Online Education using Blockchain and Smart Contracts

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Keywords: Blockchain, Smart Contract, Online Education, Trust.

Abstract: Providing education and training to meet the changing requirements of modern society and to provide for the individual is extremely crucial. The traditional system of education, which has now been in place for a considerable time, has improved by means of involving technology. Online learning has become a recognised part of the broader landscape of education. Increasing numbers of students from different backgrounds and places are taking the opportunity to study online. However, online education in the current stage is facing considerable challenges due to lack of trust and accreditation, which could lead to undesirable consequences. The primary target of this research is to investigate the feasibility of using blockchain and smart contract as technologies to provide an infrastructure for online education that enhances trust, privacy, and security.

1 RESEARCH PROBLEM

The delivery of education and training to meet the changing requirements of modern society and to provide for the individual is extremely crucial. Thus, the traditional system of education that has now been in place for a considerable time has improved by means of involving technology. Web-based applications are being applied to improve communication, collaboration and share resources, promoting active learning, and delivering online education. Recently, many educational institutions globally; such as MOOCs, the Shaw Academy, Coursera, etc.; have offered online courses to facilitate lifelong learning with the aim of combining pedagogical, technical and organisational concerns into a broader set of sociocultural factors. Therefore, the online education environment may be taken as the latest form of learning mediated by state-of-the-art technologies which illustrate that online education has a significant role to play in future educational practice and, that understanding issues and challenges in respect to online education are of vital importance for future research communities. One challenge is trust, because naturally, all educational institutions require trust for credibility. Every educational institution awarding certification must be authenticated and accredited. Anything without accreditation means that there is a risk of fraud from either students or institutions (Watters, 2016). A further challenge is centralisation - all data is stored in one place - which places the system at risk of a single point of failure (YANG et al., 2017). An important challenge of online education is providing timely and effective feedback to students during their learning activities and assessment. Within any stage of the education system, there is a need for formative assessment. However in online education, this is difficult because of challenges relating to tracking details of learning activities (Chen et al., 2018). An additional challenge is that the traditional teaching ratings that are based upon student feedback tend to be one-sided, lack subjectivity, and do not assist with improving teaching (Chen et al., 2018). One suggested way to deal with claims such as these is blockchain, due to the immutability, traceability, and reliability of the technology. The developed smart contract existing between teacher and learner can be taken into the educational setting. Students can be presented with real-time awards and blockchain could provide a balance that measures learning progress and outcomes.

The purpose of this research is the investigation of the feasibility of using blockchain and smart contract technologies in the field of education. This has resulted in the following research questions which have been designed for our investigation.

RQ1: How Feasible and Effective is Blockchain Technology in Implementing such Learning Systems? Will a learner's blockchain, become too large, or will it remain manageable and small enough in size that we can add activities and records to it throughout a learner's lifetime?

RQ2: How can Blockchain Technology be Integrated within the Online Education System?

Build homogeneity between the characteristics of blockchain and the operations and transactions in the online learning system and create an environment for learning by maintaining the massive volume of educational transactions.

RQ3: How can the Operations and Transactions of each Participant in the Learning Process(students, educators, etc.) in Online Education Architecture be specified? Aggregate them, identify the relationship between them, subsequently propose a taxonomy that illustrates the operations and transactions that should be on-blockchain and which one should be off the chain if required.

1.1 Blockchain

"A blockchain, originally blockchain, is a growing list of records, called blocks, which are linked using cryptography. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data. By design, a blockchain is resistant to modification of the data" (contributors, 2019). Blockchain technology is the core of cryptocurrency. Satoshi and Nakamoto (2008), point toward its presence within Bitcoin, in the numerous ledgers contained within many nodes (Nakamoto, 2018). Given this aforementioned connection to the financial world, its relevance to education comes through an understanding of its various components. Principally, the blockchain itself exists as a dispersed record of digitized events (Sharples et al., 2016). Applying Karim Sultan (2016), it is possible to define blockchain as a decentralized database containing sequential, cryptographically linked blocks of digitally signed asset transactions, governed by the consensus model. This definition presents the central parts of blockchain technology. First, blockchain operates within a set of distinct rules, and it is a peer-to-peer networked database that allows its applications to share, track and audit digital assets (Sultan et al., 2018). Another significant part in blockchain is 'distributed consensus. This is a method whereby the legitimization of a new block is considered and if it is included within the chain? This can be undertaken to utilize consensus algorithms; specially PoW, PoS, and PBFT. A limited block size would be up to 1 Mb and could contain limited data. It could be applied to the recording of educational data (example exam records). Moreover, those holding the cryptographic public key can see all the stored information (in all computers connected to the blockchain), but they cannot change it. Even the original author is unable to do this. Data is timestamped and, it is a timed record of the added information (Sultan et al., 2018).

