Smart Contracts for e-Learning

Tsz Yiu Lam
1443964

Supervisor: Dr. Brijesh Dongol

Department of Computer Science
Brunel University London

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I would like to dedicate this paper to Mum, Dad, Vivien, Viviana and Jorden.

Abstract

The properties of a distributed ledger could bring new features to e-Learning. Properties such as immutability and peer executed smart contracts could bring a new level of trust, transparency and personalisation to the education market.

This project focused on features that would improve the experiences of students and teachers in assessments, and curriculum personalisation. They were identified as two of the key concerns in the current UK higher education industry that can be improved by a distributed ledger powered e-Learning platform.

The logic of the smart contracts and data models for such a platform were proposed. A working prototype was also developed based on the IBM Hyperledger Composer project.

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Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements.

Tsz Yiu Lam

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Chapter 1

Introduction

The global e-Learning industry already generates US$60 billion per year, and by 2019, over half of all courses will be taken online (Pantò and Comas-Quinn, 2013, p.17). This rising trend presents an opportunity to improve higher education.

Some current problems in higher education are related to transparency. [TODO: what is transparency?] Tension exists between the educational provider and the learners over assessments. "There is abundant evidence that assessors are not particularly good at making exams valid, reliable, or transparent to students." (Brown Jr, 1999, p.62).

There is also a lack of curriculum personalisation for higher education learners in the UK [TODO: due to..., ref Rob] Condie and Munro (2007) pointed out that the personalisation of the education curriculum for learners helps "overcome barriers, raising self-esteem and achievement". Current web, mobile and computer technologies today can provide more personalisation of education curricula, but lacks [TODO: common marketplace? promise of delivery? transparency for employers?]

Being able to deliver education curricula and conduct assessments in a transparent, conflict-free way would be central to a future e-Learning marketplace that is open, trusted and autonomous. This is where immediate value could be provided by distributed ledger systems and smart contracts.

A distributed ledger is a type of database that is spread across multiple sites, such as different institutions, companies or participants. Validators or operators of this ledger are trusted not to collude and defraud actors in a transaction. The technology enabling this distributed ledger is popularly known as a blockchain, where a block of records is chained to the next with a cryptographic signature, creating immutable records through a consensus corroborated by all the operators. (Walport, 2016, p.17) The security, immutability and verifiability of all actions on a blockchain provides the system with maximal transparency. [TODO: cite something]

Smart contracts are "contracts" that are "defined by the code and executed (or enforced) by the code" (Swan, 2015, p.16). They are logic embedded in a blockchain that defines the rules and penalties around an agreement and automatically enforce those obligations (Gulhane, 2017), and can be used to exchange or transfer digital assets when certain conditions are met.

The potential of blockchain enabled systems in education has been noted by the community, with Swan (2015, p.62) proposing that “learning smart contracts could automatically confirm the completion of learning modules through standardized online tests”. Appropriate configurations in permissions and visibility can also provide improved security and privacy to e-Learning.

1.1 Aims and Objectives

The aim of the project is to:

Design a system that fulfill educational assessments and rewards with smart contracts on a blockchain, providing improvements in assessments and curriculum personalisation for learners and teachers.

To satisfy this aim, the following three objectives were planned:

1. Identify issues in e-Learning that can be improved by a blockchain based system.
2. Propose network data models and the smart contract logic in the proposed blockchain for e-Learning.

3. Build a demonstrator system that includes client side applications for learners and teachers.

1.2 Project Approach

1. Review literature on current issues in e-Learning and education, and existing work in blockchain in education.
2. Further gather requirements for a blockchain solution for e-Learning using interviews with stakeholders.
3. Design smart contract logic and data models for assets and participants in the proposed blockchain solution.
4. Analyse popular blockchain development platforms that can be used to produce the desired solution.
5. Build the distributed ledger network and client side applications for learners and teachers.
6. Evaluate the design of the deliverables using interviews with stakeholders and relevant subject matter experts.

1.3 Dissertation Outline

Chapter 2 discusses the background for my project, and identifies some key techniques that can be adopted during the development of the proposed solution.

Chapter 3 explains how the project will be undertaken . . . etc, etc.

Chapter 4 design

Chapter 5 implementation

Chapter 6 evaluation

Chapter 7 conclusion, future work

Chapter 2

Background

2.1 Review of Relevant Education Research

Identifying issues in traditional higher education today that a future system can better tackle better is one of the objectives of this project. This informs the scope of the project and the design of the deliverables.

