GlobeChain: An Interoperable Blockchain for Global Sharing of Healthcare Data - A COVID-19 Perspective

Sujit Biswas
University of Dhaka

Kashif Sharif
Beijing Institute of Technology

Fan Li
Beijing Institute of Technology

Anupam K. Bairagi
Khulna University

Zohaib Latif
Hanyang University

Saraju P. Mohanty
University of North Texas

***Abstract*—Contagious diseases are prevalent even in the current era of advanced technology. A uniformed initiative is required to build a reliable interactive information exchange service targeting vaccination data management and other medical services. The conventional data exchange mechanism is centralized, creating many vulnerable issues such as a single point failure, data leakage, access control, etc. This article introduces a Blockchain-based medical data-sharing framework (called GlobeChain) to overcome the technical challenges to handle the outbreak records. The challenges that might arise due to the proposed Blockchain-based framework are also presented as a future direction that grabs the proposal's effectiveness.**

I. Introduction

THE whole world is now battling against the Corona Virus Disease 2019 (COVID-19). The COVID-19 pandemic is spreading globally with different mutations [1]. The information about the virus shedding patterns, compartmentalization, the quantity of viral shedding, mutated form, etc., are required for real-time sharing globally for optimal specimen collection and advanced research. Information and Communication Technology (ICT) can leverage the outbreak controlling steps one step ahead ubiquitously.

Social distancing is suggested as the primary prevention of infectious diseases [2]. Due to overcoming the economic crisis, taking care of the patient, and preventive for spreading the virus, many ICT-based and Internet-of-Things-based tools are being utilized [3]. Different countries have been using various technology-based apps for contact tracing, recognition, information processing for detecting, warning, and vaccine receiver's recognition.

II. Blockchain Towards Robust Global Health Information System

A. Global Health Information System (GHIS)

Different countries handle continuous medical records as per state-specific unique laws, regulations, and services. Critical health information is not freely shared globally due to concerns like competitive economy, privacy, and security. Stopping the spread of COVID-19 presents a global problem that demands a global response. While these national services can potentially be merged with the global initiatives, information security and privacy are a significant concern. Any standardized and universally agreed protocol is required for GHIS with the following fundamental properties. For example: 1) Distributed collaborated global data sharing architecture. 2) Unstructured database for any smart device. 3) Handy dataset to facilitate early detection and research. 4) Data sources should be trusted and transparent.

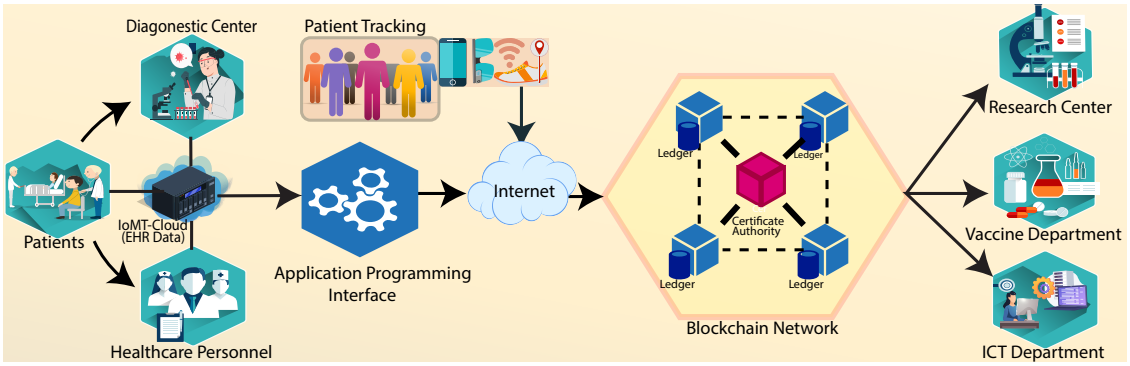

Fig. 1. National Peer Network.

B. How the Blockchain Can Contribute?

As Distributed Ledger Technology (DLT), Blockchain (BC) can bridge state-specific health information management systems and establish an efficient and transparent health information management system. It has a tamper-proof public/private ledger to ensure higher degrees of accuracy and trust [4]. In Blockchain Network (BCN), Peer-to-Peer (P2P) network services create single point failure-free uninterruptible services. Smart contracts can alleviate multiple organizations' exchange information based upon predefined eligible service rules. Internet-of-Medica-Things (IoMT) devices collected data can be integrated with peers directly without human interaction that accelerates the service spirit, safe data storage, and reduced processing cost and time. Independent organizations can be connected with BC peers that serve the national BC network (see Figure 1). A smart contract is used to define the terms and conditions between existing servers and peers where Certificate Authority (CA) registers the server as a trusted member to be a national BC network member.