1.2 Smart Contract

A Smart contract is an event condition action stateful computer program, executed between two or more parties that are reluctant to trust each other unguardedly (Molina-Jimenez et al., 2018a). In other words, it is self executed code that runs to apply roles and conditions between two or more parties. By applying a smart contract using blockchain technology, there is not only a reduction in third-party cost within the transaction process, but furthermore, there is significant transaction security. A teacher or student working within a smart contract would be able to see a variety of educational issues Solved (Watters, 2016). When coupled with blockchain technology, the detail that is verified via the smart contract platform and recorded Within blockchain ledgers, is potentially incredibly useful. An example would be the meetings recorded between a student and his/her tutor. This data can be supportive of the institution and improve trust. However, there is a question of where to execute the smart contract. Does it run off chain, which means it is executed within a centralized architecture, or on blockchain which means it is executed within a decentralized architecture ? A Smart contract can be either centralized or decentralized that is because it can be implemented to run off-chain in a centralized environment, and on another hand, it can be implemented to run on blockchain which is a decentralized environment (Molina-Jimenez et al., 2018a) (Molina-Jimenez et al., 2018b). Our proposed solution is to have a smart contract that is running on blockchain where various activities occur on chain such as trust related issues, for instance, communication, immutability related matters. For example, learning records and replication-associated matters such as awards. Also, we will have a centralized smart contract that runs off-chain in order to execute operations that cannot be conducted on the blockchain because of any logical or technical reasons (such as performance) that make executing such operations on blockchain undesirable. We hope that Smart contracts can be used to play a primary role in controlling the learning process either on blockchain or off-chain as shown in Figure 4. Figure 1 distinguishes between centralised and decentralised (distributed) approaches (Molina-Jimenez et al., 2018a) (Molina-Jimenez et al., 2018b).

2 OUTLINE OF OBJECTIVES

This research project will attempt to investigate the use of blockchain and smart contracts to provide an

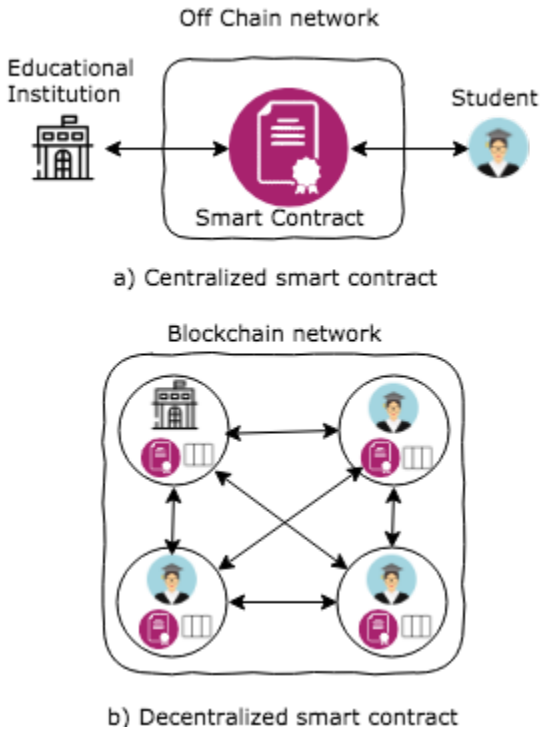

Figure 1: Centralised and descentralised smart contract.

infrastructure for online education that enhances trust, privacy and security.

Objectives:

- Determine if the technology is fit-for-purpose for the recording of academic achievements.
- Identify a set of clear opportunities and challenges for the take-up of blockchain technology in Online education.
- Build an administrator prototype of online education using blockchain and smart contract.
- Evaluate our proposed solution and the observation of the experiments.

