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CoVAC: A P2P smart contract-based intelligent smart city architecture for vaccine manufacturing

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ABSTRACT

With the Corona Virus Disease 2019 (COVID-19) outbreak, vaccination is an urgent need worldwide. Internet of Things (IoT) has a vital role in the smart city for vaccine manufacturing with wearable sensors. According to the advanced services in intelligent manufacturing, the fourth resolution is also changing in Industry 5.0 and utilizes high-definition connectivity sensors. Traditional manufacturing companies rely on trusted third parties, which may act as a single point of failure. Access control, big data, and scalability are also challenging issues in existing systems because of the demand response data (DRD) in advanced manufacturing. To mitigate these challenges, CoVAC: A P2P Smart Contract-based Intelligent Smart City Architecture for Vaccine Manufacturing is proposed with three layers, including connection, conversion, and intelligent cloud layer. Smart contract-based blockchain is utilized at the conversion layer for resolving access control, security, and privacy issues. Deep learning is adopted in the intelligent cloud layer for big data analysis and increasing production for vaccine manufacturing in smart city environments. A case study is carried out where access data are collected from the various smart plants for vaccines using smart manufacturing to validate the effectiveness of the proposed architecture. Simulation of the proposed architecture is performed on the collected advanced sensor IoT plants data to address the challenges above, offering scalable production in the vaccine manufacturing for the smart city.

1. Introduction

Effective vaccine development for COVID-19 is an essential part of human life worldwide in the current global epidemic. Furthermore, the Internet of Things (IoT) is regarded as a next-generation communication for smart cities and Industry 5.0. Based on the current and advanced requirements in the smart city applications, such as a smart vehicle, smart healthcare, smart manufacturing, the fourth resolution IoT devices and sensors are converting in the fifth resolution as Industry 5.0 (Singh, Sharma, Pan, & Park, 2021). Thus, Industry 4.0 is also changing in Industry 5.0. It provides a vision of an industry that objectives beyond efficiency and productivity as the individual goals and reinforces the industrial environment’s role and contribution to society in the requirements of innovative city applications (Sheela & Priya, 2021; Skobelev & Borovik, 2017). IoT supports information transfer and networked intercommunication of appliances, medicines, chemicals, and other advanced wearable sensor devices in vaccine manufacturing for smart healthcare (Antal, Cioara, Antal, & Anghel, 2021). The CPS (Cyber-Physical System) is a subset of IoT built on the tight integration of cyber entities, playing roles of computation, communication control, and physical things such as natural environment and biological and human-oriented systems for hospital networks (Jeong & Park, 2020). It is implementing mechanisms for conceptualizing all aspects of the networked designed systems for the Smart City Environment. In recent years, the IoT and CPS are emerging fields wherein computation, and communication mediums relate to IoT and wearable sensors devices during smart city and manufacturing data execution (Singh et al., 2019). IoT sensors and actuator devices facilitate the connection between the physical and cyber worlds and traditional embedded and control systems used for transforming innovative techniques with CPS for the COVID-19 pandemic in the IoT Smart City Infrastructure (Abie, 2019).

Nowadays, most countries are trying to develop the COVID-19 vaccine for their population and provide it to other countries. For the requirement of the vaccine manufacturing in COVID-19, Innovative production in industries has an essential and active role in the Smart City because the fourth generation is changing in the fifth generation as Industry 5.0 (Kim, Jang, Li, & Sung, 2020). It provides the best solutions, including preserving resources, more production, high connectivity in...
smart manufacturing with advanced sensors, actuators, and IoT devices (You, Hwang, Kim, & Cho, 2021). CPS and Artificial Intelligence work with various vaccine manufacturing companies to deliver high-level connectivity in designing techniques, analysis, and modeling with cyberspace in advanced industrial environments (Baig & Zeadally, 2019). Still, there are many challenges in the IoT environment, particularly in smart city applications such as smart healthcare (COVID-19 Pandemic) and Smart Manufacturing, such as big data, centralization, scalability, communication latency, access control, security, and privacy. The growing number of IoT wearable sensors in Industry 5.0 enhanced vulnerability such as Cyber-attacks and Distributed Denial of Services (DDoS) in Smart healthcare for the COVID-19.

In traditional IoT applications, the Role-based access control model (RBAC), Attribute and Capacity-based access control model (ACBAC) is validated by a third-party centralized entity that has centralization issues. Blockchain (Smart Contract) is an emerging and significant technology for providing security and privacy in Smart Healthcare because it has various immutable, authentic, tamper-proof, and transparent features (Chou, Liao, Chen, Chang, & Lin, 2019). In addition, smart Control-based Access Control is used in the proposed architecture for vaccine manufacturing and addresses the single point of failure challenge. On the other hand, Deep learning technology focuses on data science to enhance performance and big data analysis and produce many scalable vaccines in COVID-19 manufacturing companies with hidden layers (Park et al., 2021). It gives the automatic environment, including self-verification, self-executing the vaccine in the COVID-19 healthcare system for Smart City. Deep Learning is the latest and fruitful technology, which offers scalable production in vaccine manufacturing for the smart city with the help of hidden layer functionalities and max-pooling LSTM (Long-short term memory) (Selvaraj & Sundararavardhan, 2020). With the help of Max Pooling LSTM in the proposed architecture for smart vaccine manufacturing, the computational cost is reduced by the number of parameters to learn, and LSTM feature vector sets of each production are evaluated with intervention codes and time variance. Max Pool Matrix is created, and the Max Pooling function is defined.

