CCIoT-CMfg: Cloud Computing and Internet of Things-Based Cloud Manufacturing Service System

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***Abstract*—Recently, Internet of Things (IoT) and cloud computing (CC) have been widely studied and applied in many fields, as they can provide a new method for intelligent perception and connection from M2M (including man-to-man, man-to-machine, and machine-to-machine), and on-demand use and efficient sharing of resources, respectively. In order to realize the full sharing, free circulation, on-demand use, and optimal allocation of various manufacturing resources and capabilities, the applications of the technologies of IoT and CC in manufacturing are investigated in this paper first. Then, a CC- and IoT-based cloud manufacturing (CMfg) service system (i.e., CCIoT-CMfg) and its architecture are proposed, and the relationship among CMfg, IoT, and CC is analyzed. The technology system for realizing the CCIoT-CMfg is established. Finally, the advantages, challenges, and future works for the application and implementation of CCIoT-CMfg are discussed.**

***Index Terms*—Advanced manufacturing systems (AMSs), cloud computing (CC), cloud manufacturing (CMfg), Internet of services (IoS), Internet of things (IoT), Internet of users (IoU).**

I. Introduction

IN RECENT years, network, information, management, and other technologies and theories have been fast developed and widely applied. At the same time, the growth of competitive market globalization and customer demand diversification have led to the increasing demand of agility, networking, service, green, and socialization of manufacturing. In order to realize the goals of TQCSEFK (i.e., fastest Time-to-market, highest Quality, lowest *C*ost, best *S*ervice, cleanest *E*nvironment, greatest *F*lexibility, and high *K*nowledge), a variety of advanced manufacturing systems (AMSs) and modes have been proposed. The typical ones are flexible manufacturing (FM) [1], computer-integrated manufacturing (CIM) system, agile manufacturing (AM) [2], concurrent engineering [2], dynamic alliance [2], networked manufacturing (NM), green manufacturing [3], sustainable manufacturing [4], global manufacturing [4], manufacturing grid (MGrid) [5], industrial product service systems (IPS^2) [6], crowdsourcing, and so on.

After 20 years of development, these AMSs have been playing a very important role in the development of modern manufacturing and industry. More and more AMSs devote to adapt to the trends and requirements of informatization, globalization, and servitization of manufacturing, and a lot of key technologies have been studied, including manufacturing resource and service modeling and encapsulation [7], [8], resource and service optimal-allocation and scheduling [9]–[13], service workflow management [14], [15], [35]–[37], and supply chain management [16], [17].

However, the socializations of the resources sharing, value creation, users participation, supply-demand matching, on-demand use, and personalization in manufacturing run much clearer and faster [18], [19] as shown in Fig. 1. Due to lacking of common specifications and standards, open architecture, and without realizing intelligent perception and connection of underlying physical manufacturing resources to the internet, the wider applications of these AMSs are hindered. As well, the low-degree servitization of manufacturing resources and capabilities (MRs&Cs) based on knowledge limits the number, ability, and usage mode of services provided to users. In addition, due to the lack of effective operational mechanisms of resources and services and reliable safety solutions, it makes the application and development of the above AMSs difficult. Finally, the on-demand management of MRs&Cs is still the bottleneck to improve the collaboration and intelligence of AMSs.

At the same time, service-oriented technologies (SOTs) [20], advanced computing technologies (ACTs), virtualization technology, embedded technology, cyber-physical systems (CPS), cloud computing (CC) [21], and Internet of things (IoT) [22] have been quickly developed and widely applied. These new technologies have provided new methods to address the bottlenecks faced by the existing AMSs. For example, the SOTs such as service-oriented architecture, web service, ontology, and semantic web can provide enabling technologies for the construction of a virtual manufacturing and service environment; the ACTs such as high-performance computing technologies, grid computing, and parallel computing can provide enabling technologies for solving complex and large-scale problems; the virtualization technology can hide the physical characteristics of the manufacturing resource and capability in an AMS from users; the IoT technology can realize the effective connection, communication, and control from physical world to information world. Especially, by providing the new method for intelligent perception and connection of anything, and the on-demand use and efficient sharing of resources, respectively, IoT and CC have been widely studied and applied in many fields.

