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Determination of Inter-Operability Credentials for Multi-Attribute Cloud Manufacturing Under Distributive Blockchain Executable IoT Protocols: A Concise Review

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ABSTRACT
Global distribution of products manufacturing organizations tends to favor countries who have deliberately reinvented manufacturing templates along the lines of modern technological developments. These production enterprises have embraced emerging digital technologies harnessed from varying aspects of data science, blockchain technology, machine language encryption, deep learning, digital twin,AI,autonomous devices, etc.; with which advanced production practices such as cloud manufacturing can be embedded on IoT protocols thus resulting remote management of the machines and plants. In view of these developments, the paper intends to conduct a brief review of current practices and future anticipatory prospects incidental to interoperability credentials required between the interfaces of these identified technologies for purposes of increased manufacturing efficiency. As a review concern, the study considered existing practices as projected by various industries and academia. These practices were found to be the results of demands in the industry and the conventional templates developed to guarantee significant compliance to regulatory requirements. The findings of the paper thus border on the relevance of defining the various interoperability credentials that are necessary for the achievement of the manufacturing design objectives. This imply that future designs of manufacturing lines and associated facilities and utilities would be made on the basis of application of these advanced data management protocols. The brief summary of crucial aspects of interoperability credentials in this paper thus sets agenda for clear definition of interface performance delineations in future manufacturing templates that must take advantage of emerging data technologies for manufacturing competitiveness.

Key words: *cloud manufacturing, smart contracts, embedded protocols, 3D printing, syntactic and semantic credentials, hashchains, cryptographic encryption*

INTRODUCTION

Interoperability credentials for manufacturing systems deals with the ability of manufacturing facilities to exchange and utilize information under enabling platforms of shared expectations or outcomes. Consequently, interoperability is the ability of two or more entities to interact and cooperate [1]. Accordingly, ISO 16100-6:201(E) views interoperability as "the ability to share and exchange information using a common syntax and semantics to meet an application specific functional relationship across a common interface" [2]. This means that interoperability is the capability of two or more systems or components to exchange and consume the information that has been transmitted.

Consequently, interoperability credentials define the *enabling structural interface* that can result the ability of a system receiving and process relevantly intelligible information of mutual interest transmitted by another system, within an associated network or link [3]. Conservatively, interoperability credentials for multi-attribute manufacturing requires that two or more machines or engaged production systems execute or make a perfect exchange of data content, in such a way that there would be complete absence of distortion or undeserving delays from either the source machines, their processing units or application terminals [4]. As an extension of these views, it has been observed that interoperability also implies the deployment of computer-based models that integrate and expedite the coordination of defined tasks by the flow of information across organizational boundaries and intermediaries with particular emphasis on inter-enterprise distributed resources and work flows [5].

Hence, interoperability credentials rely on the interface conditions of engaging systems, and how these conditions support the system's capability to deliver on its objectivities. Thus, interoperability credentials with respect to advanced manufacturing syntax can be evaluated under the following composite conditions: -

i. *Vertical Credentials:* This dimension of interoperability credentials integrates interactions between thefollowing resources; namely, operational software tools of the manufacturing enterprise, the applicable departments that enhances the utilization of the software, process platforms, equipment synergies, quality control and the implemented management system.

ii. *Horizontal Credentials:* These credentials integrate structural interfaces between smart automation and autonomous devices, edge and cloud computing infrastructures including cloud platforms that enables manufacturing operations.

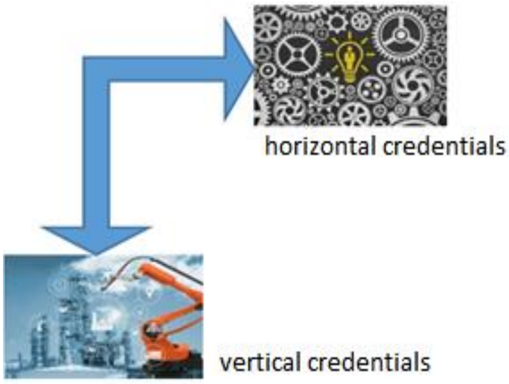

Fig. 1 Combinatorial syntax of vertical and horizontal interoperability credentials image sources: www.acrecent.com and www.allerin.com

Further, an articulated integration of these credentials has the capability to generate smart manufacturing conditions that are capable of significant cost reduction and exponentially increasing production capability and product quality.

