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

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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).

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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 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].

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.
Among network layers, numerous devices link the Internet. These computers, storage devices and control devices can be integrated as services and provide support to accomplish specific tasks, and provide virtual computing for terminals [24]. These may also create many applications for industries. These software component technologies, including object-oriented design and service-oriented architectures, are built on abstractions that match software better than physical systems [25,26]. These features will improve convenience in the personal and industrial sectors.

In the near future, information will be the core resource of every enterprise. Every company will endeavor to provide the best services to their customers. By searching customers’ demand, data on the manufacture of products, customer service, and PLCM will be available to industries, which is just the core of quality of service (QoS).

Thus, big data and cloud services will inevitably play an important role in our daily manufacturing [27,28]. With these cloud service platform, we can easily storage and analyze our data, exchange information among companies, integrate production chain between enterprises and transform our production mode. But we must think about several questions, such as how to find the demands of customers, what machines should cooperate with others, where is the best place for selling, and what is the problem with our product. The answers will easily find through cloud and obviously provide significant improvement to companies. As we show in the Fig. 2, in the process of implement of service-oriented cloud-assisted ICPS, we can divide it as three steps. The first is to deploy infrastructure to make equipments become smart and can communication with others. The second step is to supply them platform for processing their data and information. The last is to provide various applications to promote their production efficiency and industrial chain. What’s more, cloud multimedia services can provide an efficient, flexible, and scalable data processing method and offer a solution for the user demands of high quality and diversified file formats. We can easily obtain every device’s real-time station and every user’s demand, so we can provide high quality, high speed, humanization, individualization and real-time service [29].

Our paper will focus on the SOA’s following advantages that are essential for industrial system.

2.1. Comprehensive and distributed services

For every company, these comprehensive and distributed services provide support to manage their workflows, optimize their manufacturing chains, provide high quality and low price product to their customers, etc. With the various kinds and different levels of services to choose from, our enterprises can select the most fitting server depending on the timeliness, reliability and energy efficiency desired. For instance, a company can accurately find the customers’ demand and give them real-time help, which is based on the data that was composed from customers’ location, hobby, context-aware searching [30,31] and some others.

2.2. Transparency services

In industrial systems, we may often encounter equipment that can’t be extended to more applications due to the core layer limits. Because, every enterprise prefer selling their products to selling their technologies because these data and technologies is their life-line and they do not want to share with others. This is just a problem of protecting private information. However, for service-oriented architectures, the services will be transparent for all the industries and they can easily monitor the performance of all the devices and find problems in a timely fashion.

![Fig. 2. The mode of service-oriented ICPS.](Image)
2.3. Service security

An increasing number of data attacks and information leakage has influenced the core interests of enterprises. It may even destroy the industrial chain just like the Iran petroleum system accident. For another part, many companies may spend much more money to buy some well-known security mechanisms to protect their workflow. However, these mechanisms are not suitable for ICPS networks and systems because they can’t provide any fine-grain access control. Service-oriented architecture, on the other hand, allows fine grain access control on every service and method on a case-by-case basis. This is similar to the end-to-end plugins that are made by Google, which provides terminal-to-terminal email encryption. User data will be encrypted when it leaves the browsers, and will be decrypted when the message is received by the recipient.

Comparing the ICPS and traditional manufacturing systems, we can find that, with the support of cloud and some other technologies, the industrial manufacturing will become more efficient, flexible, fast and humanized. Just as show in Table 1, the ICPS will help us to realize sustainable manufacturing and green business.

3. Key enabling technologies

During the process of ICPS, WSN, internet of things, industrial cloud technologies and some other enabling technologies will take so much promotion to it. We can divide ICPS into three levels, the first is infrastructure that is aim to connect every device and realize smart interoperability. This process can be represented as M2M communication that is committed to make all of machines connective. The second level is network level, which is to achieve intelligent communication. In which, industrial wireless network plays an important role. The top level is cloud, which is a big service platform to storage information, analysis data, supply applications, etc.

