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A New Reform of Mining Production and Management Modes under Industry 4.0: Cloud Mining Mode

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Abstract: In the context of Industry 4.0, using a new generation of information technology to activate and transform traditional industries will maintain the long-term competitiveness of traditional industries. The mining industry is also going through the process of informatization transformation. Through a literature survey, we analyze the current situation and challenges faced by mine production and operation management. Many mining companies are expanding in scale, but their operation and management methods are inefficient, and their business processes and organizational management methods need to be reformed. We propose a new mode named CM mode (cloud mining mode). We define this as integrating the core business of the mine (such as production and operation management, mining technology, planning services, etc.) into the cloud through effective use of cloud technologies, cloud resources, and cloud services. A large number of human and intellectual resources move to the cloud. A new mode of operation and management of mining industry clusters is thus formed; it is open, cooperative, and coordinated. We present five elements of the CM mode: data resources, digital technologies, digital talents, cloud business form, and cloud cooperation mode. We establish a "cloud–edge–terminal" technical framework of the CM mode, and describe its technical characteristics. We also describe three main application scenarios of the CM mode, and highlight the development path and key points of construction. The CM mode highlights a new development direction for the production and management of intelligent mines, and is of great significance for giving full play to the value of intelligent construction.

Keywords: intelligent mines; cloud mining; efficient operation management; cloud business; open cooperation

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1. Introduction

Industry 4.0 [1–3] refers to the use of CPSs (cyber–physical systems) to digitize the supply, manufacturing, and sales information in production, and finally achieve fast, effective, and personalized product supply. When people mention the era of Industry 4.0, they will think of its many characteristics: interconnection, data, integration, innovation, and transformation; its core feature is interconnection—that is, equipment, production lines, factories, suppliers, products, and customers are linked together. Therefore, the technology of cloud computing and the Internet of Things is constantly developing. Many large enterprises have taken advantage of public and private clouds to move some workloads from premises to the cloud because it is more cost-effective. In addition, this gives workers flexible forms of work organization. Workers will be freed from monotonous, routine work to focus on innovation and value-added services. Under the wave of Industry 4.0, many countries are undergoing a deep integration of industrialization and informatization. Advanced technologies (such as IoT, AI, big data, cloud computing, edge computing, digital twins, etc.) have been applied to many industries and fields [4,5]. These technologies have also fully penetrated the intelligent construction of mining enterprises.

At present, the social division of labor is becoming more and more refined and professional [6]. How can information and knowledge be obtained and shared at a lower cost and with higher efficiency? How can the collaboration method be more efficient and convenient? How to iteratively innovate the business system and development model? The digital transformation of mining enterprises is facing greater challenges, but also brings many opportunities.

COVID-19 has affected the work and life of people around the world, especially as people are forced to work remotely and collaborate online. In turn, this brings great impetus to the transformation of enterprise operation and management modes. “Cloud technologies, cloud resources, and cloud services” are booming and becoming important driving forces behind the digital transformation of enterprises [7–10]. The “cloud mode” of remote collaboration, distributed management, service sharing, and pay-as-you-go is gradually showing its value. Enterprises are gradually moving from closed to open; from independent existence to cooperation and sharing. The cloud business model will give full play to the value of digital transformation, such as by promoting organizational structure optimization, innovating business processes, and changing management modes [11,12].

Therefore, based on the status quo of the mining industry, existing pain points, and development trends, combined with the development of IT technologies and the development of business models, we propose a new mining production and operation model. We hope to guide the further development of related industries, management modes, and technologies. We review the construction process and status, and summarize the challenges and development trends existing in mine operations (Section 2). We propose the CM mode (cloud mining mode) and its definition, connotations, and composition (Section 3). We describe the technical architecture and application characteristics of the CM mode—especially the way to change its status (Section 4). We also describe three application scenarios of cloud mining, and three stages and key points of gradual realization (Section 5).

The new mode constructs an industrial ecosystem of sharing, interconnection, and cooperation; it embodies the collaboration from mining technology to production management, from system construction to operation and maintenance, from owner to service, and from front end to back end. The new mode mainly solves the synergy problems in the group operation of mining enterprises and the cooperation problems between related enterprises. We hope that through our summary and elaboration we can guide the mining industry chain enterprises to attain a systematic understanding of the cloud mode. We hope that multiple parties will cooperate and participate in the construction and improvement of industries, technologies, and management modes, and work together towards cloud mining.

