Enhancing the security of E-Health services in Bangladesh using blockchain technology

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Abstract The telemedicine service concept was mainly established to benefit the underprivileged people from rural areas of a country. However, due to the low literacy and awareness rates among rural population of Bangladesh, the service is not much effective. This paper represents a study on the awareness of the rural population of telemedicine service in Bangladesh and few key findings indicate how the awareness could be increased. The research also suggests that utilizing blockchain technology can enhance the data security and privacy. The research reveals some of the findings which can raise the awareness and popularity of telemedicine service among rural population. We have proposed implementation of blockchain technology which can vastly improve the security issue.

Keywords Telemedicine · E-Health · Blockchain · Survey · Awareness rate · Bangladesh rural areas

1 Introduction

The world of E-Health is expanding while receiving promising outcomes consistently to save lives. All healthcare professionals are considering this as a significant part of the healthcare system's future [1]. Since it is pretty critical to maintain patients' healthcare data privacy, there are certainly some challenges and issues existing in ensuring this privacy and security of telemedicine service [2]. This paper concentrates to explore the reality of E-health in the

rural areas of a developing countries like Bangladesh where the majority of the population is living in the rural places with poor proficiency rate. Furthermore, some significant barriers like proper healthcare system are still lacking in those areas [3]. Although the Bangladesh Government stepped up to execute E-Health ideas and ran pilot projects, many tasks did not reach satisfactory goals because of lack of awareness among the population [4]. The concept of E-Health is not yet entirely accumulated by the stakeholders in developing countries. A few elements in E-Health that ought to be contemplated and security issues are considered as a critical part of it [5].

Establishing a sustainable system helps the growth of the nation's development along with social healthcare. At the same time, security of data becomes a major concern in telemedicine service since it could leave a severe negative impact [6]. Few issues are prominent in this sector's development, i.e., attitude of the people towards the service, ignorance towards the service, conflicting demands, inappropriate strategy for the system, inconsistent policies for the service. In this research, the data were collected through well-designed surveys from a sample population in a face-to-face, paper-based manner. This paper represents multiple aspects of telemedicine services and proposes an efficient strategy to improve the services. Furthermore, the paper proposes an architecture for the network using blockchain to mitigate security and privacy issues.

2 Background

A massive industry has developed based on the fundamental human right of healthcare. Unfortunately, the services defer across countries due to various reasons such as healthcare policies, socio-economic standards, weather,

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geographic location, immunity, education, development or research on medical care, etc. Nonetheless, the demanding global healthcare industry is already being considered as the largest service-providing industry due to its rapid growth. Developing countries like Bangladesh usually do not possess the same stature of services as of developed countries [7]. The great necessity of a well-established and efficient telemedicine service in every country is realized in this COVID-19 pandemic, as maintaining physical distance was one of the crucial aspects for providing healthcare service in such situation.

Telemedicine administrations avail specialists counseling over system network using the live feed, test results being shared among research or clinical offices, checking patients using persistent information transmission, patient to doctor online meetings, and even medical procedure or active recuperation happening through remote access. Inevitably, any telemedicine project may become vulnerable to security threats in the virtual world with weak security measures [8]. Furthermore, some ethical and legal issues may arise for a telemedicine service if proper authorizations of data are not established in the service [9]. Although there are some common security issues in telemedicine service that can be seen repeatedly in many of its projects, the patients and the data are the most effected entities due to these issues [10]. Coordinated telehealth models improve comfort, access, and proficiency of care by offering stroll in telehealth administrations. In order to resolve most of the security and ethical issues in telemedicine service, blockchain can play a significant role in developing an efficient and secure system [11, 15]. This research explores the real-life rural area stature for telemedicine service implementation by evaluating the attitude and awareness levels. With further investigation of the security and ethical concerns of telemedicine service, this paper proposes an efficient telemedicine network utilizing blockchain.

3 Research methodology

This section elaborates the methodology which was followed to conduct the research work.

3.1 Design of the study

In Bangladesh, over 27% of adults are still illiterate which presents severe challenges while implementing the telemedicine research program. Another critical step of the study was to define the population that is to be researched upon. To understand the characteristics of the population, few factors such as geographic location, transportation, rate of literacy, financial capability, existing healthcare system,

etc. were taken into consideration. After determining the location and population, a suitable sample was considered from which necessary data was collected, and these data were analyzed to identify the level of awareness. Based on survey results, workshops and campaigns were designed to raise the knowledge and awareness of the sample population. A demo project of telemedicine service was arranged for the sample population to get real-life data. Another phase of the survey was conducted after running the campaign. Finally, these collected data were analyzed to identify few key findings and used for conclusion. Figure 1 shows the workflow of the conducted research.

