Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7765897

CRITICAL ANALYSIS OF INTEGRATION OF BLOCK CHAIN IN SMART HEALTHCARE SYSTEM

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ABSTRACT

The entire healthcare system has experienced a transition from the conventional hospitalization model to a decentralized patient-oriented model; hence the evolving 5G network is supposed to support healthcare systems by significantly addressing various concerns in the healthcare sector such as AI-based surgeries, remote consultancies, etc. Healthcare sector is expected to expand at a rapid pace, the future Smart Healthcare systems may demand networks with more bandwidth, latency, etc. With the introduction of sensor-based intelligent healthcare applications, the demand for high-speed connectivity shall arise for linking many devices and appliances. 5G communication networks are combined with IoT devices to increase coverage of the network and reduce security concerns. As the healthcare systems shall be connected to internet & network-enabled devices in 5G networks, they shall fall under the category of cyber-physical systems and thus, they would be highly vulnerable to cyber-attacks. Various other problems of existing healthcare systems are - a complex network of system intermediaries, an increase in the cost of drug recovery & lack of transaction traceability that can be resolved using blockchain technology. Blockchain fosters decentralized, open, persistent, comprehensive, and safe architectural techniques. The inclusive perspective of Blockchain-based healthcare model shall offer services such as efficient access & storage of personal clinical as well as genetic data management, inventory management & supply chain management system, medical research related records, digital health cards & wallets, transparency, secure and hassle-free transactions, personalized medical treatment & care etc. This paper deals with the incorporation of Blockchain in the 5G healthcare sector and discusses its role in dealing with security and privacy concerns.

Keywords: Smart Healthcare, 5G networks, Blockchain, IoT, Cloud-Based network, Cyber-physical System.

1. INTRODUCTION

Previous few years have observed that healthcare sector is playing important role in economy of many countries. Countries are spending a lot over healthcare specially during the time of COVID-19 [1], this sector and its updating is at utmost priority in maximum countries. Healthcare is adopting IoT technologies as IoT plays a very important role in smart and tele medication, onsite and remote monitoring, changes observed in behaviour of patient etc. The

more and more use of smartphones leads to development of mobile e health system. 5th Generation communication(5G) with Internet of Things (IoT) [2] based approaches are proposed for monitoring patients of long-lasting diseases such as diabetic patient. The wearable IoT devices like smart watches, smart clothes and many more are used for monitoring health of patients (e.g. blood pressure, blood sugar etc) continuously. The easy and impactful usage of wearable IoT devices needs an effective two-way transmission between devices and cloud server [3]. Cloud server is a virtual server which can be easily accessed using internet. It is different from physical server because in physical server we are installing and storing in a room, but cloud is an online system which can store large data, balance loading time, and automate the processes. The IoT devices like sensors, smart watches etc sends the collected data like sleeping hours, heart rate etc to cloud using internet. Thus, the combination of 5G network with IoT devices are best option to implement smart healthcare.

1.1 Smart Healthcare

Smart healthcare stands for providing healthcare enabled services with the help of smart gadgets like wireless blood pressure monitor, smartwatches, wireless smart glucometer etc using networks like extensive area network, body area network etc. There are various applications such as biometric system, sensors etc which have medical science information such as:

- Diagnosis of disease [4]
- Treatment of disease
- Prevention from disease

The gadgets which are usually termed as intelligent gadgets collect information from these applications and many other sources and process the collected information [5]. It means different people like doctors, nurses, patients etc can access this information and get the correct solutions to their problems which will lead to following points at a time in medical field:

- Minimization of medical errors [6]
- Improvement in efficiency
- Reduction of cost

The main objectives of smart healthcare are:

- Optimization of resources [7]
- Enhancing Quality of service (QoS)
- Reducing interference in channels

- Enhancing energy efficiencies

The basic requirements for smart healthcare are categorize under two categories:

(a) Network

- Low latency network [8]
- High bandwidth network
- Ultra-high Reliability of network

(b) Devices connected to network

- High Battery life of connected devices which will in turn enhance life of network.[9]

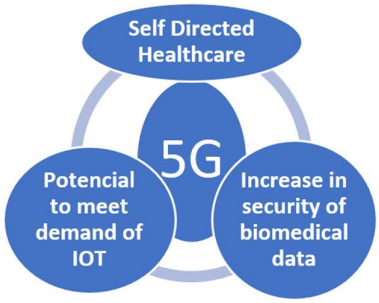

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Figure 1: Various advantages of 5G in smart healthcare

The above figure shows the various advantages of 5G communication which are helpful for smart healthcare.