2. Background of Reform

2.1. Current Situations and Challenges

The mining industry has undergone development from traditional mining methods to mechanization, automation, and digitalization, and is now exploring unmanned and intelligent operations [4]. Standardization is an important issue facing enterprise group management. In the era of globalization, multinational companies integrate resources all over the world. Companies have formed a business model of integrating management and control via the headquarters, and providing products and services to the global market [13,14]. China’s government put forward the “One Belt One Road” cooperation initiative in 2013. Many companies have seized upon this development opportunity to conduct overseas mergers, acquisitions, and cooperative investments [15]. The same is true for mining companies; the group’s mines are gradually spreading across the world, and the scale of the company is expanding, but the organizational structure and operating methods are still traditional, making management and coordination difficult [16,17]. Specifically:

1. It is difficult to coordinate production management in several mines:

A notable feature of mining group management is the coexistence of multiple mines, multiple processes, and multiple businesses. Mines are scattered in different regions. This has inevitably brought many difficulties [18,19]. The front (mine side) and the rear (group side) are inefficient in coordination and comprehensive management. It is very difficult to share resources within the group. Each mine must be equipped with professionals in geology, surveying, mining, beneficiation, transportation, safety, management, etc. This seriously increases the group's human resources burden. Moreover, due to the hard work in the mines, recruiting has become very difficult. The management level between the group and the mine is lengthy, which causes a serious delay in the communication of information up and down;

2. The efficiency of cooperation between industry chain and supply chain companies is very low:

The construction of modern mines involves many fields and specialties [4,5]. The mining business includes production, scheduling, manpower, materials, planning and budgeting, safety and environmental protection, management, etc. The industry chain companies include information and communication, equipment manufacturing, engineering construction, transportation service, design institutes, consulting agencies, etc. Mine operations were once referred to as "operational silos" because of the low degree of integration between the various mining businesses, resulting in inefficient business connections. When industrial chain enterprises carry out technical services, mining services, system construction, system maintenance, and other cooperation, inevitably, business personnel will frequently have to go to the mines for field investigation. A lot of time is wasted on the road, and in the follow-up work it is impossible to ascertain the field situation effectively all the time. Affected by geographical barriers and insufficient access to information, the cooperation efficiency between enterprises is very low.

In addition, with the widespread application of digital and intelligent systems, the guarantee system for normal operation is also an important issue facing the current mining industry [6]. The core business of a mining company is the comprehensive utilization of mineral resources, and the application of digital technology alone is not enough to optimize management, improve efficiency, and save costs. Through reforms in organizational structure and cooperation methods, companies can focus on core business and improve management efficiency.

2.2. Driving Force of Reform

Since the 1990s, Finland, Canada, Sweden, and other countries have successively formulated development plans for "intelligent mines" and "unmanned mines", in order to gain a competitive advantage in the mining industry. Professor L. Wu first proposed the concept of a "digital mine" in 1999 in China [20]. Mining enterprises have been developing continuously for more than 20 years, following the road of digital and intelligent transformation, and have achieved many results. Remote control and autonomous operation equipment have enabled unmanned operation in local areas of underground mines [21,22]. Complete industrial ring networks and wireless networks covering entire mines have enabled the timely transmission of information and data [23,24]. The innovation of 3D modeling technologies can accurately model the ore body [25,26]. Remote management and control platforms have laid a good foundation for the remote production and operation of mines. Mine production is developing towards remote control and unmanned operation [27].

Many mines are geographically remote, and their working environment is difficult. The aging of the labor force is serious, and safety problems are very prominent [18]. The Chinese government proposes to promote the intelligence of traditional industries in its national strategy. In guiding the construction of intelligent mines, it is proposed to gradually promote the cloud-based deployment of traditional services, in order to achieve mines with an entirely unmanned production process. The mining production and management modes are undergoing profound changes [28].

The innovation and application of modern technologies have given birth to new economic models, such as platform economy, sharing economy, cloud service, etc. [9,29–31].