3.1. Industrial cloud technologies

ICPS is the process of integrating computation into manufacturing chains and other areas of LCM. It is necessary to process the data that come from different companies, different devices and various communication networks. Then, we need to analyze it and acquire the key information for our daily production, which is the format of smart manufacturing. Furthermore, with the support of cloud technologies, it will generate an increasing number of applications to improve the manufacturing chain.

3.1.1. Industrial cloud computing

Due to the explosive growth of data volume and real-time service concept, we need more rapid methods to deal with these data. Cloud computing will change the traditional way of passive market research model and use the active perception, discovery to realize accurate insight into market information. In addition, cloud computing is to use public servers and network device [32]. It will reduce most cost on equipment and allows companies to focus on increasing their core value services. What’s more, due to the advantages of cloud platform, most service system is scalability and flexibility. It can easy to transplant to another platform.

In industrial manufacturing chains, due to the demand of manufacturing and PLCM, cloud computing is different from traditional cloud technologies and has its own characteristics. In the information age, the core competitiveness of a company is fast information and real-time responses, which require the cloud technologies to provide fast, accurate and uninterrupted computing from social resources and manufacturing resources. In another part, Industry 4.0 will generate countless data from various domains like sensors, machines, social networks and LCM. This means the cloud computing must integrate these data and find the useful information. The growing popularity of social computing, which is used to help people understand and study the various problems in the social sciences, and promote benefits and an enhanced level of human social activities through ICT. In industries, this technology will help business to analyze the social behavior and computational system to find social demand, and optimize life cycle management. Now, with the increase of social computing platforms like Twitter, Facebook and YouTube, it will speed the development of intelligent manufacturing and provide personalized and real-time service to customers.

3.1.2. Industrial big data

Big data and cloud computing are highly interdependent. Without cloud computing, big data is useless and vice versa. Now, with the development of industrialization, the quantity of machines have several times as many as human beings, and the amount of data generated from manufacturing chains continually increases. Industrial sensors, radio frequency identification systems, bar codes, industrial automation control systems, enterprise resource planning, computer aided design and other technologies are increasingly rich in industrial data volume. These data are huge and unstructured, which is difficult to process, so we must use some professional tools to solve it.

Recently, however, applications can process these big data within a “tolerable elapsed time” [33]. The goal of industrial CPS is to find the customers’ demand and provide personalized product and real-time PLCM, so it is necessary to collect and analyze these data [34]. The most challenging aspect is to explore the large volumes of data and extract useful information or knowledge for future actions [35].

In our survey, there are 48 h of video uploaded to YouTube, 100 thousand statuses in twitter, and billions of other messages every minute. What’s more, these data have high volume, variety data types and formats, so we must use some special database and hardware environments to collect and process them. The volume

<table>
<thead>
<tr>
<th>Table 1</th>
<th>The compare with traditional manufacturing system and ICPS.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Traditional manufacturing system</strong></td>
</tr>
<tr>
<td>Production mode</td>
<td>Manual control, assembly line operation</td>
</tr>
<tr>
<td>Working style</td>
<td>Semi-mechanical assembly-line operation</td>
</tr>
<tr>
<td></td>
<td>Isolated machines, work by themselves</td>
</tr>
<tr>
<td></td>
<td>Mechanical equipment function is single</td>
</tr>
<tr>
<td></td>
<td>Manual maintenance</td>
</tr>
<tr>
<td>Production cost</td>
<td>Material waste, only suitable for mass production</td>
</tr>
<tr>
<td>Flexibility</td>
<td>All the designs are determined by designers</td>
</tr>
<tr>
<td>Real-time</td>
<td>Customer cannot get their ideal product until the enterprise has designed and produced it</td>
</tr>
<tr>
<td>Personal-oriented service</td>
<td>The transaction is terminal after the sale</td>
</tr>
</tbody>
</table>

