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Editorial

Editorial "Blockchain Technology—A Breakthrough Innovation for Modern Industries"

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In June 2022, the Italian national project PRIN (Research Projects of National Relevance), W.E. B.E.S.T., commenced with a duration of three years. This project evaluates the applicability of blockchain technology (BCT) in the industries of Italian wine and extra virgin olive oil, with a focus on developing an effective traceability system. The goal is to ensure maximum transparency for consumers by providing detailed information about the key stages of production and the essential characteristics of these products. Further details about the project can be found on its official website: https://www.we-best-prin.it/ (accessed on 28 November 2024).

As part of the W.E. B.E.S.T. project, this Special Issue of Computers, titled "Blockchain Technology—A Breakthrough Innovation for Modern Industries", is motivated by the increasing demand for enhanced trust, efficiency, and accountability in supply chains, particularly in sectors where product integrity and quality assurance are critical. Blockchain technology offers innovative solutions to these challenges, making it a key focus for academic and practical exploration.

This Special Issue is a collaborative effort by Guest Editors directly involved in the project and an international partner from the University of Luxembourg. It aims to advance research and development in areas central to the project's goals, with a particular focus on blockchain's role in fostering transparency, sustainability, and innovation across industries. Additionally, it gathers fresh ideas and innovative perspectives, providing a platform for researchers to contribute to and shape the evolving discourse on blockchain technology. It aims to identify emerging trends, explore practical applications, and address existing challenges in the field. By fostering interdisciplinary collaboration, this initiative also helps to connect researchers and practitioners, facilitating the exchange of knowledge and best practices.

This Editorial provides an overview of the contributions included in the Special Issue, emphasizing their theoretical significance, innovative methodologies, and practical applications. The Special Issue features a collection of ten contributions, comprising nine original research articles and one comprehensive review, which are summarized below.

Contribution 1 by D. Melo, S.E. Pomares-Hernández, L.M.X. Rodríguez-Henríquez, and J.C. Pérez-Sansalvador, titled "Unlocking Blockchain UTXO Transactional Patterns and Their Effect on Storage and Throughput Trade-Offs", provides an analysis of the transaction models and execution processes of Bitcoin and Ethereum, revealing the importance of the trade-off between storage and transaction throughput in permissionless blockchains. The authors employed DAG and spent-by to analyze transaction patterns and concluded that UTXO is a dense storage model but offers greater flexibility in throughput scalability.

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Finally, the authors split transactions based on the UTXO model into three patterns to determine the optimal dense transaction pattern and demonstrated through experiments that the split pattern provides the best compromise between throughput and storage.

Contribution 2 by J. Govea, W. Gaibor-Naranjo, and W. Villegas-Ch, titled "Securing Critical Infrastructure with Blockchain Technology: An Approach to Cyber-Resilience", explores the potential of blockchain technology to address the challenges related to cyber threats, emphasizing its immutability, decentralization, and transparency features. Through a literature review, use-case analysis, and the development and evaluation of prototypes, the authors proved that blockchain implementation has significantly improved security, efficiency, and scalability, reducing security incidents by 40% and optimizing business processes. Despite these gains, challenges in scalability, interoperability, and regulation remain. This work highlights the practical adoption of blockchain in strengthening infrastructure, providing a foundation for future research and development, and opening avenues for interdisciplinary collaboration to optimize and customize blockchain applications in vital sectors.

Contribution 3 by X. Yin, H. Qiu, X. Wu, and X. Zhang, titled "An Efficient Attribute-Based Participant Selecting Scheme with Blockchain for Federated Learning in Smart Cities", proposes a practical solution for federated learning in smart cities. The study addresses key challenges, such as ensuring privacy, preventing improper participant involvement, and designing incentive mechanisms. By introducing an attribute-based participant selection scheme and leveraging a consortium blockchain for auditing and incentivization, the authors improved training efficiency and promoted the secure and reliable adoption of federated learning in urban environments. The study advances the understanding of federated learning by integrating attribute-based access control and blockchain, offering a novel framework to enhance privacy, data integrity, and participant selection. Moreover, it provides a scalable and secure solution for implementing privacy-compliant federated learning in smart cities, improving the efficiency and reliability of urban systems like healthcare, transportation, and emergency management.

Contribution 4 by H. Taherdoost entitled "Blockchain Integration and Its Impact on Renewable Energy" explores the transformative role of blockchain technology in the renewable energy sector. Employing a comprehensive literature review, the study highlights how blockchain can reduce costs, enhance renewable energy utilization, and optimize energy management. However, it also identifies critical challenges, such as uncertainties, privacy concerns, scalability limitations, high energy consumption, and issues related to legal compliance and market acceptance. The findings underscore the importance of addressing resistance to change and fostering trust in blockchain systems, advocating for collaboration among industry stakeholders, regulators, and technology developers to fully realize the potential of blockchain in renewable energy integration.