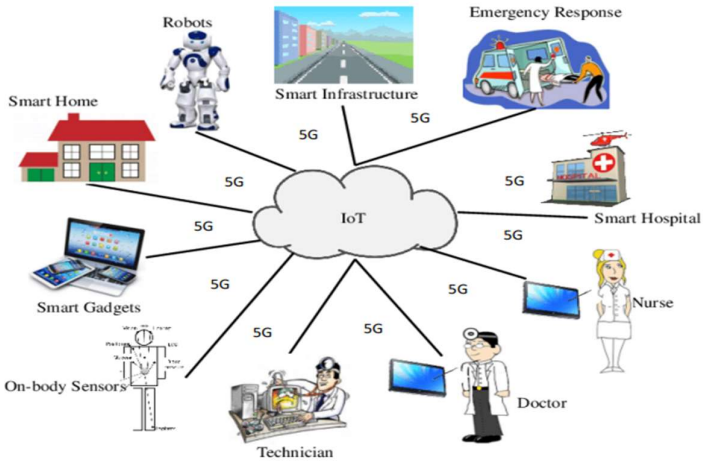

Figure 2: Use of 5G and IoT in smart healthcare

The objectives and requirements of smart healthcare clearly explains need of deployment of 5G network with IoT devices in this sector. Figure 2 shows the role of 5G and IoT devices [2] in smart healthcare. The various fields such as smart home, smart gadgets emergency response etc are maintained and retrieved by IoT devices using fast emerging 5G network.

1.2 5G and IoT in healthcare

IoT stands for Internet of Things. It is a dynamic network (it means it can configure itself based on standard protocol) which is flexible but complex in nature. It has various applications such as:

- Remote monitoring [10]
- Smart sensors
- Medical device integration.

One of the growing fields is synthesis of sensor-based system and sensors with D2D communication [11]. D2D stands for device-to-device communication. In this IoT takes centre position and 5G wireless networks are at terminal. The major challenges are:

- Management the data collected by different devices
- Getting meaningful output from collected data

5G is latest emerging networks. The requirement of smart health care applications is the network with high data rates. So 5G provides it using the concept of small cells. Small cells are nothing but the nodes with two essential aspects [12]:

- It has low power radio access
- It ranges from few millimetres to mile

There are 3 basic types of small cells based on its ranging. The name and description of cells is as follows [13]:

- **Femtocells** - It has range of 0.1 km and can cater 30 users hence it can be used capacity and coverage over small area.
- **Picocells** - Picocells provide wireless coverage over 1 km and can cater 100 users hence they boost the coverage.
- **Microcells** – Microcell has coverage of 30 km over 2000 users.

Small cells base station provides high throughput data transport by using high frequency

Apart from above stated small cells there are macrocell [15] which is installed on high output

power station and has range of 20 miles. The major advantage of using the concept of macrocells is as follows:

- Separate user and control plane: It enable user's equipment to relate to both macrocell and small cell-based station as user plane provides data transportation and control plane looks after connectivity and mobility.

In general, a cellular network has a heterogeneous network comprising of all above mentioned small cell base stations which is called as HetNets [16].

The main advantage of 5G network is fast response time and higher data capacity than 3G and 4G.the comparison shown in Table 1 clearly explains the significance of using 5G in healthcare sectors due its advantages over 3G and 4G. [17]

Table 1: Comparison between 3G ,4G and 5G

Comparison	3G	4G	5G
Introduced in year	2001	2009	2018
Technology	WCDMA	LTE, WiMAX	MIMO, mm Waves
Access System	CDMA	CDMA	OFDMA, BDMA
Internet service	Broadband	Ultra-broadband	Wireless world wide web
Bandwidth	25MHz	100MHz	20 GHz to 300 GHz
Advantage	High security, international roaming	Speed, High Speed handoffs, global mobility	Extremely High Speed, Lower latency
Application	Video Conferencing, etc	High Speed Applications, etc	Medical procedures, Robots etc