Existing research studies provided the five-layer architecture in Smart Manufacturing with Industry 5.0 environment to mitigate the vaccine manufacturing-related issues by the automatic distributed environment. Still, it has various challenges such as big data analysis, access control, scalability, computational bandwidth, etc. To overcome the above, three-tier Architecture for Vaccine Manufacturing in Smart City is proposed, wherein smart contract-based distributed networks provide efficient and secure access control of vaccine plant IoT data in a decentralized manner. It has three functional entities: Contract Registration (CR), Contract Manager (CM), and Contract Access Control (CAC) for secure communication of vaccine plant IoT data in a distributed network. The Intelligent Cloud layer offers scalable production and big data analysis of vaccine manufacturing with Deep Learning as a future prediction and uses hidden layers. It utilizes the real-time measurement of vaccination data such as chemical reactions, water flow, and electricity in the smart vaccine manufacturing industry for the smart city environment.

The following steps are deployed as the main contribution of this research work:

- Propose a CoVAC: A P2P Smart Contract-based Intelligent Smart City Architecture for Vaccine Manufacturing.
- Design a Deep Learning at the Intelligent Cloud layer for scalable vaccine production and data analysis in Smart City.
- Validate the proposed architecture’s effectiveness; we implemented it and measured the performance in terms of standard parameters.
- Finally, compare our proposed work with the existing research and provide a vaccine manufacturing company’s case study.

The rest of this paper is organized as follows: Seminal Contribution work is discussed in Section 2, Section 3 proposes a CoVAC: A P2P Smart Contract-based Intelligent Smart City Architecture for Vaccine Manufacturing and case study with an estimated algorithm; Section 4 provides validation of the proposed architecture and shows how to provide analysis of access control, scalability, security, and privacy with decentralized storage; Finally, Section 5 presents the conclusion.

2. Seminal contribution work

This section discusses existing research study contributions for Vaccine Manufacturing in Smart City and finds some challenges. Key considerations are also explained in this section, such as Access Control, Data Decentralization, Big Data Analysis, Production Scalability, Security, and Privacy, to address challenges in the existing research.

2.1. Related contribution

Many researchers have studied vaccine manufacturing infrastructure in smart city applications as smart manufacturing in the Industrial environment with different technologies, discussed open research challenges, and proposed futuristic ideas, schemes, and architectures to address these challenges. These studies have merits and demerits. Recently, Chamola et al. (Chamola, Hassija, Gupta, & Guizani, 2020) described the role of IoT, AI, Blockchain, and 5G in the COVID-19 pandemic and provided a detailed review as to the reliable sources as well as merits and demerits to mitigate the impact of the COVID-19 outbreak. Nonetheless, they did not offer any architectural scheme for vaccine manufacturing in IoT. Saini et al. (Saini et al., 2020) proposed a smart contract-enabled access control scheme for cloud smart healthcare systems to secure communication of electronic medical records with the distributed ledger. However, this research did not entirely resolve the latency and scalability problem in processing and fetching the EMR for the smart healthcare system. The machine learning-based scheme proposed by Kumar et al. (Kumar, Solanki, & Tanwar, 2021) for COVID-19 in Human Bodies provides a list of datasets and solutions for predicting the stage of infection with COVID-19. However, this research did not deal with the vaccine manufacturing details for use in the proposed scheme. Peng et al. (Peng et al., 2020) provided a supervision method for vaccine production which is dependent on double-level blockchain. The first level offers the security for private vaccine-related production data with production and corresponding hash value. The second level also offers a secured environment for public vaccine-related production data with production records hash and vaccine information. Scalability and latency are the main merits of this research.

Hathaliya et al. (Hathaliya, Tanwar, Tyagi, & Kumar, 2019) proposed a biometric-based authentication scheme for healthcare records in healthcare 4.0 in which they identified various security challenges in electronic healthcare records and resolved them. However, this research did not provide efficient, scalable EHR records for healthcare 4.0, and it is only public healthcare records, not vaccination IoT healthcare data. Das et al. (Das, Bera, & Giri, 2021) proposed a robust and secure framework for vaccine delivery and tracking on COVID-19 infrastructure based on the Internet of Medical Things (IoMT) cloud. However, it provided an immutable, transparent, and decentralized environment. But it did not offer scalable production of the vaccine, access control is also the issue of this research. Liu et al. (Liu, Lin, & Wen, 2018) propose blockchain-enabled data collection and a secure sharing scheme with Ethereum and deep reinforcement learning (DRL) for a reliable and safe industrial IoT environment. But this research has scalability and high-definition connectivity issues. Access control issues were resolved by blockchain methods for IoT and provided distributed and truthfully access control with multiple subject-object pairs by Zhang et al. (Zhang, Kasahara, Shen, Jiang, & Wen, 2018). However, this research cannot be used in the advanced smart city application. Zhu et al. (Zhu & Zhang, 2018) proposed the smart monitoring system for computer numerical control (CNC) machines based on a cyber-physical production system (CPPS) for increasing the production of data in Industrial applications.
and analyzing big data. But this research has centralization, communication bandwidth, scalability issues based on the advanced requirements of a smart city.

