On-chain Services for Education in Slums and Refugee Camps

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***Abstract*—A mechanism has been developed whereby students receive rewards in a cryptocurrency, the SmileyCoin, as they progress in their studies in an open on-line educational system, the SmileyTutor, developed for personalised learning, not testing. The students' study in SmileyLibraries, using tablets donated to the libraries by the SmileyCharity. They then use these coins to make purchases in stores, which are registered as services on the SmileyCoin blockchain. Students can also opt to receive a Universal Basic Income in SmileyCoin. The approach was implemented by the SmileyCharity in response to school closures due to COVID-19 and reached 5000 students in Kenyan slums and refugees camps as of June 2024. A SmileyGuide is placed in charge of the project within each SmileyLibrary. The SmileyCharity reimburses the SmileyGuides for the actual costs associated with the SmileyStores, effectively buying back the SmileyCoin. The blockchain is a critical component of the mechanism where reimbursements are made for students purchases in a non-trusted environment.**

***Keywords*—cryptocurrency, blockchain, technology in education, universal basic income**

I. Introduction

The SmileyCoin cryptocurrency was introduced in 2014 [1] as a method to reward students using the open and freely accessible SmileyTutor (formerly tutor-web) educational system [2–4]. The coin is a Bitcoin derivative [5], from Litecoin source code [6], with a premine used to set up the SmileyCoin Fund to support projects such as the SmileyTutor, but subsequently also borrowing features from several other coins, including Auroracoin's implementaion of multiple hashing algorithms [7]. Earlier developments included a mechanism to reward SmileyCoin investors and automatic donations to charity, both implemented by splitting the coinbase [1].

Given that the SmileyCoin is intended as somewhat unusual reward mechanism in education, it much be considered in relation to (a) the use of incentives in education in general and (b) the use of cryptocurrencies in the context of students and schools. Both of these aspects are described in detail in [1] and references therein.

The first users and test subjects of the reward system were students at the University of Iceland (UI) but students in Kenyan community libraries have since far exceeded the Icelandic students in number. For a reward system to be useful, the rewards have to have some sort of value to the recipient and in the first year, a coffee shop on the UI campus sold coffee for SMLY. Shortly thereafter a web page, smly.is was set up to sell a variety of coupons for SMLY. The web page was simple enough: A menu of coupon providers was shown. Once a coupon was selected, the page showed an address where the student could send their SMLY. Coupons initially included discount coupons from companies, for movie tickets and even a domestic airline. The web page functionality has since been closed as it is superseded by the services described in this paper, which now include registrations of coupons (described in Annex A).

When introducing the cryptocurrency to new users such as students in a new class, it has become quite clear that use cases are critical. The mere availability of options such as purchasing coffee or various discount coupons for SMLY lends immediate usefulness to the coin and clearly arouses curiosity and interest. In the Kenyan case, the primary use case is that the students borrow tablets which they can subsequently purchase by earning SmileyCoin through hard work in the SmileyTutor. Later on, more general store purchases have been enabled in Kenya. Further options are needed for students in other countries. Some of the implemented options have been developed using new on-chain services described below. Overall, the process is that students in low-income regions usually borrow tablets in local libraries affiliated with the Smiley Project, called a SmileyLibrary and are allowed to use the tokens within the library in a store, typically called a SmileyStore.

The SmileyTutor has been developed as a research tool into the effectiveness of different on-line educational strategies. The system along with and results from this research are described in detail elsewhere [2–4, 8, 9]. The SmileyCoin is similarly intended as a research tool, testing different methods and uses of cryptocurrencies and blockchain technology. Most of the SMLY developments and tests to date have been either purely

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experimental or been in relation to student rewards. Examples of general tests and developments range from on-chain messaging to an online ATM (Automatic Teller Machine) for swapping between Litecoin and SmileyCoin, where all messaging is on-chain. The coin has also been used as a basis for a course on blockchain and cryptocurrencies, leading to multiple student projects including on-chain anonymous elections.

