KnowLedger - A Multi-Agent System Blockchain for Smart Cities Data

Demonstration Track

Bruno Fernandes
University of Minho
Braga, Portugal
bruno.fernandes@algoritmi.uminho.pt

André Diogo
University of Minho
Braga, Portugal
a75505@alunos.uminho.pt

Fábio Silva
Polytechnic Institute of Porto
Felgueiras, Portugal
fabiosilva@di.uminho.pt

José Neves
Algoritmi Research Center
Intelligent Systems Associate Lab
University of Minho, Braga, Portugal
jneves@di.uminho.pt

Cesar Analide
Algoritmi Research Center
Intelligent Systems Associate Lab
University of Minho, Braga, Portugal
analide@di.uminho.pt

ABSTRACT

Smart Cities introduce novel problems related to the management of inordinate amounts of data of different types and sources. Hence, solutions are required where data may be committed by any actor, being, at the same time, freely available to the community. With this in mind, this study introduces *KnowLedger*, a multi-agent system (MAS) blockchain to store structured data, where a new protocol, entitled as Proof-of-Confidence, is used to award those who commit accurate and reliable data. The obtained results show that the MAS proved to be beneficial not only for data collection but mainly for the maintenance of the blockchain, with the agents being responsible for the entire workload, from data collection to mining.

KEYWORDS

Blockchain; Multi-Agent Systems; Proof-of-Confidence; Smart Cities

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1 INTRODUCTION

During the last decades, the amount and diversity of data that are being collected by individuals, institutions, and companies has grown exponentially. Such data can then be used to produce knowledge and support the decision maker. Indeed, Machine Learning models tend to perform better upon the presence of larger volumes of data.

This manuscript presents *KnowLedger*, a multi-agent system (MAS) blockchain to store structured data. Its main goal is to store data in a way that it becomes freely available to the community, promoting accurate and reliable data. To avoid data integrity and trust issues [6–8], *KnowLedger* makes use of a disruptive blockchain solution that is operated and maintained by fully-autonomous intelligent agents. To prevent malicious agents from spamming *KnowLedger* with incorrect data, a new protocol, entitled as Proof-of-Confidence (PoC), was established. The PoC enables a scoring environment for a system comprised of a multitude of agents, where each one is encouraged to provide accurate data.

It is worth highlighting that the use of blockchains in association with MAS is an emerging topic [1], with many studies being focused on producing conceptual work [1, 5, 10]. In fact, multiple studies have highlighted current limitations of state-of-the-art blockchains in supporting MAS design and implementation [1, 2], being this the main reason why *KnowLedger*'s blockchain was designed and conceived from scratch. Taking the opportunity to present new developments in the domain of agent-based blockchain systems, this demonstration focuses on the ability of MAS to operate a blockchain, with a set of fully-autonomous intelligent agents being responsible for the data collection process while others are responsible for working and maintaining the blockchain.

2 THE BLOCKCHAIN

In Smart City scenarios, one must consider the existence of large amounts of data and high velocity data streams [9]. Hence, to reduce the computational load of the solution, *KnowLedger* implements a multi-chain architecture to maintain independent sets of data, with childchains representing geographical locations and datachains isolating different data types (Figure 1).

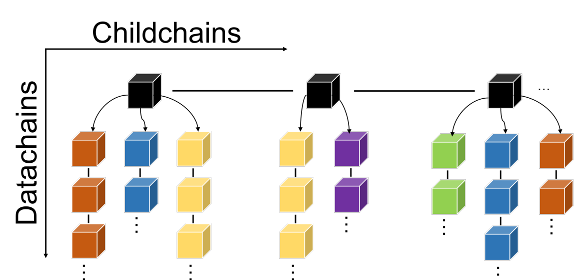

Figure 1: KnowLedger's blockchain representation

Within *KnowLedger*, both Proof-of-Work (PoW) and the conceived PoC are used to confirm blockchain consensus. It presents

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however some key differences in regard to the used PoC, in particular, (1) the unit of transaction is the collected data, tagged with a timestamp and the agent's identification; (2) the cumulative score of an agent is monotonically increasing; and (3) the median score per transaction provides a way to measure the confidence on an agent. Blocks are considered full when they are populated with enough transactions as to achieve either a fixed amount of ceiling or fill the maximum allocated block size (currently, 2 MB). It should be noted that *KnowLedger*'s transactions, differently from other blockchains, do not require a recipient since nothing is being exchanged between agents (only data is being committed). As data transactions do not codify any semantics of expenditure, as in cryptocurrencies, they are never invalidated by cancellations, lack of funds, or other expiration of any kind.