3 STATE OF THE ART

3.1 Online Education

A recent online report (Allen and Seaman, 2016) indicates that enrolment within online education is a growing trend, with a rate of 3.9%. 5.8 million U.S students enrolled in distance learning, and of these, half were learning within a fully online environment. Therefore, there is a clear growing market for online education. Nonetheless, recent developments (MOOCs & OER) reveal that there is a need to address various problems. One problem is the motivation that the student requires to complete online classes (Allen and Seaman, 2014). Due to this, attrition rates in distance learning are much higher than in a face-to-face setting. Specific researchers are placing the attrition rate for online education as high as 75% (Croxton, 2014), which is of considerable concern. It should be stated that this is evidenced within MOOC's. Here course completion stands at a low 6.5% (Jordan, 2014). Where flexibility and convenience regarding learning times are regularly cited in online learning, the attrition rate is worrying. A variety of studies support these dropout rates (Croxton, 2014) (Adamopoulos, 2013). With this in mind, the empirical position appears to be that where a student is more satisfied with the online experience, they are less likely to withdraw. Understanding the exact correlation between satisfaction and retention is not thoroughly researched or understood, but motivation is a possible additional factor (Joo et al., 2013). To summarise, a student showing greater course satisfaction with online learning will have the motivation to continue, and moreover, they will in all likelihood be retained on the course. It is our hope that student satisfaction and motivation can be enhanced by making use of emerging technologies such as Blockchain and Smart Contracts.

3.2 Blockchain-related Projects in Education

Currently, the use of blockchain within education is at the experimental stage (Watters, 2016) where blockchain is being employed within some higher education institutions to provide support for degree management and summative evaluation (Sharples and Domingue, 2018) (Skiba, 2018). The reason for this is because blockchain records are far more specific, authentic and revealed to be anti-theft. The application of blockchain to education leads it towards formative evaluation, the tracking of the educational development of students and the actual implementation of learning delivery. A number of interesting research projects that investigate the application of Blockchain technology to education can be found. For instance, the University of Nicosia is the first school which uses blockchain technology to manage students' certificates received from MOOC platforms (Sharples et al., 2016). Also, The Massachusetts Institute of Technology (MIT) has developed a credentials system based on blockchain. This system aims to give more control over the certificates the students earn, and without having to rely on third-party intermediaries such as universities and employers to store, verify and val-

idate credentials. Blockchain technology and strong cryptography have been used in conjunction to develop the Blockcerts open platform for digital certificates and reputation (Chen et al., 2018). In addition, The Knowledge Media Institute (KMI) in the Open University has proposed the Open BlockChain project. The objective of this project is to facilitate a network that can spearhead blockchain projects in higher education. KMI is particularly interested in enhancing standards for badging, certification and reputation on the web with the use of the blockchain as a trusted ledger (Merija and Jānis, 2018). Sony Global Education also connected blockchain technology to a global assessment platform that stores and manages degree evidence (Chen et al., 2018). Furthermore, Turkanovic proposed the EduCTX platform which is a decentralized global platform for managing, storing and sharing digital certificates based on blockchain technology (Turkanović et al., 2018).

4 METHODOLOGY

This research approach involves:

1. **Literature Review of any Published Literature On:**
   (a) Applications of blockchain and smart contract technologies to education.
   (b) Non-financial applications of blockchain technology more commonly.
   (c) Digital methods for storing, securing, sharing and verifying academic credentials.
   (d) Online distance education and the learning process.
   (e) Any related subject.
2. **Desk Research Employing Primary Sources Covering:**
   Technical specifications of major blockchain implementations.
   (a) Blockchain types.
   (b) Blockchain characteristics.
   (c) Blockchain Platforms.
   (d) Consensus Mechanism.
   (e) Smart Contract implementation on blockchain.
3. **Interviews**
   With a sample of researchers, experts, industry representatives, educators, accreditors, testers and learners of relevant stakeholders in the blockchain and educational fields to design an online education scenario that complies with the solution that we proposed and moreover, covers the learning process.
4. **Prototyping Proof of Concept.** To examine the feasibility of our solution, a prototype will be created covering:
   (a) Technical specifications of the proposed framework that will be built on top of blockchain technology, as well as its structure and operations.
   (b) Determine the participants and their responsibilities in each stage of our solution.
5. **Build a Smart Contract of Our Possible Solution.** The smart contract in this research will be implemented as seen in Figure 4 to control the communication and operations between participants, either on blockchain or off chain. Basically, in on-blockchain, the smart contract is decentralized, given that it is on the blockchain. In contrast, the smart contract in the off chain is a centralized type. The smart contract in this research will:
   (a) Determine the contractual transaction between participants.
   (b) Determine the smart contracts architecture (centralized and decentralized) depending on the environment (on blockchain or off-chain).
6. **Evaluation.** To appraise the quality/suitability of our solution we will conduct an evaluation on a (FOCUS GROUP) to answer the following questions:
   (a) Monitoring – Are we are heading in the right direction regarding the development of our solution?
   (b) Justifying – Is our solution is valuable?
   (c) Validating – Have we made we make the correct decision/s in our solution?
   (d) Improving – Can we improve our solution by changing something or certain elements?
   (e) Research – Determining if our solution adds something to the knowledge set?