Further developments include implementations of Universal Basic Income, on-chain coupon sales and general on-chain registration of organizations intending to receive SmileyCoin, as described below.

II. Extending Blockchain Functionality for Use in Slums and Refugee Camps

A. Background

In this section we will describe how one can extend the traditional blockchain in such a way that it can be made more directly useful and have increased usability within the slums and refugee camps. The goal is to make use of the SmileyCoin as easy as possible for students who may not even be used to handle traditional financial transactions, let alone credit cards or mobile money. Thus, students using borrowed tablets should be able to pay SmileyCoin to a SmileyStore using a simple pull-down menu to identify their store. This requires the ability to look up the list of stores from within the cryptocurrency wallet, which again requires SmileyStores to be registered somehow. This is implemented by registering the stores on the blockchain, thus providing immediate access from block explorers as well as all wallets, including web-wallets commonly used by students.

In addition to simple registration, it is quite useful to be able to sell coupons through the blockchain, but this requires encryption of the coupon before writing its value to the chain [10, 11]. This uses a feature of Bitcoin-derived blockchains, namely that the public key for a user's address becomes known once an amount associated with the address is spent. The public key is embedded in the corresponding transaction. Although there may be many public keys embedded in a single transaction, these are usually all associated with the same wallet and it becomes irrelevant which one is used if the sole point is to transmit something back to the sender.

B. On-chain Registries

To make cryptocurrency use as easy as possible, one method is to register services directly on the blockchain. This will then permit direct lookups from within the corresponding wallets. In principle the service could be anything, but on-chain services are the obvious starting points. Such services might be smart contracts which automatically respond to payments, but could also be simpler services such as information releases in response to payments.

The first step to implement an on-chain service is to define how to store information about the service, followed by a coding scheme to be used. Here a "service" is a SmileyCoin address plus a classifier for the service type. This is done here using a layer-2 protocol, i.e., a protocol which is defined outside the blockchain but uses the chain for syncing and/or messaging. Such protocols are fairly common in the traditional (Bitcoin-style) blockchain world, though possibly best known through approaches to offload work such as high-frequency cryptocurrency transactions from the blockchain onto sidechains or other databases [12].

As an example of an on-chain service, consider on-chain registration of organizations. One can first generically define a *service* such as shoe-sales as a single address. This service is then a top-level definition of a service. A deposit address for a specific shoe-store can then be registered as an entry under this service-class. Depending on permissions granted by the registration system, registration and deletion may be allowed to the owner of the shoe-store or the owner of the service (aka the holder of one or both private keys).

The principle of on-chain registries is really quite trivial since most blockchains already contain a text-field normally called the OP_RETURN field. As an example, consider the creation of a service called "eBooks" using the command:

smileycoin-cli createservice eBooks
B52ABWfoQCW8SgLFJX2PkobkTysUF19zk3 8

the "8" is an indicator of an "organization" resulting in SMLY transaction with id (TxID).

8f1e9e0c37f98f837aa812981e64d38dd08d5b906dfde285
0f67817f07aedb08

When viewed in a block explorer, it can be seen that this transaction includes a special code "NS" to indicate a "New Service".

Use cases of these "services" are described in the following subsection. Again, when viewed in a block explorer it is seen that the transaction includes a payment to a specific address:

B9TRXJzgUJZZ5zPZbywtNfZHeu492WWRxc

and this address is a control address for the creation of new services.

It is important for a given use case that there is a way to indicate which OP_RETURN fields are actual registrations and not just random noise. Here, a fixed deposit address is used as an indicator, along with the "New Service" code.