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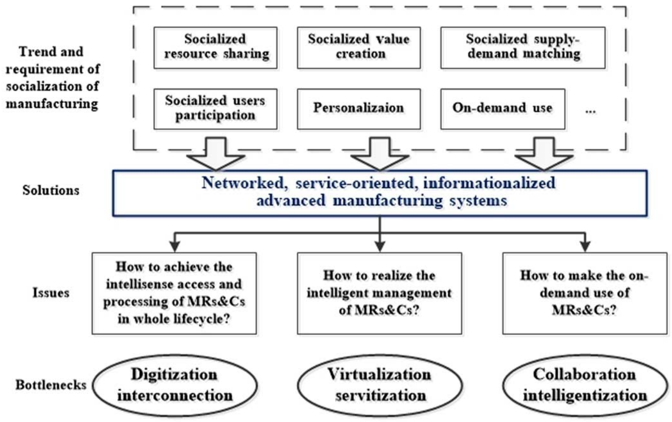

Fig. 1. Bottlenecks of AMSs and the potential solutions.

In order to realize the full sharing, free circulation, on-demand use, and optimal allocation of various MRs&Cs, it investigates the applications of the theories and technologies of IoT and CC in manufacturing at first in this paper. The relationship and difference among IoT, CC, and cloud manufacturing (CMfg) are discussed after the CC- and IoT-based CMfg system (i.e., CCIoT-CMfg) and its architecture were proposed. In order to realize the implementation of a CCIoT-CMfg system, the technology system is established from the three key stages (i.e., service generation, service management, and service applications). Finally, it points out the opportunities and challenges for the application and implementation of CCIoT-CMfg.

The remainder of the paper is organized as follows. Section II presents a brief overview of the applications of IoT and CC in manufacturing systems. The CC- and IoT-based CMfg (CCIoT-CMfg) service system and its architecture are proposed in Section III, and the relationship among CC, IoT, and CMfg is described. The technology system for implementing CCIoT-CMfg is established and studied in Section IV. The key advantages and challenges for implementing CCIoT-CMfg are given out in Section V, and Section V summarizes the whole paper.

II. Applications of IoT in Manufacturing System

IoT originated from the radio frequency identification devices (RFIDs) system proposed by MIT Auto-ID Labs in 1999. In the Tunis World Summit on Information Society in 2005, the International Telecommunications Union (ITU) extended this concept largely in “ITU INTERNET REPORTS 2005 EXECUTIVE SUMMARY: The Internet of Things,” and gave the explanation of this concept: “the intelligent connectivity for anything at anytime and anywhere” [23]. With IoT, various data required (e.g., the information of sound, light, heat, electricity, mechanics, chemistry, biology, and location) can be acquired in real time by RFID technique, global position system (GPS), sensors, infrared sensors, laser scanner, gas sensors, and other devices. Under the influence of related researches and developments, nowadays IoT has developed from connecting things to things to the combination and integration of information space and physical world. More and more researchers pay attention to address the accessing of the ubiquitous terminal devices to the Internet, and the management and applications of the ubiquitous services in different industries based on web services, CC, and other related techniques.

Although, so far, there is still no clear and uniform definition and architecture about IoT, it has been used in various application backgrounds; for instance, the applications of smart homes or smart buildings, smart cities, smart business, smart inventory and product management, health-care, environmental monitoring, social security and surveillance, and so on [24]. Especially, it has been fundamentally changing the practical production and supply chain process and management with the aim of intelligent manufacturing.

Specifically, after introducing the generalized IoT into manufacturing industry, it can be used to address the “4Cs” (Connection, Communication, Computing, and Control) of MRs&Cs for the following different applications in manufacturing, as shown in Fig. 2.

1) Applications in the workshop [25]: It can achieve the complete connection between terminal devices (i.e., various MRs&Cs) and the enterprise information management system for the automatic control of the IoT-enabled manufacturing execution in workshops. Therefore, three functions should be addressed: the access, identification, and control of the physical manufacturing execution process from materials and semi-finished products to the final products. The data identified and acquired from the IoT-enabled manufacturing layer are the production-related and product-related input of the enterprise information system. Moreover, the automatic control of manufacturing execution activities is the result under the output of the system to the PLC and other controllers. It is the general applications of IoT in workshops.
2) Applications in the enterprise [26], [27]: It promotes the integration of the production-related information, the product-related information, and other business management information, as well as the integration of the IoT-based workshop and other enterprise information subsystems. Enterprises can generate their own manufacturing services (MSs) for the participation into the external supply chain, in addition to the management of the internal supply chain. It results the origin of the local Internet of services (IoS).
3) Applications among enterprises [28]: It addresses the information integration, storage, retrieval, analysis, use, data security, and other issues during these ubiquitous service management and application process among massive different enterprises. Consequently, CC and cloud platform technologies provide the new ideas and technical supports for the ubiquitous networking service management and application of IoT. In addition, the operation platform holds the on-demand social enterprises corporation, and makes the formation and application of IoS.

