Microprocessors and Microsystems 39 (2015) 1262–1270

Contents lists available at ScienceDirect

Microprocessors and Microsystems

journal homepage: www.elsevier.com/locate/micpro

Cloud-assisted industrial cyber-physical systems: An insight

Xuejun Yue [a], Hu Cai [b,*], Hehua Yan [c], Caifeng Zou [c], Keliang Zhou [b]

[a] South China Agricultural University, Guangzhou, China
[b] JiangXi University of Science and Technology, Ganzhou, China
[c] Guangdong Mechanical and Electrical College, Guangzhou, China

ARTICLE INFO

Article history:
Received 9 June 2015
Revised 16 August 2015
Accepted 17 August 2015
Available online 7 September 2015

Keywords:
Industry 4.0
Cloud computing
Cyber-physical systems
Big data
Industrial wireless networks

ABSTRACT

The development of industrialization and information communication technology (ICT) has deeply changed our way of life. In particular, with the emerging theory of "Industry 4.0", the integration of cloud technologies and industrial cyber-physical systems (ICPS) becomes increasingly important, as this will greatly improve the manufacturing chain and business services. In this paper, we first describe the development and character of ICPS. ICPS will inevitably play an important role in manufacturing, sales, and logistics. With the support of the cloud, ICPS development will impact value creation, business models, downstream services, and work organization. Then, we present a service-oriented ICPS model. With the support of the cloud, infrastructure platform and service application, ICPS will promote the manufacturing efficiency, increase quality of production, enable a sustainable industrial system and more environmentally friendly businesses. Thirdly, we focus on some key enabling technologies, which are critical in supporting smart factories. These key enabling technologies will also help companies to realize high quality, high output, and low cost. Finally, we talk about some challenges of ICPS implementation and the future work.

1. Introduction

The rapid development of information communication technologies (ICTs) has significantly changed design, manufacturing, logistics, and service. Especially in the process of Industry 4.0, due to the deep integration of micro controller and physical devices, our machines and tools are becoming more automated and self-sufficient, increasingly replacing manual labor. The integration of computing, communication, and control technologies has led to developments in real-time sensing, the dynamic control of large-scale engineering systems, information services, and production life cycle management (PLCM). Yet these technologies still do not fulfill our needs. The final aims of cyber physical systems (CPS) [1–3] are to realize "intelligent monitoring" and "intelligent control". These are the processes which need to realize real-time information extraction, data analysis, decision making and data transmission. On the other hand, the human race is meeting two tremendous challenges: global climate change and the energy crisis. The demands of sustainable development and green business have become more prominent in our daily life, and ICT as a key support to optimize manufacturing chain will play an important role in it. So, the work of integration of physical world and cyber world is inevitable [4–6]. And many countries has made CPS as a national development strategy and put it on the top of the priority list.

Germany's implementation of Industry 4.0 has received great attention in the business world, resulting in more companies wanting to improve their manufacturing chains to realize it. CPS is effective in combining computation with a physical process, thus achieving the goal of integration of industrialization and ICT [7]. Furthermore, CPS combines embedded computers, networks, sensors, and actuators [8,9], which are important for smart manufacturing. Such as in the process of PLCM, ICPS will help meet customer demand by monitoring every part of production, realizing real-time logistics, and providing comprehensive customer services. Additionally, applications of CPS will have the giant potential to change the world in many fields [10]. These include population crisis, environment protection, health care, easing transportation pressure, the control of smart grids, saving energy, etc. It is also easy to envision new capabilities, such as supply to manufacturing chains, to realize smart production, smart logistics, smart grids and real-time services.

* Corresponding author.
E-mail addresses: yuexuejun@scau.edu.cn (X. Yue), hucai_2014@163.com (H. Cai), hehua_yan613@163.com (H. Yan), caifengzou@gmail.com (C. Zou), zhoukl@163.com (K. Zhou).

http://dx.doi.org/10.1016/j.micpro.2015.08.013
0141-9331/

Currently, due to the increased popularity of smart manufacturing and smart factories, ICPS cannot fulfill our demand. In the process of Industry 4.0, traditional industries are hard to integrate industrial sources, social sources and share them [11]. What is more, companies need more hardware and software platforms to optimize their industry chains. Moreover, the fast growing data volume is hard to process. But now, the ICPS technologies cannot support ultra-fast computing and high throughout reliable networks, which are essential for businesses. Without enough resources, it cannot provide real-time and reliable services to corporations. Thus, an industrial cloud to support to ICPS will be highly beneficial. Industrial clouds will supply all kinds of manufacturing services and realize the open collaboration between manufacturing resources and services, as well as to enable a high degree of social resource sharing. Moreover, this will supply a big platform to generate a series of new service models for PLCM, including supply standards, specifications, and sharing resources. Meanwhile, industrial cloud will take more optimization to ICPS that now discussed.

