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Decentralized Network Building Change in Large Manufacturing Companies towards Industry 4.0

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Abstract

In complex industrial ecosystems together with an increasing global competition, success depends on a complete value chain transformation. The use of Industry 4.0 standards is therefore gradually emerging in many industries to ensure significantly higher factory productivity, flexibility, and efficiency. However, selected methodology and results are required to be studied to fully understand the digital transformation as well as its characteristics. This research presents a system conversion study, from centralized to decentralized systems, using epidemic membership protocols on a large manufacturing company towards Industry 4.0.

The system conversion shows that the epidemic membership protocols provide an ability to rewrite the structure of the overlay topology. The experimental results are presented in two categories: (1) convergence speed and (2) accuracy of the epidemic applications. These provide the information for the performance guarantee of the global aggregate computation. The expectation of this paper is to present a preliminary study focusing on the system conversion methodology in the context of Industry 4.0. There are several recent publications based on Industry 4.0; however, nothing has been done to address any methodologies applied in Industry 4.0 or their simulation results.

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Keywords: epidemic protocols; extreme-scale network systems; system conversion; industry 4.0

1. Introduction

In an increasingly global competitive market, Industry 4.0 is widely used across the world, particularly in ensuring higher performance with better product quality and higher competitiveness[1]. Industry 4.0's core concept lays in decentralized systems through the Cyber-Physical System (CPS) to change every level of industry by improving hardware and software, while representing new approaches to the implementation of Industry 4.0 throughout the industry[2,3]. As a result, a complex systems with a huge amount of data are built and data mining techniques[4] are required to extract information for a better decision making.

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According to Rubmann, 2015[5], intelligent Industry 4.0 is the key point to control, communicate, compute, and transform production systems 30 percent faster and 25 percent more eciently in comparison to current well-developed systems. Manufacturing will be transformed from single automated work units to a fully integrated system in which one work unit can connect to each other enhancing flexibility, speed, productivity, and quality in order to best serve individual customer requirements. Consequently, the system transformation requires existing installation to be adapted, especially for large companies. In contrast,adoption of new structures are preferred to be developed from scratch in the cases of small or medium companies[6].

The objective of this research is to demonstrate the eciency of decentralized systems over centralized systems on very large and complex manufacturing systems using the epidemic protocol technique. The epidemic membership protocols are used to distribute information and compute data aggregation in extreme-scale network systems. For example, many sensors allow for better communication capabilities in todays modern industries. The messages or information can be distributed across the system. However, applying centralized or decentralized systems depend largely on the specific situation analysis. This study consequently shows the ability to swap centralized for decentralized. Several works emerging in many fields that inherit the characteristics of epidemic protocols have been deployed in extreme-scale network systems such as Peer-to-Peer (P2P) overlay networks[7,8,9], distributed computing[10], mobile ad hoc networks (MANET)[11,12,13], wireless sensor networks (WSN)[14,15,16,17,18], failure detection[19,20], exascale high performance computing[21,22,23], data mining[24,25], the data aggregation[26,27,28,29], etc.

The literature review reveals that little work has been done on a system conversion from centralized to decentralized manufacturing systems. To fill the research gap, this study aims to test the feasibility of transforming system using the epidemic membership protocols methodology in a large manufacturing process system. The assumption adopted in this study is that transforming such centralized systems to decentralized systems would help ensure safe and efficient operation of the manufacturing process system. The epidemic membership protocols can be able to maintain the randomness of the network topology. Another greatest advantage of this high randomness is the fault tolerance. This paper generated and analysed the preliminary results from the simulation and provided some suggestions in applying the distributed system towards Industry 4.0.

The paper is organized as follow. Section 2 provides a literature review of the centralized and decentralized systems applied in manufacturing environment. Section 3 defines simulation model. Section 4 presents general experimental setting. Section 5 provides experimental analysis and results. Section 6 presents the conclusions and recommendation for future work.

2. Description of Centralized Systems and Decentralized Systems

To understand the structure of the transition from Industry 3.0 to Industry 4.0, centralized and decentralized systems are required to be clearly explained. This section classifies the characteristics and details of a decentralized computer system over a conventional centralized network. The architectures of each system are shown in Fig. 1 and 2.

2.1. Centralized Systems

The most familiar form of topology is centralized systems, whose structure is typically similar to the client/server. A server aims to centralize all functions and information taken from clients by directly connecting to them. Clients share their resources by sending and receiving information to a server[30]. In centralized systems, a server will compute the global aggregation by processing all of local information sent by clients in the system.

There are many advantages of centralized systems and one of the most notable advantages is its simplicity of having a single database design. As a result, this approach is easily managed and represents high data consistency or coherence. Greater information security is another advantage of centralized systems over decentralized systems because all processes are controlled from a central location. However, this approach is fault intolerant because having only one control center puts it at a higher risk of a system breakdown than having multiple control centers. In addition, increasing system scalability is limited because of the server's capacity[30].