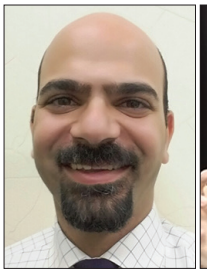
Blockchains for Scalable IoT Management, Access, and Accountability





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Blockchains have emerged as a key technology for allowing cryptocurrency (e.g., bitcoin) users to transfer funds, validate transactions, and record information in a fully distributed manner. Adopting blockchains as introduced for cryptocurrency to support IoT applications is not, however, straightforward, and presents major challenges that need to be overcome. These challenges arise mainly from the limitations and features that are inherent in IoT devices, such as their limited resource capabilities, the traffic bottlenecks that could occur at network edges, the scalability challenges that arise from the large numbers of IoT devices, the device mobility challenges, and the privacy and security issues. For instance, the proof-of-work (POW) approach, imposed in Bitcoin to secure and ensure robustness of the blockchain against malicious behaviors, requires powerful computation and incurs long delays, making it unsuitable for IoTs. Scalability also presents another key challenge, as most existing IoT architectures are centralized, a challenge that can potentially be overcome using blockchains. Also, security/privacy and device mobility pose legitimate concerns that present bottlenecks for the development and adoption of many IoT applications, which can also be addressed through the use of blockchains. Depending on the type of application, the no longer need for a trusted third party raises a privacy/security threat that can be exploited to compromise sensitive IoT data, and the low-latency requirement of some IoT applications puts new constraints on the allowed time needed for validating and adding blocks to the blockchains.

This special issue highlights new blockchain architectures and techniques that can be leveraged to enable scalable management, access and accountability of massive numbers of IoT devices to effectively support various IoT applications. Under a rigorous peer-review process, nine papers have been selected for publication in this special issue. The first article, "Securing Smart Cities through Blockchain Technology: Architecture, Requirements and Challenges," focuses on the use of bockchains technology to support and enable smart city services. It identifies the requirements needed for incorporating blockchains technology, and proposes an architecture for securing smart cities using these blockchains. The article also presents smart city case studies that adopt the proposed blockchain approach, and discusses open research challenges that require future investigation.

The second article, "Blockchain for Managing Heterogenous Internet of Things: A Perspective Architecture," focuses on the integration of blockchains technology with IoT systems. It discusses the limitations of exiting IoT systems and highlights the challenges related to integrating IoT systems with blockchain technology. The article introduces an architecture for employing blockchains to manage large-scale, heterogenous IoT systems.

The third article, "Blockchain-Empowered Secure Spectrum Sharing for 5G Heterogeneous Networks," focuses on the use of blockchains for securing spectrum resource sharing in the context of 5G networks. It proposes a two-stage approach where the first stage promotes spectrum sharing via an incentive mechanism and secures spectrum-sharing transactions via blockchains, and the second stage formulates and solves the spectrum allocation problem via combinatorial optimization. The article concludes by outlining several open research issues that still need to be addressed.

The fourth article, "Integrating Blockchain and IoT/ITS for Safer Roads," describes how the Safe System approach offers a holistic structure of various innovative solutions in the context of IoT and Intelligent Transportation Systems (ITS). It introduces a necessary extension to the Safe System approach while considering emerging technologies such as connected and computing vehicles and vehicle autonomy. The article shows how blockchains can play a crucial role in ensuring road safety, as well as the safety of its connected elements.

The fifth article, "DIoTA: Decentralized Ledger based Framework for Data Authenticity Protection in IoT Systems," presents a two-layer decentralized ledger architecture together with a lightweight data authentication mechanism for facilitating IoT devices and data management. The article provides a detailed performance and security analysis of the proposed architecture using experimental data.

The sixth article, "Communication Aspects of the Integration of Wireless IoT Devices with Distributed Ledger Technology," focuses on the integration of Distributed Ledger Technologies (DLTs) in the context of resource-limited IoT devices. It discusses the limitations and opportunities offered by DLTs, and highlights the challenges encountered in the process of integrating resource-constrained IoT devices with distributed trust networks. The article also describes the common traits of lightweight synchronization protocols, and proposes a novel classification, rooted in the IoT perspective.

The seventh article, "Hash Access: Trustworthy Grant-Free IoT Access Based on Blockchain," proposes a trustworthy IoT access protocol that leverages blockchain radio access network (B-RAN) architecture to enable multi-operator networks without shared authentication. B-RAN allows to establish trust among initially trustless operators and to efficiently utilize resources across networks. To mitigate the loss of network efficiency caused by selfish behavior among untrustworthy IoT devices, the proposed protocol allows to induce IoT devices to follow an access rule and control data traffics. The proposed framework unifies the IoT access and the underlying B-RAN to reduce confirmation delays.

The eighth article, "Blockchain Applied to Vehicular Odometers," focuses on leveraging blockchains technology for enabling

efficient management of vehicular odometer data. The article presents and discusses the requirements, design choices, and construction details of a blockchain architecture for vehicular odometers, and validates the proposed architecture through proof-of-concept prototyping.

Finally, the ninth article, "Application-Aware Consensus Management for Software-defined Intelligent Blockchain in IoT," focuses on addressing the blockchain consensus management and configuration challenges arising from IoT application dynamics. The article proposes a software-defined blockchain architecture, a consensus function virtualization approach, and a transfer scheme to enable dynamic configurations for blockchains and to perform efficient management of virtualized consensus resources.