This has brought great changes to people's working methods and service modes; it also creates good conditions for the innovation of production and management modes of mining enterprises. We describe the driving force of reform from four perspectives:

- Advanced technologies are widely used in mines [32–34]. The combination of big data analysis and artificial intelligence can monitor and effectively predict hidden dangers on the production site in real time. Automatic control combined with machine learning can improve the accuracy of repetitive tasks. Cloud technology has established a comprehensive management platform for mining enterprises, and laid the foundation for enterprise cloud operation and maintenance. Edge computing minimizes latency from data generation to respond in real-time production operations;
- The solution and top-level design are gradually improving [35–37]. Relevant national policies and standards are gradually promulgated, highlighting the direction for the intelligent construction of mines. Through the construction of infrastructure and the establishment of operating platforms, the cloud integration of mining business systems will be promoted. At present, the industrial cloud platform is developing rapidly [3,9]. For example, the Predix cloud established by GE in the United States has become the first cloud service platform specifically developed for industrial data and analysis. Siemens has launched the "MindSphere" industrial cloud platform, designed as an open ecosystem. MineRP, the world's only enterprise mineral resource planning platform, has successfully implemented electronic business process management solutions for clients in the platinum, gold, iron, and diamond mining industries;
- Several industries have achieved remarkable results in digital transformation. Intelligent logistics, intelligent warehousing, and intelligent homes have become reality [38–40]. Intelligent cities and intelligent enterprises are gradually being built [41]. The cement industry and the pharmaceutical industry can already build a full-process intelligent factory [42,43]. This is precisely where the three cores of Industry 4.0 play an important role: automatic control systems, the Internet of Things, and cloud big data, which bring a whole new way of working and production;
- BHP Billiton, Rio Tinto, Anglo American, and other groups have established remote operation control centers in Perth, Australia; they have achieved centralized control and remote operation of unmanned mining trucks and automatic railway transportation systems in mines more than 1000 km away. These enterprises establish a visually integrated supply chain from mine to port, which will significantly improve overall operational efficiency.

In short, with the development of software and hardware, and the popularization of intelligent equipment, the data sharing and service capabilities of intelligent systems will be increased. More cloud platforms based on the Internet will be established [21]. Technical personnel, management personnel, and operational personnel will be transferred from the front end (production line) to the back end (intelligent control center). The production operation and organizational management mode will be transformed to the cloud. This cloud mode is not only about improving efficiency and saving costs; digitization also brings a safer work environment, can promote collaboration between teams, and increases the attractiveness of work for the next generation of workers.

3. Definition, Connotation, and Composition

3.1. Explanation of Definition

Cloud mining (referred to as CM) mode refers to a cloud-based integration of core mining operations (such as production and management, mining technologies, and planning services) through effective use of cloud technologies, cloud resources, and cloud services. A large number of human and intellectual resources move to the cloud. A new mode of operation and management of mining industry clusters is formed, which is open, cooperative, and coordinated.

Cloud technologies refer to the general name of network technology, information technology, integration technology, and application technology based on the cloud computing business model [44]. Cloud resources refer to the formation of shared resources after data, software, and hardware in production and operations are uploaded to the cloud. These can be used and provided on demand [7,8]. Cloud services are also network services that provide dynamic, virtualized, and easily expandable resources through the Internet [45]. The migration of human and intellectual resources to the cloud is the core element of the new mode. This refers to a new working mode for employees of mining enterprises, including data processing, resource sharing, production control, business communication, and cooperation through cloud platforms.

3.2. Content and Relationship of Elements

"Cloud mining" is not a new mining method or digital technology, but a new mining operation and management mode. The digital and intelligent construction of mines is an important technical guarantee for the realization of "cloud mining". This mode embodies changes in corporate development concepts, decision-making concepts, organizational structure, operation management, technical capabilities, and external cooperation. The ultimate goal is to build a cross-border integrated industrial ecosystem, making the development of mineral resources more efficient and their management more scientific.

We divide the CM mode into five elements; the specific content is as follows, and the logical relationship is shown in Figure 1:

- Data resources, including fundamental data and derived data [4,7]: Data resources are collected in mining production, management, operation and maintenance, marketing, and other links. Fundamental data include basic geological data, environmental perception data, equipment operation data, human resources data, financial data, material data, transportation data, sales data, warehousing data, etc. Derived data are generated by processing and analyzing fundamental data;
- Digital technologies [9]: The first are digital mining technologies, involving software and hardware automation, remote operation of equipment, etc. The second are perception technologies, involving smart sensors, smart cameras, wearable devices, high-precision detectors, etc. The third are transmission and integration technologies, involving 5G, WIFI6, the Internet of Things, blockchain, radio frequency identification, etc. The fourth are data analysis and utilization technologies, involving big data analysis, machine learning, cloud computing, artificial intelligence, etc.;
- Digital talents: Under the CM mode, mining companies need comprehensive talents with ICT professional skills and traditional mining production knowledge. ICT professional skills include data management analysis, product development, smart manufacturing, digital operation, marketing, etc. Enterprise personnel are transferred from on-site work mode to cloud work mode, and collaborate on the cloud platform;
- Cloud business form: Under the CM mode, data, software, and hardware resources are integrated into the cloud platform. On the cloud collaborative platform, remote control of various operating systems in the mine production cycle is possible. The business of the enterprise is fully interconnected via cloud collaboration, including production, human resources, finance, materials, mechanical and electrical, safety and environmental protection, scheduling, management, planning, and decision making. The system, the business, and the personnel can all be called to the cloud;
- Cloud cooperation mode: The CM mode is a cloud work and cloud cooperation mode. The internal business (such as execution, implementation, supervision, assessment, etc.) of the enterprise will be more efficient. External business cooperation will be more convenient and reliable, and will no longer be subject to geographical constraints, departmental boundaries, or information barriers. The upstream and downstream enterprises of the industrial chain work together to build a cloud cooperation mode. This mode is characterized by remote collaboration, distributed management, service sharing, and pay-as-you-go.