To complete the registration for this use case, an actual organization needs to be registered in the service class "eBooks". To register an organization, a new command is used:

smileycoin-cli addorg eBooks
B7ewEtKxArmu9TAEncJyRPxjkFk6BrGnoq
"Project_Gutenberg"

resulting in a TxID of:

8a84b14b92995e3dddce606e9993c8e4226e1d38d686476
5fec6d45c2151cb02

It should be noted that the OP_RETURN field is really quite simple, as seen in a block explorer:

NN B7ewEtKxArmu9TAEncJyRPxjkFk6BrGnoq Project_Gutenberg

indicating that this is a "New Non-profit" registered under the name "Project_Gutenberg", corresponding to the indicated deposit address. Note that the transaction also includes a payment to the owner of the service defined earlier in the createservice command.

In most cases one would expect that only the owner of the service is interested in or permitted to register the sub-units (organizations or recipients) in which case the payment is not of interest. However, it is certainly possible to envisage a company asking people to sign up to receive newsletters or the like. The payment can then be set to an appropriate amount.

C. On-chain Registries for Universal Basic Income

Students are the largest user group of the facilities described here, particularly students in low-income regions and refugee camps. By the end of 2023, simple stores (SmileyStores) had been set up in some 38 locations to permit sales of small items for SmileyCoin. Students who earn SmileyCoin in the SmileyTutor can thus purchase small items for SMLY. There is no guarantee that a student or librarian in a Kenyan slum knows how to operate cryptocurrency wallet so the library stores have all been registered on-chain and payments are done by the student using simple menu operations.

The students can earn SmileyCoin while studying in the SmileyTutor, but there is something to be said for providing even easier access to some basic nourishment. One way to do this is to make available a minimal Universal Basic Income to all students who join the libraries.

UBI can be implemented using the general service-mechanisms mentioned above. First, a service class is defined and identified by the library:

smileycoin-cli createservice ubiRukira B8eiYCFeeFgaQMW18EyKFj6giMJ4xnFsYK 2

"2" being the code for a UBI service. After this the UBI recipients are registered into the group, one at a time. This is preferably done anonymously. In this case study the librarian collects the addresses which the service handler subsequently records into the chain:

smileycoin-cli addubi ubiRukira BD8mKfoCLkQbpRiHkvi6RQeLrGAd3rhVMe

A better system would be to have an improved blinding mechanism as would be implemented in a voting scheme, but this is not (yet) feasible.

III. Implementation: African Case Study

The system has been implemented in African slums and refugee camps. The SmileyCharity had worked with a handful of schools earlier, but when schools closed during COVID-19 the charity implemented the **library model** whereby tablets were donated to libraries (which remained open), students accessed the SmileyTutor by borrowing the tablets, and earned some SmileyCoin as they progressed through the drillsets in the SmileyTutor.

A. Usage

An overview of the development is given in Fig. 1. The implementation of the SmileyTutor and the associated reward system started in a few locations around Nairobi. These included the Kibera Community Library, which is a part of the Kenyan National Library System, the Mashimoni School of Hope run by Challenge Aid and a handful of others. It was quickly followed by several other sites, once the systems caught on.

The development of the use of the SmileyTutor and SmileyCoin from COVID-19 and onwards in Fig. 1 shows 7 curves. The curves describe different measures of activity. From the top: (1) The number of activated accounts in the SmileyLibraries; (2) The number of users who have completed a drill set to excellence (grade at least 97.5%); (3) The total number of SmileyCoin (in millions) earned by students; (4) The number of tablets donated and delivered to SmileyLibraries; (5) The number of tablets sold to students, and paid for in SmileyCoin; (6) The number of students who have obtained at least one million SmileyCoin and (7) The number of students who have completed the material related to the mathematics portion of the Kenyan Certificate of Secondary Education.