Distributed blockchain-based protection framework provided for enhancing the robustness and self-defensive capability of modern power functions against cyber-attacks by using meters as systems in a peer-to-peer network for the smart city (Liang, Weller, Luo, Zhao, & Dong, 2018). Access control and latency are the main issues of this research. Buccafurri et al. (Buccafurri, Labrini, & Musarella, 2020) provided a solution for smart city infrastructure based on Ethereum Smart Contracts, e-IDAS (electronic Identification, Authentication, and trust Services)-based attributes and identity management, and the distributed file system. Still, this research did not provide security analysis for the smart city infrastructure. Chen et al. (Chen et al., 2014) developed a mathematical programming model for the generic World Health Organization’s Expanded Program on Immunization (WHO-EPI) vaccine distribution networks in developing countries. However, in this work described is focused on vaccines for routine immunization. Still, it has several challenges, such as complexity, centralization, scalability, and privacy.

Researchers have proposed solutions/ schemes/ architectures for vaccine manufacturing in the smart city environment with existing works. However, very few researchers utilized the fusion of Blockchain and Deep Learning-enabled smart city solutions for vaccine manufacturing. As a result, they did not resolve various challenges entirely, including access control, centralization, scalability, security, and privacy. Therefore, three-tier Intelligent Smart City Architecture for Vaccine Manufacturing is proposed with Blockchain (Smart Contract) and Deep Learning technology to overcome these challenges and offer more secure vaccine production in the smart industry. Comparison with Existing Research Study is shown in Table 1.

### 2.2. Key considerations

Five key considerations, including access control, data decentralization, big data analytics, production scalability, security, and privacy are leveraged in the proposed architecture for Vaccine Manufacturing. The importance of the realized vital factors is as follows:

- **Access Control**: It is an essential requirement for the proposed architecture because access control is the challenge of the existing research. Control Access Control (CAC) is used in smart contract-based distributed blockchain networks. Each CAC provides the access control procedure for plant-device combination in vaccine manufacturing as a smart city environment, which executes static and dynamic validation rules by examining the plants’ performance. CAC also has the authority to add, delete, and update access control protocol rules.

- **Data Decentralization**: Based on the traditional manufacturing companies, all are dependent on the third parties, then a single point of failure or centralization issue is faced by the manufacturing companies. However, blockchain technology is used for the proposed architecture, and no need for a third party to address this issue. After the validation, all vaccine-related data is stored at the intelligent cloud layer, and decision making, data analysis, and scalable vaccine production is completed.

- **Big Data Analysis**: Smart manufacturing use IoT and sensor devices, and every IoT device generates some data. So, a massive amount of data is generated for smart manufacturing in smart city infrastructure. For Big data analysis and decision making at the intelligent cloud layer, we apply deep learning technology in which hidden layers analyze the data for vaccine manufacturing and predict more outputs.

- **Production Scalability**: Scalable production is also an essential need for every manufacturing company. For the scalability of the COVID-

| Seminal Proposals       | Consideration               | Key Technology       | Case Study with Estimated Algorithm | Data Access Methods/ Parameters | Vaccine Manufacturing Infrastructure | Environment/Architecture | Year   |
|-------------------------|------------------------------|----------------------|-------------------------------------|--------------------------------|-----------------------------------|------------------------|--------|
| (Chamola et al., 2020)  | Vulnerability, Data Accumulation | Blockchain, AI, IoT | No                                  | Review of COVID-19 Pandemic    | No                                | Distributed            | 2020   |
| (Saini et al., 2020)   | Access Authentication, User Verification, Misbehavior Detection | Blockchain         | Yes                                 | ECC and EdDSA Algorithm-based Encryption and store data on Blockchain Networks | No                    | Distributed            | 2020   |
| (Kumar et al., 2021)   | Data Prediction and Detection | Machine Learning    | No                                  | Machine Learning-based technique for Coronavirus data sets | No                                | Centralized            | 2021   |
| (Peng et al., 2020)    | Data Integrity, Security and Privacy | Blockchain         | No                                  | Consensus approach, non-tampering features | Yes                               | Distributed            | 2020   |
| (Hathialya et al., 2019)| Data Accessibility, Data Authentication | Biometric Technology | No                                  | Biometric-based approach       | No                                | Centralized            | 2019   |
| (Das et al., 2021)     | Vaccine Distribution, Tracking | Blockchain         | No                                  | Cloud-Assisted Secure Vaccine  | No                                | Distributed            | 2021   |
| (Liu et al., 2018)     | Data Secure Sharing, Reliability | Blockchain         | No                                  | Deep reinforcement learning    | No                                | Distributed            | 2018   |
| (Zhang et al., 2018)   | Privacy Preservation, Access Control | Blockchain, Deep Learning | No                                  | The smart contract is used for IoT data access | No                                | Distributed            | 2018   |
| (Zhu & Zhang, 2018)    | Transmission efficiency, Adaptability | Cyber-Physical Production | Yes                                | Computer Numerical Control Tools | No                                | Centralized            | 2018   |
| (Liang et al., 2019)   | Availability                  | Blockchain         | No                                  | Mining and Generation blocks   | No                                | Distributed            | 2018   |
| (Buccafurri et al., 2020) | Security and Privacy | Blockchain         | No                                  | Ethereum-based Smart Contract  | No                                | Distributed            | 2020   |
| (Chen et al., 2014)    | Size and Complexity           | Linear Programming  | No                                  | Vaccine Distribution-based on Linear Programming | Yes                               | Centralized            | 2014   |
| Proposed Work          | Data Accessibility, Availability, Security, and Privacy | Blockchain, Deep Learning | Yes                                | Ethereum Smart Contract-based Data Access | Yes                               | Distributed            | 2021   |
19 vaccine manufacturing, Max Pooling LSTM-based Deep learning is used at the intelligent cloud layer in the proposed architecture and offers the scalable production of COVID-19 vaccines with the help of hidden layers analysis functionality.