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of data is very large (as large as exa-bytes), and arises from various domains, including public information, sensors, climate and other channels [36–38]. Several new types of "octopus" data collection platforms now exist, the most common tools including the following: (1) ScraperWiki [39], a web-based platform for collaboratively building programs to extract and analyze public (online) data. (2) Needlebase [40], which can schedule a scraper to run at regular intervals, while re-formatting data to clarify it, filter it, or make it compatible with other sets of data. Then, it visualizes and combines data from more than one source. (3) Hadoop [41] contains a distributed file system (HDFS), and supports high error tolerance. It can be deployed in low-cost hardware to increase throughput. (4) Thingspeak [42] is a free web service hosted by an I/O bridge that lets you collect and store sensor data and develop IoT applications. The data from multiple sensors can be sent to ThingSpeak from Arduino, Raspberry Pi and some others. Then, ThingSpeak can integrate with matlab to analyze and visualize these data, etc.

As shown in Fig. 3, all kinds of applications collect these initial data and store them in different ways. Due to the different structure of data, we need to extract and integrate them. Then, we use some professional algorithm to analyze it and find the useful information like customers’ demand, transport conditions, weather changes and medical status. We can image a scene that when we share our new ideas of some products with friends through social networking, we may never wish to realize these functions right now. However, with the support of cloud technologies, enterprises can use data mining to search your demands, then use 3D printing to produce personalized product and deliver the goods to you can use data mining to search your demands, then use 3D printing to produce personalized product and deliver the goods to you through smart logistics.

### 3.2. Industrial wireless networks

In the form of modern intelligent manufacturing, the maximum demand is to realize collaboration among companies, devices and terminals. This corporate synergy takes the form of horizontal integration, which is to gather the advantages of various companies to provide better services. However, in an enterprise, the demand is to coordinate each device to work together and produce better goods. The end-to-end integration aims to use sensors, controllers and actuators to realize intelligent monitoring [43,44], intelligent manufacturing, intelligent logistics, and real-time communication.

In this process, the most important thing is information exchange, which includes information interactions between devices, companies, and clouds [45]. Especially in our manufacturing chain, where all kinds of machines, sensors, and equipment must work at the same time, we don't have enough workers to perform these tasks. Instead, we transmit some program to these machines to make them work by themselves and even some places where people can't reach, which is needed for remote operation.

In this scenario, wireless networking as a substitute for traditional Ethernet has a big advantage. In the ICPS, industrial wireless networking is an important link and safeguard technology between machines, terminals and cloud [46,47]. It will allow us to flexibly communicate with any piece of equipment without any restrictions of time and place [48–50]. Moreover, it will provide support when we want to ascertain the demand. A wireless network will also mean much in the PLCM.

There are many kinds of wireless access point (AP) that suitable for industrial environment. Just as shown in Table 2, different AP has its own advantages and characteristic, but all of them will supply big promotion to manufacturing chain. In this paper, we depict some obvious advantages in industrial systems compared to traditional communication technologies.

#### 3.2.1. Reliability

In traditional communication links, with line constraints and aging, there are always much problems such as communication with terminals and areas where lines cannot reach. However, industrial wireless networks (IWN) [55,56] can fulfill our demand of real-time communication while maintaining a robust environment. Furthermore, in some special companies, the environment is corrosive and IWN is the only substitute to communicate.

#### 3.2.2. Flexibility

The IWN requires no cable ties, and the worker can easily configure the placement of sensors and meet different demands of smart monitors [57]. Furthermore, it also requires a large amount of support to control the machines (especially the mobile AGV).

#### 3.2.3. Usability

Compared to traditional Ethernet, distributed intelligent wireless sensor systems can realize the control of the industrial processes independently [58]. The AP can dynamically change depending on the environment and machines, and monitor every part of the manufacturing chain. It can help to improve the manufacturing chain to realize QoS and low cost.

#### 3.2.4. Security

Data attacks and information loss are an ever-increasing problem. Security has become a big issue and interest is growing everywhere. New forms of encryption will require companies to provide

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**Table 2**
The characteristics of some mainstream wireless AP.