There is an abundant amount of pedagogy and learning method research, which is into how to deliver more effective teaching and learning experiences, with some proposed methods such as "scaffolding", "constructivism", "problem-based learning", and "active learning".

2.1.1 Assessments: Tension and Transparency

Assessment is arguably the most important process in the business of education as it "drives what is learnt and taught" and "convert learning into credentials". (Campbell, 2010, p.160) This importance inevitably grows the tension between the teacher (or educational provider) and the learners over assessments.

Suhre et al. (2013) looked into motivation on study progress in a higher education setting by collecting data from 168 first-year university students for six months. The study found three main factors that motivates academic progress: intrinsic abilities, personal motivations such as a need to achieve or fear of failure, and transparency in exams and assessments.

- Students' perceptions of degree programme organization and transparency of exams are also significantly correlated with academic performance;
- Academic pressure is substantially influenced by the perceived transparency of assessments.

Transparency here refers to both the clarity of assessment goals and the procedures for assessing these goals. It should be clear to learners what knowledge is required for a sufficient level of mastery. (Suhre et al., 2013)

2.1.2 Personalisation in Education

Cover personalisation broadly and in terms of curriculum (which modules to take, customised passing thresholds) which can be negotiated on the blockchain. To be added if there is time for the project to cover this area.

2.2 Review of Relevant e-Learning Research

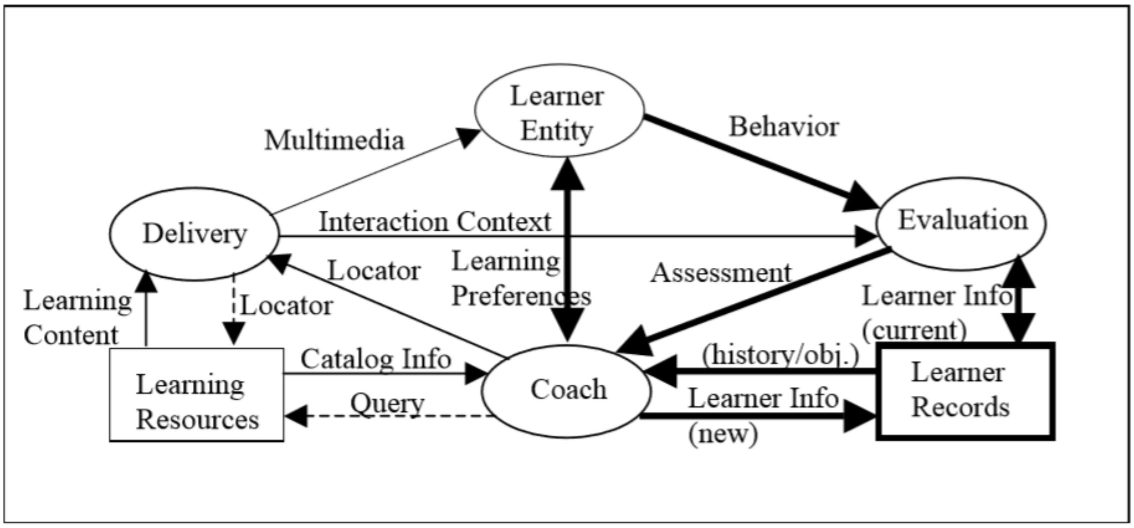

Fig. 2.1 Learning Technology Systems Architecture, IEEE P1484.1/D9 (Farance and Tonkel, 1999)

E-learning has been growing as an industry and research area, and various standards have been devised. One of the most useful is IEEE P1484.1/D9: the Learning Technology Systems Architecture (LTSA). It provides a valuable way of organising the scope and discussion around proposed e-Learning systems, identifying four main components: learner entity, coach, delivery and evaluation; and two main resources: learning resources and learner records (See figure 2.1).

Identifying what a future, blockchain based system could improve in these critical areas can further enhance this project. Garrison (2011) identified several areas that current e-Learning research and practices focus on:

- Enhancing the learning community and social presence
- Enhancing the cognitive (practical inquiry and critical thinking) presence, especially with asynchronous (pre-recorded)
- Self-regulation and motivation: a self-regulated learner achieves more
-

2.2.1 Self-Regulation and Motivation

An e-learning programme should equip a learner with these self-regulation skills, and the e-learning system should provide tools that facilitate and enable the motivation strategies.