- **Security and Privacy:** One of the fundamental vital considerations is security and privacy. Therefore, it is the primary requirement for smart city applications, including smart factories, smart parking, intelligent automotive industry, and many more. Blockchain technology (Smart Contract) is utilized at the conversion layer to secure the environment, offer distributed communication of vaccine manufacturing-related IoT and sensor data, and address integrity and privacy issues.

3. A P2P smart contract-based intelligent smart city architecture for vaccine manufacturing

Some challenges include access control, big data, scalability, communication bandwidth, integrity, security, and privacy based on the existing research. Thus, this section discussed the proposed intelligent smart city architecture for vaccine manufacturing with a Smart Contract-based access control model, a Deep Learning-based Intelligent Cloud Model and resolved the above challenges in the smart city and vaccine manufacturing-based worldwide requirements COVID-19 Pandemic. Abbreviation description is shown in Table 2.

### 3.1. Architecture model overview

The first layer of the proposed intelligent smart city architecture is the connection layer. It has various IoT and wearable sensor devices such as a temperature meter, flow meter, electricity meter, and smart containers, {S_1, S_2, …} connecting to the smart vaccination plants {SVP_1, SVP_2, SVP_3, SVP_4} for vaccine manufacturing in a smart city environment. Every plant has a specific function such as purification, inactivation, formulation, filling, freeze-drying, and transportation. These plants automatically collect the raw IoT data for vaccine manufacturing, including temperature, electricity, pressure, vibration, light, rotational speed, torque, force, and others from various IoT devices and sensors. The blockchain concept (Smart Contract) is adopted at the conversion layer wherein contract registration (CR), contract manager (CM), and contract access control (CAC) are acquired for secure communication in a distributed network. Each CAC provides the access control procedure for plant-device combination, which implements static and dynamic validation protocols by checking the plants’ behavior. CAC also has the authority to add, delete, and update access control rules and policies. CM provides a hacking behavior method for facilitating dynamic validation. CM receives hacking reports from CAC and punishes the perpetrator after checking the hacking release report. CR manages the access control and hacking behavior methods and registers all pieces of information such as name, address, smart contract, id, and others. The peer-to-peer network has a smart contract connected to smart vaccine factory plants with IoT and wearable sensor devices. Raw IoT sensing data are transferred to the conversion layer and stored in the Blockchain distributed network. Smart contract-based distributed blockchain accessed address control, security, and privacy challenges at the conversion layer for vaccine manufacturing in a smart industrial environment. Fig. 1 shows an Overview of Proposed Intelligent Smart City Architecture for Vaccine Manufacturing.

For production scalability and centralization, Deep learning is adopted at the intelligent cloud layer with the help of hidden layers, providing various application services such as automatic decision making, configuration, management, distribution, and scalable production in smart vaccine manufacturing for COVID-19 Pandemic.

### 3.2. Smart contract-based security and access control model for vaccine manufacturing

The smart contract-based security and access control model are categorized into two sub-modules: 1) Smart contract-based Ethereum platform; and 2) Smart contract-based access control (Singh et al., 2019; Zhang et al., 2018). The working methodological flow of Smart Contract-based Access Control for Vaccine Manufacturing is shown in Fig. 2, which has four parts. The Flow chart of the proposed architecture as smart contract-based access control at the conversion layer is illustrated in the first part, and the methodology of the access control is described in the second part. Finally, in the third and fourth parts, we depicted the list of basic rules and penalty rules for hacking resources for vaccine manufacturing in the smart city environment. These rules are dependent on the smart contract (Programming Agreements as Pre-defined Conditions for Vaccine Manufacturing), which is stored on the Ethereum blockchain, followed by the Contract Manager and Contract Access Control.

**Smart Contract-based Ethereum Platform:** Ethereum is used as a public blockchain for proposed architecture in vaccine manufacturing. Based on distributed computing methodology, it offers smart contracts’ functionality and has the following components:

a) **Encrypted Address:** It is the mathematically secure address that allows assets on the existing Blockchain. This address is used in smart contract-based accounts.

b) **Consensus Algorithm:** It is a computational cryptographical puzzle to verify the transactions solved by all the miner nodes in the Blockchain networks. This mathematical puzzle is based on the consensus algorithm and rewards the miner node who has solved it. Then, validate by other miner nodes. After the validation process, one block is added to the Blockchain.

c) **Data Transactions:** It is a message with various information data such as the present and previous nodes’ hash value, transaction data, and timestamp. This message is a binary form and is used in the network (Ethereum transaction).

d) **Smart contract:** It is a self-executing contract with the terms of protocols between sender and receiver and directly written into the lines of codes. This code is stored in the distributed blockchain network. Mining is a process of validating the transactions by miner nodes.