<table>
<thead>
<tr>
<th>Manufacturers</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens [51]</td>
<td>Supply multi band protocol</td>
</tr>
<tr>
<td>MOXA [52]</td>
<td>Logic separation for different user groups</td>
</tr>
<tr>
<td>Korenix Jetwave [53]</td>
<td>Advance security mechanisms</td>
</tr>
<tr>
<td>Advantech [54]</td>
<td>100 ms turbo roaming</td>
</tr>
<tr>
<td></td>
<td>Contain safety features and filters</td>
</tr>
<tr>
<td></td>
<td>QoS effective network traffic</td>
</tr>
<tr>
<td></td>
<td>Network self-healing</td>
</tr>
<tr>
<td></td>
<td>5.8 GHz communication band</td>
</tr>
<tr>
<td></td>
<td>High throughput, long distance communication</td>
</tr>
<tr>
<td></td>
<td>Multiple jump technology</td>
</tr>
<tr>
<td></td>
<td>Multiple security mechanisms</td>
</tr>
</tbody>
</table>

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more support during the transmission of information and business dealings.

3.3. M2M communications

In the traditional manufacturing chain, every machine was isolated and worked independently. In the time of intelligent manufacturing, M2M technologies will integrate these devices and realize cooperative work [59,60]. It can also include limited human intervention. All of the equipment is connected to the Internet and is more valuable when it works interdependently than individually. Additionally, more and more autonomous and smart services can be generated based on the interconnected devices.

WSNs are the basic supplements of M2M [61], and M2M is the foundation of CPS. With all machines connected to the Internet through ICT and WSN, the physical world has been connected to the cyber world. However, CPS needs the cyber world and physical world to interact with each other, which is an evolution of M2M in intelligent information processing [62]. In the development of ICPS, M2M will play a significant role. The development of communications will include human-2-human, human-2-machine, and machine-2-machine. This is points to the development of a number of application cases that are service-oriented and exposed from physical devices, such as sensors, RFIDs, actuators, and machines. With the integration of these equipment and terminals, the cyber world and physical world can be linked together and generate many kinds of service-oriented applications to industries.

3.3.1. M2M area networks

M2M area networks aim to furnish connection and communication between all kinds of smart machines and sensors and some other smart terminals. They can be divided into personal area networks, which include IEEE 802.15, Zigbee, Bluetooth, and local networks, which include WIFI, wireless M-Bus, and power line communication. According to the range of radiation, transmission speed and energy constraints, the area network can supply different services like file sharing, video, smart grids, and RFID.

3.3.2. M2M application

With the development of economy and the improvement of social information level, how to build a ubiquitous network society has become a great concern of the government, academia and enterprises in many countries. In addition, the increasing number of devices and productions including the fast development of social network need rapidly deploy solutions that can optimize your business processes and help deliver better and faster services. The M2M application is delivered as a cloud-based service to reduce complexity and maintenance concerns [63]. It will also take companies robust, proven technology based on the highly secure, industry-leading network infrastructure. What's more, the M2M application has built to handle large-scale deployments, high transaction rates, and support a large number of concurrent users and reporting assets.

In industry, the key architecture of smart factories is to realize horizontal integration, vertical integration and terminal-to- terminal integration. Industries realize the interaction of devices and terminals will improve the efficiency of manufacturing chains and monitor and maintain every part of it. In another way, smart enterprises need to realize the complete product life cycle management. All parts must coordinate and connect with each other to realize flexible and sustainable development, from design, materials and processes to logistics, employment and customer service. What's more, every product is a smart terminal. It will know where the user came from, and predict where the user will go and what can the user can do. M2M communication can supply this to us.

ICPS is just the evolution of M2M and achieves the goal of sustainable development, green businesses and smart manufacturing.

4. Key challenges

As a whole, researchers have made some progress in the construction of industrial CPS, and the development of cloud technologies has played an important role in this system. However, CPS remains in the embryonic stage. A variety of issues and challenges need to be further solved at different layers of the architecture and from different aspects of system design to ease the integration of the physical and cyber worlds. In this chapter, we outline some challenges as follows.