In addition, recently, Xu *et al.* [31] have reviewed the advances of IoT in industries, Bi *et al.* [32] studied the application of IoT in modern enterprise systems, Fan *et al.* [33] studied IoT-based smart rehabilitation system, and He *et al.* [34] have researched the application of IoT in the development of vehicular data cloud service.

At present, in manufacturing field, IoT technology is rapidly developing under the support of RFID, sensors, smart technology,

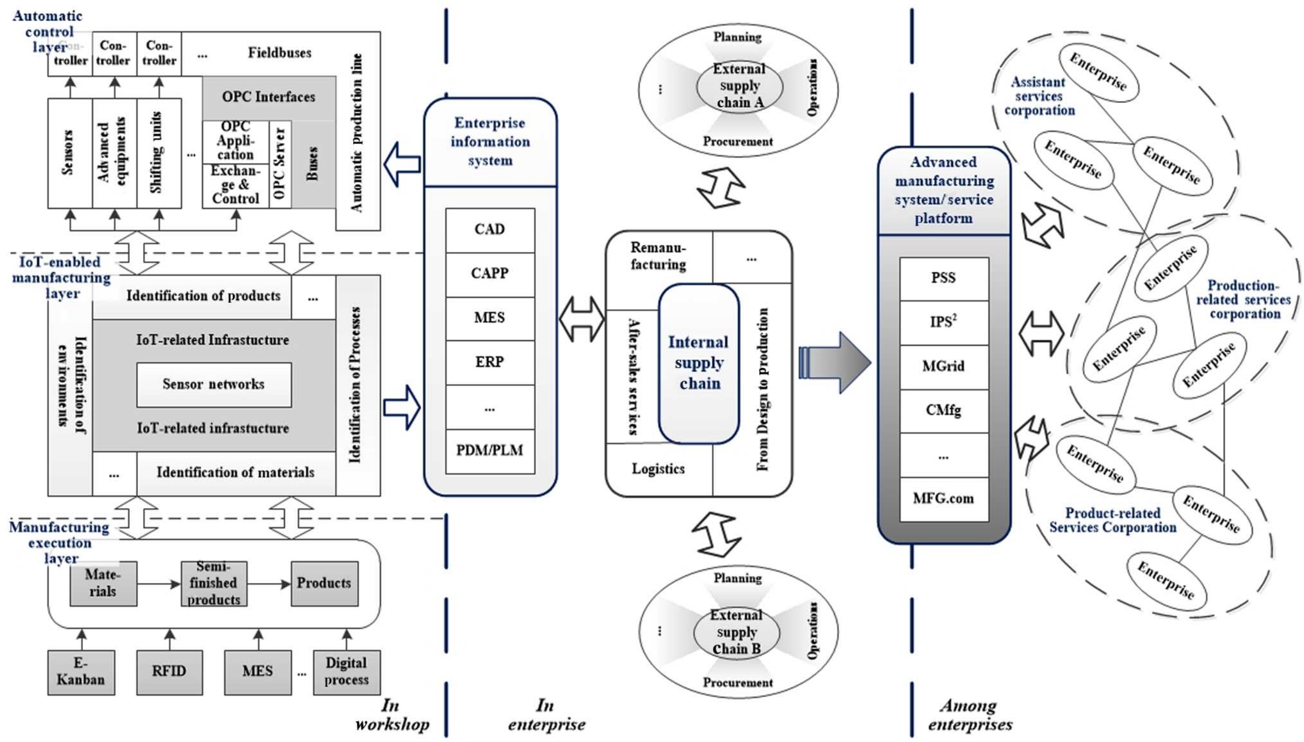

Fig. 2. Applications of IoT in manufacturing.

and nanotechnology, and is expected to promote interconnection of anything. Then, introduction of IoT is helpful to construct a platform for sharing and interconnecting all kinds of manufacturing resources. In addition, the development and application of high-performance computing technology provides the possibility of solving more complex problems and carrying out large-scale collaborative manufacturing. Thus, as the manufacturing resources supply-demand match with less agility and low resources utilization rate in AMSs, CC provides new ideas and opportunities to solve the current problems in AMSs. Its corresponding commercial models and cloud security products provides a new technical means to address security issues in AMSs. Coupled with the current rapid development of embedded systems and technologies provide enabling technologies for realizing the intelligent embedding of physical terminal manufacturing equipment and the interconnection of M2M (including man-to-man, man-to-machine, and machine-to-machine) in manufacturing.

III. IoT- AND CC-BASED CMFG SYSTEM

A. Concept and Running Principle of CMfg

CMfg is a computing- and service-oriented manufacturing model developed from existing advanced manufacturing models (e.g., ASP, AM, NM, and MGrid) and enterprise information technologies under the support of ACTs (e.g., grid computing and CC), IoT, virtualization and SOTs, and advanced management technologies [29], [30].