### Table 2 Abbreviation Descriptions

| Notations | Descriptions | Notations | Descriptions |
|-----------|--------------|-----------|--------------|
| \( T_m \) | Temperature Meter | \( a_1, a_2, a_3, \ldots \) | Smart Vaccine Plant Attributes |
| \( F_m \) | Flow Meter | \( U \) | Possible Data Value \( a_1 \) |
| \( E_m \) | Electricity Meter | \( N_i \) | Total No. of Possible Data Value \( a_1 \) |
| \( S_r \) | Smart Contract | \( X_1, X_2, X_3, \ldots \) | Access Rules |
| \( SVP_1, SVP_2, SVP_3, SVP_4 \) | Smart Vaccine Plants | \( M \) | Attributes List |
| \( SP_1, SP_2, SP_3, SP_4 \) | Smart Planning | \( U_{1}, U_{2} \) | Start and end time |
| \( SE_1, SE_2, SE_3, SE_4 \) | Smart Execution | \( W \) | One Time Interval |
| \( SC_1, SC_2, SC_3, SC_4 \) | Smart Controlling | \( G \) | Discrete-Time Interval |
| \( C_a \) | Contract Registration | \( P_{0}, P_{a}, P_{s}, \ldots \) | Production Sequences |
| \( C_a \) | Contract Manager | \( Y_1, Y_2, Y_3, \ldots \) | Production Codes |
| \( CAC \) | Contract Access Control | \( P_t \) | Time Variance |
| \( N \) – CAC | New CAC | \( c_1, c_2, c_3, \ldots \) | Intervention Code |
| \( U \) – CAC | Update CAC | \( E_{2LM} \) | LSTM Feature Vector |
| \( D \) – CAC | Delete CAC | \( P_t \) | Time Sequence of Each Production Records |
Smart Contract-based Access Control: It is dependent on the contract registration (CR), contract manager (CM), and contract access control (CAC) in Blockchain functionality at the conversion layer of the proposed architecture. CAC offers access control for vaccine plant and device combinations. With the checking, the vaccine plants’ behavior, implements static and dynamic validation protocol rules, access control offers with smart contract. CAC has overall authority to add, delete, and update access control rules and policies. Thus, CAC is categorized into
three methods, including New (N-CAC), Update (U-CAC), and Delete (D-CAC) for addition, update, and deletion policy rules. CAC is managed by a smart vaccine plant (Database Server) for vaccine manufacturing in the Smart City environment.

Let \( N \) is the total no. of smart vaccination plants attributes, indexes as \([a_1, a_2, \ldots, a_n]\). \( U_i = \{u_{i1}, u_{i2}, \ldots, u_{il}\} \) denotes the possible data values of \( a_i \). \( N_i \) is the total no. of possible data values of \( a_i \) (Pop et al., 2019).

Attributes list:

\[
M = \{a_1, a_2, \ldots, a_n\}, \text{ where } a_i \in U_i
\]

(1)

Access rules : \( X = \{X_1, X_2, \ldots, X_n\} \), where \( X_i \in U_i \)

(2)

Attribute list \( M \) satisfies access rules \( X \) if and only if \( a_i \in X_i \), where \( i = \{1, 2, \ldots, n\} \)

(3)

Let raw data such as temperature, electricity, pressure, vibration, light, rotational speed, torque, force, and others of IoT and sensor devices be offered on-time interval \( W \). \( L_i = \{L_{i1}, L_{i2}\} \) is the start and end times.

Thus,

\[
W = \bigcup_{i=1}^{N} L_{i} \text{ and } \bigcap_{i=1}^{N} L_{i} = \emptyset
\]

(4)

In each time interval \( L_i \), \( G \) is the ordered discrete time interval, where sensors and IoT devices are sampling new raw data.

\[
L_i = \{l_i | l_i < l_{i+1}, V_k = 0, 1, 2, \ldots, G - 1\}
\]

(5)

All vaccine-related data values sent by advanced wearable sensors are monitored at the time interval \( L_k \) as \( |L_k| \).

Algorithm 1: Smart Contract-based Access Control for Vaccine Manufacturing

Input: Data resources from vaccine plants such as Purification, Packaging, Freeze-Drying at connection layer with Smart City Environment.

\(N\) = Total no. of smart vaccination plants attributes, indexes as \([a_1, a_2, \ldots, a_n]\), \( U_i = \{u_{i1}, u_{i2}, \ldots, u_{il}\} \) denotes the possible data values of \( a_i \) \( M = \{a_1, a_2, \ldots, a_n\} \) is attributed list which is used for vaccine manufacturing.

Output: Secure vaccine data access at the conversion layer and transfer it to Intelligent Cloud for storage and analysis.