   In the evaluation process we will combine two of the evaluation methods (Questionnaires and Interviews) in two stages as following:
   - Formative Evaluation - This evaluation takes place during the project to guide future development.This type of evaluation will take place after completing every task.
   - Summative Evaluation – This evaluation occurs after the completion of a project to evaluate its success.

Table 1: Mapping appealing features of blockchain to the research concerns.

Problem	State of the art of blockchain
1. Trust Issue	-Trustless Environment
2. Single point of failure	-Decentralization. (P2P System) -Ledger Replication.
3. Fraud. 4. Manipulation 5. Dishonesty.	- Immutability - Auditability - Transparency

5 EXPECTED OUTCOME

Table 1 above roughly illustrates the research interest in blockchain and smart contract as enabling technologies. It maps a few appealing features of blockchain to some of the research concerns. We indicate the main contribution which bridges the existing gap as follows:

1. Blockchain Prototype with considering:
   - Technical specifications of major blockchain implementations.
   - Blockchain types (Public, Private, consortium).
   - Blockchain Platforms (Ethereum, Hyperledger, etc).
   - Programming language.
2. Build Smart Contract by considering:
   - Smart Contract Architecture.
   - Representation Language (Solidity, GOLAN, Java, etc.).
   - The advantages and disadvantages.
3. Report the observation.

The outcomes of this research do not only apply on online education scenario, can be extended to any other learning environment that is distrusted.

6 STAGE OF THE RESEARCH

6.1 Motivation Scenario

In summary, with technology radically transforming the way learning is imparted, blockchain and smart contracts can be viewed as highly promising, are beneficial for the eradication of fraud, and allow greater transparency regarding traceability. Moving from finance to education, blockchain is increasingly being explored by educational institutions. The assumption is that the educational institution can be connected to a blockchain network, and that any specifications that govern the relationship between students and the institution, will be on smart contracts within the blockchain. Moreover, registered students will have access to this. A prospective student can choose from the list of courses and enroll, and as the course progresses the educational institute course will be rated by the student body before they receive their end grade and degree. The registration will be controlled by the smart contract along with the ratings process and enrolment.

An example of this is a student named Alice. Alice is inspirational and looks toward educational institutions that will assist her in her development. Alice would like to take an English language course online, and finds an educational institution in which her course is highly ranked, and she looks to enroll.

1. Alice ***send*** on blockchain to the smart contract to register.
2. Alice then sends a ***request*** to look at the specific courses that are offered by her intended educational institution.
3. Alice finds a course that matches her requirements, with modules looking at the development of the English Language from Chaucer to the age of Shakespeare.
4. Alice ***requests*** to enrol.
5. After ***sending*** an enrolment request, Alice will have to await confirmations. Plus, she must fit certain regulatory requirements for example:
   - If she applies after the closing date she will be rejected.
   - If the course is already full she will be rejected.
6. If successful she will ***receive*** a confirmation.
7. Her lecturer, is called Bob. He will ***deliver*** the opening module to her.
8. The assignment, completes it and ***sends*** the back to Bob.
9. Throughout her course Alice is continually assessed by way of assignments set by Bob and other lecturers.
10. The assignments and subsequently ***store*** the grade and solution locally.
11. At the end time on the course, Alice will ***rate*** the experience at the educational institution.
12. Bob will ***place*** the encrypted end score for Alice onto the blockchain. Her final grade will be a weighted average of her scores throughout the course.

13. Grade will be dependent upon her overall percentage (A 1st for 70% and above etc.).
14. Alice will ***gain*** the course badge depending on her grade. This badge is stored on the blockchain.
15. A score of less than 40% would equal an end fail for any student. No badge will be awarded as a result.

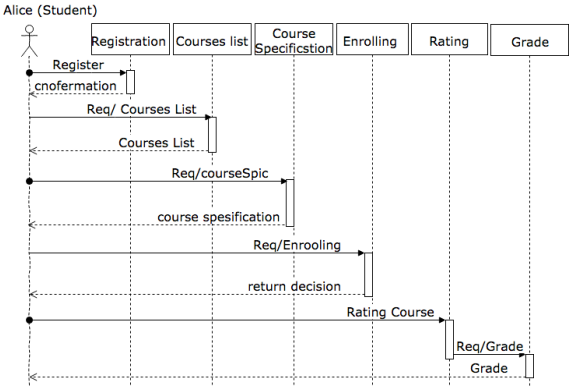

Figure 2: Student Sequence Operations Diagram.