Table 1 explains the emergence of technology from WCDMA (Wideband Code Division Multiple access) in 3G [17] which offers data speed of 384 Kbps to LTE (Long Term Evolution) and WiMAX (Worldwide Interoperability for microwave access) in 4^{rth} Generation network which ranges up to 31 miles and finally reaches to MIMO (Multiple- input and multiple-output) [17] and mm Waves (millimetre waves) in 5G network which provides maximum speed and coverage. 3G and 4 G have CDMA (Code division multiple access) [17] access method which was helpful in radio communication, but the quality of audio degrades when signals of many cell sites (none of them are prominent) are present in subscriber's side (this is called as

channel pollution).

5G has [18]:

- OPDM (Orthogonal frequency division multiple access)
- BDMA (Beam division multiple access)

The above-mentioned access methods reduce channel pollution by assigning subsets of subcarrier.

The faster connection speed of 5G [19] is helpful in transforming:

- Relationship between healthcare providers and patients
- Integration of electronic communication and medical care
- Easy monitoring of patients by doctors even if patients are at home (Patients can wear remote medical sensors which can transmit signals to the healthcare providers)
- Dynamic management of treatment of patients.
- Consultation over webcam.

Due to above mentioned reasons we can deduce that introduction of 5G (generally with combination with IoT devices) can give great economic boost up to medical sector. This emergence is very beneficial for maintaining a digital ecosystem [20] which can help in:

- Medical research
- Conditions of diagnosing a disease
- Upgradation of healthcare experiences
- Maintenance of personalized view of patient's health record which is accessible at every time and everyplace.

2. EXISTING 5G ARCHITECTURE FOR HEALTHCARE

The 5G architecture for healthcare comprises of data centre, core network, Master Base Station (MBS) and Session Border Controller (SBC) transmission, Small base stations, and body area network [21]. Figure 2 clearly explains the role of each mentioned component in 5G healthcare architecture. Various enabling technologies are Device to Device communication (D2D communication), Millimetre waves (mm waves: spectrum of band ranging between 20 GHz to 300GHz) communication, Edge computing, Network function visualization (NFV) incorporated with software defined network (SDN) [21].

- The **D2D communication** [14] means communication between two devices without involving Base station.
- **Millimetre waves (mm waves)** communication leads to reduction of unused bandwidth
- **Edge computing** helps in real time computing of data.
- **NFV** helps the system to replace the expensive hardware devices and software base network tool (which generally which run on virtual server). It also ensures scalability and flexibility of network.
- **SDN** makes network more agile, flexible and supports the needed requirements of smart healthcare in 5G network
- **MBS** supports full duplex communication
- **SBC** supports secure voice over IP by working over incompatible signals or media flows from application server or end devices.
- **Body area network are** simply WSN where wireless sensors are placed over or inside the body of patients for biomedical data.
- **Weird Backhaul is** also known as Ethernet backhaul which creates a direct connection from amplifier router to secondary amplifier routers which are also known as Mesh Point.