Biographies

Bechir Hamdaoui [SM] is a professor in the School of EECS at Oregon State University. He received M.S. degrees in both ECE (2002) and CS (2004), and a Ph.D. degree in ECE (2005) all from the University of Wisconsin-Madison. His research interests are in the general areas of computer networks, wireless communication, and computer security. His current focus includes cloud computing, data analytics, security and privacy, distributed optimization and control, service and network management, the Internet of Things, and cognitive radio and dynamic spectrum access. He has won several awards, including the ICC 2017 Best Paper Award, the 2016 EECS Outstanding Research Award, and the 2009 NSF CAREER Award. He serves/has served as an Associate Editor for several journals, including *IEEE Transactions on Mobile Computing*, *IEEE Transactions on Wireless Communications*, *IEEE Network*, and *IEEE Transactions on Vehicular Technology*. He has also chaired/co-chaired many IEEE conference programs/symposia, including the 2017 INFOCOM Demo/Posters program, the 2016 IEEE GLOBECOM Mobile and Wireless Networks Symposium, and many others. He served as a Distinguished Lecturer for the IEEE Communication Society for 2016 and 2017. He currently serves as the Vice-Chair for IEEE Communications Society's Wireless Communications Technical Committee.

Ammar Rayes is a distinguished engineer at Cisco's Advanced Services Technology Office focusing on network analytics, IoT, and machine learning. He has authored three books, and over 100 publications in refereed journals and conferences on advances in software and networking related technologies and over 25 patents. He is the Founding President and board member of the International Society of Service Innovation Professionals (www.issip.org), Editor-in-Chief ofthe journal *Advances of Internet of Things*, and Editorial Board member of the European Alliance for Innovation — Industrial Networks and Intelligent Systems. He has served as an Associate Editor of *ACM Transactions on Internet Technology* and *Wireless Communications and Mobile Computing*, a Guest Editor of multiple journals and several *IEEE Communication Magazine* issues, co-chaired the Frontiers in Service Conference, and appeared as a Keynote Speaker at several IEEE and industry conferences. At Cisco, he is the founding chair of the Cisco Services Research and Cisco Services Patent Council. He received the Cisco Chairman's Choice Award for IoT Excellent Innovation & Execution. He received his B.S. and M.S. degrees in EE from the University of Illinois at Urbana and his Ph.D. degree in EE from Washington University in St. Louis, Missouri, where he received the Outstanding Graduate Student Award in telecommunications.

Nizar Zorba is a professor with the Electrical Engineering Department at Qatar University, Doha. He has authored five international patents, two books, contributed to seven book chapters, and co-authored over 100 papers in peer-reviewed journals and international conferences. He led and participated in over 35 research projects (Qatari, European, Spanish) and engineering projects (Boeing, ESA, MTC). He received his B.Sc. degree in electrical engineering from JUST University, Jordan, in 2002, and his Ph.D. degree in signal processing for communications from UPC Barcelona, Spain, in 2007. He is an Associate Editor of the *Springer Journal on Wireless Communications and Networking*, and Symposium Chair of IEEE ICC 2019. Currently, he is the secretary of the IEEE ComSoc Communication Systems Integration and Modeling Technical Committee (TC CSIM). His research interests span 5G networks, IoT optimization, demand-response in smart grids, and crowd management.

Lingyang Song received his Ph.D. degree from the University of York, United Kingdom, in 2007. He was a research fellow with the University of Oslo, Norway, until rejoining Philips Research, United Kingdom, in 2008. In 2009, he joined the School of Electronics Engineering and Computer Science, Peking University, where he is currently a Boya Distinguished Professor. His main research interests include wireless communication and networks, signal processing, and machine learning. He was a recipient of the IEEE Leonard G. Abraham Prize in 2016 and the IEEE Asia Pacific Young Researcher Award in 2012. He received the K. M. Stott Prize for excellent research from the University of York. He has been an IEEE Distinguished Lecturer since 2015.

Christos Verikoukis [M] received his Ph.D. from the Technical University of Catalonia in 2000. He is currently a fellow researcher at CTTC (Head of the SMARTECH Department) and an adjunct professor at Barcelona University (Electronics Department). He has published 120 journal papers (h-index 30) and over 180 conference papers. He has also co-authored three books and 16 chapters in different books, and he has filed three patents. He has supervised 15 Ph.D. students and five postdoctoral researchers since 2004. He has participated in more than 40 competitive projects while he has served as the principal investigator in national projects in Greece and Spain. He served as the technical manager of the ITN-GREENET, ITN-5GSTEPFWD, CELTIC-GREEN-T, and LOOP projects. He received the best paper award at the Communication QoS, Reliability & Modeling Symposium (CQRM) symposium at IEEE ICC 2011 and ICC 2014, of the Selected Areas in Communications Symposium at IEEE GLOBECOM 2014, EUCNC 2016, and the EURASIP 2013 Best Paper Award for the *Journal on Advances in Signal Processing*. He was the General Chair of the 17th, 18th, and 19th IEEE Workshop on Computer-Aided Modeling, Analysis and Design of Communication Links and Networks (CAMAD), and the TPC Co-Chair of the 15th IEEE International Conference on eHealth Networking, Application & Services (Healthcom) and the 7th IEEE Latincom. He has also served as the Symposium Co-Chair of the CQRM Symposium at IEEE ICC 2015 and IEEE ICC 2016. He is currently the Chair of the IEEE ComSoc Technical Committee on Communication Systems Integration and Modeling.