and W. Choi, "Terahertz Communication Multi-UAV-Assisted Mobile Edge Computing System," *arXiv preprint arXiv:2407.01086*, 2024.
 - [16] J.N. Syed, S.K. Sharma, M.N. Patwary, and M. Asaduzzaman, "Enhanced URLLC-Enabled Edge Computing Framework for Device-Level Innovation in 6G," *Authorea Preprints*, 2023.
 - [17] Z. Hu, C. Han, W. Gerstacker, and I.F. Akyildiz, "Tera-SpaceCom: GNN-based Deep Reinforcement Learning for Joint Resource Allocation and Task Offloading in TeraHertz Band Space Networks," *arXiv preprint arXiv:2409.07911*, 2024.
 - [18] J. Wu, Z. Yu, J. Guo, Z. Tang, T. Wang and W. Jia, "A Fast Task Offloading Optimization Framework for IRS-Assisted Multi-Access Edge Computing System," *arXiv preprint arXiv:2307.08474*, 2023.
 - [19] S. Zhao, W. Jing, X. Wer and Z. Lu, "Mobility-Aware AR Computation Tasks Offloading Based on Offline RL over Terahertz System," *In 2023 IEEE Globecom Workshops GC Wkshps*, pp. 866-871, 2023.
 - [20] M.M.Kamruzzaman, "6G wireless communication assisted security management using cloud edge computing," *Expert Systems*, vol. 40, no. 4, pp.e13061, 2023.
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