Consequent on the foregoing, the United States National Institute of Standards and Technology Program on Manufacturing Interoperability, identified some crucial interoperability credentials that can advance the effectiveness of interoperability [6]. An implicit summary of these credentials are stated as follows:

i. data transfer between similar or dissimilar systems must be made possible under commercially acceptable conditions.

ii. transfer of data between software created by the same developer must be possible for different versions of the software for the systems that should be engaged.

iii. effective compatibility platform for different versions of the software i.e. newer software should be able to run programs or files written on older software.

iv. removal of obstacles in terms of terminology used for different software to enable exchange of information or data between platforms.

v. elimination of non-standardized documentation for the processing of data transfer protocols.

vi. proper testing of applications that conform to credential requirements with appropriate systems.

The foregoing further imply that interoperability credentials must be defined for situations of inconsistent data structures and reverse embedded IoT protocols for IP protection under trustless interfaces. These interoperability performance stamps would enhance future system integration for all data handling applications within the definitions of smart manufacturing on executable trustless blockchain platforms, that are operated on segmented IoT protocols and hubs. This also means that interoperability protocols must focus on smart contracts interfaces that makes for efficient data mobility within the specific blockchain platform, instill and enhance immutabilitywhile maintaining the integrity of the identification process for all hardware constituting the system. This implies that interoperability credentials should not only assure trusted hardware identification but also support trustless transactions while maintaining hardware integrity such as consensus time and data stamps, IP protection, components encoding and segmented particularization and system operationalization processes.

In view of the foregoing, the development of manufacturing hardware must take cognizance of available smart technologies at the point of design concept reviews. Thus, plant design should support available technology interfaces and also make room for expansion and integration of multi-attribute manufacturing conditions. This inbuilt condition must be necessarily determined by the nature of interface credential definitions and the performance evaluation and review techniques for system upgrade possibilities.

INTERFACE DEFINITION FOR INTEROPERABILITY CREDENTIALS

The exchange of information and data between manufacturing systems is governed by conventional templates such as the IEEE Guide to Enterprise IT Body of Knowledge [7]. This Guide categorized interoperability credentials into:

i. syntactic interoperability credentials and
ii. semantic interoperability credential[8]

Syntactic Interoperability Credentials

These group of credentials deals with form, or shape of data in the continuous flow spectrum. This implies that data transmission between smart manufacturing systems must always assume a shape format that is understandable to the systems within the linked network. The format must be either continuous, intermittent, step syntax or well-structured alphanumeric encoding appended to an appropriate machine language; just as high level transfer syntax such as Hypertext Markup Language (HTML) is used to deliver those specially formatted data spectrum.

Consequently, syntactic interoperability credentials only borders with the format of data transfer from one system within the blockchain network to another. This implies that syntactic interoperability credential does not append or interfere with the content of the format or interfere with the format nor obstruct the quality of data to be transferred. Incidentally, active standardization of data carriage shape or formats by constant credentials reviews and upgrades can significantly impact on syntactic interoperability; just as the enhancement of the supporting structure or means of data transfer is crucial to credential optimization.

Semantic Interoperability Credentials

These smart manufacturing interoperability credentials deals with content definition and interpretation given to data transmitted between systems in the network. Although it is a machine language, the meaning assigned to the data described by the machine language in the interpretation of a trained human operator form the basis for this specialized credential; consequently, the interpretation of the machine may not be required. However, where the interface is on the basis of an embedded deep Artificial Intelligence ($_d$AI), then the human interpretation is reserved for AI best decision pathway (AI-BDP).

