Application of blockchain technology in "smart-digital hospital" cyber physical systems

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Abstract – Health informatization as an urgent problem has not yet been resolved. Quality medical care, intellectual level, communication infrastructure, management process, control of equipment, sensors are presented as a "smart-digital hospital" cyber-physical system with modern information technologies. The most important condition for "smart-digital" hospitals is that health workers inform patients about patients using the Internet of Things and mobile applications, and ensure their comfort.

Keywords: "Smart-Digital" Hospital, Cyber-Physical Systems, E-Health, Big Data, Cloud Computing, Blockchain Technology

Introductıon

The artificial intelligence, big data, cloud computing, the Internet of Things, machine learning, new technologies, network medical equipment brought together by cyber-physical systems have led to the reshaping of e-health. "Smart-digital" hospitals are based on the automation and optimization of related facilities in the technological, information and communication environment. The formation of this environment is the fourth industrial revolution associated with the discovery and improvement of new opportunities for health and, most importantly, big data. The connection of network devices to big data analysis, cloud computing methods, as well as artificial intelligence is a "smart" infrastructure.

Healthcare professionals must apply technology with the help of professionals for quality service. Big data analysis and the application of digital technologies provide individualized treatment, improved patient outcomes, and reduced health care costs. Information technology and machine learning have changed the health care environment, for example, in radiology - mammography, bone mineral densitometry, digital X-ray, panoramic X-ray, ultrasonography (USM), computed tomography (CT), magnetic resonance imaging (MRI) and angiography (DSA) devices. Thanks to the use of such devices, services in dermatology and ontology occupy one of the leading positions.

Ideal smart hospitals must integrate all communication devices and key actors involved in both the care of the individual patient and the overall operation of the hospital facility in order to have centralized control over all devices and technologies. [10]

One of the indispensable technologies for smart hospitals is artificial intelligence-based robots. Robots are one of the most loyal assistants to doctors. Doctors can provide information about any patient at any time. So, they can replace the paramedics. For example, when a doctor visits a patient's room, he may be accompanied by artificial intelligence-based robots instead of a paramedic.

At the same time, many smart hospitals are cleaned by robots.

Taking into account the current situation, it should be noted that in the near future it will be necessary to expand the use of smart hospitals.

There are a number of health benefits of the smart hospital project:

- ✓ Regulation of the work process
- ✓ Helping patients develop the ability to communicate electronically with physicians
- ✓ Partial cost reduction
- ✓ Increasing efficiency
- ✓ Improving health decisions with more information

One of the main problems for smart hospitals is security. From sensitive patient data to medical records, it's easy to see why cybersecurity is the most pressing health issue. Hospital data and equipment are gold mines for cyber

criminal groups. When a connected system, such as a smart hospital, is implemented, these gold mines become even more accessible. [13]

Therefore, specialists must first take measures to protect patient data. This can also be done through Big Data. We can also note that there are four innovations that govern the "smart" hospital:

- Blockchain is a distributed database of records of consecutive transactions, consisting of related transaction blocks and stored in a digital registry. This technology allows each patient to use the information in the VB block and ensure the protection of data when this information is shared in medical institutions, increasing the transparency of communication not only between the patient and the doctor, but also between different health facilities. In the future, this technology should help remove restrictions on the widespread exchange of medical information that hinder the application of innovations.
- Biotelemetry is a method of collecting and analyzing instrumental data to monitor a patient's condition throughout the day. A variety of wearable devices are being developed, including smart watches, sunglasses, and electroluminescent clothing, which help people learn about their physiological parameters and behavior and thus improve their health. These technologies can be used to manage patients at home and to obtain objective information about what happened to the patient between visits to the hospital or clinic. In particular, it helps doctors determine how effective the treatment is and how patients are improving. In addition, these technologies help reduce the number of hospital admissions.
- Medical methods and drugs based on genomics and big data analysis. Genomics is one of the most important components of digital medicine, primarily for oncology. At the same time, it can be used, albeit to a lesser extent, to develop approaches to the treatment of central nervous system diseases, infectious and autoimmune diseases, and cystic fibrosis.
- Virtual Rehabilitation in Orthopedics Physical therapy is an important part of orthopedic treatment. With the transition to results-based medicine and the introduction of appropriate funding schemes, it will be possible to expand the scope of new devices that will help patients monitor their every move after surgery and perform daily exercises. The information received from the devices is transmitted to doctors in real time so that they can change the training protocols. The trainings are conducted under the guidance of a virtual trainer. These systems can also collect patient feedback and can then be used to determine the cost of orthopedic surgery, such as joint replacement.