3.2 Population sampling in the research

The sample location was the Duganga village where the minimum age considered was 20 years. The male-to-female ratio of the sample is balanced, 101.9:100. It was a challenging task considering the rural women are pretty conservative. After promising efforts, many women eventually understood the campaign's purpose and willingly participated in the study.

Considering the population of the village, a sample size of 500 people was determined. Again, due to the sample size, the sampling technique used in this particular study is Simple Random Sampling through lottery. There were a total of 1572 people who agreed to take part in the study. Each of them was assigned a number against their identity, and a pool was created. The identity of the participants was considered their national identification number or birth identification number provided directly by the Bangladesh government, and thus any chance of overlapping identities was eliminated. Afterward, a lottery was arranged, and a total of 500 participants were selected from that pool to form the desired sample. Since the participants were selected through a lottery, all the villagers willing to participate had an equal probability of being selected into the sample. Thus, fairness was maintained during the selection process. Table 1 represents the distribution of randomly selected sample populations according to age group. Furthermore, among all participants, the highest number of

Fig. 1 Workflow of the study

Table 1 Distribution of the sample according to age group

Age group (yrs)	Freq.	%	Valid %	Cumulat. %
20–29	145	29	29	29
30–39	125	25	25	54
40–49	101	20.2	20.2	74.2
50–59	77	15.4	15.4	89.6
60 and above	52	10.4	10.4	100
Total	500	100.0	100.0	–

participants fell between 20 and 29 years, totaling 145 participants. As the table shows, the younger age groups contain a higher percentage of participants than the older age groups. Due to the unavailability of the breakdown of age groups of the village Duganga, it cannot be confirmed if the breakdown of the data in the sample is consistent with the actual population distribution of the village.

3.3 Data collection

Once a sample from the target population was defined for this study, the next step was to design the survey questionnaires to collect data. The questionnaires were divided into two phases to determine the knowledge and awareness about telemedicine among the participants. The first set was given to the participants before launching the campaign, while the second set was given after finishing the training campaign. Both sets had 14 questions, and answers to these questions were ranked on the Likert scale 1–5 in Level of Knowledge, Awareness, and Attitude No, Maybe not, Maybe, Yes, and Absolutely respectively. The second questionnaire was designed to find out the efficacy of the training program. Due to the characteristics of sample population, it was inevitable that they would lack a robust educational background, and therefore, it required human assistance to conduct the surveys. For this purpose, a team of volunteers trained for conducting surveys was involved during the entire data collection process. Table 2 contains all the questionnaires from both phase 1 and phase 2 of the data collection process.

3.4 Carrying out workshops and campaigns

From the first survey findings, workshop materials were designed, and a campaign was carried out. The campaign also included a real-life experience of a demo telemedicine project. Carrying out these workshops and campaigns, allowed the participants to know more about different benefits of telemedicine service. Then the second survey was carried out which included some new questions that helped to better understand the participants' awareness and

attitude level. With the data from the survey, the key findings were analysed and compared with the previous findings from the first survey. The whole study brought up a much clearer picture to understand the level of awareness among these people.

4 Key findings of the surveys

Awareness and knowledge among the people are one of the essential parameters to improve the quality of telemedicine. Knowledge can encourage people to use new technology. However, the results showed that the awareness among rural population in health and medicine was still in the basic stage, and more than half of the participants had significantly lower awareness scores. This has reflected that the telemedicine concept is not popular to the rural population yet. Table 2 represents the survey results of both occasions from before and after the campaign taking place. The result was displayed in terms of percentage while referencing the scale and questionnaires.

However, after successfully running the campaign and workshops to increase the awareness about telemedicine among these people, the result showed a significant change as there was more positive response in terms of attitude and awareness. The findings show that this is a promising prospect for the country, and the rural people need to be appropriately advised and trained to get the maximum benefits from this state-of-the-art technology. Awareness criteria that require the most attention have been presented with proposed strategic plans represented in Table 3, which can be implemented.

5 Proposed system architecture of the telemedicine service utilizing blockchain

By ensuring key points described below, the whole system can be proved to be more efficient and effective in the prospect of Bangladesh.

5.1 Maximized range of service receivers

The proposed system network architecture was designed to have maximum reach-ability in rural areas. One of the critical benefits of telemedicine service is that there is availability of service. On the other hand, the availability of experienced professionals in the service provider end avails the benefit of attracting more service receivers under the system's coverage.

