# Blockchain Development for Increased Transparency and Novel Incentives Structures with Wearables in mHealth

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**Abstract.** Blockchain technologies are heavily used in concepts to disrupt monetary platforms or supply chain applications, while there are other potentially well-suited sectors. Individual, personal data like in the sector of wellbeing and health lifestyle is fragmented across multiple silos, and here, blockchains offer a real solution. The blockchain technology is able to increase transparency, provide traceability while keeping pseudonymity, and therefore, enables novel incentive concepts. Towards this end, we implement a prototype for adoption of medical standard information using the Ethereum blockchain on a WearOS device. We found that deploying and running blockchain smart contracts on a consumer smart watch is feasible. While proof of concept was shown for quantified health monitoring, vast developments pose a high technical barrier, with limited documentation available. Further identified obstacles relate to the multifarious, cross-platform means needed for integration into broader projects.

**Keywords:** blockchain, mobile health, wearable devices, wearOS, prototyping

## 1 Introduction

The introduction of blockchain lead to a hype of concepts around decentralized trust with numerous fields of application [1]. Blockchain has evolved as a capable technology to enhance information exchanges between individuals [2] and hence, increase transparency. Nevertheless, in real-world settings, blockchain cases beyond the financial service industry are scarce [3], because the technology is evolving, complex to understand, and not easy to implement. While many positive assessments of blockchains can hold [4, 5], the healthcare sector seems to be underrepresented [6].

The field of wellbeing and health lifestyle is particularly interesting due to very sensitive data and the field itself where the payer, and recipient of benefits or premiums are not necessarily the same identity [7, 8]. In line with that, incentives are diverse, and a lack of transparency opens the opportunity for fraud or adverse behavior [9].

To overcome this, the work at hand describes the development of a blockchain application that facilitates health positive actions by integrating wearable devices like smartwatches, and follows an explorative approach of prototyping [10]. We develop a

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minimal viable product to support research in progress, understand the issues and obstacles for industry transferals, and facilitate further resource-saving activities [11].

## 2 Technical Background

For the underlying blockchain we used Ethereum with its programming language Solidity [12, 13]. In a distributed ledger concept, like for the Ethereum blockchain, multiple hosts are interconnected in a peer-to-peer network and process transactions to persistently keep them in blocks. These blocks are connected through different algorithms and secured by cryptography so that every block references its predecessor. The transactions are signed in a public-private key procedure to avoid identity theft and provide only pseudonymous tracing without further external knowledge [14]. Proof algorithms validate the cryptographic puzzles and are the central security aspect since they are dynamically constructed to require a significant amount of computing power [15], and manipulating them for the network majority becomes practically impossible.

We started with a cross platform approach using Xamarin in Visual Studio 2017 on a Windows 10 machine [16, 17]. During the process, to expand on the Smart Contract functionality, we migrated to Android Studio for a native solution of the WearOs [18] application on a Huawei 2 watch [19]. The Fast Healthcare Interoperability standard (FHIR) of HL7 was used to account for the case to facilitate a healthy lifestyle [20–22].

## 3 System Design

Since we targeted a smartwatch scenario related to wellbeing, we put an emphasize on lightweight development, data security and transferring only minimal data sets. Therefore, we used Geth nodes [23–25] and a connection via the Light Protocol [26, 27], while transactions were signed locally with JSON-RPC [28] to keep the private key on the device. For development, gas price and blockchain complexity were set low.

Our use case, healthy behavioral incentives, follows the idea that people with their fitness trackers, e.g. smartwatches, get a discount on their monthly insurance premium, if they achieve timely goals in the field of quantified self. Here that means a person is supposed to take the stairs daily, which has shown to be a good proxy promoting positive health development [29, 30]. When a certain threshold, e.g. 10 floors or a pulse of 160, is reached, these events get committed into the blockchain. On that basis, an incentive for such positive health enforcement might be granted or maintained.

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### 3.1 Node Architecture

Figure 1 depicts the used nodes and their connections within the developed artifact. While it looks like a fully connected graph is required, it is not the case for the real-world app since Ethereum is able to provide a mesh network. All nodes in a possible network find each other without further ado, but the process is possibly accelerated with so called reserved nodes. While single Geth nodes can be added easily it is important to initially set the network ID to the genesis block for every instance and initialize the Geth data folder. One has to be aware that conflicts are possible for Geth (standard port 30303) and the light protocol (standard port 30304), when hosts serve multiple nodes. Clients are only able to connect after shares between the standard and light protocols are defined via the *-lightserv* command, and a maximum number of peers is set. To have a handy visualization we used a *Parity Node* in a web browser GUI [27]. We found that transactions were broadcasted faster in dense connected networks but to mitigate security risks all nodes were firewalled, and only necessary ports opened.