These technologies promise to combine human intelligence with statistical analysis tools and improve diagnostic and treatment strategies using quantitative data.

Application of Big Data technology in medicine

The big data that emerged in the 2000s is a term that has been used a lot lately. A large amount of unstructured / unstructured data is analyzed, processed, and useful information is found using specific methods. It is possible to analyze the data, to prevent the impossibility of its collection through computers, modern technologies.

Big data is a collection of data or a combination of data arrays. The concept of big data is growing day by day in digital communication and information science, as data is created by anyone and everything, from mobile devices, web servers and social networking sites [1]. The current challenge in this area is that traditional databases and existing technologies are too large, too fast, and difficult to manage.

Sometimes there is no connection between science and medicine, the cause of the disease, the treatment is not based on scientific evidence, it is carried out in the traditional way. In this regard, Big Data science has an impact in medicine, as in all fields. The amount of information indicates the accuracy, reliability and reasons for the results obtained.

Proper management of patient information is one of the most important factors in a smart hospital, and in any hospital in general. This is very important for both the doctor and the patient. Thus, in addition to protecting the patient's personal information, the doctor can obtain this information at any time.

One of the most widely used technologies for proper data management is Big Data technology. This is a technology that has shown its strength not only in medicine, but in many areas.

All medical institutions keep information about their patients. It is important to use the capabilities of centralized Big Data technology to share this information and research the results.

Note that, according to statistics, the countries that use Big Data technology the most in medicine are European countries.

Big Data is more widely used in healthcare in Europe because it offers ways and solutions to improve the health of individuals as well as the performance and outcomes of health systems.

Efforts to increase access to information in Europe are mainly socio-economic. At the same time, in order to improve the quality of prevention and treatment, great importance is attached to the use of information and new information and communication technologies (ICT) in public health. [11]

In the coming years, European health systems must respond more effectively to the exponential growth of chronic patients, who determine the most effective interventions and release the full potential of ICT. The e-health platforms that many European governments are trying to implement can be effective in improving the management of chronic patients in the community by communicating with different health professionals and patients. [11]

The reason why Big Data technology is being used more in healthcare is that it can help identify high-risk patients more quickly. This is done through the proper management of data, as mentioned above. Therefore, many healthcare organizations are investing more in Big Data technology.

The cost of health care in the United States now exceeds $ 3 trillion annually. Big Data technology, along with other health technologies, is recognized by experts as helping to track and diagnose diseases long before they occur.

In health, Big Data technology can also be used to treat cancer.

In other words, researchers predict that Big Data analysis has the potential to accelerate cancer treatment and deliver on the promise of more individualized medications and treatments. The information is used to help oncologists provide specific treatment options - biopsy samples, and other relevant information. Organizations around the world are collecting countless cases of cancer from global research and surveys. [12]

Using this information, doctors can prepare treatment for each type of cancer individually.

In addition to the above, the proliferation of mobile applications and M2M devices is expanding the use of Big Data in medicine.

Cloud Computing in Cyber-Physical Systems

Advances in cloud computing, wireless sensor systems and medical sensors are helping to remotely monitor patients through cyber-physical systems. Medical sensors collect information about the patient and send it to the gateway via a wireless network to ensure the patient's comfort. Cloud Computing technology is used to ensure the security of the data collected, given its large size and confidentiality.

The problem of integrating digital patient records, biosensors, data collected from smart devices in the field of health, and decision-making into a system in practice has not yet been fully resolved.

The number of proposed architectures of cyber physical systems in healthcare is small [2]. The structure of the cyber-physical system based on the service center is described (Figure 1).