Contribution 5 by N. Adamashvili, N. Zhizhilashvili, and C. Tricase, titled "The Integration of the Internet of Things, Artificial Intelligence, and Blockchain Technology for Advancing the Wine Supply Chain", provides valuable insights into the implementation of Internet of Things (IoT), Artificial Intelligence (AI), and blockchain technology (BCT) in the supply chain of wine, and for the identification of the potential benefits associated with their use. Through a systematic literature review (SLR), the authors explored applications of these technologies in vineyard management, wine quality control, and supply chain optimization. The study highlights benefits such as enhanced efficiency, increased transparency, and cost reduction. Concluding with a proposed framework to address implementation challenges, it also identifies key areas for future research to further integrate these technologies into the wine supply chain effectively.

Contribution 6 by L. Imane, M. Noureddine, S. Driss, and L. Hanane, titled "Towards Blockchain-Integrated Enterprise Resource Planning: A Pre-Implementation Guide", emphasizes the significant benefits of blockchain technology while addressing the challenges of its implementation, stating that it remains a novel, complex, and costly technology. The paper employs a comprehensive review of the existing literature, theories, and expert opin-

ions. It provides a framework to guide decision-makers through the pre-implementation phase, emphasizing the importance of thorough research to assess whether blockchain aligns with an organization's needs, resources, and strategic objectives. The insights from this article contribute to the current body of knowledge and can be applied in practical settings by stakeholders engaged in blockchain integration projects with ERP systems.

Contribution 7 by F. Kahmann, F. Honecker, J. Dreyer, M. Fischer, and R. Tönjes, titled "Performance Comparison of Directed Acyclic Graph-Based Distributed Ledgers and Blockchain Platforms", explores the performance differences between Directed Acyclic Graph (DAG)-based platforms and traditional blockchain systems. The study focuses on scalability challenges faced by blockchain technologies, particularly in processing thousands of transactions per second and accommodating growing numbers of network nodes. By evaluating prominent DAG platforms, the authors aimed to assess whether the theoretically improved scalability of DAGs holds true in practical applications. Through extensive testing, the study finds that DAG-based systems offer a significantly higher transaction throughput compared to blockchain-based platforms, due to their more parallel data structure. However, DAG platforms, still in an early development stage, require further maturation in terms of features and programmability to match blockchain platforms. The findings provide insights for developers considering DAG-based solutions for real-world applications, such as smart grid communication and trusted supply chain management.

Contribution 8 by J.-L. Ferrer-Gomila and M.F. Hinarejos, titled "A Hard-Timeliness Blockchain-Based Contract Signing Protocol" introduces a novel blockchain-based contract signing protocol that satisfies fairness, hard-timeliness, and bc-optimism requirements. It is designed to be fair, ensuring no honest signatory is disadvantaged, and allows signatories to end the execution of the protocol at any time, meeting the hard-timeliness requirement. Furthermore, the protocol is bc-optimistic, only utilizing blockchain functions in exceptional cases, which leads to efficiency and cost savings, especially in public blockchains. The article also clarifies the concept of timeliness, which had been previously ambiguous. After conducting a security review, the authors confirmed that the protocol meets all specified requirements and provided the specifications for a smart contract on the Ethereum blockchain, demonstrating its economic feasibility for diverse applications.

Contribution 9 by H. Hashim, A.R. Alzighaibi, A.F. Elessawy, I. Gad, H. Abdul-Kader, and A. Elsaid, titled "Securing Financial Transactions with a Robust Algorithm: Preventing Double-Spending Attacks", addresses the vulnerability of zero-confirmation transactions in blockchain technology, which are not yet confirmed on the blockchain and are susceptible to double-spending attacks. The authors propose a method to secure these transactions by replacing the Security Hashing Algorithm (SHA) 256 with SHA-512 in elliptic curve cryptography (ECDSA) to generate a more secure cryptographic identity. Their findings demonstrate that SHA-512 not only provides better throughput performance than SHA-256 but also offers enhanced security due to its larger hash size. This method significantly improves the security and efficiency of zero-confirmation transactions, protecting them from double-spending risks.

Finally, contribution 10, a review by L. Albshaier, S. Almarri, and M.M. Hafizur Rahman, titled "A Review of Blockchain's Role in E-Commerce Transactions: Open Challenges, and Future Research Directions" discusses the transformative potential of blockchain technology in e-commerce. The review highlights how blockchain's decentralized nature and encrypted transaction records can enhance security, transparency, and fraud detection in e-commerce. As e-commerce grows, so does the risk of cyberattacks targeting sensitive customer and financial data. Blockchain technology provides an effective solution by creating immutable records that can track transactions and prevent fraud, ultimately increasing trust and security in the e-commerce ecosystem.

In conclusion, this Special Issue highlights the transformative potential of blockchain technology across various industries, addressing challenges in supply chain transparency, cybersecurity, and financial transactions. The contributions demonstrate the integration of blockchain with emerging technologies like IoT and AI, providing innovative solutions

to improve efficiency, security, and scalability. While challenges remain, such as scalability and regulation, these works offer valuable insights for both academia and industry, paving the way for continued advancements and practical applications of blockchain in modern industries.

Finally, the editors of this Special Issue wish to express their gratitude to the authors, reviewers, and the editorial team of the journal *Computers* for their contributions and support.

Conflicts of Interest: The authors declare no conflicts of interest.

List of Contributions

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