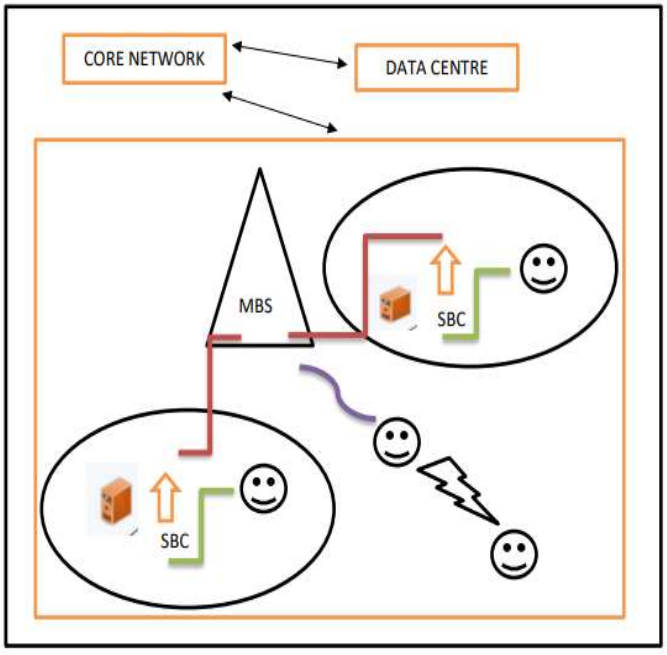

Figure 3: 5G Healthcare Architecture

Table 2: Notation table for symbols used in Figure 3

SYMBOL IN FIGURE 3	SYMBOL STANDS FOR
	EDGE cloud
	Weird Backhaul
	Body area network
	SBC
	Macro Base station transmission
	Mm Wave Backhaul
	SBS transmission
	D2D links

The meaning on all symbols drawn in Figure no 3 are explained in Table no 2. Above drawn diagram explains how the MBS interacts from SBC which in turn gets information from body area network. These body care networks provide biomedical information (collected from sensors of devices used by patient) to SBC to have secure transaction of information to MBS. The core network (using 5G communication) comprises of SDN and NFV [21]and it collects this information and save the required data in data centre. This stored data can be retrieved the set of enabled users who can use it as per their convenience i.e. anytime and anywhere. Retrieval and uploading of data are facilitated with the help of weird backhaul. The body area networks are connected to other body area network using device to device communication. The D2D [14] communication is setup so that there is no need of involvement of base station which helps in reducing channel pollution in base station.

3. CHALLENGES OF 5G AND IOT BASED HEALTHCARE ARCHITECTURE AND ENHANCED PLATFORM

The challenges associated with healthcare sector before the emergence of 5G network with IoT were as follows [22]:

- **Data Integration**: It means combination of different types of biomedical data from different devices

- **Data Anonymization**: It means the healthcare information of the patients should be modified so that patient cannot be:

→ Re identified

→ Information about patients can be earned by unauthorized users.

- **Data Cleaning**: It means recognizing and eliminating:

→ Errors from collected biomedical details.

→ In consistencies from collected biomedical details.

- **Data Reliability**: When a system operates, the measure of ability of the system to operate as it is expected to in that scenario is termed as data reliability of system.
- **Data Interoperability**: It is needed in electronic healthcare (e-healthcare) system as clinical data is distributed among heterogeneous sources.

The meaning on all symbols drawn in Figure no 4 are explained in Table no 3. This enhanced platform uses two technologies SDN and NFV. SDN combines with NFV to provide proper visualization, automation etc over virtual resources. VNF. The VNFs (Virtual Network Function) runs over Virtual Machines (VM) and NFV infrastructure is totally dependent on life cycle of VNFs. Initially all data management mechanism like data integration, data cleaning etc (which are provided by NFV infrastructure) are constructed in form of VFNs. This is done so that operations become flexible, cost effective and they can visualize different e health platforms running in different entities like hospital, clinic etc. With the transformation of mechanisms into VFNs [23] the security gateway comes into picture and it starts controlling the privileges and access of user. This controlling is very important for security purpose and it also maintain the Quality of service (QoS) provided by platform of e-health [24]. The QoS is checked by integrating the following three aspects in a form of common service:

- View of healthcare applications
- Infrastructure
- Operational support.

Finally, orchestrating the available infrastructure helps in management of lifecycles of all VNFs requests and instances. This is managed by all NFV.

By enhancing the platform of 5G with IoT devices we can partially overcome these challenges. Figure 3 shows the enhanced platform of 5G. [37-39]

