Private Blockchain in Industrial IoT






Minho Jo Kai Hu Richard Yu Li Sun Mauro Conti Qinghe Du

This special issue is devoted to sharing state-of-the-art research on private blockchain in industrial IoT (Internet of Things). A blockchain is a decentralized and distributed ledger with a chain network of blocks recording historical transactions. A transaction is a record of action. A transaction inside the block will be of: sensing/saving data, assembling parts, depositing money, processing a business deal, ordering/delivering a product part, notarizing a paperwork, and so on. Blockchains are categorized into two types, public blockchain and private blockchain. Private blockchains have been more in the spotlight in industry recently because they are much faster, cheaper, and privacy-oriented compared to the public blockchain. We expect that private blockchains will be much more widely implemented soon. This is our main motivation for preparing this special issue.

Public blockchains are literally just "public." Anyone can read, write, and join a public chain network while private blockchains are permissioned and one or multiple nodes control and restrict access of members to the chain network. The openness of public blockchain is a disadvantage. Some well known examples of public blockchains are Bitcoin, Ethereum, and Ripple, while several well known examples of private blokchains are Hyperledger Fabric and R3 Corda. Public blockchains consume a tremendous amount of energy, time and money because of the mining to achieve consensus. On the other hand, the consensus algorithm of the private blockchain is simple, which provides advantages of much faster computing time, cheaper cost, and greater scalability. Private and public blockchains have few similarities and consequently private blockchain is totally opposite of public blockchain. Private blockchain has been successfully applied in industrial Internet of Things (IoT) because of its advantages and industrial characteristics. Most industrial IoT organizations are exclusive and private (namely, less public) as well as money-oriented and time-oriented, and thus private blokchains are well suited for industrial IoT.

However, private blockchains have many challenging technological problems for various industrial IoT applications which we should attack, for example, the scalability problem, efficient consensus mechanism, robust smart contract, secure access control, replica management, interoperability and compatibility with public blockchains, deployment and feasibility in emerging networks such as VANET, edge/fog computing networks, and software-defined networking, and more.

The article "A Many-Objective Optimization Model of Industrial Internet of Things Based on Private Blockchain" by B. Cao *et al*. presents an improved algorithm based on Two_Arch2 to maximize the scalability and decentralization while reducing the latency and cost of the private blockchain, which is well fitted for industrial IoT. In Two_Arch2, two archives, convergence (CA) and diversity (DA), evolve independently. CA can reach the Pareto front rapidly, while DA keeps the diversity of the population. However, Two-Arch2 has a disadvantage of preferring the solutions in the boundary area. In order to overcome the disadvantage, the authors replaced this existing strategy with the non-dominated ranking strategy and the maximum extension distance (MED) indicator while updating the population in CA. By using the PBFT (Practical Byzantine Fault Tolerance) consensus mechanism, their proposed algorithm has shown that it can maximize the scalability of the private blockchain as well as the cost, decentralization, and latency according to the experimental results.

The article "Blockchain and AI-Based Natural Gas Industrial IoT System: Architecture and Design Issues" by Y. Miao *et al*. proposes an architecture for a private blockchain for the purpose of distributing natural gas supply with trusted gas transactions. The authors designed a forward natural gas IoT architecture based on blockchain and AI, consisting of a side-chain of natural gas block based on data dimension, and a backbone of natural gas block based on value dimension, in order to address the defects of a centralized energy supply architecture. The side-chain of natural gas block aims at avoiding tampering with data in the process of generation, transmission, and recording. In the proposed private blockchain architecture, AI is used for data mining such as natural gas load prediction which is applied for energy pricing. The proposed private blockchain architecture for natural gas transactions has proven its effectiveness through experimental simulation.

The article "Private-Blockchain-Based Industrial IoT for Material and Product Tracking in Smart Manufacturing" by M. Assaqty *et al*. is a tutorial for implementing a private blockchain in the manufacturing industry. The authors have shown that a private blockchain is successfully used in smart manufacturing in order to bridge the needs for trusted product and material tracking information exchange between parties in smart manufacturing. Private blockchain based

industrial IoT has not been widely applied in the manufacturing industry so far, especially for material and product tracking. This paper illustrates a design of private blockchain based industrial IoT in the form of a model and architecture that is expected to help the manufacturing industry in implementation. The authors define user roles of the manufacturing industry for a private blockchain and introduce implementation strategies. For better understanding of the implementation, they have carried out a simulation by using the Hyperledger Fabric framework, which is the most popular private blockchain platform in industry.

Biographies

Minho Jo (minhojo@korea.ac.kr) is a professor in the Department of Computer Convergence Software, Korea University, Sejong Metropolitan City, South Korea. He is the Director of the IoT & AI Lab, Korea University. He currently serves on South Korea's Presidential Commission on Policy Planning. He received a B.A. from the Department of Industrial Engineering, Chosun University, South Korea, in 1984, and received a Ph.D. from the Department of Industrial and Systems Engineering, Lehigh University, USA, in 1994. He is a recipient of the 2018 IET Best Paper Premium Award by the United Kingdom's Royal Institute of Engineering and Technology. He is the Founder and Editor-in-Chief of *KSII Transactions on Internet and Information Systems* (SCI/JCR and SCOPUS indexed). He is currently an associate editor for *IEEE Systems Journal*, *IEEE Access*, and *IEEE Internet of Things Journal*, and is an editor for *IEEE Wireless Communications*. His current research interests include IoT, blockchain, artificial intelligence and deep learning, big data, network security, cloud/edge computing, wireless energy harvesting, and autonomous vehicles.