Similar to CC system, there are three kinds of users in a CMfg system: 1) *providers* who own and provide the MRs&Cs where consumers were in charge, and it can be a person, an organization, an enterprise, or a third party; 2) *an operator* who operates the CMfg platform to deliver services and functions to providers, consumers, and third parties; and 3) *consumers* who are the subscribers of the MCSs available in a CMfg service platform, and they purchase the use of the MCSs from the operator on an operational expense basis according to their needs. The abstract running principle of CMfg system and the workflow among the three users have been described in the author's previous work [29], which can be briefly summarized as the following three phases.

Phase 1: *Perception, internet connection, and acquisition of MRs&Cs*: In this phase, various idle MRs&Cs from providers are intelligently sensed and connected into wider network, and automatically managed and controlled using IoT technologies (e.g., RFID, wired and wireless sensor networks, and embedded system). Then the related data and information about these MRs&Cs are collected and processed.

Phase 2: *Aggregation, management, and optimal allocation of MRs&Cs in the form of service:* The MRs&Cs are virtualized and encapsulated into different MSs based on the data and information generated in Phase 1, which can be accessed, invoked, and deployed based on knowledge by using virtualization technologies, SOTs, and CC technologies. The MSs are classified and aggregated according to specific rules and algorithms, and different kinds of MS pools or clouds are constructed.

Phase 3: *On-demand use of MS*: Different users in the whole-life cycle of manufacturing can search and invoke the qualified MSs from related MS pool or cloud according to their needs, and assemble them to be a virtual manufacturing environment or solution to

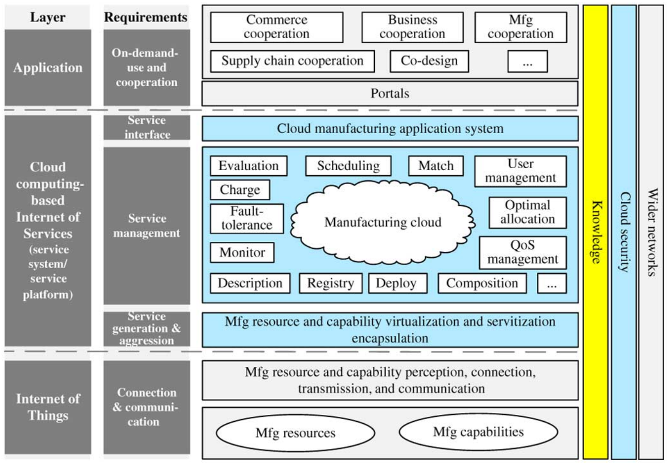

Fig. 3. Architecture of CCIoT-CMfg service system based on [29].

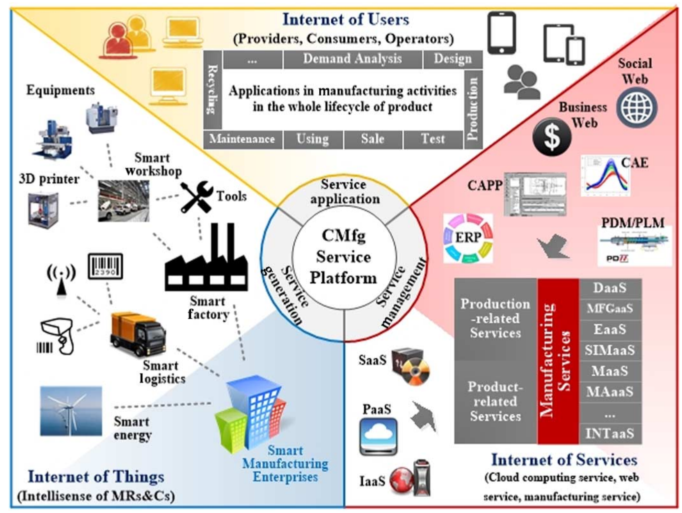

Fig. 4. Relationship among CMfg, IoT, and CC.

complete their manufacturing task involved in the whole-life cycle of manufacturing processes under the support of grid computing/CC, SOTs, and ACTs.

B. CCIoT-CMfg: CC and IoT-Based CMfg Service System

In order to address the above three problems in CMfg system, in this section, the IoT technology is applied to realize the perception, internet connection, and acquisition of MRs&Cs, and CC technology is used to realize the aggregation, management, optimal allocation, and on-demand use of MRs&Cs in the form of service. The architecture of the proposed CCIoT-CMfg system is a hierarchical structure as illustrated in Fig. 3 based on Tao *et al.* [29]. It consists of the following four layers with ten sublayers.