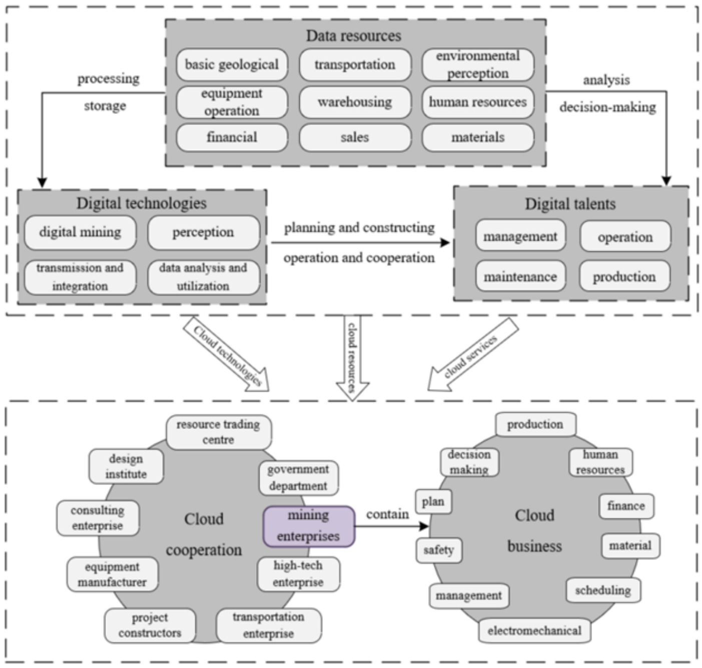

Figure 1. The logical relationship between elements of the CM mode: Specifically, data resources include all aspects of mining operations. Digital technologies are the main tool for generating, transmitting, integrating, processing, and analyzing data resources. Digital talents can use the analysis of data resources to help decision-making, and use digital technologies to complete various tasks. Under the CM mode, the businesses of mining enterprises are carried out on the cloud, and enterprises collaborate on the cloud.

4. Architecture and Characteristics

An important guarantee for enterprises to achieve reform is the transformation of technological capabilities. This is necessary in order to accelerate the application of a new generation of digital technology and the transformation of traditional production methods.

4.1. Technical Architecture

The CM mode takes cloud resources, cloud technologies, and cloud services as the core support; it adopts the technical architecture of the "cloud–edge–terminal" to establish end-to-end intelligent business subsystems, edge-intelligence-enabling platforms, and cloud-integrated management platforms; the specific content is as follows, and the technical architecture is shown in Figure 2 [46–53]:

1. Terminal intelligence:

The entire mine production environment covers intelligent sensing equipment, using sensing, measurement, automatic scanning, dynamic tracking, inspection, and other technologies [54]. In the production of mines, continuous unmanned mining technology, regional cluster control technology, autonomous driving, and operation control technology are used. The mining operation chain adopts mining equipment with autonomous driving and operation functions, including rock drilling, charging, shoveling, transportation, and support. The fixed equipment enables automatic control, including power supply, ventilation, drainage, filling, lifting, etc. On the terminal side, the purpose is to realize the coordination of mining operations, remote execution of scheduling instructions, predictability, and cloud maintenance of equipment failures;

