Editorial
First Quarter 2024 IEEE COMMUNICATIONS SURVEYS AND TUTORIALS

I WELCOME you to the first issue of the IEEE COMMUNICATIONS SURVEYS AND TUTORIALS in 2024. This issue includes 18 papers covering different aspects of communication networks. In particular, these articles survey and tutor various issues in "Wireless Communications", "Cyber Security", "IoT and M2M", "Vehicular and Sensor Communications", "Internet Technologies", "Network Virtualization" and "Network and Service Management and Green Communications". A brief account for each of these papers is given below.

I. WIRELESS COMMUNICATIONS

In the era of rapidly evolving connectivity, technological advancements have heralded a new era of innovation, particularly in the seamless integration of power line communication (PLC) and wireless communication (WLC) systems. This synergy has paved the way for significantly enhanced data transmission capabilities within indoor and outdoor environments. As we delve deeper into the inherent strengths of PLC and WLC systems, an intriguing narrative emerges, marking the advent of hybrid communication systems. These cutting-edge systems, stemming from the fusion of PLC and WLC technologies, are now poised to bring about transformative changes across various applications within the domain of electrical engineering. From optimizing smart homes and bolstering smart grids to enhancing in-vehicle communications, the potential for innovation in this intersection is boundless. Within this scholarly context, the paper [A1], authored by Ribeiro et al., stands as a pivotal contribution. This paper offers a comprehensive survey that meticulously examines the integration between PLC and WLC, systematically categorizing hybrid communication systems. Its analysis spans technical, chronological, industrial, and standardization perspectives, providing a holistic view of this field within electrical engineering. Moreover, the paper furnishes a qualitative assessment, yielding valuable practical insights. Its succinct yet informative discussions encapsulate the direction of future research endeavors, making it an invaluable resource for researchers, engineers, and practitioners alike.

Semantics-empowered communication (SemCom) is currently undergoing extensive discussions and its understanding is continually evolving. Through exchanging the most informative, timely, and effective information, SemCom is capable of improving resource utilization, communication efficiency and effectiveness towards accomplishing a task, which can provide a new paradigm and technical basis for the next generation communication systems. Along with the springing up of the SemCom research, it is now witnessing an unprecedentedly growing interest in a wide range of aspects for both academia and industry. In this context, the paper [A2] by Lu et al., provides a comprehensive survey of the fundamentals of SemCom, research taxonomy, as well as a detailed technical tutorial. The paper starts by reviewing the literature and answering the "what" and "why" questions in semantic transmissions. Afterwards, it presents the ecosystems of SemCom, including history, theories, metrics, datasets and toolkits, on top of which the taxonomy for research directions is provided. Furthermore, the critical enabling techniques are categorized by explicit and implicit reasoning-based methods, and how they evolve and contribute to modern content & channel semantics-empowered communications are also elaborated. Besides reviewing and summarizing the latest efforts in SemCom, the relations with other communication levels (e.g., conventional communications) from a holistic and unified viewpoint are discussed. Finally, the technical challenges and open issues that shed light on potential future research opportunities are discussed.

Satellite communication has undergone a significant transformation, evolving from traditional media broadcasting to data services, specifically broadband Satellite Communications (SatComs). This shift is driven by the dual challenges of meeting the escalating demand for higher capacity in urban areas and extending broadband coverage to underserved regions. Satellite communication systems, known for their ability to seamlessly integrate diverse wireless and wired technologies, emerge as a pivotal player in expanding coverage and data rates. However, with the ever-increasing demand for high data rates and extensive coverage, satellite communication faces challenges, particularly in the face of congested frequency bands. While the industry is moving towards higher bands, the immediate solution lies in optimizing the utilization of existing frequency bands. In this context, the paper [A3] by Khammassi et al., presents precoding as a powerful strategy to enhance spectral efficiency. The study provides a comprehensive survey, offering valuable insights into the recent advancements in precoding techniques for HTS communication systems. It categorizes these techniques from two crucial perspectives: problem formulation and system design, allowing professionals and researchers to gain a holistic

Digital Object Identifier 10.1109/COMST.2024.3356268

understanding of this area. Moreover, the paper delves into practical system impairments and robust precoding solutions. Further, it covers future trends, igniting further research in satellite communication.