1) IoT layer: It is responsible for MRs&Cs perception, connection, and acquisition by using IoT technologies, which consists of two sublayers, i.e., *resource layer* and *perception layer*.
2) Service layer: It is responsible for MS aggregation, management, optimal allocation based on CC, and web service technologies, which consists of the following three sublayers, i.e., *resource virtualization layer*, *cloud service layer,* and *application system layer*:
3) Application layer: It is responsible for the on-demand use of MS in the whole-life cycle of manufacturing, which consists of two sublayers, i.e., *portal layer* and *enterprise cooperation application layer*.
4) Bottom supporting layer. It consists of the following three sublayers, *knowledge layer*, *cloud security layer,* and *wider internet layer*.

C. Relationship Among CMfg, IoT, and CC

Apparently, CCIoT-CMfg is the application and extension of IoT and CC in manufacturing. The relationship among CMfg, IoT, and CC is illustrated in Fig. 4, and it can be concluded from Fig. 4 that the IoT, IoS, and Internet of users (IoU) are the three core factors of CCIoT-CMfg.

1) IoT in CMfg: IoT is the core enabling technology for the implementation of CMfg, and there, primarily, are three levels of application of IoT in CMfg. First, as investigated before, IoT is used to enable the perception, internet connection, acquisition, and automatic control of various MRs&Cs such as manufacturing equipment, which is the basic element to form smart workshop and smart factory. Furthermore, with the application and support of IoT technologies, the logistic and energy can be smart too. Based on the smart workshop, smart factory, smart logistic, and smart energy, a smart enterprise can be established, which is the key identification of a CMfg system. Second, after various MSs are generated, IoT technology is used to support the intelligent operator of services, such as intelligent connection and communication, interaction and interoperation, and collaboration among services, so as to form the IoS. Third, the users (including service provider, consumer, and operator) of CMfg are primarily internet users, while IoT is one of the enabling technologies to realize the connection and communication among these users, and to form the IoU.

2) IoS in CMfg: The IoS in this paper primarily includes CC service, MS, and web service. Compared with CC, in a CMfg system, in addition to the computational resource (e.g., processor, memory, network, and software), there are many other hardware and software manufacturing resources such as production-related service (e.g., raw materials and semi-products, manufacturing equipment, related design and manufacturing software/application system or tools, and datum about demand information, product structure data information, and process information) and product-related resource (e.g., soft and hard resources involved in the process of transportation, sales, maintenance and repair, recycling, and end-of-life treatment of a product). Therefore, in addition to the three service modes such as infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) in CC, the cloud services models in CMfg also include various MSs such as design as a service (DaaS), manufacturing as a service (MFGaaS), experimentation as a service (EaaS), simulation as a service (SIMaaS), management as a service (MaaS), maintain as a service (MAaaS), and integration as a service (INTaaS). Furthermore, the web service such as business web and social web are also involved in the business and society transactions of the mentioned MS. Compared to