III. Bridging Infectious Diseases and ICT

Digitally preserving every record of the infectious records is important for research advancement. This recorded data-driven decision-making can work as an early warning system. One way to prevent this is to slow down the transmission and monitoring the vaccine seekers by using IoMT for its touch-less service capabilities [3]. Key features of some ICT contributions for COVID-19 have been summarized in Table I.

A. ICT for COVID-19

Four parallel initiatives can relieve infectious diseases, such as quick identification, treatment, prevention, and social consciousness, where ICT plays vital roles. GPS and Bluetooth-based proximity tracking tools, contract tracing tools can identify and separate the affected one from mass people. Remote-controlled robots have been utilized to support staff, such as taking mouth swabs, ultrasound scans, and listening to organs with a stethoscope. Patients' vaccination records are stored in a clinical system with other medical records for Data Processing Service (DPS), such as data-driven decision-making. Many smartphone applications/AI-based tools can be used to create social consciousness early warning for prevention.

B. Artificial Intelligence for Contiguous Diseases

Artificial Intelligence (AI) uses heuristics, pattern matching, rules, and cognitive computing, without direct human input, which is important for controlling COVID-19. It has tremendous potentiality through Machine Learning (ML), Natural Language Processing (NLP), and computer vision applications to teach computers to use big data-based models for pattern recognition, explanation, and prediction [5]. The services can directly help to recognize (diagnose), predict, and explain (treat). Table I presents some AI-based tools for COVID-19 purposes to both adapt and defend itself against the coronavirus.

C. Vaccine Management

Efficient vaccine management (i.e., record keeping of vaccinated people) and distribution are es-

TABLE I
ICT CONTRIBUTIONS FOR COVID-19

Tools	Services	Technology	Ultimate Goal
BlueDot	Tracking, Recognize	Machine Learning	Disease Surveillance
CHATBOTS	Diagnosis	Natural Language Processing	Virtual Healthcare Assistance
LinkingMed	Diagnosis	Deep Learning Processor	Diagnosis
Thermal Camera	Diagnosis, tracking	Artificial Intelligence, Sensor	Facial Recognition & Fever Detection
Curative Research	drug Discovery	Deep Learning Processor	Development of antibodies & vaccines

sential for further monitoring the situation and decision-making, vaccination information sharing for cross-border travel [6]. Blockchain can facilitate a trusted distribution track record of billions of people across the globe. Collaborative interoperable Blockchain supported system can effectively share the world travelers' vaccination information.

IV. GLOBAL BLOCKCHAIN NETWORK

The proposed Global Blockchain Network (GBN) (called GlobeChain) offers a new way for cross-border medical data exchange services that carry near real-time COVID-19 carriers' various data. The GBN is a bridging platform of a state-specific national-level BCN where the security-privacy-assured medical information is available.

Why Blockchain: A medical record carries health information with personal identities such as mobile numbers, addresses, social security numbers, account information, and health insurance. When medical data is shared with service providers (i.e., diagnostic centers, researchers, etc.), patients and administrators aren't sure precisely what personal information is being shared [7]. In a highly secured organization, the authorization process is controlled as stand-alone services from a centralized server. Autonomously sharing and collecting medical records is not possible. While data is global content, then the security for global storing somewhere is consensually accepted to be correct. Likewise, the data-center should be distributed with multi-access control [8]. As described technical properties of Blockchain in Section II-B, it is capable of mitigating the challenges mentioned above.

Blockchain for Security: As immutable data structures, Blockchain records transactions as a block in a distributed peer-to-peer network that protects a single point failure issue. The cryptography hash of all transactions is used as a level that covers data modifications. In contrast, cross-verification of terms & conditions for every transaction is being justified through a consensus process [9]. It has a certificate authority for users' credential management and ensures authorized users access the private BC platform.

V. PROPOSED BLOCKCHAIN-BASED GLOBAL INFORMATION SHARING ARCHITECTURE

The proposed global medical data sharing architecture has been depicted in Figure 2. The architecture is applicable for every national level medical data center which are either Blockchain-based or Blockchain compatible.

Infectious disease-related symptoms (e.g., body temperature) are collected from various levels in IoMT. Healthcare data are being processed through applications while smart contracts and certificates are verified at the application level. Applications forward data to the national-level peers, where the peer executes the transactions as a leader with other Blockchain architecture components. Every national level network has at least one peer responsible for global collaboration, also recognized in this paper as a Gateway Peer (GP). The specialized GP from every national peer network forms a Global Peer Network (GPN) responsible for exchanging and approving global-level transactions based upon predefined policy.

A. Physical Level

Infectious data is collected by the collaborative task of the physical and application level. Any contiguous medical data (e.g., COVID-19) are sourced from diverse places using various IoMT data screening and monitoring. The physical level consists of a certificate authority (CA) and application where logical and security instructions are executed in the application.