Multicasting in wireless access networks is a functionality that, by leveraging group communications, turns out to be essential for reducing the amount of resources needed to serve users requesting the same content. The support of this functionality in the modern 5G New Radio (NR) and future sub-Terahertz (sub-THz) 6G systems faces critical challenges related to the utilization of massive antenna arrays forming directional radiation patterns to compensate for the limited effective antenna aperture, management of the multi-beam functionality, the unreliable nature of mmWave/sub-THz communications, group mobility while operating with directional transmissions, and the use of multiple Radio Access Technologies (RATs) having distinctively different coverage and technological specifics. As a result, optimal multicasting in these systems requires novel solutions. In this context, the paper [A4] by Chukhno et al., provides a comprehensive exploration of performance optimization methods for 5G/6G mmWave/sub-THz systems and discusses the associated challenges and opportunities. First, the article offers the basics of multicasting and surveys the 3rd Generation Partnership Project (3GPP) mechanisms to support multicasting at the NR radio interface and approaches to modeling the 5G/6G radio segment. It then provides an overview of the key system components and presents optimal multicast solutions, along with main lessons learned and takeaways, for different 5G NR deployments and antenna patterns, including singleand multi-beam antenna arrays, as well as singleand multiple RAT deployments. Furthermore, the article surveys new advanced functionalities for improving multicasting performance in 5G/6G systems, encompassing Reflective Intelligent Surfaces (RISs), NR-sidelink technology, and mobile edge enhancements, among many others. Finally, the article outlines perspectives on multicasting in future 6G networks.

Percolation is an advanced topic in graph theory that is meant to study phase transitions in complex networks. Percolation theory is quite important and finds application to various fields, where the phase transition can have different interpretations and can study several phenomena. Driven by its importance, the 2022 Field Medal in mathematics goes to Hugo Duminil-Copin for a percolation theoretic contribution in 3 and 4 dimensional spaces. In this context, the paper [A5] authored by ElSawy et al., introduce the percolation theory and the applications in wireless networks. The paper is designed for layman readers, where graph and percolation theory concepts are introduced before delving into the mathematical details, proofs, and applications to wireless networks. The paper discusses, with examples, how percolation theory can be utilized to balance the tradeoff between connectivity, privacy, and security of several types of wireless networks. The paper also highlights future research directions for percolation theory in 5G and beyond systems.

Future wireless systems are envisioned to create an endogenously holography-capable, intelligent, and programmable radio propagation environment, that will offer unprecedented capabilities for high spectral and energy efficiency, low latency, and massive connectivity. A potential and promising technology for supporting the expected extreme requirements of the sixth-generation (6G) communication systems is the concept of the holographic multiple-input multiple-output (HMIMO), which will actualize holographic radios with reasonable power consumption and fabrication cost. The HMIMO is facilitated by ultra-thin, extremely large, and nearly continuous surfaces that incorporate reconfigurable and sub-wavelength-spaced antennas and/or metamaterials. Such surfaces comprising dense electromagnetic (EM) excited elements are capable of recording and manipulating impinging fields with utmost flexibility and precision, as well as with reduced cost and power consumption, thereby shaping arbitrary-intended EM waves with high energy efficiency. The powerful EM processing capability of HMIMO opens up the possibility of wireless communications of holographic imaging level, paving the way for signal processing techniques realized in the EM-domain, possibly in conjunction with their digital-domain counterparts. However, in spite of the significant potential, the studies on HMIMO communications are still at an initial stage, its fundamental limits remain to be unveiled, and a certain number of critical technical challenges need to be addressed. In this context, the paper [A6] by Gong et al., presents a comprehensive overview of the latest advances in the HMIMO communications paradigm, with a special focus on their physical aspects, their theoretical foundations, as well as the enabling technologies for HMIMO systems. It also compares the HMIMO with existing multi-antenna technologies, especially the massive MIMO, presents various promising synergies of HMIMO with current and future candidate technologies, and provides an extensive list of research challenges and open directions for future HMIMO-empowered wireless applications.