Table 2 Questionnaires and their resultant data from the surveys

Questionnaire 1	1 %	2 %	3 %	4 %	5 %	Questionnaire 2	1 %	2 %	3 %	4 %	5 %
Q1.1 Are you aware of telemedicine services?	20.4	13.4	24.8	25.3	16.1	Q2.1 Do you think telemedicine service can be an excellent alternative to a in-person medical consultation with a healthcare professional?	4.1	14.3	16.1	19.4	46.1
Q1.2 Is telemedicine an excellent alternative to directly receiving care in-person?	15.1	17.7	30.1	22	15.1	Q2.2 Was your privacy respected in the telemedicine service?	7.8	8.7	16.5	10.7	56.3
Q1.3 Does your regional authority have a strategy regarding telemedicine services?	30.6	21.5	29	12.4	6.5	Q2.3 Did the telemedicine staff introduce themselves and explain their role?	15.2	16.8	30.1	23.3	14.6
Q1.4 Do you have any previous experience of telemed services?	51.6	11.3	16.1	8.1	12.9	Q2.4 Did you have enough advance notice for your visit?	14.6	12.6	28.2	31.1	13.5
Q1.5 Can the quality of medical services be improved by using telemed services in remote places of Bangladesh?	29	15.1	38.2	11.8	5.9	Q2.5 Did you receive clear instructions on how to get to the studio?	21.4	12.6	29.1	20.4	16.5
Q1.6 Are you worried about the privacy of your data in telemedicine service?	18.7	20	26.3	16.2	18.8	Q2.6 Was the information about the technology precise?	9.7	16.5	30.1	23.3	20.4
Q1.7 Do the advantages of telemedicine services outweigh the issues?	11.8	13.4	39.8	19.9	15.1	Q2.7 Could you see the consultant clearly?	14.6	18.4	35.9	12.6	18.4
Q1.8 Would it be helpful to store health data digitally?	4.8	8.1	40.9	30.1	16.1	Q2.8 Could you hear the consultant clearly?	14.6	15.5	31.1	20.4	18.4
Q1.9 Do you think that you should have the right to access and see your health record?	5.9	3.2	20.4	21.6	48.9	Q2.9 Were you given ample opportunity for questions?	11.6	14.6	36.9	24.3	12.6
Q1.10 Are you worried about getting the proper benefits of telemedicine services?	18.3	15.5	30.1	19.4	16.7	Q2.10 Was the follow-up process made clear?	14.5	17.5	26.2	21.4	20.4
Q1.11 Do you think that ordinary people/mass people are aware of these services?	35.5	25.8	17.8	9.1	11.8	Q2.11 Would you trust your data in a Blockchain based telemedicine service system?	4.2	7.1	17	31.3	40.4
Q1.12 Is it a cost-effective service for receiving healthcare professionals' consultation?	13.4	10.8	24.2	30.1	21.5	Q2.12 Would you use telemedicine again?	10.7	16.5	24.3	26.2	22.3
Q1.13 In developing countries, would implementing telemed services in remote/rural areas be challenging?	3.2	6	18.8	28.5	43.5	Q2.13 Would you recommend this service to family and friends?	6.8	11.7	17.5	28.2	35.8
Q1.14 Do you think telemedicine service would be a viable solution to improve overall healthcare facilities in Bangladesh?	5.8	8.6	28	32.3	25.3	Q2.14 Should the government prioritize and encourage the private sectors to develop telemedicine services for deprived people?	3.2	12.4	14.5	27.4	42.5

5.2 Strong encryption of data for ensuring privacy

Telemedicine system must ensure the privacy of user data. The network structure involves different entities and plays a key role in connecting them by maintaining secure solid infrastructure [13]. The proposed architecture is designed

to concern the human-machine integration and keep the system secured by ensuring data privacy and encryption through the utilization of Blockchain. Blockchain stands out to be one of the most secured and efficient out of multiple cryptosystems available for such purposes. The idea behind the proposed architecture was to store private

Table 3 Strategic plans in terms of individual awareness criteria

Criteria	Strategic plan
Little experience in using telemedicinal services	Workshops from the institutional/governmental level should be organized, where the showcase/demonstration of the benefits of E-Health/telemedicinal services would be carried out
Lack of services or resources in nearby hospitals	Government and Private hospitals could be motivated to provide free telemedicinal care in remote places of the country to increase the popularity of the telemedicinal treatment scheme
Raising awareness among the mass public	Workshops organized in the regional schools by NGO/Governmental organizations, with the help of live demonstrations, can help raise awareness among the literate group of people, who individually, in turn, can convince their family members to benefit from the telemedicinal service
Privacy and Security issues observed in existing telemedicine service projects	Implementing a secured system using Blockchain makes the entire system more secure, user interactive, and ensures proper authorization of data access
Lack of initiatives by the regional authorities	Regional authorities should take more initiatives to disseminate information and raise awareness among the people regarding telemedicinal services

data with strong encryption and secure transactions with blockchain [14]. The proposed system architecture enables various consultants to have easier access to the patients' data. The system enables the users to have total clarity on their transactions and mitigate the risks in data privacy. The system consists of three modules that produce the complete architecture of the system which are described below:

Client: The Client Agent is a piece of software responsible for data ingress and digress. It's where the doctor/agent could input new data, or the patients can view their data. The Client application is the gateway of visual informatics to the end-user and a channel for collecting new, modifying existing and displaying data. The communication would be held using an encrypted channel with a shared key pair issued and signed by the system. A session is started by verifying two private keys and signatures from users for session initialization. After a successful verification process, a shared key is signed and generated, then pushed into both the doctor, patient, and system keychain so that the specific session can be accessed and given access to the system.

Data Storage: 'Data Storage' are clusters of mass storage to retain any binary files associated with a transaction, e.g., photos, videos, and test reports. This module is responsible for encrypting incoming files and decrypting outgoing files on verification. Data, such as images, videos, and audio, will be encrypted on a disk with a shared key. Each encrypted data chunk will be padded with a special marker specific to the user to strengthen the security, retain the sequence, and then join together again encoded in a native system type. Encryption and decryption of the data management is shown below in pseudo code:

```
# For Encryption and Split
Function encChunkerize:
While File not reach endOfFile
    read chunkSize bytes and assign to chunk
    Encrypt chunk using scrambleEncryptData
    return chunkList

# Encryption method
Function scrambleEncryptData:
    convert buffer to string, then to chunk
    Concat User.special_character String
    Encrypt chunk using AESSharedKeyData
    convert chunk to Binary and reassign
    return chunk

# For Decryption and Split
Function decChunkerize:
while File not reach endOfFile
    read chunkSize + User.special_character
    length of bytes and assign to chunk
    Decrypt chunk using unScrambleEncryptData
    Add chunkName in chunkList
    return chunkList

# Decryption method
Function unScrambleEncryptData:
    convert buffer bytes to string, to chunk
    Remove User.special_character string
    Decrypt the chunk using AESSharedKeyData
    convert chunk to Binary, reassign to chunk
    return chunk

# Join splitted file data
Function joinChunk:
    Initialize an empty Buffer container
    ForEach chunkFilePath in chunkList:
        read chunk and concatenate data with container
    Write container to Disk
```

Smart contract (Blockchain): For establishing secur-ed ends within the system, the smart contract was proposed by utilizing Blockchain. Blockchain will hold each session's data as a transaction and build up the secured distribution network. Blockchain stores data in several blocks that are chained together with previous stages of the process. When new data arrive, they are entered into a new block that contains no previous data and it is then chained with the previous blocks. Blockchain was used in a decentralized

method in proposed system so that no single entity possesses complete control, instead, all user ends of the system can collectively retain control. Decentralized blockchain has proven to be immutable, which means, the data entering blockchain cannot be reversed back to its previous state. Any data transactions within the proposed system would be permanently recorded and viewable to anyone will require permission from all the ends to modify.

5.3 Secured database and protected access

Blockchain technology is responsible for the security and trust in multiple ways. Firstly, the new blocks are always stored in a linear and chronological order, meaning a new block is added at the “end” of the Blockchain which makes it challenging to go back and alter the contents of the block. Each individual block contains a hash value, along with previous blocks’ hash value and the time stamp. Hash codes are generated by the math functions that convert digital information into a string of numbers and letters. If modified, the hash value of a block changes. Hence, any user tampers data stored in the system, all other nodes would then cross-refer each other and quickly detect the change which establishes an exact and transparent order of events. To change the system’s function or modify data, a majority of the decentralized network’s computing power would need to permit the said changes [15]. Thus, the system preserves the originality of the data, and it can not be changed unless authorizations are made from all entities. Whenever a modification is authorized, the blockchain architecture preserves the previous version of the data under a particular hash value and store the new version of the data with new hash value. As a result, the system can fetch any version of the data or block it at any time maintaining secure access [16]. The user interface is designed to be user-friendly and straightforward as it is intended for people with low literacy levels for comfortable and easy access.