Since everyone is allowed to contribute to *KnowLedger*, mechanisms to control the quality of the committed data must arise. This is ensured by the PoC protocol, which is described in [3]. Overall, an agent's goal is to maximize the confidence others have on him by providing accurate and reliable data. Accuracy and reliability are set in terms of data that tend to follow a pattern when committed by several actors during a period of time. This comes from the observation that physical data tends toward homogeneity for reduced time-frames. The PoC scoring is thus calculated via relative measurements, namely ratios between data values and timestamps, restricted to a specific geographic area. The formula to calculate the PoC of a transaction is thus broken into three different components, being based on a comparison between the transaction to be added, subscript a, and the transaction closest in time to it, subscript c. While the first component extracts a relative measurement between the timestamps (δ_t), the second component evaluates the data values (δ_v). The last component is a small additive base component, which guarantees a base incentive to provide data (noted as *base*):

$$\delta_t = \frac{|t_c - t_a|}{t_c} \quad \text{and} \quad \delta_v = \frac{|\sum v_{ci} - \sum v_{aj}|}{\sum v_{ci}}, i \in v_c, j \in v_a \qquad (1)$$

At the time of writing, the default PoC formula is one that values δ_t over δ_v, with a small *base* component, effectively prioritizing a dense timeline of data. Its formula is as follows:

$$\frac{(\delta_t \cdot base_t)^2 \cdot \frac{\delta_v \cdot base_v}{4} + base}{divisor} \qquad (2)$$

3 THE MULTI-AGENT SYSTEM

KnowLedger's proposal of a MAS blockchain is related to the ability of having multiple intelligent agents interacting with each other and with the blockchain. Each agent perceives the environment it is working on and takes action to maximize its reward. These agents carry important characteristics that help strengthen *KnowLedger*, in particular their autonomy and local view of the problem, with the whole MAS in itself comprising a set of agents that are able to tackle the bigger picture and manifest self-organization.

Agents have the ability to work autonomously, sharing ontologies and interaction protocols that, when coupled with blockchains, lead towards the conception of fully decentralized, immutable autonomous systems [4]. To interact with the blockchain, agents are required to have a cryptographically secure identity based on an asymmetric public and private key-pair. The public identity is the one being referenced and tracked by the blockchain, with the data supplied by an agent being signed with its private key.

KnowLedger's MAS comprises two main autonomous entities, with distinct behaviors. *Worker Agents* are the ones responsible for collecting and processing the data that are gathered from heterogeneous sources (*data capture* behavior). Architecturally, each worker agent manages its own data sources, being able to instantiate new worker agents that are, for example, responsible for a specific data type. *Ledger Agents* are the ones responsible for building and maintaining the ledger. They receive pre-processed data from worker ones, create transactions, and then mine the blocks (*mining* behavior). To guarantee that the transactions will eventually populate a block, there must be a periodic diffusion of all not yet committed transactions (*synchronization* behavior). All behaviors were implemented as simple, ticker, and cyclic behaviors. Synchronization follows well-defined ontologies, including actions, concepts, and predicates, to ensure proper communication between agents.

4 DEMO

The demonstration focuses on a production environment for *KnowLedger*, with real data from multiple cities (climatological, pollution, and traffic flow data) being collected by multiple *Worker Agents*. Each agent holds the geographic coordinates of the city being sensed. These agents then share their pre-processed data with the corresponding *Ledger Agent*. JADE was the selected framework, with FIPA standards being followed. In fact, a framework such as JADE significantly eases the synchronization protocol among peers, revealing its utility due to its simple yet rich environment. A demonstration video is available at https://youtu.be/3IIbirYfNAg.

The use of a MAS in combination with blockchains proves to bring benefits not only for data capture processes but also for the maintenance and support of the blockchain. Adding the conceived PoC to such a system led to the appearance of a solution where agents are focused on maximizing their score and, with that, provide accurate data, which is validated and approved by its peers. *KnowLedger* was designed and conceived from scratch, without any dependency to third-party blockchains, being, to the best of our knowledge, unique in regard to the manner it merges MAS and Blockchains, to its multi-chain architecture, and to the used protocol to ensure confidence on the actors and the committed data.

Advocating for open-source artifacts, all the produced software was published in an online repository (https://github.com/brunofmf/mas-blockchain-main) under a MIT License. The blockchain in itself is provided to the agents as a completely stand-alone library, being independent and unaware of the agent's platform. It is worth highlighting that the conception of solutions like the one proposed in this study is a continuous process, i.e., it requires monumental work-forces to constantly build, improve, and enhance the solution. This is to say that future work is vast and spread along several axis.

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