In the era of sixth-generation (6G) wireless communications, integrated sensing and communications (ISAC) is recognized as a promising solution to upgrade the physical system by endowing wireless communications with sensing capability. Existing ISAC is mainly oriented to static scenarios with radio-frequency (RF) sensors being the primary participants, thus lacking a comprehensive environment feature characterization and facing a severe performance bottleneck in highly dynamic emerging application scenarios such as autonomous driving. Harnessing a great potential for enhanced environmental awareness, multi-modal sensing holds many promises for developments and performance assurance in communication and sensing systems. The extensively studied ISAC should be expanded to include non-RF sensors and evolve into intelligent multi-modal sensing-communication integration. Intelligent multi-modal sensing-communication integration aims to achieve mutual assistance or enhancement at various potential technical aspects of communication and sensing systems. Recently, relevant research has been conducted focusing on various topics but lacks a unified framework and a systematic review. In this context, the paper [A7] by Cheng et al., proposes an innovative concept of Synesthesia of Machines (SoM) as a unified framework of the intelligent multi-modal sensing-communication

integration. First, this survey introduces SoM and defines three operational modes of SoM, i.e., SoM-evoke, SoM-enhance, and SoM-concert. It introduces mixed multi-modal (MMM) datasets, such as the M3SC dataset, as a prerequisite for SoM research. It then discusses challenges of the exploration of the complex mapping relationships between multi-modal sensing and communications, which can be supported by channel modeling customized for SoM. Further sections are devoted to giving a comprehensive survey on the current research status of intelligent multi-modal sensing-communication integration, covering the technological review on SoM-enhance-based transceiver design and SoM-concert-based environment sensing. In summary, this survey promotes the intelligent multi-modal sensing-communication field by proposing the SoM framework and thoroughly reviewing the current research status.

II. Cyber Security

Every attempt to access the Internet through a web browser, email sent, VPN connection, VoIP calls, instant message, or other use of telecommunications systems involves cryptographic techniques. The most commonly applied technique is asymmetric cryptography, which is generally executed in the background without the user even being aware. It establishes a cryptographic code based on the computational complexity of mathematical problems. However, this type of cryptography, widely used in today's telecommunications systems, is under threat as electronics and computing rapidly develop. The development of fifth-generation cellular networks (5G) is gaining momentum, and given its wide field of application, security requires special attention. This is especially true faced with the development of quantum computers. One solution to this security challenge is to use more advanced techniques to establish cryptographic keys that are not susceptible to attack. An essential part of quantum cryptography, Quantum Key Distribution (QKD) uses the principles of quantum physics to establish and distribute symmetric cryptographic keys between two geographically distant users. QKD establishes information-theoretically secure (ITS) cryptographic keys resistant to eavesdropping when created. An alternative solution is post-quantum cryptography, introducing novel yet classic cryptosystems immune to known quantum and classic algorithms. This solution is likely only temporary since as yet unknown algorithms, both quantum and classic, may still be discovered and render its security unusable in the future. In this context, the paper [A8] by Mehic et al., survey the security challenges and approaches in 5G networks concerning network protocols, interfaces and management organizations. The paper starts by examining the fundamentals of QKD and discusses the creation of QKD networks and their applications. Then, it outlines QKD network architecture and its components and standards, with a summary of QKD and post-quantum key distribution techniques and approaches for its integration into security frameworks such as VPNs (IPsec and MACsec). It also discusses the requirements, architecture, and methods for implementing the FPGA-based encryptors needed to execute cryptographic algorithms with security keys. It continues the discussion of the performance and technologies of post-quantum cryptography and finally examines reported 5G demonstrations that have used quantum technologies, highlighting future research directions.