Process:
1: Begin:
2: for each Fog Node \( F_i \) in the \( F \)
3: /* Registration of N-CAC Method for Vaccination Manufacturing Data */
4: \( \text{Create} \) Contract Access Control (CAC)
5: \( \text{Transfer} \) a transaction to add the CAC on the Blockchain N/Ws
6: \( \text{Call registration method}() \) of CR to register the required details
7: \( \text{for} \) registration of Hacking Management Method for Vaccination Data, Repeat Steps 3 to 5.
8: /* U-CAC Method Updating existing CAC for Vaccination Manufacturing Data */
9: \( \text{then Create} \) a new CAC \( \rightarrow \) Replace Old CAC
10: Use point 3 and transfer a transaction to run update_method() of CR to update the CAC field
11: Information (Name, ID, Password)
12: /* D-CAC Method Deleting existing CAC for Vaccination Manufacturing Data */
13: \( \text{Transfer} \) a transaction to run delete_method() of CR to remove the stored data in the existing database
14: \( \text{Transfer} \) a transaction to run the delete CAC in the Sm_Contract.
15: End

Smart Contract-based Access Control for Vaccine Manufacturing in smart city environment is discussed pointwise in Algorithm 1. This algorithm has three parts: registration of new contract access control, update policy of contract access control and delete record policy of contract access control for vaccine manufacturing data in the smart city environment. All working process is mentioned in Algorithm 1 step by step. Database server-based Contract access control as Vaccine Manufacturing Plants in Smart City Environment is discussed in Algorithm 2 point by point. Based on the proposed architecture, various vaccine manufacturing plants are available, with distinct functions such as purification, packaging, freeze-drying. Furthermore, these plants are connected to the IoT and wearable sensor devices, called the proposed architecture’s connection layer. Smart manufacturing is the main application of the proposed work as vaccine manufacturing data transfers from the connection layer to the conversion layer and then to the intelligent cloud layer. Furthermore, access control, security, and privacy are provided at the conversion layer with smart contract (Blockchain). After that, scalable production of vaccines with manufacturing plants provided by Deep LSTM. It used various hidden layers and analyzed the data, and predicted more output compared to traditional works.

Algorithm 2: Database Server-based CAC as Vaccine Manufacturing Plants in Smart City Environment

Input: Data resources from vaccine plants such as Purification, Packaging, Freeze-Drying at connection layer with Smart City Environment.

\(N\) = Total no. of smart vaccination plants attributes, indexes as \([a_1, a_2, \ldots, a_n]\), \( U_i = \{u_{i1}, u_{i2}, \ldots, u_{il}\} \) denotes the possible data values of \( a_i \) \( M = \{a_1, a_2, \ldots, a_n\} \) is attributed list which is used for vaccine manufacturing.

Output: Secure vaccine data access at the conversion layer and transfer it to Intelligent Cloud for storage and analysis.

Process:
1: Begin:
2: if (intelligent data center calls the get_contract() function of CR)
3: then CR access the CAC
4: CR returns the address and CAC2 to the database server
5: Transfers the transaction by access_contract() function of CAC.
6: (Until a new block is mined and added to the Blockchain Network)
7: if (Generated + Hacking Behavior)
8: then transfer report to the CM by manage_hacking_behavior() function
9: CM returns punishment as a penalty to the CAC.
10: Return access results = Database Server and Base Station at Edge Nodes \( \{B_1, B_2, B_3\} \).
15: End

Addition, update, and deletion policy rules for CAC: Contract Access Control uses rules and regulations which is based on smart contract programs. These programs utilize various functions such as Add_policy(), Delete_policy(), and Update_policy(). Addition, Deletion, and Update policy rules offered by the functions mentioned above in the smart contract program with the vaccine plant, respectively, CAC manages all. When every vaccine plant and IoT device agrees above rules and regulations for the new resources and transfers the data. Transfer a transaction to call functions as Add_policy(), Delete_policy(), and Update_policy() to CAC for access control in the vaccine manufacturing plant in the Industry 5.0 Environment. All miners (systems) follow the smart contracts’ property, such as computing the consensus algorithm or mathematical puzzle through the mining process so that no miners can hack with access control.

3.3. Deep learning-based intelligent cloud for vaccine manufacturing in smart city

We are improving the product in the smart vaccine factory for intelligent manufacturing with the use of deep learning. LSTM (Long Short-term Memory) is utilized for the Deep Learning-based Intelligent Cloud Layer for the scalable production of Vaccine Manufacturing in the smart factory with the smart city environment as shown in Fig. 3. LSTM is a particular variant or a subset of RNNs; the functionality of LSTM is approximately similar to the RNNs. LSTM networks are mainly used to address the “Short term memory” problem of RNNs. So, we can say that LSTM mitigates the learning of long-term dependencies in sequence prediction problems. However, it requires various issues such as machine translation, speech recognition, and more in smart city applications, such as vaccine manufacturing, smart factory. LSTM is a
collection of multiple layers connected as chain form, used the gates that can eliminate or append information to the cell state constantly. According to Fig. 3, Pooling LSTM $H_t$ is used by Old and New LSTM, which is attached to the MaxPooling Matrix. Old LSTM and previous production cell state values are stored in the memory element. The production code cell state $Y_t$ is based on the Max Pooling Matrix. Old LSTM state value. Then $Y_t$ and New LSTM is employed for polling the LSTM function. So, new LSTM is dependent on Old LSTM, which is stored in the memory.