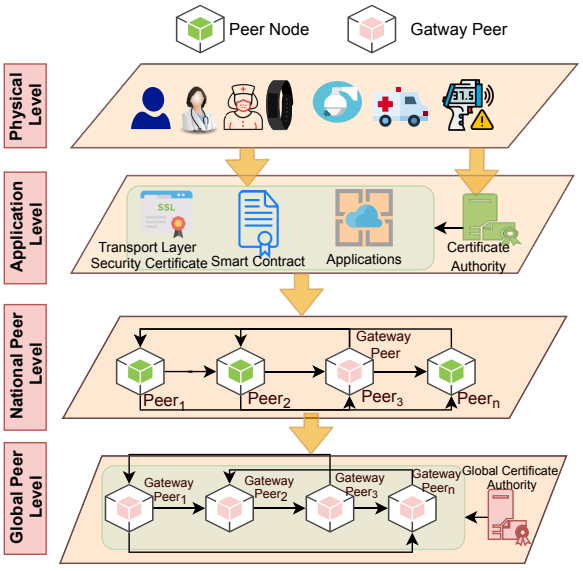

Fig. 2. The Proposed Blockchain Architecture for Global Data Sharing - The GlobeChain.

1) Certificate Authority (CA): Certificate Authority (CA) mainly responsible for registration and unique credential generation for every participant in the BC network. A national network may have multiple CAs which must be capable of collaborating with each others. For example, Alice wants to travel from country A to country B as a COVID-19 +ve patient. As a local user of country A, CA^A shares credentials to CA^B with the help of national CA/CAs, which are linked with Global Certificate authority (GCA).

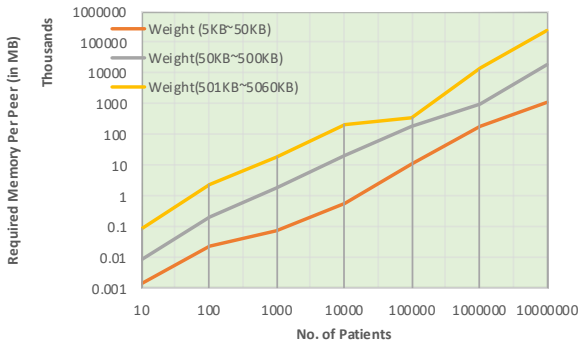

Fig. 3. Transaction Weight in Global Blockchain Network.

2) Applications: The application is a registered entity that works as a front-end platform for users and devices. Any registered application executes the smart contract and other certificates such as Transport Layer Security (TLS) to ensure the user's authentication and validation. It prepares the unstructured transactions with the help of SDK executable in peers. Finally, peer confirmed transactions are acknowledged through the application.

B. National Peer Network (NPN)

National Peer Network (NPN) is structured with multiple peers (see Figure 1). Different health organizations forward transactions to the nearest peer through the application or Blockchain compatible server. Peers validate transactions based upon smart contracts and return to the leader. Leader forms a block including simultaneously generated transactions with proper justification of 51% peers' valid response. A newly generated block is linked with a previously added block sequence in national peers.

C. Global Peer Network (GPN)

Every NPN has a particular peer node, Gateway Peer (GP), responsible for cross-border data exchange. It bridges multinational Blockchain-based health data centers through GP and forms Global Peer Network (GPN). GPs exchange information with the Global Certificate Authority (GCA). GPs perform as an independent Blockchain network where GCA recognizes the GPN members with the help of respective CA. GPs hold a separate smart contract that does not belong to NPN. Transactions in GPN are being executed as a regular process of BC while consensus forms in GP's participation. The records are stored in a regular block of respective GPs. It allows GlobeChain's individual chain for NPN and GPN (multiple chain).

Global Certification Authority (GCA): Unlike CA, GCA does not hold all credentials in CAs, and it carries certifications temporarily if any global transactions are required. The information are exchanged if, and only if one crosses the immigration of country. The immigration server accesses the national health BC network through an API.

VI. Implementation Challenges

Migration of typical centralized national health system to Blockchain compatible system is very challenging due to diverse protocols. For smooth transaction execution and synchronization among

multiple BC protocols and meaningful understanding between different consensus algorithms is a crucial [10]. Another challenge is continuous data recording and maintaining the massive burden of data. It is estimated that over 2314 exabytes of data will be generated globally from the healthcare industry by the end of 2020 [11]. Figure 3 presents a prediction of overall transaction weight to handle such a massive volume of transactions under a GBN. It shows three scenarios of whether transaction weight may vary from patient to patient depending on the size of medical reports. If transactions vary 5KB-50KB, 50KB-500KB, and 501KB-5MB, the transaction weights increases for every case. It is challenging to handle this massive memory volume under a global Blockchain network while Blockchain still faces scalability issues.