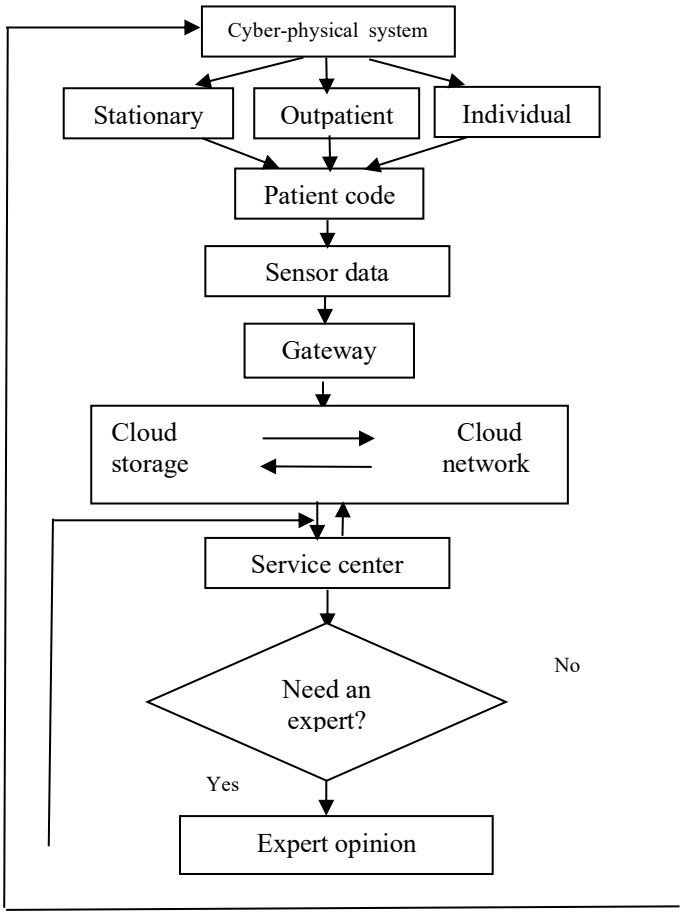

Figure 1. Healthcare service center

To ensure the security of the system, the patient's code is entered and encrypted in the inpatient / outpatient / individual setting. Data collected from various sensors used in inpatient / outpatient settings (used by individual patients) are sent to the cloud storage via a gateway, calculated and sent to the service center. At the service center, doctors access patient data from the cloud. If necessary, expert doctors are consulted, otherwise a decision is made. By deciphering the patient's code, a doctor-patient relationship is established and certain measures (counseling, treatment) are carried out on the patient.

Blockchain in medicine

There are a number of challenges in terms of blockchain technology innovation:

- Lack of formation of medical systems;
- Trust of patients, doctors;
- Be careful not to place special information in the system.

Modernization of "smart-digital hospitals" supports the quality of patient examination, data protection, making the right medical and diagnostic decisions, increases the functional compatibility of technological processes in e-health.

As blockchain is a new technology, the creation and application of innovative projects in the IT space must be taken into account.

Problems encountered in traditional health as a result of the application of modern healthcare information technologies (outdated information exchange mechanism, long-term medical tests and medical records, storage of patient data in various hospitals, misdiagnosis and inadequate treatment of patients due to lack of medical history) absence of information on the medical information portal). Recently, the application of blockchain technology to health,

medicine and pharmacy has led to useful successes. This technology offers new approaches to data sharing, storage, protection and management (Figure 2).

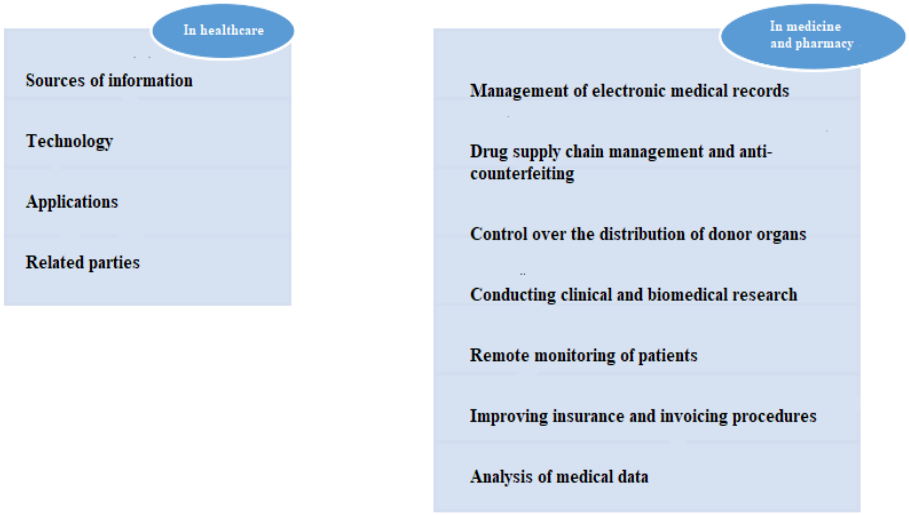

Figure 2. Models with a new approach to blockchain technology

The main block of applications in health care is electronic medical records. Electronic records belong only to the doctor-patient.