Further, under this cover, the European Telecommunication Standard Institute (ETSI) requires that the meaning of a data content should be reserved to whatever consensus interpretation within the framework, that can be given to the communicated or transmitted data, by the human operator. Consequently,the data sequence, structural content, nature of facts transferred through data and how the facts are applied for the desired result to occur, all forms the basis of semantic interoperability credentials.

The study again observed that multi-attribute smart manufacturing operates on the platform of vertically integrated interoperability factors that enables exchange of information that maybe technical or commercially related under a constant synergy between communicating machines and externally integrated platforms[9].As has been observed, the cost of defective interoperability credentials is enormous; in the United States alone, manufacturing enterprises have constantly recorded some annual economic losses in the range of $1billion [10].The resultant effect of this condition is the limited flow of supply chain networks and low performance assessment in terms of quality service delivery. In order to solve this problem, Zeid *et al* proposed a single solution for all manufacturing partners of associated products. This industry wide standardization recipe requires that, industries or organizations under this loop utilize a common interface protocols in addition to other user-oriented protocols between different manufacturing units [11].

Further, multi-attribute manufacturing systems under IoT enablement have been observed to adopt open standard of general platforms where interoperability protocols possess common index credentials (CID) that enables interconnectivity on many cloud or edge computing terminals and interfaces. In addition to the foregoing, horizontally integrated interoperability conditions impose conditions and standards for enablement of cloud based interoperability computing resources.

Thus, as specified in the ISO/IEC 19941 standard, cloud based computing can also be extended to cloud or virtual manufacturing with enabling interoperability credentials.Therefore, multi-attribute manufacturing can be significantly applied under cloud manufacturing interoperability if the following interface credentials are supported or sustained:

i. *resource mobility interoperabilitycredential*which defines and determines the mobility sequence for transfer and exchange of data by the use of supporting internet protocols such as; HyperText Transfer Protocol (HTTP) and Message Queuing Telemetry Transport (MQTT) [12].
ii. *req-res, interoperability credential*encapsulates the interface credentials for cloud manufacturing on IoT enablement and requires that a data request is responded to, on the basis of specialized conditions, one of which is a computer simulated responses partially requiring human input and decision. In this situation *req-res* (Request-Response) interface can be viewed as cloud computing resources designed to offer such response where the parameters are the same, or similar.
iii. *regulatory credentials for cloud manufacturing* offers IoT enabled manufacturing terminals the necessity for assurance that there is full compliance with public policies with respect to data mobility, machine interaction and applications compliances. This regulatory framework is a crucial credential for manufacturing platforms utilizing IoT protocols.

The foregoing implies that cloud manufacturing under distributed blockchain executable protocols specific for IoT platforms would require advanced cloud support resources and cyber-physical technologies. These specialized technologies include: IBM Watson, Google Cloud Platform, Oracle and many others. Cloud manufacturing can subscribe to these platforms to communicate design and production processes with associates and clients. This IoT enabled platform is a data sharing platform that can be integrated into a blockchain loop to provide services such as database management, networked production scheduling, big data analytics and supply chain services.

BLOCKCHAIN CREDENTIALS FOR IOT AND CLOUD MANUFACTURING CAPABILITIES

This review observes that some high technologically driven organizations are neck deep in research works that are intended to result the fusing in of factories into IoT and cloud computing utilities to be linked by active blockchain networks [13]. According to the Frankfurt School Blockchain Centre report, several start-up organizations are exploiting the implementation of blockchain in the areas of supply chain management and materials audit. The report further drew attention to the emerging roles that the combination of IoT and blockchain will play for Industry 4.0 initiatives and how some companies are enhancing and enabling their production capacities by the implementation of 3D printing and blockchain solutions. This combination is intended to drive new manufacturing processes with highly efficient systems programmed on zero defect quality products. Thus, smart contracts in terms of 3D-blockchain enabled printing has replaced a lot of traditional manufacturing strategies. This is made possible by defining the interface interoperability credentials between manufacturing oriented blockchain technology and 3D printing technology.