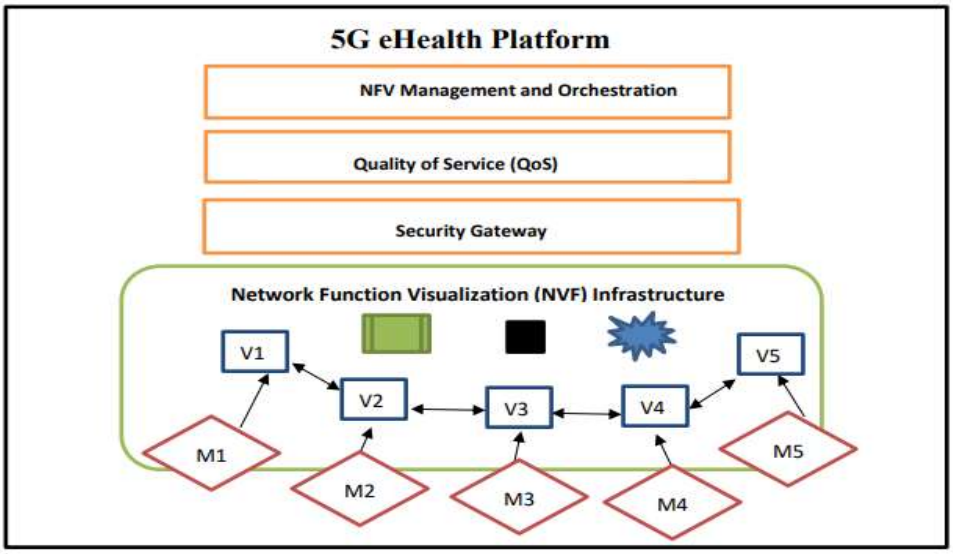

Figure 4: Enhanced 5G eHealth Platform

Table no 3: Notation table for symbols used in Figure 4.

SYMBOL IN FIGURE 4	SYMBOL STANDS FOR
V1 V2 V3 V4 V5	Virtual machines (VM) no 1 ,2 ,4 and 4 respectively containing their corresponding Virtual Network Function (VNF)
M1 M2 M4 M3 M5	M1= DATA INTEGRATION M2= DATA ANONYMIZATION M3= DATA CLEANING M4= DEVICES RELIABILITY M5= DATA INTEROPERABILITY
	Devices
	Data bases
	Software Defined Network (SDN)

- **(M1) Data Integration:** It includes identification of specification and APIs, specification classification, API's mapping, and dynamic data acquisition.[25]
- **(M2) Data Anonymization:** It includes data type identification and then perform anonymization of data by applying data generalization and suppression.[25]
- **(M3) Data Cleaning:** It includes data validation, completion, and verification.[25]

- **(M4) Devices Reliability:** It include checking of device availability, timestamp threshold and date and device quality correlation.[25]

- **(M5) Data Interoperability:** It includes ontologies creation, relationship-based data store, data mapping and translation.[25]

3.1. Challenges of 5G and IoT based Healthcare architecture and enhanced platform

Even after application of enhanced 5G platform few concerns were still unanswered. The major concerns include transparency, accountability, record accuracy, secure transaction, lowering of cost, collaboration, and agility [26]. This paved the way for incorporation of blockchain in 5G healthcare sector as decentralized nature of blockchain is beneficiary for answering such concerns [27].

3.1.1 Blockchain

Blockchain is a decentralize ledger [28] i.e. it is a data structure with set of blocks and rules to add data. Blocks are arranged chronologically using a cryptographic hash function [29]. Figure 5 shows general structure of Blockchain. It is like link list data structure where address of current node is stored in address part of next node. Three fields are

- Header of Block [30]
- Previous function's hash [30]
- Data. [30]

Block header contains header information. Hash of previous function and data are contained in next field. Data is generally set of transaction.