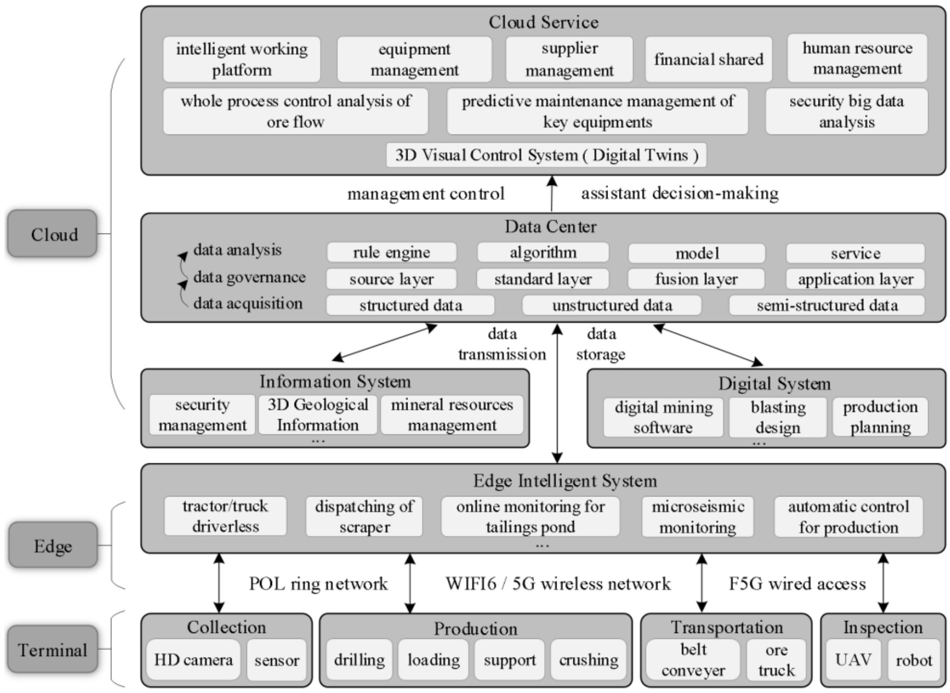

Figure 2. The technical architecture of the CM mode.

2. Edge enabling:

Based on the industrial Internet and wireless communication technologies, we can establish an interactive network for data transmission of mine production, management, and operation. The mine data warehouse and multisource heterogeneous information fusion technology [45] are used to establish the edge intelligent management and control center. The storage, filtering, and processing of the terminal data enable the intelligent perception and dynamic modeling of the mining environment, the safety identification and early warning of the mining scene, and the intelligent scheduling and cluster control of the mining equipment. On the edge side, the purpose is to achieve preliminary analysis, early warning, decision making, and scheduling;

3. Cloud sharing and collaboration:

The core of the CM mode is cloud collaboration. This means the establishment of a cloud production management platform within the group, as well as a cloud cooperation platform between supply chain and industrial chain enterprises. The data filtered and processed by the edge will be transmitted to the cloud control platform. Data mining, cloud computing, artificial intelligence, and other technologies are used to control and optimize front-end production in real time [55]. Distributed resource management is used to comprehensively control the personnel, property, and materials of mines and factories. Blockchain [56] technologies are used to build a shared and cooperative value network centered on mining enterprises. On the cloud side, the purpose is to achieve interconnection on the cloud cooperation platform, assign tasks and resources according to elements, and play their roles efficiently.

4.2. Superiority of the CM Mode

The core goal of mineral resource development is "safe, efficient, and green"; the new mode is the same—its characteristics are reflected in the following section. Figure 3 shows the comparison between the current status and construction goals of production and management modes from multiple aspects.

1. Production operation and maintenance are sufficiently secure and collaborative. When the entire operation process and fixed facilities are automated and intelligent, a large

number of mine technicians will be transferred from the production site to the cloud. Technicians use the cloud platform to coordinate the management of business systems, achieving intrinsic safety far away from dangerous sources. This helps to improve production efficiency;

2. Decision and analysis are driven by data. When the multisource heterogeneous data covering the whole process are fully collected, big data analysis is used to describe, predict, diagnose, and guide production and management. Through the analysis of user needs and industry overview, we can agilely respond to market changes. This helps to improve the scientific rationality of decision making;
3. Organization and management are more efficient and interconnected. When the mine's production data and operating status are displayed on the cloud platform in real time, the personnel conduct business communication and task assignment in the cloud. The organizational structure will be flattered and streamlined. Decision-making instructions will no longer be transmitted layer by layer, but directly sent from person to person. This helps to improve the efficiency of management and operation;
4. Industry clusters are more open and cooperative. When a digital cooperation platform centered on mining companies is established, companies in the supply chain and industry chain will conduct business exchanges and cooperation via the cloud. The barriers between various companies will be broken down, and a shared digital mining ecosystem will be built together. This helps to improve the utilization of mineral resources.

