Chapter 53
Blockchain-Based Industrial Internet of Things for the Integration of Industrial Process Automation Systems

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ABSTRACT

The industrial internet of things is expected to attract significant investment to the industry. In this new environment, blockchain presents immediate potential in industrial IoT applications, offering several benefits to industrial cyber-physical systems. However, works in the blockchain literature target environments that do not meet the reality of the factory and do not assess the impact of the blockchain on industrial process requirements. Thus, this chapter presents an investigation of the evolution of industrial process automation systems and blockchain-based applications in the horizontal and vertical integration of the various systems in a supply chain and factories. In addition, through an investigation of experimental work, this work presents issues and challenges to be faced for the application of blockchain in industrial processes. Evaluations and discussions are mainly focused on aspects of real-time systems in machine-to-machine communication of industrial processes.

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INTRODUCTION

Industry 4.0 refers to the fourth industrial revolution that transforms industrial manufacturing systems into Industrial Cyber-Physical Systems (ICPS), introducing emerging paradigms of information and communication, such as the Internet of Things (Serpanos & Wolf, 2018). By 2025, investments in the Industrial Internet of Things (IIoT) in the world should reach US$ 950 billion (Grand View Research [GVR], 2019). The forecasts are that investment in this market will grow by 30% during the forecast period. All this because the IIoT insertion in the factory brings excellent benefits, such as the possibility of increasing productivity by 30%.

IIoT devices have unique features such as low processing and memory, low bandwidth for data transmission, and limited autonomy (Sisinni, Saifullah, Han, Jennehag, & Gidlund, 2018). With the popularization of these devices and faced with such restrictions, it was necessary to develop new types of communication protocols designed to address these limitations. Generally, the protocols used work with the Publish-Subscribe paradigm, which allows data to be available to multiple consumers. Also, some devices may communicate with each other, either directly or through some intermediary, which is called Machine-to-Machine (M2M) communication (Kshetri, 2017).

M2M communication has shown immediate potential in industrial applications (Bartodziej, 2017). However, M2M communication based on the Publish-Subscribe paradigm uses a communication model through an intermediate node that becomes a point of failure. Also, M2M communication latency can affect the time requirements of real-time systems, compromising deadlines. Intending to establish a decentralized Peer-to-Peer (P2P) network and without the need for a reliable intermediary, several works are introducing blockchain-based smart contracts in various industrial environments. The main benefits pointed out in these works are safe, traceable, and independent communication of processes.

Blockchain-based ICPS can benefit from the vertical integration of Industrial Process Automation Systems (IPAS), creating an IIoT data flow from the production level by sensors/actuators to the short- and long-term decision-making levels by corporate servers/workstations. However, advances in recent blockchain and other technologies (hardware and software) do more harm than good when the ICPS needs to meet tight time constraints. The execution time of an ICPS depends on the context, which leads to uncontrollable variability. In addition, programming languages are generally Turing complete, which makes the runtime undecidable (Lee, 2005). Besides, industrial plant updates with new equipment that are expensive and unrealistic for small and medium industries and will replace that equipment that already work perfectly.

Although it is possible to find much research in the literature on blockchain-based smart contracts in the literature, this technology in the industrial field is still in its early stages. In particular, Lin and Liao (2017) initiate a discussion on blockchain-based smart contract platforms in the industrial environment. Reyna, Martín, Chen, Soler, and Díaz (2018) investigated the possibility of blockchain integration with IIoT and presented issues and challenges. The work of Nawari and Ravindran (2019) discusses the potentials and limitations of the application of smart contracts in the architecture, engineering and construction sectors. Alladi, Chamola, Parizi, and Choo (2019) present challenges and research on blockchain applications for IIoT.

However, most existing research suffers from the following limitations: there is no convergence of blockchain and smart contracts with the horizontal and vertical hierarchy of IPAS; There is no study explicitly discussing blockchain and smart contracts for real-time systems, but this topic is of great importance for the development of industry 4.0. Therefore, although blockchain-based smart contracts can