- Admission
  - Stationary
  - Outpatient
- Patient questionnaire
- Daily registration of the patient
  - Temperature
  - Pulse
  - Pressure
  - Blood sugar
  - Oxygen in the blood
- Infectious diseases
- Vaccination
- Electronic version of medical records
  - Examination by a doctor
  - Analysis results
  - Diagnosis
  - Medical records
  - Recipes
  - Stationary output

In healthcare, the transmission of data between enterprises (clinics, pharmacies, insurance, research centers) should be managed by blockchain technology. In some countries, the exchange of customer information between institutions without the consent of customers is prohibited. For example, such requirements exist in the European General Data Protection Regulation (GDPR). A joint project between MIT Media Lab and Beth Israel Deaconess Medical Center, MedRec [4], allows patients to fully control their data and independently determine who can access it. Healthbank [5], Factom [6], Gem Health Network (GHN) [7], HealthCombix [8] and others. projects are also working in this direction.

The following processes can be managed with blockchain:

- Can track patient information;
- Data cannot be falsified;
- Data cannot be deleted;
- Data is protected in the blockchain.

In the pharmaceutical industry, the management of the supply chain of low-quality and counterfeit drugs and the fight against them remains a major problem.

Counterfeit drugs threaten people's lives and health.

The blockchain, which manages the supply chain of manufacturers, retailers, healthcare workers, pharmacists and patients, can solve this problem by providing transparency, control and management at all stages of production, supply and sale of medicines (at low prices).

The process of obtaining high-quality donor organs for transplantation is closely monitored by regulators in many countries with the introduction of the blockchain. For example, as part of the 2019-2021 innovation strategy, the UAE Ministry of Health, which promotes innovative healthcare solutions, creates a blockchain-based donor register to track the origins of organs and ensure that the donor agrees to use them [9].

The "Hayat" Registration is designed to register individuals' legal claims as donors.

Clinical and biomedical research facilitates the process of collecting data from patients. Blockchain allows you to build information about factors that directly or indirectly affect research results, there are the following benefits for medical research:

- Recording of data during the research;
- Real-time updates;
- Ensuring data control;
- Clarification of the origin of the data;
- Data protection;
- Rapid detection of recent pandemic threats.

Blockchain helps to remotely monitor patients using sensory and mobile applications, optimize the data collection process, speed up data exchange and analysis, and allows efficient use of the Internet of Things (IoT) and data processing.

Health insurance companies run a high risk of misinforming patients with the right information. By managing the accuracy of the data, the blockchain reduces risks and tariffs between the customer and the company, as well as the following benefits:

- Simplifies the information by reviewing it;
- protects against fraud;
- obtains the necessary information quickly;
- quickly detects incorrect information;
- creates a connection between health, the enterprise and the client;
- prevents interference.

Blockchain algorithms not only provide storage, processing and protection of data, but also analyze medical data, artificial intelligence and interact with the Internet of Things.

Medical registration is carried out individually and in groups. The system consists of a cloud storage and a blockchain. The blockchain stores small (data uploaded to the cloud, permission to read them), and the cloud storage stores large files (answers from laboratory and instrumental analysis, CT and MRI images with tens of megabytes). Unlike blockchain, data uploaded to the cloud is encrypted.

The number of medical data depends on its evaluation. Individual records consist of three elements related to type-time-quality.

Data types can be static (genetic, biometric) or dynamic (laboratory analysis). Time, date of receipt of data, indicates the obsolescence of qualitative data, as well as analytical responses (not more than 6 months).