2.2.2 Security and Privacy

The security of e-learning systems have also been a concern. For example, El-Khatib et al. (2003) noted that “While many advances have been made in the mechanics of providing online instruction, the needs for privacy and security have to-date been largely ignored. At best they have been accommodated in an ad-hoc, patchwork fashion.”

2.3 Properties of Blockchain Technologies

Impossible to collude: executed by transparent code, increase trust and enables reputation building for even new entrants to the education market Protects learner: guaranteed records and rewards Administration costs of higher education Smart Contract: secure and cutting the middleman

Characteristics of a blockchain ledger such as Hyperledger: 1. Shared Ledger: shared across education and government authorities 2. Smart Contract: Swan (2015, p.62) proposed that "rules embedded in learning smart contracts could automatically confirm the completion of learning modules through standardized online tests". 3. Privacy: a. Appropriate Visibility b. Transactions are secure, authenticated and verifiable 4. Consensus: All shared ledger parties agree to transactions

Openness and transparency of online courses and online assessments is encouraged: using an interpreted language, instead of a compiled one, to write the smart contract, so the actual code is visible on the blockchain and can be easily inspected be removed or altered Resilient to loss of infrastructure: records are distributed over a network of participating computers

2.4 Existing Efforts in Blockchain for Education

2.4.1 Blockcerts

A current blockchain in education use case: Blockcerts Blockcerts is an MIT backed open standard for blockchain certificates. Education providers can use it to store the records of certifications they have awarded, in a way where they are immutable and decentralised.

2.4.2 OpenLearn

Chapter 3

Approach

3.1 Agile Project Management

3.2 Software Development and Testing

Chapter 4

Requirements Elicitation

4.1 Interviews with Education Professionals

And now I begin my third chapter here ...

4.2 Interviews with Student Representatives

Chapter 5

Design

5.1 Participants, Assets and Transactions in the Blockchain Network

And now I begin my third chapter here . . .