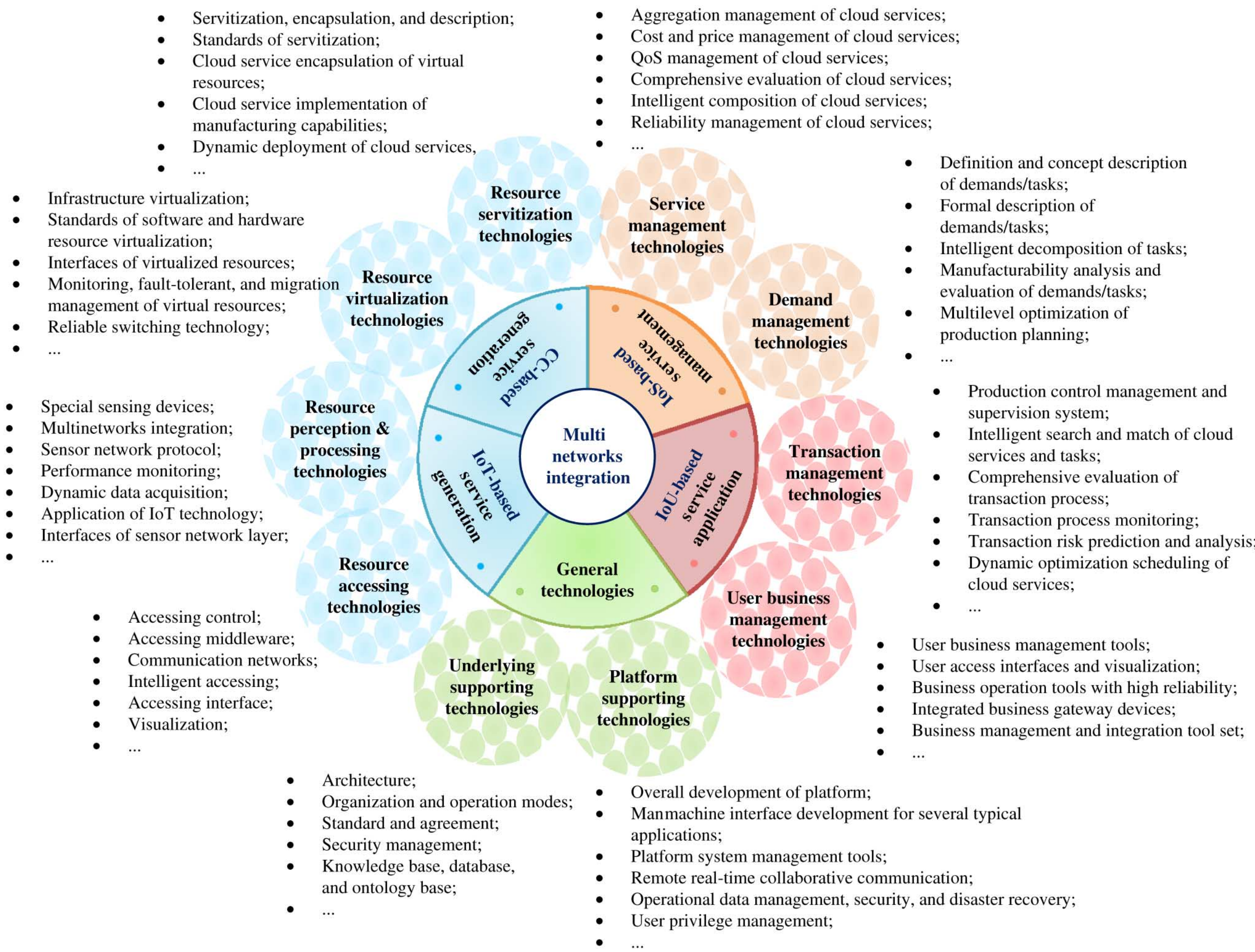

Fig. 5. Venn diagram of key enabling technologies of CCIoT-CMfg.

the servers, storage, software, and other computing resources, manufacturing cloud services have greater need for IoT and multinetworks integration technology, in addition to the support of CC and virtualization technologies.

3) IoU in CMfg: IoU results from the applications in the entire life cycle of product. The ultimate goal of CMfg is the ubiquitous applications for society, as well as IoT and CC. Then the IoU among providers, consumers, and operators in manufacturing is the third level as the result of the on-demand applications of services. Based on the IoU, various enterprises corporation networks can be generated agilely under the dynamic demands.

IoT and CC are the two core enabling technologies of CMfg. In a word, the joint action and collaboration of IoT and CC bridges the physical world and information world in manufacturing, and promotes the full realization of CMfg and the corresponding manufacturing industry and enterprises informatization.

IV. Technology System for Implementing CCIoT-CMfg

From the concept, operation principle, and architecture of CCIoT-CMfg, the technology system of CCIoT-CMfg and the system implementation can be summarized as five categories: general technologies, IoT based service generation technologies, CC-based service generation technologies, IoS-based service management technologies, and IoU-based service application technologies. As shown in Fig. 5, general technologies include underlying supporting technologies and platform supporting technologies. IoT-based service generation technologies include resource accessing technologies, resource perception, and processing technologies. CC-based service generation technologies cover resource virtualization technologies and resource servitization technologies. IoS-based service management technologies include service and demand management technologies, and IoU-based service application technologies consist of transaction and user business management technologies.

A. Underlying Supporting Technologies

Underlying supporting technologies are the related concepts and technologies to build up the CMfg platform and to support the operation of the platform. The specific technologies involved include: 1) architecture of system; 2) organization mode, business mode, profit mode, and other modes; 3) standards, protocols, and norms for the virtualization access of hardware and software resources, the description of cloud services and users' requirements, and the integration of existing information; 4) safety and reliability management; and 5) construction of knowledge base supporting service description, search, composition, invocation, and transaction for the applications of various industries.

B. Resource Accessing Technologies

Resource accessing technologies are mainly realizing intelligent access of all kinds of physical manufacturing resources based on IoT and providing various corresponding access devices. The resources need to be accessed, include manufacturing equipment, simulation test environment, test lab environment, high performance computing and other IT infrastructures, large design/analysis/simulation softwares, the existing information systems (ERP, PDM, SCM, and PLM), etc. Therefore, the main technologies involved to realize this goal include: 1) embedded systems or chips, soft plug, interface technology, protocols, and norms of hardware resources; 2) the specific access devices and adapters for the physical hardware resources; 3) the underlying communication networks of the physical hardware resources; 4) the access technologies of high-performance computing and other IT infrastructures; 5) the adaptation and access middleware technologies of the large design, analysis, and simulation softwares; 6) integration and adaptation technologies of existing information systems; and 7) human computer interaction (HCI) interface and visualization of the access of manufacturing resources.