6 Discussion and conclusion

This paper indicates people with relatively low knowledge and awareness can overcome the challenge with proper guidance or training. Proposed system with blockchain can mitigate possible issues of security and privacy issues of telemedicine service. Increasing the rate of literacy and awareness can accelerate in better implementation of telemedicine services. It is found, before training 38.7% of people were aware of telemedicine services whereas after training 64% of the same sample people would recommend the services to their friends and family. Implementing the proposed highly efficient and secure system could produce

effective and successful results in terms of data security, data accessibility, and user-friendliness.

References

1. Wernhart A, Gahbauer S, Haluza D (2019) eHealth and telemedicine: practices and beliefs among healthcare professionals and medical students at a medical university. *PLOS One*. <https://doi.org/10.1371/journal.pone.0213067>
2. Pramanik PKD, Pareek G, Nayyar A (2019) Chapter 14—security and privacy in remote healthcare: issues, solutions, and standards. In: Jude HD, Balas VE (eds) *Telemedicine technologies*. Academic Press, Cambridge, pp 201–225. <https://doi.org/10.1016/B978-0-12-816948-3.00014-3>
3. Zobair KM, Sanzogni L, Sandhu K (2020) Telemedicine healthcare service adoption barriers in rural Bangladesh. *Aust J Inf Syst*. <https://doi.org/10.3127/ajis.v24i0.2165>
4. Hossain Chowdhury A, Mohamed Mohamad A, Zishan Md SR, Rabiul Ahsan, Sharun Siti M (2019) Awareness on E-Health among undergraduate students in Bangladesh. *Indian J Public Health Res Dev* 10:636–641
5. Hossain CA, Zishan MSR, Ahasan DR (2014) A review on the security issues of telemedicine network. *Int J Innov Res Elect Electron Instrument Control Eng* 2:2183–85
6. Razali RA, Jamil N (2020) A quick review of security issues in telemedicine. In: 2020 8th International conference on information technology and multimedia (ICIMU), Aug, pp 162–165. <https://doi.org/10.1109/ICIMU49871.2020.9243549>
7. Khemapech I, Sansrimahachai W, Toachodee M (2019) Telemedicine—meaning, challenges and opportunities. *Siriraj Med J*. <https://doi.org/10.33192/Smj.2019.38>
8. Jalali MS, Landman A, Gordon WJ (2021) Telemedicine, privacy, and information security in the age of COVID-19. *J Am Med Inform Assoc* 28(3):671–672. <https://doi.org/10.1093/jamia/ocaa310>
9. Kaplan B (2020) Revisiting health information technology ethical, legal, and social issues and evaluation: telehealth/telemedicine and COVID-19. *Int J Med Inform*. <https://doi.org/10.1016/j.ijmedinf.2020.104239>
10. Márquez G, Astudillo H, Taramasco C (2019) Exploring security issues in telehealth systems. In: 2019 IEEE/ACM 1st international workshop on software engineering for healthcare (SEH), May pp 65–72. <https://doi.org/10.1109/SEH.2019.00019>
11. Ahmad RW, Salah K, Jayaraman R, Yaqoob I, Ellahham S, Omar M (2021) The role of blockchain technology in telehealth and telemedicine. *Int J Med Inform*. <https://doi.org/10.1016/j.ijmedinf.2021.104399>
12. Guo R, Shi H, Zheng D, Jing C, Zhuang C, Wang Z (2019) Flexible and efficient blockchain-based ABE scheme with multi-authority for medical on demand in telemedicine system. *IEEE Access* 7:88012–88025. <https://doi.org/10.1109/ACCESS.2019.2925625>
13. Buldakova TI, Sokolova AV (2019) Network services for interaction of the telemedicine system users. In: 2019 1st International conference on control systems, mathematical modelling, automation and energy efficiency (SUMMA), Nov. pp 387–391. <https://doi.org/10.1109/SUMMA48161.2019.8947552>
14. Wan L, Eysers D, Zhang H (2019) Evaluating the impact of network latency on the safety of blockchain transactions. In: 2019 IEEE international conference on blockchain (blockchain), Jul. pp 194–201. <https://doi.org/10.1109/Blockchain.2019.00033>

15. Guo H, Li W, Nejad M, Shen C (2019) Access control for electronic health records with hybrid blockchain-edge architecture. In: 2019 IEEE international conference on blockchain (blockchain), Jul. , pp 44–51. <https://doi.org/10.1109/Blockchain.2019.00015>
16. Mitani T, Otsuka A (2019) Traceability in permissioned blockchain. In: 2019 IEEE international conference on blockchain (blockchain), Jul. pp 286–293. <https://doi.org/10.1109/Blockchain.2019.00045>