Smart vaccination plants $\{\text{SVP}_1, \text{SVP}_2, \text{SVP}_3, \text{SVP}_4\}$ record input data on the Blockchain network at the conversion layer. These plants consist of smart planning $\{\text{SP}_1, \text{SP}_2, \text{SP}_3, \text{SP}_4\}$, smart execution $\{\text{SE}_1, \text{SE}_2, \text{SE}_3, \text{SE}_4\}$ and $\{\text{SC}_1, \text{SC}_2, \text{SC}_3, \text{SC}_4\}$ smart control. Production sequences are $\{P_{t1}, P_{t2}, P_{t3}, \ldots P_{tn}\}$ for vaccine manufacturing in the smart vaccine factory. Various Production codes $\{Y_1, Y_2, \ldots Y_n\}$ are connected to every sequence.

It is a vector form and represented by $Y_t \in R^m$, with $m$ as vector length. Time variance is denoted by $\partial \tau$, with $\{C_1, C_2, \ldots C_k\}$ used as the intervention codes. The LSTM feature vector set of each production is calculated by:

$$T_{LSTM}^{t} = \{m_{\tau}, \partial \tau, n_t\}$$

$P_t$ is the time sequence of each production record. With the use of intervention codes and production codes, create the MaxPool matrix and generate binary codes with normalized form. It is represented by $\{D_1, D_2, \ldots D_n\}$.

With MaxPool function define max pooling (Elisa, Yang, Chao, & Cao, 2018).

$$\begin{align*}
    x_t' &= \max \{\rho^{t1}, \rho^{t2}, \ldots \rho^{tm} \} \\
    P_t' &= \max \{\theta_t^{c1}, \theta_t^{c2}, \ldots \theta_t^{cm} \}
\end{align*}$$

With Normalized Pool function, define sum normalized pooling (Pham, Tran, Phung, & Venkatesh, 2017)

$$\begin{align*}
    \theta_t' &= \frac{\rho^{t1} + \rho^{t2} + \ldots + \rho^{tm}}{\sqrt{\rho^{t1} + \rho^{t2} + \ldots + \rho^{tm}}} \\
    \tau_t' &= \frac{\theta_t^{c1} + \theta_t^{c2} + \ldots + \theta_t^{cm}}{\sqrt{\theta_t^{c1} + \theta_t^{c2} + \ldots + \theta_t^{cm}}}
\end{align*}$$

Where $\rho^{t1}, \rho^{t2}, \ldots \rho^{tm}$ are embedded vectors gained from matrix and intervention vectors are $\theta_t^{c1}, \theta_t^{c2}, \ldots \theta_t^{cm}$.

Now, the max pool chain (Pop et al., 2019) is evaluated by:

$$H_{1,2, \ldots n} = \frac{1}{s_i+1} \sum_{s_i=1}^{n} H_t$$

It is denoted by the H pool. Then, the LSTM network output is used as input in the neural network with a hidden layer. Finally, we get more production output of vaccines in a smart healthcare environment with various plants. It provides various applications such as self-production, self-distribution, and self-decision support in the smart factory. With the proposed architecture, we can provide secure communication of IoT smart city vaccine data related to COVID-19 with efficient access control and increase production in the smart vaccine manufacturing factory. As the application of smart city, it is protected from Cyber-attacks and Distributed denial of services (DDoS).

### 3.4. Case study with estimated algorithm for vaccine manufacturing

Widely used in access control with secure communication dependent on the role of IoT data in various applications such as smart healthcare, smart hospital, and others, access control is one of the most popular processes for retrieving IoT data such as RBAC-SC (Role-based Access Control-Smart Contract) (Cruz, Kaji, & Yanai, 2018), which has been proposed. As a smart contract-based method presented for the trans-
organizational utilization of roles with users in IoT applications, it declares the user role and checks the information, user challenges, and response by users. For increasing the Smart factory vaccine production, LSTM DAAS (Long Short-Term Memory Deep learning as a Service) (Singh, Jeong, & Park, 2020) is an elementary method. It has been utilized in disease prediction in healthcare. Thus, we use the RBAC-SC and LSTM DAAS methods as an estimation algorithm in our proposed intelligent smart city architecture. We present a case study for validating the effectiveness of the proposed architecture. This case study is related to the vaccine factory for smart production. It has three plants for Water, Electricity, and Gas. All plants access the data from IoT and advanced wearable sensor devices such as temperature, light, proximity, humidity, passive infrared, actuators, and quality meter. Every plant has a smart pipe for valuable data value. This case study’s main objective is to find the amount of generated data with better communication and computational cost and energy consumption value from every plant. We can connect LSTM DAAS (Singh et al., 2020, 2021) in the application layer for increasing production in a Smart vaccine company. With the help of deep learning, the company can deploy the system to perform visualization and generate a computerized report for the entire production of a vaccine production facility in the Smart City Environment.

In Fig. 4, we illustrated Vaccine Manufacturing Company X Block diagram-enabled Use Case functionality for secure and scalable production vaccine manufacturing in the smart city environment.