With the deluge of interconnected Internet of Things (IoT) devices around the globe, the current fifth generation of cellular networks (5G) and beyond is focusing mainly on fulfilling such massive connectivity needs, which has been catered so far by 5G's massive Machine-Type Communication. Nowadays, there has been an increasing witnessed integration of IoT in several critical applications, such as in military operations, unmanned aerial vehicles, and e-health, to cite a few. Nonetheless, the forecasted colossal number of interconnected devices is expected to bring unprecedented levels of information security vulnerabilities. In the context of IoT devices, inheriting the implementation of the well-established higher layer security schemes represents a hurdle due to the restricted communication and computation resources on such devices. To this end, physical layer security (PLS) paradigm has manifested notable merits in reaching a sustainable security solution, which is based on harnessing the inherent physical layer features and parameters, along with stochastic channel coding, to provide secure communications without resorting to traditional cryptographic schemes. In this context, the paper [A9] by Illi et al., presents a detailed survey and tutorial on the potential and applicability of various PLS techniques on IoT networks. First, an enhanced taxonomy of the various existing PLS techniques and schemes is elaborated in accordance with main information security pillars. Then, the paper provides a tutorial by reviewing the analytical fundamentals of PLS from the perspective of confidentialityand authentication-achieving techniques. Then, PLS-achieving techniques for confidentiality, authentication, and malicious node detection are thoroughly reviewed, with an emphasis on the potential of emerging wireless communications technologies, such as advanced multiple access techniques, joint communication and sensing, and reconfigurable intelligent surfaces, in realizing robust PLS schemes and to highlight their security challenges and limitations. Finally, current challenges faced by the integration of PLS schemes in current IoT networks are outlined with several future research opportunities.

III. IoT and M2M

The emerging field of artificial intelligence of things (AIoT, AI+IoT) is driven by the widespread use of intelligent infrastructures and the impressive success of deep learning (DL). With the deployment of DL on various intelligent infrastructures featuring rich sensors and weak DL computing capabilities, a diverse range of AIoT applications has become possible. However, DL models are notoriously resource-intensive. To this end, the algorithm-system co-design that jointly optimizes the resource-friendly DL models and model-adaptive system scheduling improves the runtime resource availability and thus pushes the performance boundary set by the standalone level. In this context, the paper [A10] by Liu et al., aims to provide a broader optimization space for more free resource-performance tradeoffs. The cross-level optimization landscape involves various granularity, including

the DL model, computation graph, operator, memory schedule, and hardware instructor in both on-device and distributed paradigms. Furthermore, due to the dynamic nature of AIoT context, which includes heterogeneous hardware, agnostic sensing data, varying user-specified performance demands, and resource constraints, this survey explores the context-aware inter-/intra-device controllers for automatic cross-level adaptation. Additionally, we identify some potential directions for resource-efficient AIoT systems. By consolidating problems and techniques scattered over diverse levels, we aim to help readers understand their connections and stimulate further discussions.