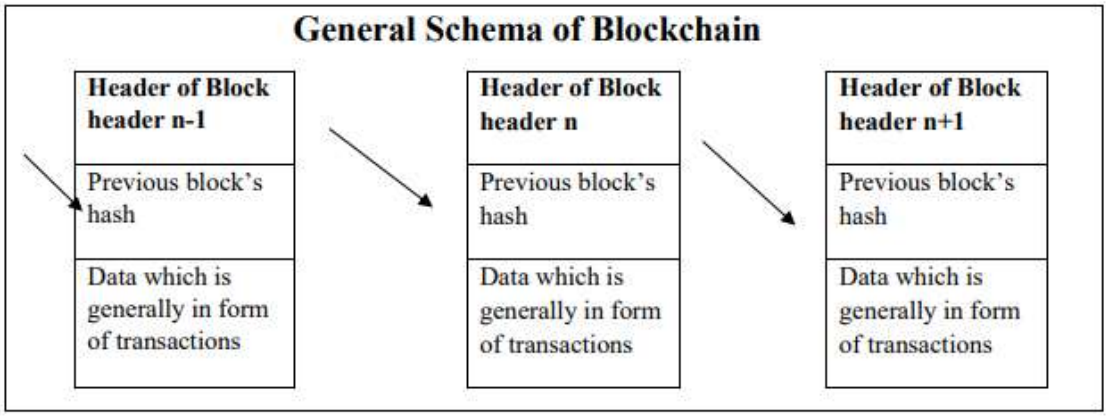

Figure 5: Blockchain Schema

The developments in blockchain can be summarised as: -

- BLOCKCHAIN 1.0
  - Introduced in 2009
  - Anyone can become maintainer of block chain (referred as miner)

- Supports scripting language known as Bitcoin Script
- Due to realization of potential of block chain to solve digital world problem nest versions of blockchain are created based on smart contact. [32]

- BLOCKCHAIN 2.0
  - Launch of Ethereum in July 2015
  - New cryptocurrency ether was released
  - It supports scripting language which was much advanced than Bitcoin script
  - Emergence of Initial Coin offering [31]

- **BLOCKCHAIN 3.0**
  - Trusted computing using smart contract
  - Consumption of large number of resources and energy by proof of work
  - Privacy is major concern which is much desirable in lot of practical application. [31]
  - Evolution of different block chain platform like IOTA (Block Chain platform based on Tangle and optimized IoT devices), Ripple, Z cash etc. [32]

4. BLOCKCHAIN IN HEALTHCARE SCENARIO

Since 2009 with initial aim of solving double spending problem with the help of decentralized cryptocurrency [32], block chain has evolved in the field of healthcare, banking etc supporting the execution of trusted code via smart contact having: -

- Faster Consensus algorithm [32]
- Peer association using unique identities (This is also known as Permissioned blockchain) etc. [31]

Healthcare sector involves sharing of lot of medical and financial data hence security and privacy is a major concern [33]. Block chain is helpful as it provides solutions for accountability issues between both sides involved in process. The usage of blockchain in healthcare sector provides: -

- Integration of health record on a secure infrastructure [34]
- Secure communication between the parties involved in communication [34]
- Delivery of clinical report in effective manner. [34]

In the field of healthcare, we can integrate the block chain which is clearly explained in Figure 6

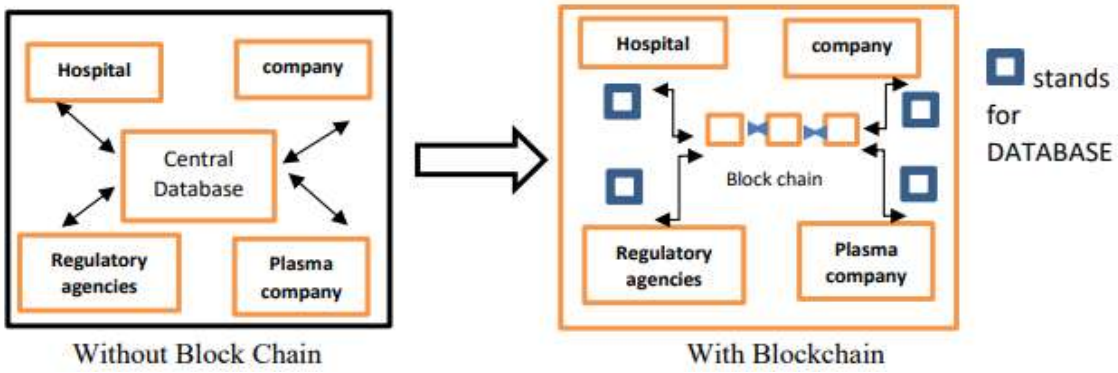

Figure 6: Healthcare data with and without integration of Blockchain

4.1 Framework of Healthcare using Blockchain Technology

The blockchain based system comprises of patient health record which contains patient and clinic generated report, drug record and used medical device record [35]. These all things are encrypted (E) and sent to Data Lake in the form of digital signals (DS). Here the security and privacy of data is achieved by the decentralized nature of blockchain. So before entering Data Lake E+DS takes place. When data is needed by any application for health analysis etc decryption of digital signals is performed and complete timestamp-based history can be retrieved for users mentioned in table 4