4.1. Industrial cloud

In industrial environments, information islands are an important reason to reduce production efficiency. Mutual equipment cooperation is not smooth, information cannot interact, the state cannot be notified in a timely manner, and these aspects will restrict the development of enterprises. Industrial clouds refer to cloud-computing modes that provide software services to industrial enterprises, and social resources can share cloud service platforms which can be easily searched by companies. Industrial clouds will greatly reduce the threshold of manufacturing information construction. In the process of building smart factories and Industry 4.0, it will be as the pivotal player to help to realize horizontal integration between factories and vertical integration in a manufacturing chain.

However, the data from different factories and different machines have their own characteristics and formats. Developing methods to integrate these data and realize sharing among factories is therefore very important. Industrial clouds can extract and integrate these data to help industrial organizations to overcome the information gap in industrial domains by providing information exchange systems. In this way, it will reduce conversion and downtime of equipment and increase the production efficiency. In another way, it will also provide an efficient solution to search for business partners, industrial processes, components, and technologies, as well as to respond to industrial issues to strengthen cooperation between plants, and improve the interaction and cooperation between the equipment. For example, in the manufacturing chain, we can integrate different pieces of information from different enterprises and cooperate with each to finish a product. Moreover, we can monitor the product’s entire life cycle and collect the information to supply to customer service. What’s more, the industrial cloud will also help to monitor the condition of machines all the time and report the information to the maintenance department. It will find the problems with equipment in advance, reduce equipment downtime, and improve production efficiency.

In another way, industrial clouds will provide a big cloud platform and generate various services to companies to optimize their office business. In this cloud platform, they can achieve internal and external collaborative work, message synchronization anytime and anywhere, and realize unlimited imagination in the office system. Furthermore, in this platform, these services are free and are updated frequently, which will save costs and increase their production efficiency.

4.2. Data mining

Due to the popularity of big data, data mining has developed much interest in many domains, such as business intelligence, web searching and digital libraries. Data mining involves discovering novel, interesting, and potentially useful patterns from large
data sets and applying algorithms to the extraction of hidden information [64]. It can form many usage applications including risk analysis, targeted marketing, customer retention, and portfolio management. The objective of any data mining process is to build an efficient predictive or descriptive model of a large amount of data that not only best fits or explains it, but is also able to generalize to new data [65]. Based on a broad view of data mining functionality, data mining is the process of discovering interesting knowledge from large amounts of data stored in either databases [66], data warehouses, or other information repositories. Based on the definition of data mining and the definition of data mining functions, a typical data mining process includes data preparation, data mining and data presentation [67].

In factories, everywhere and every time has data generation, the main data resources come from designing, manufacturing chains, logistics information, equipment condition monitoring, and social network information. Different kinds of data present big challenges to process, store, transform and analyze to represent the desired result, which is very essential to industries. Moreover, much of these data are semi-structured or unstructured, which is different from traditional structured data. All of these characteristics determine that we must use different algorithm to analyze them. For instance, we must use classification modeling to analyze discrete data while we use regression modeling to process continuous data. For another part, with numerous data arising from different data sources and in different formats, big challenges may arise that will vitally affect our analysis result. In this paper, we will focus on the following aspect of data sources, and talk about some of their key problems for data mining [68].

Just as we show in Table 3, all of these problems will cause distortion of data, which will reduce the value of its analysis. Furthermore, data security and privacy have become an essential task for every corporation to solve. Data assault and leakage have deeply affected the interests of many enterprises. So, data mining will also be a big problem in the industry.

4.3. Real-time processing and reliability

Industrial wireless networks are essential for industrial systems to realize smart monitoring and timely control. In different industrial systems, due to different requirements, companies need various qualities of service, which are reliability, energy efficiency, low latency and high throughput [69–71]. These are especially important in real-time control systems, which need the data to be transmitted in a timely manner. This is similar to mobile automated guided vehicles, which are used to transport and load commodities in the manufacturing chain. Sometimes, IWNs must cooperate with the machines and production transfer belts to realize seamless connection. Thus, the control signal must be transmitted to the components timely and accurately.