C. Resource Perception and Processing Technologies

Resource perception and processing technologies aim at realizing the intelligent sensing of physical resources based on IoT and the intelligent analysis and processing of related data. The specific content involved in these technologies include: 1) special sensing devices, as well as the integration technology with the existing sensing equipment and networks; 2) related development of intelligent sensing system; 3) the suitable sensor network protocols, interfaces, standards, norms, and other formulations for CMfg system; 4) architecture of resource sensor networks (including wireless communications, high-speed network, pervasive communications, sensors, future Internet, 3G, and 4G), and the deployment of hard and soft sensing devices; 5) quality of service (QoS) management of perception network; 6) dynamic acquisition, analysis, and pretreatment of the perception data; 7) performance monitoring, fault tolerance, and interoperability of perception network; and 8) switching interface and human machine interface (HMI) of perception network.

D. Resource Virtualization Technologies

Resource virtualization technologies are mainly to achieve virtualization of all kinds of MRs&Cs based on CC, and the centralized management of the virtual resource pool. Therefore, the key virtualization technologies include: 1) virtualization technology of platform infrastructures; 2) standards and norms of virtualization of software and hardware resources; 3) virtualization of the interface of hardware resources; 4) virtual image generation technology of hardware and software resources; 5) monitoring and management of virtual platform infrastructures; 6) monitoring, fault tolerance, and migration management of virtual hardware and software resources; and 7) high reliability collaborative switching technology of virtual environment.

E. Resource Servitization Technologies

Resource servitization technologies are mainly to generate the corresponding cloud services of the various virtual MRs&Cs and carry out the integrated management of cloud services. It includes: 1) the encapsulation and description language and methods of the virtual resources; 2) norms, standards, and protocols of the servitization of the virtual resources; 3) cloud services realization of manufacturing capacities; and 4) dynamic deployment of cloud services.

F. Service Management Technologies

Service management technologies mainly realize the comprehensive management and optimal allocation of cloud services, including: 1) automatic aggregation and classification management of cloud services; 2) dynamic construction and maintenance of cloud services; 3) QoS management; 4) comprehensive utility evaluation modeling, evaluation, equilibrium, and coordination of cloud services; 5) automatic composition of cloud services; 6) the construction of cloud services composition network and its dynamic characteristics; and 7) reliability management of cloud services.

G. Demand Management Technologies

Demand management technologies are used to receive manufacturing tasks, carry out the detailed analysis of function and implementation processes according to task description, and divide the tasks intelligently. The specific technologies include: 1) definition and formal description of tasks (users' demands); 2) automatic decomposition of tasks (including functional analysis and process analysis of the requirements); 3) manufacturability analysis and evaluation of tasks; and 4) multilevel optimization of manufacturing planning.

H. Transaction Management Technologies

Transaction management technologies provide supporting technologies for realizing automatic matching, transaction process monitoring, comprehensive evaluation management, optimal scheduling of cloud services, and manufacturing tasks. It includes: 1) smart match and search of the functional and process requirements of simple tasks and cloud services; 2) intelligent discovery and composition of manufacturing process demands and transactions; 3) comprehensive evaluation techniques of transaction process; 4) transaction logic, methods, and control technology of manufacturing capabilities; 5) transaction process monitoring techniques of manufacturing capabilities; 6) risk prediction and analysis of manufacturing capabilities transaction; 7) resource management and capability providing mechanisms in CMfg environment; 8) optimal dynamic scheduling technology of cloud services; 9) management engine of transaction processes; and 10) knowledge management, semantic analysis, and adaptation engine of manufacturing tasks.

I. User Business Management Technologies

User business management technologies mainly provide the supporting for interface and tools for users' business in CMfg environment, and for convenient processing of users' tasks. The technologies involve the following details: 1) development of enterprise business modeling, business model version management, data conversion, and other user business management tools; 2) development of various user access interface and visualization, such as mobile end-user access technology based on embedded devices, and application access technology based on desktop virtualization technology; 3) development of highly reliable operating tool for business; 4) integrated business gateway devices and related technologies; and 5) business management and development of the integrated tools.