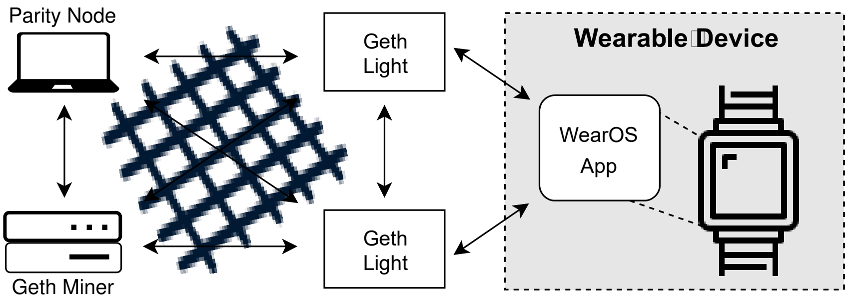


**Figure 1**. Node architecture

### 3.2 Contract Relations

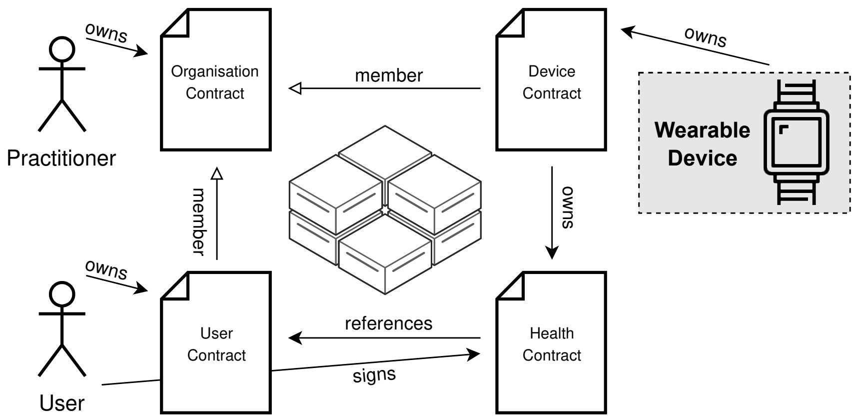


**Figure 2.** Contract relations

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Parts of the FHIR standard including a minimal role management for different actors was implemented in smart contracts as shown in Figure 2. Here, the FHIR identifier was mapped onto the Ethereum network addresses.

The signed contract, i.e. *Health Contract*, is central, since it is processed by multiple other contracts. Since it keeps a reference to the user, and therefore which organization (e.g. insurance company) he belongs to, it is possible to verify the user for later changes. The *Organization Contract* largely represent the FHIR organization at the time of development and is thought to carry information about the insurance's contracts including health benefits and possible discounts. Managers, coaches, and similar admins are active members, which are able to change passive members of this contract, i.e. users and their devices. Changing those practitioners is possible without mining effort when such a function is executed locally with the key word *constant,* implying that there is no data change. The *User Contract* is only a struct, carrying identifiable information of the user itself, but useful for gathering data in a logic collective.

With the *Health Contract*, achieved goals and corresponding values, e.g. floors climbed, were added to the blockchain. A noteworthy difference is that the private key is not used by a human, but transactions are created and signed by the device itself. We implemented multiple constrains to enable functionality like giving the average and allowing only entries within 24 hours prior to the mining time of the recent block. Lastly, the user has to sign the health contract, while the right to sign is derived from the referenced user contract and the sender of the message.

## 4 Discussion and Conclusion

We showed that it is possible to gather data with wearables from the user and write them into the blockchain without any detours. With the use of blockchain technology such, or more sensitive health events, may be tracked timely, persistently, and safely. Additionally, it is possible to make specific data available and track changes for persistently saved data. This is especially useful for cross-functional teams at insurance companies, which are working on blockchain use cases. It is of high interest for health insurance funds to motivate insurees to positive behavior and thereby reduce costs, for example. Hence, we also intend to further develop and evaluate the artifact.

Though blockchain technology itself is believed to go beyond the *Peak of Inflated Expectations* [31], developing this minor application posed a challenge. Solidity and other blockchain concepts are not only a programming language but follow new paradigms and require different ways of building apps. Additionally, at that point in time supporting technologies as well as the documentation were not at a comprehensive level, complicating the learning process and leading to bugs and a lack of functionality.

An alternative to Ethereum would be the Hyperledger project. The sub project Hyperledger Burrow is partially congruent to the Ethereum Virtual Machine [32], but offers more energy efficient proof algorithms. The challenges around the

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decentralization aspect, like the complex organization of FHIR, are similar to the IoT world [33]. Uses cases have to be non-time sensitive or allow for off-chain scenarios, since the validation is slow and wearable devices are not necessarily powered. Handling private keys was an issue in our implementation, is security critical in a real-world application, and is a source of errors as of today. Unless the integrity of the wearable, and therefore the private key, is ensured, it is possible to execute every transaction of a user. Additionally, the application is unforgiving to practical errors, like broken or lost devices. The introduction of an extended role management, e.g. a medical admin, leads to even more entry points for security treats and is a known conundrum of blockchain technologies [34]. For instance, saving identifiable meta data of the FHIR standard off-chain to ensure pseudonymization, implies a partially public blockchain as solution.

Judicious development in the shown directions is mandatory to gain necessary experience helping research and industry thrive the potential of blockchain for decentralized health related use cases and integrate such apps into broader systems.

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