Table -1 Overview of blockchain use cases in the manufacturing industry

Use case	Examples	Description
Supply Chain Management and Digital Product Memory	– IBM and Maersk	– Tracking of containers during the shipping process
	– Provenance	– Recording of all important product information throughout the entire supply chain
	– Everledger	– Registers certifications and transaction history of diamonds on blockchain
Internet of Things and Industry 4.0 applications	– Factom Iris	– IoT device identification over blockchain
	– Super Computing Systems	– Sensors that timestamp data on the blockchain to save them from manipulation
	– Tile Data Processing – tilepay	– Marketplace to allow customers to sell their data from IoT devices
	– IOTA	– Cryptocurrency and blockchain protocol especially developed to meet the demands for IoT applications
	– IBM Watson IoT	– Platform to save selected IoT data on a private blockchain and share it with all involved business partners
3D printing	– Genesis of Things	– Platform to enable 3D printing via smart contracts
	– Moog Aircraft Group	– Ensuring safe 3D-printing of aircraft parts via blockchain

Source: Dieterich et al., 2017 (Ref.13, at p. 6)

The implication of Table 1 above is that the use cases are positive identification of interface applications and areas of possible deployment. Further, Table 1 is also a demonstration of the definition accorded the blockchain-IoT-cloud manufacturing interoperability and interface credentials.

Use Case 1 Analysis

A careful observation of Table 1 indicates IBM and Maersk joint venture in the tracking of shipping manifest and logistics process. According to Groenfeldt [14], the result of IBM and Maersk testing of the deployment of blockchain in manufacturing logistics as related to their proof of concept (PoC), that a blockchain can be used to determine the mobility locations of items in transit. Since this view is of a practical nature, it implies that such interface advancement under well-structured inter-operability credentials could result the inclusion of other crucial players such as the banks, insurance, security agencies, customs, etc., whose interests could also be defined and captured in the design of the blockchain. This demonstration by the IBM-Maersk venture go to show that blockchain interoperability credentials for IoT and the rest of cloud manufacturing is significantly dependent on information and data exchange between engaged utilities under a common platform of enabling interface credentials.

Thus, ownership and originality certification design templates andmanufacturer’s warranty for packaging etc., can be entered into the blockchain by authorized persons and verified/authenticated by other members of the blockchain. This process of consensus validation creates immutable data in trustless transactions and increases the confidence of parties to the blockchain.

Use Case 2 Analysis

The application of blockchian-cloud manufacturing interface was demonstrated in the "Genesis of Things" (GoT) project which integrated the services of Cognizant Technology, GM Innogy SE and Commerzbank AG [15]. The intention for this application was to initiate a blockchain platform that will enhance a 3D printing supply chain. The proof of concept for the product considered the design and manufacture of titanium cufflinks. This product was embedded with a unique ID and digital product memory and manufactured under a blockchain platform, where the original designer registered the product as his own node of the blockchain using a digital encryption to protect the design from plagiarism.

At the point of product registration on the blockchain, the designer may be required to provide crucial parameters and features of the product since the design files uses smart contracts to automatically negotiate the price or condition of purchase. The design file also contains particulars to enable the sourcing of the closest 3D printing facility within the cloud inorder to negotiate production costs and associated conditions. This is achieved by the IoT network which receive and transmit data through high impact sensors and actuators. After negotiation of conditions with the customers, the design file also negotiate the means of mobility for the finished product to arrive user's destination, thus eliminating the middlemen in all of the stages of the activities.

It is important to note that upon production of the item, the blockchain originates a digital product memory, which encapsulates the complete product history, which includes raw materials sources and characteristics, processingprocedures, quality control and ownership, etc. It is important to note that this knowledge of transaction history, details of product design and the specific production system is a crucial aspect of the blockchian system under trustless and general consensus conditions. Thus, divergent members with varying interests on the product(s) could belong to this blockchain under the deployment of appropriate IoT, as a data transmission platform.