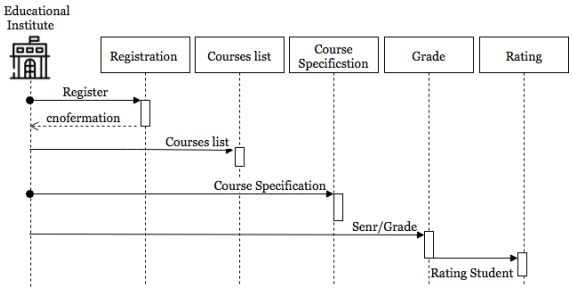

Figure 3: Educational Institutions Sequence operations Diagram.

Operations are in bold, such as request to register, a rejected request, assessed, send a notification, store data, gain reward, etc. Though the operations are relatively straight forward, they are realistic enough to illustrate our arguments. Also, as can be seen in our motivation scenario, the communication between participants occurred on two different platforms" on-chain and off-chain"as follows:

- On Blockchain: steps 1 to 6, 10, and 12 to 15.
- Off-chain: steps 7 to 10.

6.2 Prototyping Proof of Concept

To achieve the objectives of this research, we have proposed a prototype Figure 4 to cover the needs of the learning process while covering the gaps in the current systems. It is evident that the characteristics of blockchain previously presented in section 1.1 may

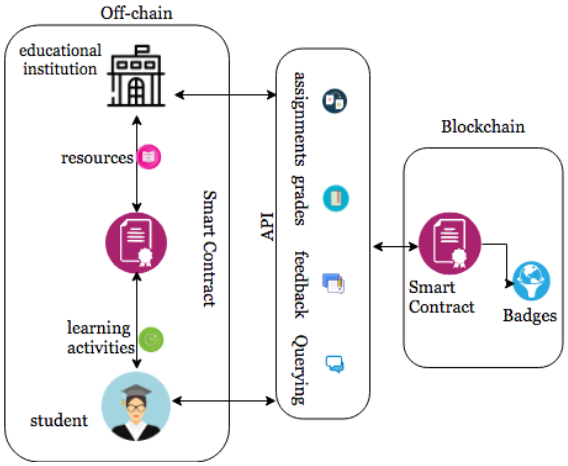

Figure 4: Possible Solution System.

not be sufficient to cover those gaps in the educational process, requiring a large number of correspondence between the parties, which contain sensitive data that may not be suitable for storage on the blockchain. The process may also require the instruction to save comprehensive data that does not match the characteristics of the blockchain. However, given the need for a learning environment where trust, consistency, traceability, and transparency are present, blockchain is extremely appropriate. To cover this gap, we proposed a prototype that in education applications, will combine both approaches into solutions where some sensitive operations are conducted on the blockchain, while the others are off-chain.

The scenario prepared in section 6.1 outlines in principle several of the contractual processes that occur between the parties during the learning process, for example, registration request, restrictions and application, acceptance of the offer and sending confirmation, etc. In Figure 4, the on and off contractual chain operations are presented. We have illustrated these operations and clauses in bold in our scenario. Although simple, they are realistic enough to represent our arguments. From the description above and as illustrated in Figure 4, our solution contains two specific types of operations: on blockchain and off-chain operations and transactions. They are classified as follows:

1. On-Blockchain: Various activities occur on the chain. Trust related issues, for instance, communication, immutability related matters, for example, learning records and replication-associated matters such as awards.
2. Off-chain: What cannot be conducted on Blockchain.

7 CHALLENGES

This research contains several challenges that need to be addressed. First, the ability to manage the complexity of working with blockchain technology by the participants either students or educators is one of the primary challenges of this research. Second, modeling such a solution requires a comprehensive understanding of different blockchain platforms characteristics, in-depth knowledge of education and learning environments as well as related datasets, logs, and other relevant matters. Third, incorporating our solution into the blockchain environment without compromising blockchain decentralization. Merging the learning procedure within the blockchain environment will be challenging. We will also implement our solution both off-chain in a centralized fashion, as well as on-chain, meaning that the nature of the system will be hybrid instead of being fully decentralized. A fourth challenge will be the selection of the most appropriate methods and tools that would best accommodate these research challenges. Fifth, this research includes coping with new concepts, for instance blockchain and smart contracts, as well as bridging the knowledge gap regarding creating and testing education and learning issues. Finally, it will be essential to conduct interviews with several stakeholders (such as educators, students, administrators, etc.), in order to obtain their perspectives regarding how they perceive the use of blockchain and smart contracts as a medium for the learning environment.

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