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Approaches to Front-End IoT Application Development for the Ethereum Blockchain

Matevž Pustišek[a,] *, Andrej Kos[a]

[a]*University of Ljubljana, Faculty of Electrical Engineering, Tržaška 25, 1000 Ljubljana, Slovenia*

Abstract

There are several distributed ledger protocols potentially suitable for the Internet of things (IoT), including the Ethereum, Hyperledger Fabric and IOTA. This paper briefly presents and compares them from the IoT application development perspective. The IoT applications based on blockchain (BC) can incorporate the on-chain logic –the smart contracts– and Web, mobile or embedded client front-end application parts. We present three possible architectures for the IoT front-end BC applications. They differ in positioning of Ethereum blockchain clients (local device, remote server) and in positioning of key store needed for the management of outgoing transactions. The practical constraints of these architectures, which utilize the Ethereum network for trusted transaction exchange, are the data volumes, the location and synchronization of the full blockchain node and the location and the access to the Ethereum key store. Results of these experiments indicate that a full Ethereum node is not likely to reliably run on a constrained IoT devices. Therefore the architecture with remote Ethereum clients seems to be a viable approach, where two sub-options exist and differ in key store location/management. In addition, we proposed the use of architectures with a proprietary communication between the IoT device and remote blockchain client to further reduce the network traffic and enhance security. We expect it to be able to operate over low-power, low-bitrate mobile technologies, too. Our research clarifies differences in architectural approaches, but final decision for a particular ledger protocol and front-end application architecture is at strongly based on the particular intended use case.

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Keywords: architecture; blockchain; Ethereum; front end application; IoT

* Corresponding author. Tel.: +386 1 4768844.
E-mail address: matevz.pustisek@fe.uni-lj.si

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1. Introduction

We can observe the initial attempts to jointly use the Internet of things (IoT) and the distributed ledger technologies. These attempts tend to study the feasibility of such an application development approach, provide proofs of concept (PoC) and explore possible business opportunities. The IoT [1] is a well-established concept referring to numerous interconnected things along with the corresponding cloud or fog based applications. It is revolutionizing the Internet and is being deployed in various applications domains. The distributed ledgers on the other hand –which are currently mostly implemented with blockchain technologies (BC)– are still emerging [2]. Nevertheless, they are likely to disrupt the field of ICT systems, services and application just as strongly as the IoT.

The scope of the existing BC systems is divergent in terms of technological features, as well as in their acceptance among the user- and developer communities. With first examples of BC based IoT solution deployments, certain inefficiencies in current BC design started appearing. Micropayments for example have become almost unrealistic in Bitcoin network due to high transaction fees and long transaction confirmation times. The scalability needed for IoT (expected billions of devices) is often limited due to the size of the blockchain and limited transaction rates. The existing BC protocols try facing some of these inefficiencies with functional extensions. In parallel, new ledger protocols are being developed, with IoT requirements built-in from the scratch.

Both developments –the IoT and the BC– are naturally seeking to be combined in common solutions, which thus provide an immense space for application development and use. However the right approach and the selection of appropriate technologies is far from being straightforward. It can crucially depend on the details of the intended use case. A seemingly small change in the foreseen use can lead to a drastic increase in complexity and additional efforts to adapt the solution, or might even be impossible.

The objective of our research is to analyze and present the practical constraints in the development of IoT applications based on Ethereum (ETH) BC. We therefore elaborate and compare the architectural approaches for the design of the front-end IoT device applications based on ETH BC. We implemented three versions of these architectures and evaluated them in terms of performance and security. The research provides directions for the IoT application developers to enable them selecting the appropriate system design and avoiding unrealistic expectations imposed to IoT devices and BC technologies. Their architectural approach can be thus shaped according to the intended use and the specifics of the planned IoT system.

In Section 2 we briefly present the state of the art including the three distributed ledger protocols that currently appear as viable candidates for IoT BC technologies and some cases of use of BC in IoT. In Section 3 we outline the principles of BC application development for IoT. Section 4 presents and compares four different architectural approaches for BC enabled IoT devices and analyzes their positive and negative sides, derived from our practical experimentation. Section 5 concludes the paper with a reflection to the expected future developments in BC for IoT.

2. State of the art

The blockchain technologies are well known fundament of cryptocurrencies, but offer many other possible applications areas, too. There are two key application domains for BC with differing business requirements [3]: the financial technologies (FinTech) and the IoT. Although both the domains require the basic common feature of a decentralized trusted ledger of transactions, substantial differences can be found in e.g. the principle use, volumes and rates of transactions, stringency of the security requirements or in cost of transactions. In FinTech the main challenge is to assure absolutely secure and trusted financial payments, with low transaction volumes and some tolerance to the transaction delays. In the IoT on the other hand, numerous devices and massive transaction volumes are expected, with micro- and nano-payments required for the IoT asset and data monetization. Transaction costs become a relevant issue here, as well as the transaction delays needed for near-real-time operation.

There are not many successful use cases of the IoT BC solutions that reach beyond simple proof-of-concept (PoC) or above the Technology readiness level (TRL) 4 and that incorporate more than just a couple of devices. This is not surprising as the BC IoT application domain still is in its infancy. The activities are directed primarily towards the clarification of the role of the BC in the IoT, testing limitations in implementation and exploring possible business opportunities. Nevertheless, some interesting use cases have been presented, primarily in the domains of smart grid and electric charging, logistics and IoT device management.