In this regard, advanced applications of blockchain thus require time stamping of all data to assure other interested parties of the immutability, coherency and integrity of the transactions [16]. Further, as more organizations achieve or progress towards cloud manufacturing, the need for data platforms interconnectivity will require that, access to data generated from the wide network of IoT devices and machines, should smoothly run at full capacity on appropriately executable blockchian protocols. This application can enable customers trade their data after registration and get paid under direct peer-to-peer real-time payment on the basis of their chosen legal tender, without any central validating authority, thus, increasing trust and fidelity of embedded manufacturing system.

BLOCKCHAIN / IOT INTERFACE OPPORTUNITIES FOR FUTURE APPLICATIONS

This review observes that the growth in blockchain deployment for manufacturing is on the steady increase and would continue to reshape current and future attitudes to the development of enterprise technologies. In view of these findings, suffice to say that blockchain disruptive applications in manufacturing services has brought about increased industrial benefits especially in manufacturing outputs, where cloud manufacturing is the focus. Consequently, we have outlined below key opportunities for future prospects of blockchain- IoT- cloud manufacturing interoperability interface. Three of the identified opportunities are intended to support other cutting edge digital technologies that could be deployed to expand or reinvent manufacturing processes.

This view is clearly supported by current IoT practices, such as the deployment of AUMA cloud data management technology [17] implementedby the installation of AUMA software on digital devices like phones and tablets for real-time communications with industrial production facilities that has been installed with their sensors and actuators. Thus, a systematic entry into such existing blockchain network by other organizations may be achieved by using specialized hashchains and cryptographic encryptions with interface protection credentials for IP protocols defined by the original operators. Further, this AUMA software is designed in the form of digital app activated on google play store.

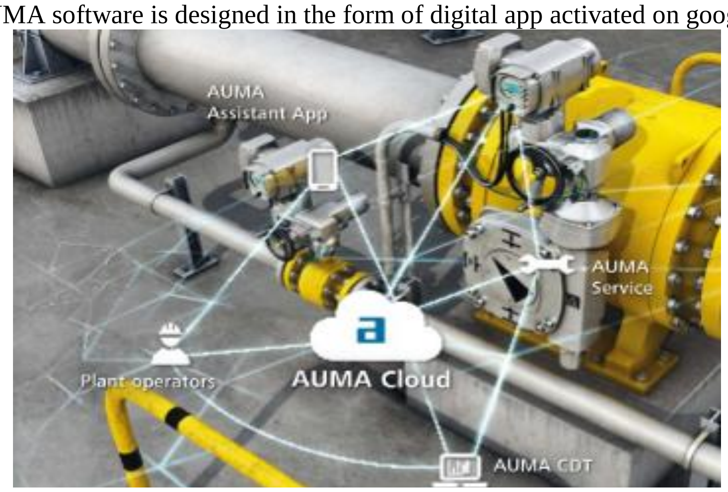

Fig. 2 Cloud manufacturing enhanced by interoperability interface credentials
Source: Hydrocarbon Engineering (Ref 15 at p. 35)

As could be noticed in Fig 2 above, actuators, sensors and enabled cameras are used to obtain real-time operational data from the various units of the oil production process and logged into a central AUMA cloud server. Uplink of this server through IoT protocols can result remote control and cloud manufacturing of this plant. Instructively, this facility is programed in an app and can be downloaded into digital devices such as internet ready mobile phones and tablets. These devices could be used for real-time remote production analytics and diagnostics on IoT protocols. Consequently, an addition of blockchain platform to this app would open up great manufacturing opportunities to users and many persons who have direct or remote interests in the scheme.