The proliferation of ubiquitous Internet of Things (IoT) sensors and smart devices in several domains embracing healthcare, Industry 4.0, transportation and agriculture are giving rise to a prodigious amount of data requiring ever-increasing computations and services from cloud to the edge of the network. Fog/Edge computing is a promising and distributed computing paradigm that has drawn extensive attention from both industry and academia. Resource Management (RM) is a non-trivial issue whose complexity is the result of heterogeneous resources, incoming transactional workload, edge node discovery, and Quality of Service (QoS) parameters at the same time, which makes the efficacy of resources even more challenging. Thus, conventional or heuristic methods do not work well in a dynamic fog computing environment due to their inability to adapt to constant changes. Moreover, the implications of fog computing in physical world applications necessitate fault-tolerant and adaptive resource management mechanisms which can be achieved through an efficient and optimized task or workload scheduling. Hence, to acquire efficiency at the infrastructural level, optimal management of resources can't be compromised. Presently, research is trending in the direction of inculcating AI with computing paradigms, hence making the system autonomous. In this context, the paper [A11] by Walia et al., presents a comprehensive review of resource management issues and challenges in Fog/Edge paradigm by categorizing them into provisioning of computing resources, task offloading, resource scheduling, service placement, and load balancing. In addition, existing AI and nonAI based state-of-the-art solutions have been discussed, along with their QoS metrics, datasets analysed, limitations and challenges. The survey provides mathematical formulation corresponding to each categorized resource management issue. Our work sheds light on promising research directions on cutting-edge technologies such as Serverless computing, 5G, Industrial IoT (IIoT), blockchain, digital twins, quantum computing, and Software-Defined Networking (SDN), which can be integrated with the existing frameworks of fog/edge-of-things paradigms to improve business intelligence and analytics amongst IoT-based applications.

IV. Vehicular and Sensor Communications

Over the past decade, Unmanned Aerial Vehicles (UAVs) have provided pervasive, efficient, and cost-effective solutions for data collection and communications. Their excellent mobility, flexibility, and fast deployment enable UAVs to be extensively utilized in agriculture, medical, rescue missions, smart cities, and intelligent transportation systems. Machine learning (ML) has been increasingly demonstrating its capability of improving the automation and operation precision of UAVs and many UAV-assisted applications, such as communications, sensing, and data collection. The ongoing amalgamation of UAV and ML techniques is creating a significant synergy and empowering UAVs with unprecedented intelligence and autonomy. This survey aims to provide a timely and comprehensive overview of ML techniques used in UAV operations and communications and identify the potential growth areas and research gaps. We emphasize the four key components of UAV operations and communications to which ML can significantly contribute, namely, perception and feature extraction, feature interpretation and regeneration, trajectory and mission planning, and aerodynamic control and operation. We classify the latest popular ML tools based on their applications to the four components and conduct gap analyses. This survey also takes a step forward by pointing out significant challenges in the upcoming realm of ML-aided automated UAV operations and communications. It is revealed that different ML techniques dominate the applications to the four key modules of UAV operations and communications. While there is an increasing trend of cross-module designs, little effort has been devoted to an end-to-end ML framework, from perception and feature extraction to aerodynamic control and operation. It is also unveiled that the reliability and trust of ML in UAV operations and applications require significant attention before the full automation of UAVs and potential cooperation between UAVs and humans come to fruition. In this context, the paper [A12] by Kurunathan et al., presents a comprehensive overview of ML techniques specially designed for UAV applications, as well as their advantages and drawbacks under different UAV-aided operations and communications. Specifically, the survey paper categorizes the UAV-compatible ML techniques holistically based on the performance metrics that they are designed against, and the applications that they embrace in support of feature extraction, environment modeling, UAV control, and data collection of UAV operation.

Radar sensors have demonstrated substantial potential across various healthcare applications, particularly through the utilization of machine learning (ML) approaches. Among different applications, human vital sign monitoring and activity recognition stand out as the most prominent. Vital sign monitoring is particularly significant, offering early detection for several chronic diseases. Similarly, activity recognition is crucial in healthcare, as the inability to perform activities may lead to critical suffering. The integration of ML is breaking down the barriers of conventional radar-based healthcare radar solutions. In this context, the paper [A13] by Ahmed and Ho Cho presents a detailed survey and tutorial. First, the challenges and limitations imposed by conventional approaches in healthcare radar sensing are outlined, and afterward, potential solutions based on ML are discussed. The survey concludes that for vital sign measurement, traditional approaches are mainly used, and ML is deployed on top of

that. For activity recognition, researchers are relying heavily on ML approaches. Currently, concepts such as generative ML and reinforcement learning are not utilized properly in radar-based healthcare research work.