5.2 Logic and Events in Smart Contracts

Chapter 6

Implementation

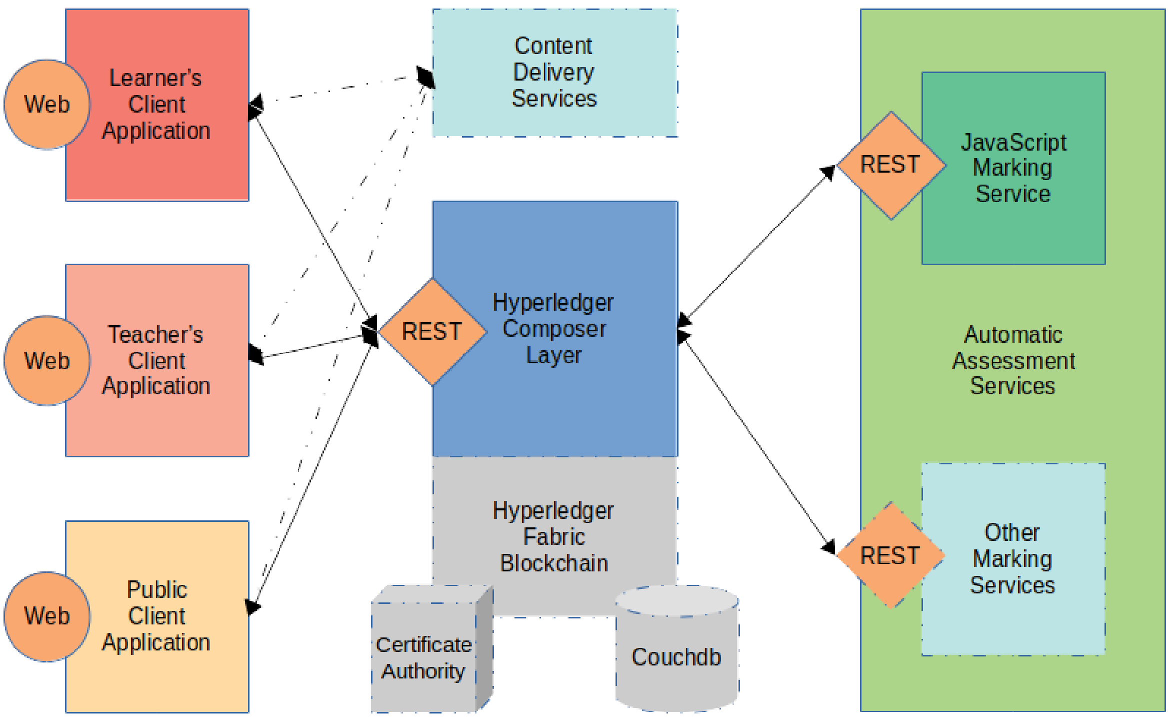

Fig. 6.1 Technical architecture overview for the demonstrator system built

6.1 CLI and API

6.2 Learner Client Application

6.3 Teacher Client Application

Chapter 7

Evaluation

purpose of eval

7.1 Methodology

instruments: appdx

sample

7.2 Interviews with Education Professionals

7.3 Interviews with Student Representatives

7.4 Analysis

7.5 Conclusion

Chapter 8

Conclusion

8.1 Future Work

and here I write more ...

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Appendix A

How to install LaTeX

Windows OS

TeXLive package - full version

1. Download the TeXLive ISO (2.2GB) from
   https://www.tug.org/texlive/
2. Download WinCDEmu (if you don't have a virtual drive) from
   http://wincdemu.sysprogs.org/download/
3. To install Windows CD Emulator follow the instructions at
   http://wincdemu.sysprogs.org/tutorials/install/
4. Right click the iso and mount it using the WinCDEmu as shown in
   http://wincdemu.sysprogs.org/tutorials/mount/
5. Open your virtual drive and run setup.pl

or

Basic MikTeX - TeX distribution

1. Download Basic-MiKTeX(32bit or 64bit) from
   http://miktex.org/download
2. Run the installer
3. To add a new package go to Start » All Programs » MikTex » Maintenance (Admin) and choose Package Manager

4. Select or search for packages to install

TexStudio - TEX editor

1. Download TexStudio from
http://texstudio.sourceforge.net/#downloads

2. Run the installer

Mac OS X

MacTeX - TEX distribution

1. Download the file from
https://www.tug.org/mactex/

2. Extract and double click to run the installer. It does the entire configuration, sit back and relax.

TexStudio - TEX editor

1. Download TexStudio from
http://texstudio.sourceforge.net/#downloads

2. Extract and Start

Unix/Linux

TeXLive - TEX distribution

Getting the distribution:

1. TexLive can be downloaded from
http://www.tug.org/texlive/acquire-netinstall.html.

2. TexLive is provided by most operating system you can use (rpm,apt-get or yum) to get TexLive distributions

Installation

1. Mount the ISO file in the mnt directory

   ```
   mount -t iso9660 -o ro,loop,noauto /your/texlive####.iso /mnt
   ```

2. Install wget on your OS (use rpm, apt-get or yum install)

3. Run the installer script install-tl.

   ```
   cd /your/download/directory
   ./install-tl
   ```

4. Enter command ‘i’ for installation

5. Post-Installation configuration:
   http://www.tug.org/texlive/doc/texlive-en/texlive-en.html#x1-320003.4.1

6. Set the path for the directory of TexLive binaries in your .bashrc file

For 32bit OS

For Bourne-compatible shells such as bash, and using Intel x86 GNU/Linux and a default directory setup as an example, the file to edit might be

```
edit $~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/i386-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

For 64bit OS

```
edit $~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/x86_64-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
```

```
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

Fedora/RedHat/CentOS:

```
sudo yum install texlive
sudo yum install psutils
```

SUSE:

```
sudo zypper install texlive
```

Debian/Ubuntu:

```
sudo apt-get install texlive texlive-latex-extra
sudo apt-get install psutils
```

Appendix B

Installing the CUED class file

LATEX.cls files can be accessed system-wide when they are placed in the <texmf>/tex/latex directory, where <texmf> is the root directory of the user's TEXinstallation. On systems that have a local texmf tree (<texmflocal>), which may be named "texmf-local" or "localtexmf", it may be advisable to install packages in <texmflocal>, rather than <texmf> as the contents of the former, unlike that of the latter, are preserved after the LATEXsystem is reinstalled and/or upgraded.

It is recommended that the user create a subdirectory <texmf>/tex/latex/CUED for all CUED related LATEXclass and package files. On some LATEXsystems, the directory look-up tables will need to be refreshed after making additions or deletions to the system files. For TEXLive systems this is accomplished via executing "texhash" as root. MIKTEXusers can run "initexmf -u" to accomplish the same thing.

Users not willing or able to install the files system-wide can install them in their personal directories, but will then have to provide the path (full or relative) in addition to the filename when referring to them in LATEX.