Table no 4: Notation table for figure 7

NOTATION	MEANING
P	PATIENTS
C	CAREGIVERS
MDM	MEDICAL DEVICE MANUFACTURER
R	RESEARCHER
IC	INSURANCE COMPANY
H	HOSPITALS
PC	PLASMA COMPANIES
RG	REGULATORY AGENCIES

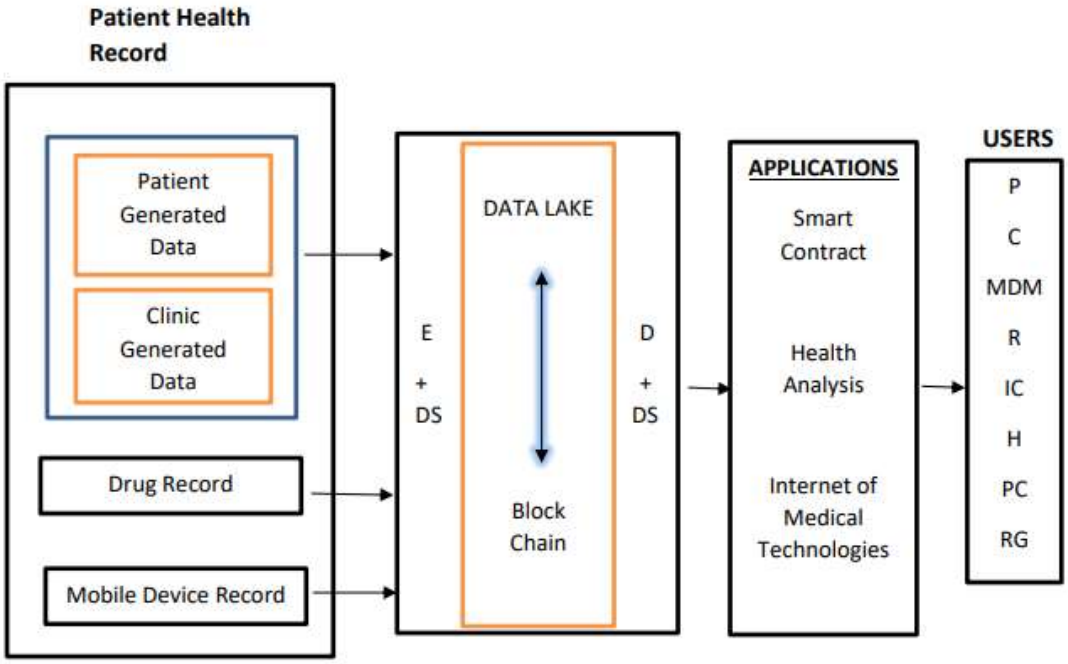

Figure 7: Framework of Healthcare system based on Block chain

This framework helps in various ways such as: -

- Aggregate DNA from different holders without collecting it in a central database.
- Provides access to large set of genetic data and clinical records with privacy.[36]
- Allow to track and cross verify private health related data with secure communication.
- Automatic calculation of cost and payment done using coins on block chain technology is quite effective and interactive.

5. CONCLUSION AND FUTURE SCOPE

The Blockchain technology can easily help in dealing the security and privacy measures in field of healthcare. Conclusion can be summarised in the form Table 5:

Table 5: Critical analysis of Blockchain approach in field of healthcare

Issues	**Can be achieved using blockchain or not**
Data Integration	Achieved
Data Anonymization	Achieved
Data Cleaning	Partially achieved
Data Reliability	Achieved
Data Interoperability	Can be achieved better by incorporating Blockchain in Fog computing
Transparency	Achieved

Accountability	Achieved
Record accuracy	Achieved
Secure Transaction,	Transactions are secured but possibility of 51 percent attack cannot be ruled out
Lowering of cost	Achieved
Collaboration, and agility	Achieved

Future work will include incorporation of blockchain with various emerging technologies like fog computing to ensure more security in transactions and will also help in data cleaning and data interoperability. Fog computing typically provides a better way to collect and process data from these devices than the cloud does. Instead of storing data at the cloud or at a remote data centre, fog computing provides a way to gather and process data at local computing devices. Incorporation of blockchain with Fog looks convincing and exciting.

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