V. Internet Technologies

The computing demand for massive applications has led to the ubiquitous deployment of computing power. This prevailing trend underscores the pressing necessity for higher-level computing resource scheduling services. The Computing and Network Convergence (CNC), a new type of infrastructure, has become a hot topic. To realize the envisioned objectives of CNC, such as computing-network integration, ubiquitous collaboration, latency-free, and ready-to-use, an intelligent scheduling strategy for CNC should integrate and collaborate with the network. However, the Computing and Network Convergence is built on the cloud, edge, and endless terminals, making the scheduling problem more difficult due to its wide-area requests, available flexibility arrangements, interconnections, and resource adaptations. In this context, the paper [A14] by Tang et al., presents a comprehensive tutorial and survey. First, this paper delves into scheduling objects in CNC, including advanced resources such as in-network resources. Subsequently, the paper offers guidance for optimizing a multitude of scheduling objectives, which can at times be conflicting, such as energy-saving, Quality-of-Service, and AI-driven. Furthermore, this survey explores schedulers in typical scenarios, including real-time tasks, AI tasks, the cooperation of geo-distributed data centers, and high-performance systems, highlighting their contributions, advantages, and limitations. Finally, the challenges and future research directions have been introduced for stimulating continuous efforts toward fully realizing the CNC.

The evolution of machine learning (ML) has significantly impacted resource management, interference management, autonomy, and decision-making in wireless networks. Traditional ML methods primarily rely on centralized approaches, where data is amassed at a central server for training. However, this centralization raises substantial concerns regarding data privacy. In response to these concerns, federated learning (FL) has emerged as a pivotal development. FL enables edge devices to collaboratively train ML models while maintaining data privacy, a stark contrast to traditional methods that compromise data security. In FL, local datasets remain on individual devices, and the focus is on developing a unified global model for a specific task that involves all devices. However, FL is not without its challenges, particularly in adapting models to devices with diverse data distributions. This is where meta learning becomes relevant, facilitating the adaptation of learning models to different data distributions using a minimal amount of data samples. In this context, the paper [A15] authored by Liu et al., offers a comprehensive review. This tutorial uniquely explores the design, optimization, and evolution of FL, meta learning, and federated meta learning (FedMeta) methodologies and their application in wireless networks. It goes beyond the scope of standard tutorial papers by analyzing the interconnections between these learning algorithms. Additionally, the paper scrutinizes their respective advantages and limitations in real-world applications. The authors aim to provide a thorough understanding of these methodologies, paving the way for their effective implementation in wireless network settings. This study stands as a significant contribution to the field, guiding ongoing efforts to optimize and apply FL and meta learning in practical scenarios.

VI. Network Virtualization

Network Slicing (NS) is envisaged to play a significant role in 5G and beyond networks. This raises the requirement to explore NS-related security and privacy issues. However, existing literature only provides a limited discussion on NS security and privacy aspects. Furthermore, the content related to NS security and privacy is largely overlapping and only provides a high-level overview. Many aspects, including, NS attack scenarios, detailed discussion on NS security solutions, detailed threat taxonomy, comprehensive analysis of NS trust and privacy, and an in-depth discussion on the lessons learned and future work related to NS security and privacy, is hardly covered in the existing literature. In response, the paper [A16] by Alwis et al., provides a comprehensive overview of the attacks, security threats, challenges, issues, solutions, and research directions in NS security. It defines a taxonomy for NS security and privacy, which is used to structure the rest of the paper. The paper discusses key NS attack scenarios in detail to provide an understanding of the security and privacy vulnerabilities in NS-enabled networks. It also discusses NS security challenges and issues, such as NS life-cycle security, inter-slice security, intra-slice security, slice broker security, and ZSM security. The paper then presents possible security solutions, such as AI/ML security, security orchestration, blockchain, and a dedicated slice for security. It also discusses the correlation between these solutions and identified threats, as well as NS trust and privacy aspects. Finally, the paper highlights gaps in existing research and development work, and suggests possible future research directions in NS security and privacy.