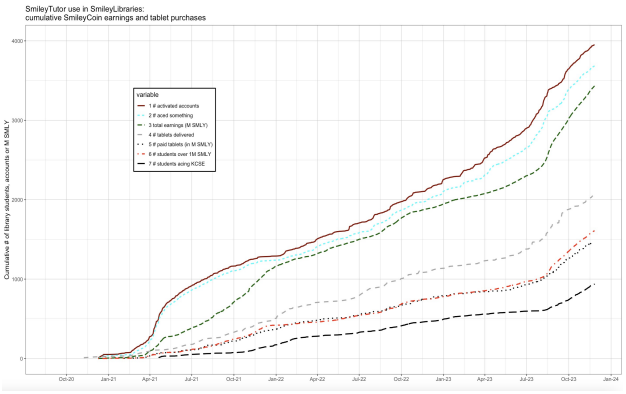

Fig. 1. Development of use.

B. SmileyStores

Library stores (SmileyStores) were set up for the students to make purchases of items ranging from snacks, sanitary pads or data bundles through food for their families or even the tablets themselves (see Fig. 2).

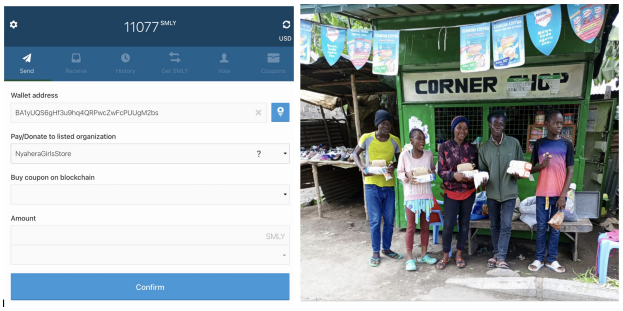

Fig. 2. (a) Snapshot of wallet from wallet.smileyco.in, after selecting a specific SmileyStore and (b) SmileyStore in Nakuru, Kenya.

C. Traceability and Other Details

The **SmileyCoinFund** is an organization with a board which handles a single SmileyCoin address, containing some 9bn SmileyCoin as of July 2024. This is a **multi-sig** address, i.e., multiple signatures are required to spend from the fund. The board accepts applications for SmileyCoin grants to be used for educational purposes. The only applications to date have been from the SmileyTutor and all applications have resulted in a grant. For transparency, all grants are not only sent from the SmileyCoinFund address to a SmileyTutor address, but include a text descriptor describing the grant. The board operates according to a mandate which has been signed both digitally and physically, with a hash of the digital document stored on-chain.

Tablets sponsored by the SmileyCharity to the SmileyLibraries are all labelled with stickers containing a QR-code corresponding to a SmileyCoin address. The student can purchase a tablet by scanning the code and depositing a million SmileyCoin to the address.

The process also involves registering each participating SmileyStore on-chain, which allows the students to select their store from a pull-down menu in a web-wallet. This also allows the charity to look up how much has been deposited to the store in a given week, and reimburse the SmileyGuide appropriately. This particular approach eliminates the need for any receipts and is what makes the project feasible in the slums.

A result of this approach is that purchases can be verified and traced. For example, the student has a receipt for payment directly on the blockchain and this can be verified by anyone through scanning the QR code and verifying the payment on the blockchain. Similarly, the SmileyCharity reimburses individual SmileyGuides by looking up on-chain how much has been deposited to each SmileyStore address.

IV. Conclusion

The present paper is the first technical description of the implementation of a reward mechanism within the SmileyTutor educational system. Quantitative measures on the effects of using the SmileyTutor system are reported elsewhere [13].

The approach described in this paper has been adopted in 45 locations in Kenya, termed SmileyLibraries. Representatives of these locations met at a workshop in Nairobi to describe the results, giving overwhelmingly positive feedback on this use of rewards, with an emphasis on the positive effects of giving students access to stores in SmileyLibraries. In addition to these purely qualitative results, surveys among students indicate that by far most students see the SmileyTutor primarily as a vehicle for studying, but they also intend to use the SmileCoin for purchases.

The blockchain has also been extended to permit on-chain coupon sales such as Amazon gift cards. These are not currently used in the African case study but have been used for students in Iceland and are described in Appendices A and B.