Further, the remaining three of the identified opportunities focus on practices of blockchain platforms and protocols that has interface interoperability with production models that can be operated under cloud manufacturing, they are as follows:

i. Data and Design Details Follow-up Support

Current practice here indicate interface opportunities for which blockchain is interoperably embedded into cloud manufacturing and digitally feed by IoT protocols. Under this opportunity, data exchange across digital platforms on the cloud facility is, easy, accurate and secure with interwoven complex chains.

Consequently, blockchain can provide permanent, concurrent digital records that are immutable.These records may include, parts geometrics, raw materials compositions, design templates and condition, etc., hence, enabling user-to-user encrypted visibility, thereby ensuring a single source and flow of information available to all parties in the transaction. In view of current practices and future anticipations, upscale manufacturing entities would increase the production output where many participants can form nodes or sub-nodes in the blockchain as to login their anticipations and concerns.

ii. Optimization of Intellectual and Virtual Property Rights

Blockchain enabled manufacturing system, running on cloud and IoT protocols has the capability to optimize intellectual and virtual properties on any executable platform. Thus, safeguarding and protection of the manufacturing company's IP, is a crucial concern, especially where created intellectual or virtual properties could be misappropriated or stolen and there is need for proof of concept and hashing validations to ascertain who the original owneris, assuming a dispute is occasioned. In order to solve this puzzle, a 2019 Boston Consulting Group report [18], reiterated that a blockchain developerhas designed an internet protocol that allows participants to register their IP in a secure blockchain that crates a digital certificate to timestamp the ownership, originality, existence, and other relevant credentials to the protocol.

Further, Blockchain can be optimized to enhance the maintenance and fidelity of an IP where digital assets have been monetized under smart contracts protocols. This optimization opportunity according to the Boston Consulting Group report can also be applied where machines linked to a blockchain through an IoT protocol can accept and producevarious components and parts of designs sent to it from external sources or remotely retrieved from its database and internal files from an external terminal or nodes connected to the blockchian. In the AUMA cloud design reported in this review, the software app is made to respond to only digital files from its own devices within a defined facility.

iii. Quality Control and Management Upon User Consensus and Validation

All manufactured products succeed or fail on the basis of their quality profile. The implication of this view is that blockchain enabled IoT platform can be used to control the quality of the manufacturing processes from raw materials to finished products including performance assessment of the machines connected to the blockchain and linked up to the cloud through the IoT and cloud protocols. The direct implication of this opportunity is that it creates platforms for consensus, consistency, transparency and immutability of the records, thus, increasing the trust and fidelity of the manufacturing system. Thisopportunity for proper documentation subsequently increases the need for quality as a determinantofuser's interests in the various transactions on the blockchain.

It should further be noted that, these immutable documentations for product quality assessment produces a transaction tracking and tracing enablement on the IoT-blockchain interface; thus enhancing cloud computing, storage and manufacturing capabilities. This feature can be achieved by an embedded program within the IoT-blockchain interface that takes measurements and readings directly from the machines and automatically writes them to the blockchain without any human interference, or any central validating authority. Consequently, under a trustless condition, parties will be able to utilize blockchain certificate management capabilities to access in transparent manner all relevant documents pertaining to any transaction and also make decisions on the basis of this transparent blockchain system, since authenticity of the records is not in doubt.

iv. Provenance and Configuration Management

Current practice has shown that in industries such as aero-dynamics, the multi-components systems can be configured and managed by all manufacturers from different countries and companies but networked in a single blockchain. The manufacturing capabilities of these companies can be remotely connected under extended cloud manufacturing program supported by IoT-blockchain interoperability credentials.

Consequently, all design files, structural details and crucial information can be entered into the blockchain and made executable by individual party hashing keys at their individual nodes for protocol protection. This means that manufacturers can utilize the benefits of a blockchain to determine the origin of raw materials, production processes and parts geometric configurations. It can also be used to verify the suitability and specificity of parts before use.