Long-running continuous queries in distributed stream processing systems are often exposed to harmful system dynamics, like changing workloads and available resources during their run-time. Efficient adaptation to such changes is a critical challenge, and operator migration is the central mechanism to adapt the system to new needs. Operator migration entails (1) state management to move the state of the operator from an old host to a new host, and (2) stream management to change data stream routing in the overlay network. Decisions on when to migrate the data and where to migrate them to are key aspects of operator migration. Modern operator migration solutions are designed to ensure that continuous queries run smoothly, without data loss and minimal disruption; even if the size of the state to be migrated is very large. In this context, the paper [A17] by Volnes et al., presents a tutorial that has been developed to familiarize the reader with operator migration, shedding light on its core elements and providing insights into the design nuances of existing solutions. The

authors developed a conceptual model that breaks down the basics of operator migration, introducing a unified language and categorizing current solutions. This model distinguishes between the mechanisms (how to migrate) and policy (when to migrate), providing a structured and algorithmic view of different design options. The algorithmic view is complemented with an empirical study that reveals significant findings: for instance, an incremental checkpoint-based migration approach drastically reduces operator downtime by almost 20 times compared to a more naïve approach. As a final point, the paper presents some reflections and future research directions.

VII. Network and Service Management and Green Communications

Human Digital Twin (HDT) refers to a technology that accurately maps the physical twin (PT) of a human entity to a digital virtual world and creates a virtual twin (VT). The VT can dynamically reflect and analyze the physiological, psychological, and social status of PT in real-time, realizing an ultra-realistic and highly interactive portrait. This feature allows HDT to potentially revolutionize human lifestyle in various fields and drive emerging technologies such as metaverse, brain-computer interface, generative AI, holographic communication, etc. A typical application scenario is personalized healthcare, where HDT can achieve remote real-time monitoring, accurate diagnosis, customized treatment planning, immersive simulation surgery, remote surgery, and tailored rehabilitation programs. This not only increases the quality of healthcare services for humans but also reduces the burden on traditional medical systems. However, the implementation of HDT also faces complex and interdisciplinary challenges. In this context, the paper [A18] by Chen et al., present a tutorial and survey. The paper focuses on analyzing the network architecture and related requirements and solutions of HDT in personalized healthcare from the perspective of communication networks. Firstly, the paper discusses the differences between HDT and traditional DT, and introduces the framework and functions of HDT. Then, the paper analyzes the design requirements and difficulties of HDT in personalized healthcare applications from the perspective of communication networks. Next, the paper overviews the network architecture of HDT, which includes the data acquisition layer, communication layer, computing layer, data management layer, and data analysis and decision-making layer. On this basis, the paper extensively surveys the key technologies to implement this network architecture. Finally, the paper proposes the future research directions of HDT, aiming to inspire and guide researchers in the communication network field to further explore and pay attention to HDT.

I hope that you enjoy reading this issue and find the articles useful. Last but not the least, I highly encourage you to submit your work which fit within the scope of ComST. For detailed instructions on the preparation and submissions of manuscripts to ComST, please check the URL below: http://dl.comsoc.org/livepubs/surveys/. I will be happy to receive your comment and feedback on our journal.

Appendix: Related Articles

[A1] M. V. Ribeiro et al., "Seamless connectivity: The power of integrating power line and wireless communications," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 1–40, First Quart., 2024, doi: 10.1109/COMST.2023.3327321.

[A2] Z. Lu et al., "Semantics-empowered communications: A tutorial-cum-survey," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 41–79, First Quart., 2024, doi: 10.1109/COMST.2023.3333342.