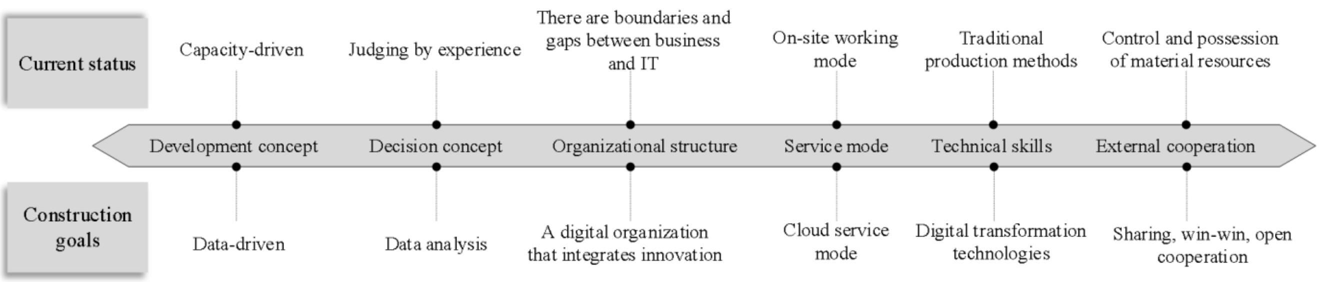

Figure 3. Comparison of current status and construction goals of production and management modes.

5. Application Scenarios and Construction Paths

5.1. Application Scenarios

The CM mode makes it easier to configure all resources by leveraging the economies of scale of cloud services. This can greatly reduce the cost of mining production and management, and improve the response efficiency of the business; its main application scenarios can be described from the following three perspectives [29–32]:

1. Operation scenarios of professional mining service companies:

Advanced technology is an important guarantee for the digital transformation of mines. However, companies with mineral resources do not have the capabilities of digital construction and later maintenance, and they usually outsource to professional mining service companies. The service companies have mature and reliable digital technology systems, expert talent teams, intelligent equipment systems, etc.; they can provide design plans and solutions for the intelligent construction of mines. Through the establishment of a cloud production and management platform, it is possible to achieve remote management and control of various mines;

2. Operation and management scenarios of mining groups:

Large mining groups have mine resources all over the world. The mining group establishes cloud collaborative work platforms to integrate the production and operation management systems of each mine. Through big data analysis, integrated operation and management can be achieved on the cloud's collaborative work platform. Management services include product output analysis, selection technology analysis, financial analysis, dynamic resource allocation, and business management analysis;

3. Cooperation scenarios of supply chain and industrial chain companies:

The entire supply chain and industrial chain collaborate on a cloud platform to form a digital industrial ecosystem centered on mining enterprises. Mining companies upload their production and operation status to the cloud platform in real time, and share data by setting access permissions. By building a value network, business requirements such as system upgrades, equipment maintenance, planning, and engineering construction are released on the cloud platform to seek the best partners. Government agencies can use the cloud platform to understand the production status of mines and supervise in real time. Design and research institutes can evaluate the progress and completion of work in real time, and optimize and improve in a timely manner. Equipment manufacturers can ascertain the operating status of the equipment, and carry out remote maintenance and troubleshooting in real time. Consulting service companies can provide experts for remote consultation and business guidance.

In each scenario, based on a unified cloud platform, the headquarters of the group deploys various production operating systems and digital mining apps in the cloud, and each mine can use the software services and technical services provided by the cloud according to their actual needs. Meanwhile, the data generated in the production, operation and maintenance, management, and other links are processed and uploaded to the cloud. Businesses such as geological modeling, reserve estimation, production planning, and mining design can be completed on the cloud platform. The operators who specifically handle this business are distributed in various places covered by the cloud. Businesses such as technical consulting, mining services, production operation, and maintenance can even be provided remotely by a third-party team. The operation, maintenance, upgrade, and expansion of the platform and software can be completed by the provider. The service mode is changing from on-site to the cloud. The technical personnel, operation and maintenance personnel, and management personnel will use the cloud platform to accept tasks, access resources, and work together (see Figures 4 and 5). Some mining companies (such as China Baowu) [57] are trying to build their digital mining systems towards a SaaS model; this is an initial attempt at such an information model.