Algorithm for data entry into the e-health system

The data entry algorithm is as follows:

- Data is uploaded to the cloud storage

- Data is checked, patient identification is anonymous
- Encrypted via symmetric encryption
- Using the RSA algorithm, the keys are transmitted to one of the nodes of the blockchain through communication channels
- The user data password is decrypted.

A common key (symmetric encryption) is used for encryption and decryption known to both parties (Figure 3).

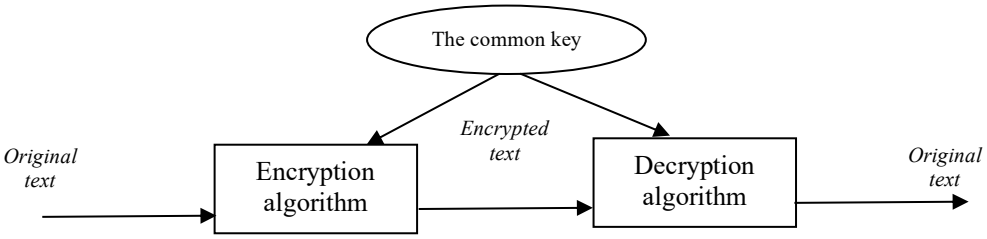

Figure 3. General scheme of symmetric encryption

Symmetric encryption is more useful, especially for encrypting data that is not intended to be transmitted. Due to the complexity of transmitting only valuable data, symmetric encryption, which is used as a means of protection, must be communicated with the other party so that the information is not read or altered. The encryption algorithm is as follows:

1. Information is transmitted
2. Information is encrypted using simple numbers (keys) - substitution method
3. All letters are encrypted alphabetically
4. Encrypted information is transmitted to the other side
5. Withdraw in alphabetical order, decrypt the information.

In addition to these encryption methods that use character substitution (four basic types: mono-alphabet, homophonic, polyphaletic, and polygram), there are more complex algorithms when the encryption process itself is a complex multi-step mathematical transformation.

The next step is to transfer the keys to one of the nodes of the blockchain through communication channels using the RSA (Rivest, Shamir, Adleman) algorithm. RSA describes a block code. The open and encrypted text algorithm is as follows:

- Generation of keys
  - Choose two simple numbers (p and q)
  - must find the product (n = p * q)
  - Calculate the Euler function (φ (n) = (p-1) (q-1))
  - selection of open exponent (e = 3)
  - calculation of the hidden exponent (d = e-1 (mod φ (n)))
  - declare public key ({e, n})
  - save the locked key ({d, n})
- Encryption
  - select the text to decrypt (m)
  - calculation of ciphertext (c = me mod n)
- Decryption
  - calculation of initial data (m = cd mod n)

The plain text is transmitted to the client.

The future of smart hospitals

Along with the development of healthcare, smart hospitals will continue to develop. As mentioned earlier, given the current situation, as well as new experiences in health care, we can say that the demand for smart hospitals will increase in the near future.

Undoubtedly, patients will prefer hospitals that will serve them safer and older. Eventually, this will push other hospitals to become smart hospitals.

Hospitals have long been reluctant to adopt evolving technologies and practices, primarily due to high investments. However, as the cost of technology declines sharply and hospitals are forced to adopt new technologies in the face of rapidly evolving use cases that constantly repeat the importance of digital communication. In addition to helping patients, these changes will benefit hospitals themselves by digitizing asset tracking, employee management, and planning for better operational efficiency. [14]

Conclusion

The modern technological transformation of healthcare in cyber-physical systems has become a global trend. The main tasks here are: to increase the availability, convenience and quality of medical care for people around the world; timely, accurate diagnosis; in-depth medical analysis; frees doctors from daily work. These problems can be solved in any size and in medical organizations with the help of high technologies, with the allocation of serious computing power and technical support of IT specialists, obtained only through cloud services.

As we have mentioned, one of the main requirements in a smart hospital is proper data management. It is known that this is done through Big Data. Although most European countries currently use Big Data, the use of Big Data in hospitals will increase in the near future with the introduction of more Smart Hospitals. Thus, it will facilitate the work of both patients and doctors.

It is known that robots are one of the indispensable technologies for the smart-digital hospitals of the future. In particular, technology giants such as Japan are now using robots in many areas. Such cases are expected to be observed in many countries in the future. Implementing this will undoubtedly provide a more affordable standard of living for both ordinary citizens and human workers.

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