Experiments have been made with replacing the Litecoin-derived SmileyCoin with a new Substrate-based blockchain [14]. Substrate is programming environment developed by Parity Tech to help developers create modular, extensible and interconnected blockchains. This new chain will be known as SMLY3.0 and will overcome most, if not all, of the technical limitations we have run into with SmileyCoin. These issues relate to the limitations of storing data on the blockchain, since OP_RETURN data fields can contain at most 80 bytes, but in addition the new approach will allow much more complex smart contracts. Experiments are also underway with SMLY3.0 as tokens on Etherium-derived chains.

Migration some of the functionality to more flexible blockchains will make decentralized finance possible, as well as native connections to crypto currency exchanges. The new chains will also be more modular and much easier to change and update, along side being a Proof of Stake (PoS) chain, instead of Proof of Work (PoW).

Along with SMLY3.0 on more flexible blockchains work is underway on new smart contracts, where drills can be accessed on-chain. In principle the drills may reside on the chain itself, embedded in a smart contract, or they may be accessed from the smart contract, through an oracle [15].

Appendix A Encrypting on the Blockchain

Ideas on encryption using Bitcoin-style public-private keys have floated around in the public sphere for some time. Although message encryption is not a primary function of most cryptocurrency networks, it was noted already in 2013 that ElGamal encryption (ElGamal, 1985) can be used with these key pairs (Anonymous (jackjack) 2013). This idea has been picked up and implemented in the SmileyCoin core wallet so that the simple command:

smileycoin-cli replywithmessage TxId message

on the Linux command line will extract the public key corresponding to the first input to the transaction, encrypt the message with this key and broadcast a transaction with a nominal number of SmileyCoin along with the encrypted message, in the OP_RETURN field of the transaction.

This simple implementation of on-chain messaging ensures some privacy of the message, yet is enough to form a basis for selling encrypted information on-chain.

Note that there is nothing technically new here: All that has been done is to combine existing technology to allow encrypted messaging on a blockchain. The actual anonymity is of the same level as the anonymity of Bitcoin transactions.

Appendix B On-chain Coupons: Orders and Deliveries

As the SmileyCoin was originally intended as a reward mechanism for students, it is important to set up as many uses as possible. Initially this was done by agreements with an on-campus coffee shop and subsequently (discount) coupons were sold for SMLY through a web-

page (stefansson and lentin, 2017). In the currently active versions, all coupon-services have been moved on-chain as follows.

A basic **coupon code** is a string which the holder can use to redeem goods or obtain a discount on goods. These are commonly used on gift cards for many companies and companies often give coupon codes in large numbers to individuals or charities who can either use them or sell to raise funds for a good cause. A **group of coupon codes** pertaining to a single real-world service will be called a **coupon** in what follows. A single organization may have many such code groups, e.g., for different amounts or different products.

On the SmileyCoin blockchain, a service-type of "1" indicates a coupon-selling organization:

smileycoin-cli createservice "Góði_hirðirinn"
B8X6inPSdvMHis7fxacLvkYH2ZKJeez5HP 1

This defines a service which can subsequently list several coupon collections. This particular organization (The Good Shepherd) is a large non-profit second-hand store in Iceland. Once the on-chain service is defined, individual coupon groups also need to be set up, e.g. a 1000 ISK gift card (about 10USD). Other items on the command line are the expiration date, the price (in SMLY) and the deposit address for payments to get a coupon code.

smileycoin-cli addcoupon "Góði_hirðirinn" "RVK"
"1000kr_Gjafa_Kort" "22/08/202122:00" 200000
BRvtsu7f4ZzNKxwg5bj7yXLE7UTQvW7WDE

Note that the above does not specify the actual codes.

The SmileyCoin wallet has been expanded to look up all registered coupons using the command-line interface (getallcouponlists) and an open-source block explorer has been correspondingly modified to transmit the same output through an API call. The web-wallet correspondingly has a menu to display all coupons available for purchase.

