IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received February 21, 2020, accepted March 7, 2020, date of publication March 17, 2020, date of current version March 27, 2020.

*Digital Object Identifier 10.1109/ACCESS.2020.2981415*

# A Survey on Decentralized Consensus Mechanisms for Cyber Physical Systems

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This work was supported by the Ministry of Science and Technology, Taiwan, under Grant MOST 108-2410-H-161-004.

**ABSTRACT** Modern industry *4.0* applications are shifting towards decentralized automation of computing and cyber-physical systems (CPS), which necessitates building a robust, secure, and efficient system that performs complex interactions with other physical processes. To handle complex interactions in CPS, trust and consensus among various stakeholders is a prime concern. In a similar direction, consensus algorithms in blockchain have evolved over the years that focus on building smart, robust, and secure CPS. Thus, it is imperative to understand the key components, functional characteristics, and architecture of different consensus algorithms used in CPS. Many consensus algorithms exist in the literature with a specified set of functionalities, performance, and computing services. Motivated from these facts, in this survey, we present a comprehensive analysis of existing state-of-the-art consensus mechanisms and highlight their strength and weaknesses in decentralized CPS applications. In the first part, we present the scope of the proposed survey and identify gaps in the existing surveys. Secondly, we present the review method and objectives of the proposed survey based on research questions that address the gaps in existing studies. Then, we present a solution taxonomy of decentralized consensus mechanisms for various CPS applications. Then, open issues and challenges are also discussed in deploying various consensus mechanisms in the CPS with their merits and demerits. The proposed survey will act as a road-map for blockchain developers and researchers to evaluate and design future consensus mechanisms, which helps to build an efficient CPS for industry *4.0* stakeholders.

**INDEX TERMS** Blockchain, consensus algorithms, cyber-physical systems, IoT, smart grid, supply chain management, intelligent transportation.

## I. INTRODUCTION

Traditional systems rely on building electro-mechanical devices, which are focused on scientific calculations rather than raw computations. Moreover, Industry *4.0*-based applications are more inclined towards computing and storage facilities. To meet out the aforementioned needs, modern systems have evolved to provide robust, intelligent, and automated support to a plethora of applications in the physical world. These applications exchange data, communicate, and integrate embedded physical processes, and monitor results based on web services through low-powered networking infrastructures like GPRS, 3G, Zigbee, and Bluetooth. The embedded sensors used in such applications provide real-time haptics and support customized actuations on physical devices, which has improved user-personalization and experience by reducing latency in communications. Thus, these systems were termed as *cyber-physical* systems, which mainly integrate three elements, namely, physical processes, networking, and computational services. Networks and computers control feedback loops manage the physical processes and computations. CPS makes modern-day applications more secure and productive by reducing the cost of building and maintaining physical demands. It leverages the capabilities of old machines by deploying smart sensors over wireless sensors networks (WSN), which sends data over

The associate editor coordinating the review of this manuscript and approving it for publication was Eklas Hossain.