Further, since the features of the components of the manufacturing system are all contained in the blockchain their immutability makes configuration management possible in the sense that parts addition, substitution, upgrades and repairs all retainactive digital certificates of authenticity, functionality and measurable expectations and performance. In response to this opportunity, Honeywell has developed online capacity for marketing of aviation parts [15]. This online capacity uses blockchain to achieve accurate quality documentation for every component in the market.

v. Machine as a Service (MaaS) on Blockchain-IoT Protocols

Manufacturers of engineering systems are increasingly utilizing emerging technologies to enhance the quality of their products or advance the application technology to the operations benefits of their products. Under the MaaS program, manufacturers make their finished products an extension of their businesses in the sense that instead of selling the machines to interested purchasers or investors, they meterrize the production outputs and remotely monitor the machine'sproduction performance using a combination of blockchain, IoT and cloud manufacturing interfaces. Further, users of the meterrized machines are required to pay a commitment fee after which they pay on the blockchain,on the basis of production outputs, as they proceed with the machines. Thus, manufacturing flexibility is a top priority of the MaaS system which has specifically encrypted IP protection and automated payment platforms that determine cost of service with digital invoicing and payment certificates validated by the manufacturer.

vi. Automated Maintenance Agreement

Automated maintenance deals with service arrangements that come with the installation of the machines. This outsourcing of maintenance requires installation documentation with respect to all machineries registered in the blockchain records. These machineries or their components are digitally copied into the blockchain and reserved as *digital twins*. As the machines work, process embedded sensors relay their state of health to a central processing unit where automated decisions are made with respect to maintenance timing. Smart contracts are originated on the blockchain and directed at the maintenance organization who prepares the necessary papers including invoicing upon completion of the task. Payment for rendered service is effected automatically.

It is important to note that all transaction records are logged into the blockchain which in turn timestamps and forms immutable records of the machine's operational log. A certified copy of these documents from the blockchain printouts can form the basis of decision making for a willing purchaser of the enterprise or the machine.This automated maintenance program enhances the reliability ratings of the machines and also expedite the assessment of operational conditions of the machines or plants. It further helps to create machine auditable records of operational performance which would serve as the basis for historical condition monitoring and proof of maintenance in satisfaction of the warranty conditions. It also serves as basis for maintenance experience for the repair company.

CONCLUSION

This brief review on interoperability credentials required for the proper execution of cloud manufacturing using well defined blockchain-IoT interface has significantly considered current practices and future anticipations as emerging technologies are deployed to advance manufacturing practices in an era of increasing competition in technology applications.

The review defined interoperability within the context of data transmission, reception and processing in line with key objectives of the interface combinatorial conditions. Hence, the enabling structural interface to support the combination of varying data technologies and industrial manufacturing hard wares has been discussed and the relevant critical credentials necessary for such enablement has been considered. Thus, data structures and containment resources have been viewed along the lines of systemic integration of the various application software and programs into mainstream manufacturing conditions. These inbuilt conditions must be necessarily determined by the nature of interface credential definitions and their performance evaluation and review methods implementable for system upgrades and reengineering possibilities.

Additionally, the interface interoperability requirements between external data storage, processing and control platforms and the hard core production flow lines is as important to the advancement of cloud manufacturing as the conceptualization and development of the products that must be driven by such combinations. Further, under distributed blockchain executable protocols for IoT enabled systems, advanced cloud support services and cyber-physical technologies are mandatorily required for data sharing, integration and latency consistency across all applicable resources. Further, the two use casesanalyzed in the review draw attention to the cutting edge application of these technologies by various companies and how these applications are reshaping manufacturing enterprises especially where digital memories and digital twins are monetizable resources within a blockchain; thus eliminating the need for protection of intellectual and virtual property rights infringements on the basis of immutable ownership timestamps that are executable on the blockchain.

Conclusively, the review considered two sets of opportunities which are stated under six approaches. The first three sets of the identified opportunities are intended to support other cutting edge digital technologies that could be deployed to expand or reinvent manufacturing processes; while the remaining three identified opportunities focus on practices of blockchain platforms and protocols that has interface interoperability concerns with production models that can be operated under cloud manufacturing.

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