Blockchain as Smart Contract and Deep Learning LSTM functionality as Block Diagram is described for the new vaccine manufacturing company X. It is based on the proposed architecture with CAC, CR, and CM (Algorithm 1 and 2). It offers secured and efficient access control and scalable production with the help of Hidden layers of Deep Learning in Vaccine manufacturing company X in the smart city.

4. Performance evaluation and results

The data was acquired and delivered to the blockchain and deep learning using the OPC-UA industrial standard, wherein we evaluated the size of valuable data from vaccine plants such as purification, inactivation, formulation, filling, freeze-drying, and transportation functions in smart vaccine manufacturing for the Smart City as healthcare. We used four wearable sensors on each plant—such as an electric transducer, flow meter, power meter, and accelerometer—to measure the current, flow rate (water, electric, gas), pipe power, and noise, respectively as in Table 3

Ethereum-enabled blockchain and smart contracts are leveraged for access control, security, and privacy at the conversion layer. It offers distributed paradigms. Therefore, 4 GB-40 GB internal memory is a must with the minimum requirement. Node.js v8.9.1 (6.8.0 version) installed for reviewing the performance of several node tests and communication rounds for successful data authentication with miner nodes in the blockchain networks. Feature selection criteria depend on ICD-9 codes for a particular vaccine production of the smart industrial environment in smart city as vaccine manufacturing. Corda v 3.0 and CordaDApp node are utilized to simulate blockchain setup to perform node testing. Communication and computational cost are evaluated for COVID-19 vaccine manufacturing in terms of gas consumption as shown in Fig. 5. This is because 1Ether→10^9 gwei (Javed et al., 2020).

\[ \text{GasUnit} = 4\text{gwei} \] (12)

Access data output values of various vaccine manufacturing plants from different wearable sensors with a smart pipe according to distinct time variances as shown in Fig. 6 (a), (b), and (c). These data outputs provide water flow, electricity flow, and gas flow from smart vaccine factory plants for the vaccine industry. The simulation parameter of the

| Wearable Sensor Devices | Work Description | Value | Produced Data (MB/Hr) |
|------------------------|------------------|-------|-----------------------|
| Electric Transducer    | Current Flow     | 30 (kA)| 43.20                 |
| Flow Meter             | Water Flow       | 50 (Gmp)| 43.20                 |
| Flow Meter             | Electricity Flow | 60 (Gmp)| 43.20                 |
| Flow Meter             | Gas Flow         | 40 (Gmp)| 43.20                 |
| Power meter            | Pipe Power       | 3–25 (Hp)| 43.20                 |
| Accelerometer          | Noise or Vibration | 3–10 (KHZ)| 43.20                 |

Table 3 Parameter for the Proposed Intelligent Smart City Architecture.
The proposed intelligent smart city architecture is shown in Table 3. Access Data Output Values of Various Vaccine Manufacturing Plants is shown in Table 4. Estimating data depends on the functions by reading each sensor in specific durations and communicating the 100-byte packets. According to this, redundant data has been evacuated where each data output is attached with unique observation because it utilized RBAC-SC (Cruz et al., 2018). This structured data output offers systematic access control processing for transformation in the smart contract blockchain.

Fig. 6 (d) shows the vaccine production prediction according to the vaccine manufacturing factory case study with deep learning LSTM. It offers the graph for actual output, predicts output, and shows the scalability of production in the vaccine manufacturing factory using the deep learning LSTM concept according to the proposed architecture, based on LSTM DAAS (Singh, Pan, & Park, 2021; Sun et al., 2019). The setup used Python and Keras DL API to evaluate the experimental analysis of the proposed smart city architecture. TensorFlow is utilized as a backend for evaluation of proposed smart city architecture for vaccine manufacturing. The deep learning-based intelligent cloud layer offers more output production in smart vaccine manufacturing factories and various application services such as self-management, self-decision-making, and self-healing.
support, self-configuration, and self-distribution.

5. Conclusion

This study proposed a CoVAC: A P2P Smart Contract-based Intelligent Smart City Architecture for Vaccine Manufacturing to provide security and privacy with sufficient access control. Various contracts such as Contract Registration (CR), Contract Manager (CM), and Contract Access Control (CRC) are used for secure data communication with distributed access control that can be trusted data values for vaccine manufacturing in Industry 5.0 infrastructure. We also introduced a deep learning-based intelligent cloud layer for increasing production in vaccine manufacturing factories for industrial paradigm. Furthermore, we presented a case study to validate the proposed architecture’s effectiveness with OPS-UA industrial standard parameters and offered various application services such as self-management, self-decision support, self-configuration, self-distribution, and scalable production for the COVID-19 vaccine in smart vaccine manufacturing. Finally, we compared the proposed work with the existing research for Vaccine Manufacturing in the Smart City Environment. In the future, we will expand the proposed architecture functionalities for scalable vaccine manufacturing in Smart City Environment with advanced deep learning algorithm (FNN, RNN) and Hybrid federated learning algorithm (FedSGD, FedAVG) at the intelligent cloud layer. It will provide a privacy-preservation and advanced analysis at cloud storage environment in Industry 5.0 as a smart city.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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