J. Platform Supporting Technologies

Platform supporting technologies aim at developing CMfg service platform, and providing all kinds of tools and the supporting system needs by the operation and management of platform. It includes: 1) HMI development orient to several typical manufacturing process applications in the entire lifecycle; 2) system management tools, such as the management tools supporting multiagent security, performance monitoring, and optimization; 3) remote real-time collaborative integrating communications technology and systems; 4) data management, data security, and disaster recovery of operation and maintenance; 5) data fusion, conversion, and rights management after integrating the existing information systems; 6) access control for multiple different users; and 7) typical application tools for multiple users, such as customization of platform functions and interface conversion tools.

V. Key Advantages and Challenges of CCIoT-CMfg

In addition to the general advantages and challenges of CMfg that have been pointed out in the previous work [29], specifically, CCIoT-CMfg can offer the following key advantages. With the application and support of IoT and CC technologies, the intelligent operators of 4C (i.e., intelligent perception and *C*onnection, *C*ommunication, *C*omputing, and *C*ontrol) of various MRs&Cs can be realized.

1) Both the physical hardware manufacturing resource (e.g., manufacturing equipment) and software manufacturing resource (e.g., manufacturing software/application system or tools and data such as demand information, product structure data information, and process information) can be intelligently perceived and connected into the wider networks with the support of IoT technologies such as RFID, embedded system, and various intelligent sensors (e.g., optical fiber sensor). Therefore, the required and useful information and data (e.g., performance and functional parameters, statue information, capability information, and energy consumption information) can be intelligently collected, which will be communicated, processed, and used in the whole-life cycle of manufacturing.
2) The collected information and data can be communicated and transmitted between M2M (including man-to-machine, machine-to-machine, and man-to-man) under the support of specific IoT technologies (e.g., LAN, WSN, and 2G/3G/4G network). As a result, the physical world and virtual (or information) world of manufacturing are bridged.
3) The collected and transmitted information can be processed and computed according to specific requirements under the support of different CC service, and some useful data and decision information can be intelligently generated and obtained. In addition, some MSs (such as production-related services and product-related services) can be generated based on the collected and processed information and service of various MRs&Cs.
4) According to the specific requirement of users, and based on the collected and processed data and information, the related MRs&Cs can be intelligently controlled. For example, an equipment can be allocated to execute a specific manufacturing task, or some repair and maintenance services are arranged to it.

However, many challenges remains to be addressed before CCIoT-CMfg is implemented and applied, such as design and manufacture of high-frequency chip antenna, special sensors, as well as the deployment technologies, e.g., optical fiber sensors for online and real-time monitoring high-speed rotating equipment with high working temperature; majority works of IoT in manufacturing are emphasized on the data collection of manufacturing equipment and process, but studies on how to realize the intelligent data mining and processing of these collected data, and generate the useful information to serve the manufacturing requirement is insufficient [38], [39]; the standard, protocol, safety, reliability, and management level of applying IoT and CC in manufacturing; the contradiction between manufacturing resource/information sharing and protection of privacy/core technology by using IoT and CC technologies in manufacturing; and business mode of CCIoT-CMfg, cost problems; and so on.

VI. Conclusions and Future Works

How to achieve the intelligent access and processing of MRs&Cs in the whole production processes, how to realize the intelligent management of MRs&Cs (MSs), and how to make the on-demand use of MRs&Cs (MSs) are the primary issues to be addressed; so that, for modern manufacturing enterprises, how to realize the transformation from production-oriented manufacturing to service-oriented manufacturing is one of the key bottlenecks. In order to find a way to address the bottleneck, the potential applications of the new technologies such as CC and IoT in manufacturing have been investigated in this paper. The relationships and differences among CMfg, CC, and IoT are investigated and discussed. The main innovative contributions of this paper are as follows.

1) An overview of the applications of IoT and CC in manufacturing field are summarized from three views: a) the applications of IoT in the workshop; b) in the enterprise; and c) among enterprises.
2) The potential of advanced technologies such as IoT and CC for addressing the bottlenecks faced by the existing AMSs is investigated, and a CC- and IoT-based CMfg system, namely CCIoT-CMfg, is proposed, as well as its architecture.
3) The relationship among CMfg, IoT, and CC is discussed on the mutual influences among IoT for the intellisense of MRs&Cs, IoS based on CC, and IoU for the applications in the whole-life cycle of product.
4) The technologies systems for realizing the CCIoT-CMfg is established consisting of five categories, which can provide theories and method guidance for the implementation of CMfg service system or platform.

5) The advantages and challenges for the application and implementation of CCIoT-CMfg are investigated.

In further, the implementing technologies, methods, and the new specific devices of intelligent perception, connection, and processing of various MRs&Cs based on IoT are worth to be studied, as well as the specific enabling technologies and methods for realizing the on-demand use and free circulation of various MRs&Cs under the support of CC-related technologies.

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