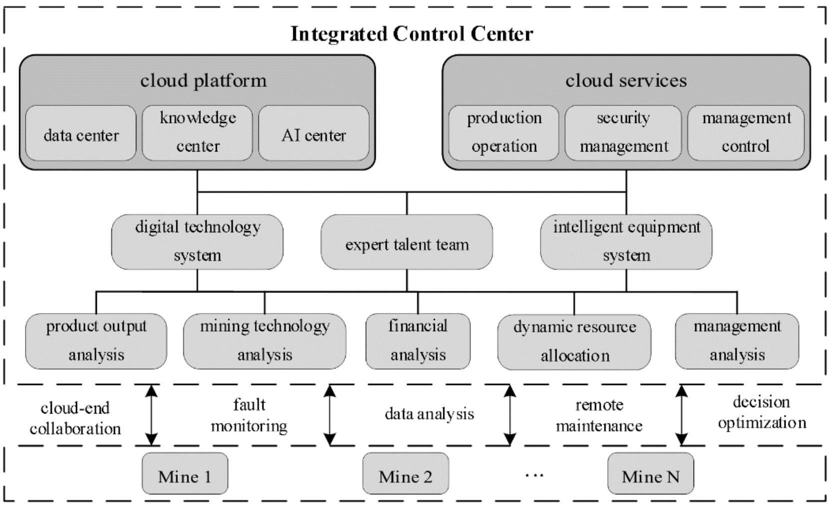

Figure 4. The structure of enterprise centralized management and control scenarios.

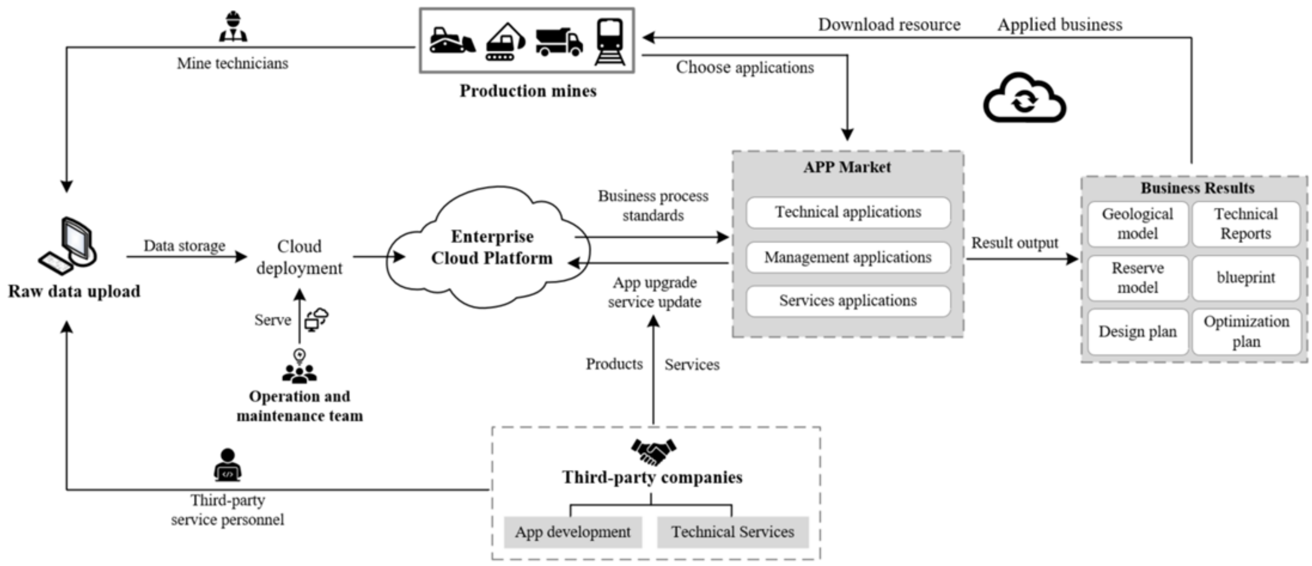

Figure 5. A mine production and operation management scenario under CM mode.

5.2. Realization Stages

Intelligent construction and changes in the new mode will not happen overnight. Intelligent equipment and digital systems can only be improved through application and upgrading [58]. The realization of the CM mode is also a gradual process, which can be divided into three stages:

The first stage is achieving the production and management intelligence of the mine. It is necessary to rationally adjust the stope structure and process to enable the unmanned operation of the entire mining operation process, and to use the sensor network to effectively obtain the data. Then, by establishing a production management and control platform, it is possible to integrate the management of production equipment, business systems, software, and hardware. Finally, by using data analysis, we can achieve intelligent mine production and management.