Kai Hu (hukai@buaa.edu.cn) has been a Professor in the Department of Computer Science and Technology, Beihang University, Beijing, China since 2004, and is the Director of the Beijing Computer Society. He received his Ph.D. degree from the Department of Computer Science and Technology, Beihang University, in 2001. He was a visiting scholar at Arizona State University in the United States in 2014. He is one of the leading scholars in blockchain in China. He has been involved as a principle investigator for many large national research projects in China. Research topics of his current interest lie in blockchain, distributed parallel computing and networks, high-performance computing, and space-ground integration network information technology.

Richard Yu (richard.yu@carleton.ca) received the Ph.D. degree in electrical engineering from the University of British Columbia, Vancouver, BC, Canada, in 2003. From 2002 to 2006 he was with Ericsson, Lund, Sweden and a start-up in California, USA. He joined Carleton University in 2007, where he is currently a professor. He has authored more than 500 papers with more than 22,000 citations and an h-index of 65 (Google Scholar), including 19 as highly cited papers (per Essential Science Indicators). He was the recipient of the IEEE Outstanding Service Award in 2016, IEEE Outstanding Leadership Award in 2013, Carleton Research Achievement Award in 2012, and the Ontario Early Researcher Award (formerly Premiers Research Excellence Award) in 2011. He serves on the editorial boards of several journals, including as Co-Editor-in-Chief for *Ad Hoc & Sensor Wireless Networks*, area editor for *IEEE Communications Surveys and Tutorials*, Lead Series Editor for *IEEE Transactions on Vehicular Technology* and *IEEE Transactions on Green Communications and Networking*. He is the Vice President (Membership) and a member of the Board of Governors of the IEEE Vehicular Technology Society. His research interests include blockchain, wireless cyber-physical systems, connected/autonomous vehicles, security, and deep learning.

Li Sun (lisun@mail.xjtu.edu.cn) received the B.S. and Ph.D. degrees in information and communications engineering from Xi'an Jiaotong University, China, in 2006 and 2011, respectively. Since 2012, he has been with the Department of Information and Communications Engineering, Xi'an Jiaotong University, as an associate professor. He was awarded the First Prize of the National Young Faculty Teaching Competition for Electronics and Information Related Specialties in 2017. He has been an editor for *KSII Transactions on Internet and Information Systems* since 2014. He was the TPC Co-chair of the IEEE GLOBECOM'17 Workshop on PHY and Cross-Layer Security Solutions for 5G Networks in 2017. His research interests include cooperative relaying networks, blockchain, wireless physical-layer security, deep learning for communications, and device-to-device communications.

Mauro Conti (conti@math.unipad.it) received the Ph.D. degree from Sapienza University, Rome, Italy, in 2009. He was a postdoctoral researcher with Vrije Universiteit Amsterdam, The Netherlands. He is a full professor with the University of Padua, Padua, Italy, and an affiliate professor with the University of Washington, Seattle, WA, USA. He has published more than 250 papers in highly respected international peer-reviewed journals and conferences in the above areas. He has been awarded with the Marie Curie Fellowship by the European Commission in 2012 and the Fellowship by the German DAAD in 2013. He is an area editor for *IEEE Communications Surveys & Tutorials*, and an associate editor for several journals, including *IEEE Communications Surveys & Tutorials*, *IEEE Transactions on Information Forensics and Security*, *IEEE Transactions on Dependable and Secure Computing*, and *IEEE Transactions on Network and Service Management*. His main research interest is in the area of security and privacy.

Qinghe Du (duqinghe@mail.xjtu.edu.cn) received the B.S. and M.S. degrees from Xi'an Jiaotong University, China, and the Ph.D. degree from Texas A&M University, USA. He is currently a professor with the Information and Communications Engineering School, Xi'an Jiaotong University. He has published over 100 technical articles. He received the Best Paper Award at IEEE GLOBECOM 2007 and the Best Paper Award of China Communications in 2017. He serves/has served as an associate editor for *IEEE Communications Letters* and an editor for *KSII Transactions on Internet and Information Systems*. He served as the Technical Program Co-Chair for the IEEE/CIC ICCC Workshop on Internet of Things (IoT) from 2013 to 2017, the Track Co-Chair for IIKI from 2015 to 2019, and the Publicity Co-Chair for the IEEE ICC 2015 Workshop on IoT/CPS-Security and IEEE GLOBECOM 2011, among others. His research interests include mobile wireless communications and networking, with an emphasis on machine learning and artificial intelligence over wireless networks, statistical quality-of-service provisioning, blockchain, secure wireless transmissions, and 5G/B5G/6G networks.