VII. Conclusion and Future Directions

Health specialists have already taken technology-dependent various initiatives for controlling COVID-19. It's a global uniformed initiative in emergency for the outbreak. For real-time global sharing of related data and for security and privacy data, blockchain is a suitable technology. Our proposed framework shows an effective way to bridge the state-specific BC network and form a unified GlobeChain supported BC network. Further advanced research targeting inter-protocols transactions, pluggable consensus independent mechanism can be the future milestone.

References

[1] A. Kalla, T. Hewa, R. A. Mishra, M. Ylianttila, and M. Liyanage, "The role of blockchain to fight against COVID-19," *IEEE Engineering Management Review*, vol. 48, no. 3, pp. 85–96, 2020.

[2] A. K. Bairagi, M. Masud, D. H. Kim, M. S. Munir, A. A. Nahid, S. F. Abedin, K. M. Alam, S. Biswas, S. S. Alshamrani, Z. Han, and C. S. Hong, "Controlling the outbreak of COVID-19: A noncooperative game perspective," *IEEE Access*, vol. 8, pp. 215 570–215 581, 2020.

[3] A. K. Tripathy, A. G. Mohapatra, S. P. Mohanty, E. Kougianos, A. M. Joshi, and G. Das, "EasyBand: A wearable for safety-aware mobility during pandemic outbreak," *IEEE Consumer Electronics Magazine*, vol. 9, no. 5, pp. 57–61, 2020.

[4] S. Biswas, K. Sharif, F. Li, B. Nour, and Y. Wang, "A scalable blockchain framework for secure transactions in IoT," *IEEE Internet of Things Journal*, vol. 6, no. 3, pp. 4650–4659, 2019.

[5] P. K. Singh, S. Nandi, K. Ghafoor, U. Ghosh, and D. B. Rawat, "Preventing COVID-19 spread using information and communication technology," *IEEE Consumer Electronics Magazine*, pp. 1–1, 2020.

[6] H. R. Hasan, K. Salah, R. Jayaraman, J. Arshad, I. Yaqoob, M. Omar, and S. Ellahham, "Blockchain-based solution for COVID-19 digital medical passports and immunity certificates," *IEEE Access*, vol. 8, pp. 222 093–222 108, 2020.

[7] H. Xu, L. Zhang, O. Onireti, Y. Fang, W. J. Buchanan, and M. A. Imran, "BeepTrace: Blockchain-enabled privacy-preserving contact tracing for covid-19 pandemic and beyond," *IEEE Internet of Things Journal*, vol. 8, no. 5, pp. 3915–3929, 2021.

[8] L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: Blockchain-integrated privacy-assured iomt framework for stress management considering sleeping habits," *IEEE Transactions on Consumer Electronics*, vol. 67, no. 1, pp. 20–29, 2021.

[9] S. Biswas, K. Sharif, F. Li, S. Maharjan, S. P. Mohanty, and Y. Wang, "PoBT: A lightweight consensus algorithm for scalable IoT business blockchain," *IEEE Internet of Things Journal*, vol. 7, no. 3, pp. 2343–2355, 2020.

[10] S. Biswas, K. Sharif, F. Li, and S. Mohanty, "Blockchain for e-health-care systems: Easier said than done," *Computer*, vol. 53, no. 7, pp. 57–67, 2020.

[11] Z. Allam and D. S. Jones, "On the coronavirus (COVID-19) outbreak and the smart city network: Universal data sharing standards coupled with artificial intelligence (AI) to benefit urban health monitoring and management," *Healthcare*, vol. 8, no. 1, 2020.

Authors' Biographies

- **Sujit Biswas** is an Assistant Professor Faridpur Engineering College, University of Dhaka, Bangladesh. Contact him at sujit-edu@fec.ac.bd.
- **Kashif Sharif** is an Associate Professor (Research) with the Beijing Institute of Technology, Beijing, China. Contact him at kashif@bit.edu.cn.
- **Fan Li** is currently a Professor with the School of Computer Science, Beijing Institute of Technology, Beijing, China. Contat her at fli@bit.edu.cn.
- **Anupam K. Bairagi** is an associate professor in Computer Science and Engineering discipline, Khulna University, Bangladesh. Contact him at cse9620@gmail.com.
- **Zohib Latif** is a Postdoc Fellow in Department of Computer Science, Hanyang University, Seoul, South Korea. Contact him at: z.latif@bit.edu.cn.
- **Saraju P. Mohanty** is a Professor in the Department of Computer Science and Engineering at the University of North Texas, USA. Contact him at: smohanty@ieee.org.