[A3] M. Khammassi, A. Kammoun, and M.-S. Alouini, "Precoding for high throughput satellite communication systems: A survey," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 80–118, First Quart., 2024, doi: 10.1109/COMST.2023.3316283.

[A4] N. Chukhno et al., "Models, methods, and solutions for multicasting in 5G/6G mmWave and sub-THz systems," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 119–159, First Quart., 2024, doi: 10.1109/COMST.2023.3319354.

[A5] H. ElSawy, A. Zhaikhan, M. A. Kishk, and M.-S. Alouini, "A tutorial-cum-survey on percolation theory with applications in large-scale wireless networks," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 160–195, First Quart., 2024, doi: 10.1109/COMST.2023.3336194.

[A6] T. Gong et al., "Holographic MIMO communications: Theoretical foundations, enabling technologies, and future directions," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 196–257, First Quart., 2024, doi: 10.1109/COMST.2023.3309529.

[A7] X. Cheng et al., "Intelligent multi-modal sensing-communication integration: Synesthesia of machines," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 258–301, First Quart., 2024, doi: 10.1109/COMST.2023.3336917.

[A8] M. Mehic et al., "Quantum cryptography in 5G networks: A comprehensive overview," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 302–346, First Quart., 2024, doi: 10.1109/COMST.2023.3309051.

[A9] E. Illi et al., "Physical layer security for authentication, confidentiality, and malicious node detection: A paradigm shift in securing IoT networks," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 347–388, First Quart., 2024, doi: 10.1109/COMST.2023.3327327.

[A10] S. Liu et al., "Enabling resource-efficient AIoT system with cross-level optimization: A survey," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 389–427, First Quart., 2024, doi: 10.1109/COMST.2023.3319952.

[A11] G. K. Walia, M. Kumar, and S. S. Gill, "AI-empowered fog/edge resource management for IoT applications: A comprehensive review, research challenges and future perspectives," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 428–460, First Quart., 2024, doi: 10.1109/COMST.2023.3338015.

[A12] H. Kurunathan, H. Huang, K. Li, W. Ni, and E. Hossain, "Machine learning-aided operations and communications of unmanned aerial vehicles: A contemporary survey," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 461–495, First Quart., 2024, doi: 10.1109/COMST.2023.3312221.

[A13] S. Ahmed and S. Ho Cho, "Machine Learning for healthcare radars: Recent progresses in human vital sign measurement and activity recognition," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 496–533, First Quart., 2024, doi: 10.1109/COMST.2023.3334269.

[A14] S. Tang et al., "A survey on scheduling techniques in computing and network convergence," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 534–570, First Quart., 2024, doi: 10.1109/COMST.2023.3329027.

[A15] X. Liu, Y. Deng, A. Nallanathan, and M. Bennis, "Federated learning and meta learning: Approaches, applications, and directions," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 571–618, First Quart., 2024, doi: 10.1109/COMST.2023.3330910.

[A16] C. D. Alwis, P. Porambage, K. Dev, T. R. Gadekallu, and M. Liyanage, "A survey on network slicing security: Attacks, challenges, solutions and research directions," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 619–669, First Quart., 2024, doi: 10.1109/COMST.2023.3312349.

[A17] E. Volnes, T. Plagemann and V. Goebel, "To migrate or not to migrate: An analysis of operator migration in distributed stream processing," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 670–705, First Quart., 2024, doi: 10.1109/COMST.2023.3330953.

[A18] J. Chen, C. Yi, S. D. Okegbile, J. Cai, and X. S. Shen, "Networking architecture and key supporting technologies for human digital twin in personalized healthcare: A comprehensive survey," *IEEE Commun. Surveys Tuts.*, vol. 26, no. 1, pp. 706–747, First Quart., 2024, doi: 10.1109/COMST.2023.3308717.

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