The real-time processing and reliability will also be exhibited by remote maintenance capability. In the new process of ICPS, all of machines are automated and unmanned. They need to equip self-detection equipment to monitor its condition. While some indicators of the machine over the warning line, we must adjust it as soon as possible to avoid downtime and mechanical damage. Due to less people participate in the manufacturing chain, so all of these sensor, actuator and network infrastructure must keep reliability for a long time.

Although, every AP supplier has its own distinctive advantage, in our survey, we can find that all of these advantages are insufficient to realize reliability and real-time communication. The most important requirements for reliability and real-time processing are latency and packet loss rate, but none of the current systems can achieve low delay and loss-free packet transmission. In fact, according to our experience, we use some APs to realize wireless roaming to reduce latency to acceptable levels, but when we use a computer to connect the AP and communicate with it, the latency and packet loss rates increase significantly. However, in manufacturing chains, some work steps are needed to achieve perfect synchronization, and this latency and data loss can destroy the entire production chain.

4.4. Information security and privacy

Currently, information security and privacy has grown popular and caused more and more interest [72,73]. Now, we can use cloud tools and other resources to search and analyze multimedia files. The final goal of big data is to share information for all systems and people. However, increased information disclosure and privacy violations have generated concerns [74]. In the time of fast development of information, ICT and ICPS aim to integrate everything in the big Internet of things system and make them interact with each other. This is a big chance to make systems more intelligent and automated, but it is imperative for humans to maintain security.

4.4.1. Retention of network security

Ethernet and wireless networks are the most important information transfer channels in the world. In the time of Industry 4.0, it is the foundation technology of ICPS. With more and more devices connected to networks, it will cause network congestion and the increase of network latency. For another part, if the network is assaulted, all of the machines will experience downtime.

4.4.2. Maintaining industrial information security

In intelligent manufacturing chains, all of the machines are embedded into microcomputers and work by themselves through some programs. This will save manual work but acquires a threat of information security. If someone invades the industrial system and modifies programs to control these machines, it could give the factory a devastating blow, similar to the case of the intrusion incident of government office systems, which has caused a breach the government can’t handle.

4.4.3. Maintain data security

Recently, most companies have connected to a cloud server and deployed its applications. The cloud is a source pool so big that no company can control it. Data explosions and attacks have become a big threat to many domains. With limited storage space, we can’t store and analyze all of the data. Furthermore, most of the rubbish information will cause high latency or even destroy our system. Thus, it is inevitable to maintain data security.

5. Conclusions

In this paper, we addressed the architecture of cloud-assisted industrial CPS, and highlighted some key enabling technologies in this process. Then, we reviewed some challenges that need to
be solved in the future. Cloud-assisted CPS is a service-oriented technology. CPS aims to link anything to the Internet, but the cloud will provide work after this is achieved. It will be based on cloud services and big datasets to realize the integration of devices with devices, devices with products, and the cyber world with the physical world. Then, it will supply real-time services and PLCM to customers and products. It is an important part of smart manufacturing and smart factories. In this process, enabling technologies will play an important role in data mining, data analysis and data transformation. It will provide support for information and communication to achieve the integration of the industrialization and serialization of data. It will always provide support for optimizing production efficiency, optimizing production and optimizing service quality. However, some challenges will affect the efficiency and quality of services. The solution of these problems will play an important role in the future. Then, these factories can be directly linked with users to fulfill their real-time demand.

In the era of Industry 4.0, the use of some enabling technologies to link the cyber world and physical world is essential and these key enabling technologies supply a big support to the system of ICPS. However, in the future, we also have many problems to solve, such as the challenges of security and privacy. Cloud computing and big data require many more applications and data sources, but they will also encumber us with much rubbish data and data violation. In another way, the building of Industry 4.0 is a long way off, some years or even some decades. We should follow the direction of the road and develop more technologies to achieve it.

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References

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