The second stage is achieving the cloud collaboration of mining groups and industrial clusters. By building a digital collaboration platform within the group to achieve the integration and optimization of the whole process elements, the upstream and downstream industry clusters establish a cloud cooperation platform together. The service mode will be changed from "on-site mode" to "cloud mode", enabling data connection and cloud collaboration.

The third stage is achieving the mining ecosystem of open cooperation, mutual benefit, and win–win. It is necessary to establish a unified big data collaboration platform to promote the openness and sharing of data. Moreover, by improving the cooperation environment between enterprises and optimizing the mechanism of industrial cloud construction, it is possible to establish a cloud mining ecosystem.

5.3. Key Points for Future Construction

The construction of the new mode cannot be achieved by one company or one team, but requires the cooperative efforts of many parties. The key points that we propose are the ones that need to be built step by step in the process of realization.

Firstly, infrastructure and platforms need to be built, and talents need to be cultivated. If personnel want to escape the harsh and dangerous on-site environment, further development of technology is needed. This requires not only the integration and intelligent transformation of production equipment, but also improvement of the reliability of sensing technology. It is necessary to establish a unified industrial Internet platform and use data mining and analysis to improve the efficiency of production, operation, and management. The underlying infrastructure services (such as cloud infrastructure, resource storage facilities, network construction, etc.), data management systems, and digital mining app deployment can all be provided by software companies so that mining groups can enjoy the services and focus on their core business. In addition, enterprises need to cultivate a group of talents who understand both mine scenes and information technology in order to serve this development and reform.

Secondly, data, software, and hardware need to be integrated into the cloud. Mine production, operation, and management data are collected at the terminal, optimized at the edge, and integrated into the cloud. It is necessary to fully tap the value of data in order to serve the optimization of a mine. Enterprises need to develop intelligent devices and industrial applications, and use cloud platforms for control and management, including condition monitoring, optimal scheduling, troubleshooting, data maintenance, and early risk warning.

Thirdly, laws and regulations must be established, and network security must be guaranteed. According to IBM Security's 2021 data breach cost report [59], remote working methods and the stability of cloud servers pose an even greater challenge to network security. Ensuring network security requires the joint efforts of governments, software companies, and mining companies, entailing continuous work. In the development of the new mode, technical specifications and construction standards must be formulated. Data index formats must be standardized, and communication protocols and interfaces must be unified. Through the unified authentication of cloud platform access rights, enterprises can share resources and collaborate with businesses, and it is necessary to formulate sharing rules and sign cooperation agreements in order to protect the core competitiveness of each enterprise.

Finally, the mining ecosystem needs to be built collaboratively. This cloud service mode consists of multiple parties, such as cloud platform providers, digital mining app product providers, mining group technical and management personnel, operation and maintenance service teams, and digital mining technology service providers. Business can be coordinated on a unified cloud platform, including design and manufacturing, supervision and services, production, and marketing. Based on data analysis, customer needs and market needs can be grasped. This new mode of open sharing can fully improve social efficiency. Supply chain and industrial chain companies should cooperate to build a digital ecosystem.

6. Conclusions and Prospects

We propose a new mode of mining production and management—cloud mining mode (CM mode). Mining companies use cloud technologies, cloud resources, and cloud services to move human and intellectual resources to the cloud platform. The core business of the mine is integrated into the cloud. Industrial clusters realize the pattern of openness, cooperation, and coordination.

The CM mode adopts the technical architecture of "cloud–edge–terminal". Data resources, digital technologies, and digital talents are integrated on the cloud platform to form an interconnected work mode and an open and shared cooperation mode. The new mode has the characteristics of remote collaboration, distributed management, service sharing, and pay-as-you-go.

Under the new mode, the company's development philosophy will be changed from capacity-driven to data-driven. The company's decision concepts will be changed from mostly empirical judgments to data analysis and cloud decision making. The service efficiency will achieve a comprehensive improvement in the ability from design to production, from inspection to receipt and accounting, and from operation to management. Mining operation companies, mining groups, and both supply chain and industrial chain companies will build an ecosystem of cooperation and sharing.

With the gradual emphasis on low-carbon economy, ecological environment, and safe production, there is an urgent need to reform the traditional extensive mining production and operation mode. The "cloud mining" mode is proposed to change the backward and inefficient production and management mode, trigger the reshaping of the industrial structure, and optimize the service format and business model. In the future, our team will work with more mining companies to promote our concept and implement our mode. This is a collaborative and ongoing effort that requires multiple parties. We need to keep trying, and as technology evolves and perceptions change, the cloud mining mode will shine into reality.

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