1.1. Provide distributed fast computing

With the development of big data and cloud computing, the multi-channel distributed computing method achieves fast computational speed. What is more, the cloud can supply a big source pool to store, process, and analyze these data, which will generate accurate data information and reduce costs.

1.2. Provide flexibility and scalability services

Everyday, there are numerous data and application uploads on the cloud. These sources can be easily searched by enterprises to help them ascertain customers' demand, design products and manage products life cycle. Meanwhile, the cloud can be as a big platform for every company to storage their data, analysis their information and utilize these upload application to optimize their manufacturing chain, increase their production efficiency and reduce cost.

1.3. Provide security

Private, public, and hybrid clouds all contain many high-reliability security mechanisms to provide safe service. This is similar to the scheme of "end-to-end security", which is used to ensure information security in the process of sending and receiving e-mails.

Moreover, with the support of clouds [12,13], data storage and exchange become faster and faster, which enables the construction of intelligent factories. In the industrial environment, with the support of the cloud, the CPS system will promote the objects of production directly or via the Internet to achieve independent information exchange, operation and mutual manipulation through machine to machine (M2M) communication [14]. This model will make great progress in the industrial processes of manufacturing, industrial engineering, material utilization, supply chain management and PLCM. Just like the expression in the Fig. 1, ICPS will focus on the building of smart factories and through cloud to combine them with smart mobility, smart grids, smart buildings, smart production and smart logistics. Furthermore, the cloud will augment optimize industry chain, increase production efficiency, data exchanges and applications [15,16]. The cloud is like a huge resource pool. In any process of the ICPS, we can deploy services via the cloud to acquire our required information and help us improve our service chain. Furthermore, the cloud can be used as a storage server and information exchange tool, making the manufacturing chain more flexible and usable to provide customers with goods of higher quality and personalization [17].

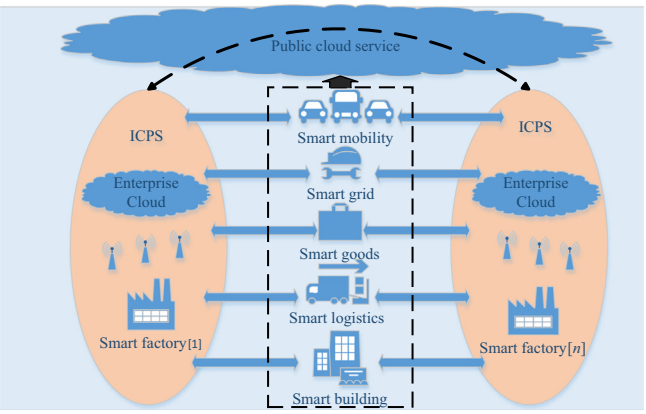

Fig. 1. The structure of cloud-assisted ICPS.

However, in the implementation of ICPS, we can find obvious gaps between the ideal situation and reality. Cloud-assisted ICPS needs high integration of the cyber world (which includes communication technologies, computing technologies, big data, etc.) and the physical world (which includes industrial manufacturing chains, sensors, actuators, etc.) [18]. The development of these enabling technologies will determine the realization of ICPS.

In this paper, we explore the novel service-oriented cloud-assisted ICPS model. We express the views that against the backdrop of Industry 4.0, this model will substantially improve production chains and can realize smart manufacturing and smart factories. Next, according to the demand of ICPS, we depict some key enabling technologies and show their larger applications in industry. We also discuss challenges that will be met in this process and propose solutions. With the support of the cloud and integration of the cyber and physical worlds, our approach can actualize smart mobility, smart grids, smart logistics and smart products.

The rest of the paper is organized as follows. Section 2 addresses the architecture of service-oriented ICPS. Section 3 talks about some key enabling technologies that are used in ICPS. Section 4 depicts the challenges that are needed to solve existing challenges. In Section 5, we express our predictions and discuss future work.

2. Architecture of service-oriented cloud-assisted ICPS

Due to the fast development of our society and fast consumption of resources, sustainability becomes an important issue and garners attention. Two key ICT technologies provide an important role in the sustainability of industrial systems: service-oriented architectures (SOA) and CPS [19,20]. SOA's advantages make it suitable for a growing number of industrial systems, including integration flexibility and the ability for processes to be composed. CPS involves the integration of the computational and physical worlds. In factories, the same principles apply as in the personal sector [21,22]. With the perfection of infrastructure service platform, it will make automation more easily. All kinds of sensors perceive the physical information around them, and transform these data to control centers. Then, the control centers will give the order to actuators to change a station. It uses the method of embedded systems to integrate computation, sensors and actuators in devices [23]. Then, industrial networks supply the support of M2M communication, break the limitation of source constraints, and achieve resource sharing and distributed computing.