In principle the coupon codes could also be stored on-chain in an encrypted format. A payment to the address should then be in the form of a smart contract which forces the coupon seller to release the coupon code to the buyer when spending the payment, with an appropriate timeout to ensure that the buyer either receives the coupon or the refund in a timely manner. There are several nuances which need to be solved, including the verification of a coupon code being what was paid for, all without publicly revealing the coupon itself.

A simpler approach is to store the actual coupon codes off-chain. A bot with access to all the coupon codes then monitors the chain activity and responds to a payment by encrypting the coupon (sendwithmessage above) and sending it to the buyer.

The web-wallet has similarly been extended with the ability to automatically decrypt encrypted messages.

For the user the purchase of a coupon has therefore become a simple clicking operation which does not require leaving the web-wallet. Although designed for students, these features are openly available to other users.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

AHJ and GS conducted the research; JL wrote the code for the SmileyTutor; BG developed the code for the services on the blockchain; GS wrote most of the paper; all authors had approved the final version.

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References

[1] G. Stefansson and J. Lentin, "From smileys to smileycoins: Using a cryptocurrency in education," *Ledger*, vol. 2, pp. 38–54, 2017.

[2] G. Stefansson, "The tutor-web: An educational system for classroom presentation, evaluation and self-study," *Computers & Education*, vol. 43, no. 4, pp. 315–343, 2004.

[3] A. H. Jonsdottir and G. Stefansson, "From evaluation to learning: Some aspects of designing a cyber-university," *Computers & Education*, vol. 78, pp. 344–351, 2014.

[4] A. H. Jonsdottir, A. Jakobsdottir, and G. Stefansson, "Development and use of an adaptive learning environment to research online study behaviour," *J. Educ. Technol. Soc*., vol. 18, no. 1, pp. 132–144, 2015.

[5] S. Nakamoto. (2008). Bitcoin whitepaper. [Online]. Available: https://bitcoin.org/bitcoin.pdf

[6] Wikipedia Contributors. (2023). Wikipedia. [Online]. Available: https://en.wikipedia.org/wiki/Litecoin

[7] H. Elendner, S. Trimborn, B. Ong, and T. M. Lee, "The cross-section of crypto-currencies as financial assets: An overview," in *Handbook of Blockchain, Digital Finance, and Inclusion*, *Volume 1, Cryptocurrency, FinTech, InsurTech, and Regulation*, Academic Press, 2018, pp. 145–173.

[8] A. H. Jonsdottir and G. Stefansson, "Design and analysis of experiments linking on-line drilling methods to improvements in knowledge," arXiv preprint arXiv:1310.8236, 2013.

[9] G. Stefansson, J. Lentin, A. H. Jonsdottir, E. Eiríksson, and A. Kristjánsson, "Mathematics and incentives in the slums," arXiv preprint arXiv:2211.06304, 2022.

[10] Anonymous (jackjack). (2013). [Online]. Available: https://bitcointalk.org/index.php?topic=196378.0

[11] T. ElGamal, "A public key cryptosystem and a signature scheme based on discrete logarithms," *IEEE Transactions on Information Theory*, vol. 31, no. 4, pp. 469–472, 1985.

[12] M. Jourenko, K. Kurazumi, M. Larangeira, and K. Tanaka. (2019). SoK: A taxonomy for layer-2 scalability related protocols for cryptocurrencies. *Cryptology ePrint Archive*, paper 2019/352. [Online]. Available: https://eprint.iacr.org/2019/352

[13] G. Stefansson and A. H. Jonsdottir, "User experience with educational technology in African slums," *INTED2023 Proceedings*, pp. 3270–3279, 2023.

[14] G. Wood, "Polkadot: Vision for a heterogeneous multi-chain framework," white paper 21, no. 2327:4662, 2016.
[15] A. Pasdar, Y. C. Lee, and Z. Dong, "Connect API with blockchain: A survey on blockchain oracle implementation," *ACM Computing Surveys*, vol. 55, no. 10, pp. 1–39, 2023.