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Decentralized Autonomous Organizations and Multi-agent Systems for Artificial Intelligence Applications and Data Analysis

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Abstract

The Ph.D research project aims to explore the potential of the Decentralized Autonomous Organization paradigm in conjunction with classic software architectures for Artificial Intelligence applications. The intended goal is to investigate and formalize a possible integration path between Multi-agent System architectures and Decentralized Autonomous Organizations. Starting from the Foundation for Intelligent Physical Agents standards, we will extend basic primitives to integrate Multi-agent Systems on Distributed Ledger Technology networks. Possible deployment of services and applications in the Internet-of-Things, Artificial Intelligence and Distributed Machine Learning areas will be tested. Application of Data Analysis techniques on datasets built on such a framework will be also addressed.

1 Introduction and State-of-the-Art

Current state of the art in Distributed Ledger Technology (DLT) and Blockchain research field mainly concerns the definition of new algorithms for innovative consensus systems. The implementation of new network infrastructures for distribution of high value-added services, including solutions with nodes connected via wireless network, is a second important stem. The focus of these research areas is to lower the resources needed to mine tokens and to maintain networks, execute transactions more quickly and, more generally, reduce the complexity of blockchain operations. Another active field of research regards the modelling of second level architectures that, based on underlying Distributed Ledgers and Blockchains, allow complex organizations such as companies and associations to be managed and represented. This is currently focused on structuring the design and management of Decentralized Autonomous Organizations (DAO) and related tools with particular focus on the interaction between human players [Wang *et al.*, 2019]. The principal platform used to develop such second-tier applications is Ethereum, here is where main projects such as Aragon[1], Colony [2]or DAOstack [3] to name few are implemented. Another platform rising in importance in this sector is Solana[4], which, based on Proof of History consensus protocol, is able to offer very cheap transaction costs and fast execution thanks to synchronization. On the Multi-agent System (MAS) side, research trends, over the last decade mainly involve the facilitation of cooperation between agents, both from speed and computing throughput perspective. An important aspect of this area regards the communication among agents, the way they exchange information and constraints to such methods in order to achieve the desired architectures. This is particularly true for team learning applications that require high scalability and adaptive dynamics for optimum search. [Panait and Luke, 2005].

2 A New Approach to DAO Architecture

The limitation of this approach is essentially connected to the use of Decentralized Autonomous Organizations almost exclusively for applications in the field of Decentralized Finance and management of legal aspects of commercial entities. The research method is focused on fungible tokens as currency and non-fungible tokens as a means to cast weighted votes on company resolutions. This approach brings several issues mainly connected to regulatory requirements that must be met both in the financial and the legal areas. Another issue lies in the technical difficulty of translating rules defined in the DAO design, usually determined at high level, into smart contracts that have a semantically explicit code.

A new approach will be investigated during the PhD; it will consider a more technical use of DAOs in order to implement a classical scheme of MAS on distributed architecture. Integration of software primitives, communication protocols and standard specifications are going to be tested. The first research activity will consist of defining a path for implementing a Multi-agent system on smart contracts with a related protocol for communication between them. The technology selected for such activity could be Solidity [5] to design and deploy contracts on the Ethereum network [6] while the standard to be enhanced to operate on blockchain will be the Agent

[1]https://aragon.org/
[2]https://colony.io/
[3]https://daostack.io/
[4]https://solana.com/
[5]https://soliditylang.org/
[6]https://ethereum.org/

Communication Language (ACL) released by Foundation for Intelligent Physical Agents (FIPA) [Poslad, 2007]

3 Steps for a Successful and Innovative Result

The main reason we think the project will be successful is that at the moment the ACL standard does not include security functions or encryption. In this scenario, the benefits of blockchain in terms of security and immutability will be transferred to the protocol. A reshaping of the protocol standard will be proposed to accommodate the new information a blockchain deployment requires. [Juneja *et al.*, 2015]. Furthermore, using the Decentralized Autonomous Organization paradigm as a frame for distributed organizations is the natural evolution of MAS; implementing agents as smart contracts of a blockchain may give birth to a whole new environment where agents' behavioural and communication rules will benefit from distributed ledger properties. Allowing secure communication among agents, along with certification of transactions and immutability of data, will therefore open MAS application to a wide range of problems that are not actually fulfilled by classic architectures. This may include a variety of applications in the Internet-of-Things and Big Data fields, such as security monitoring of sensitive sites or management of critical environmental parameters for early warning.

Another field that may benefit is the exchange of reserved information for both financial scenarios and real time applications. More broadly, all MAS applications requiring secure and trackable transactions may benefit from deployment as a DAO on blockchain. A third aspect of improvement is connected to the application of the Belief-Desire-Intention paradigm to agents cooperating in a competitive environment (agents maximizing their own objective rather than the system one). In this case a track record of other agents' decisions, publicly available on the blockchain, may be evaluated before deciding the behaviour to assume in response to competing agent moves.

4 Research Applications & Results Measuring

Tests and applications of the aforementioned innovative architectures may be numerous and in very different fields. The first step, as a base for developing more complex activities may be a test deployment of Multi-agent systems as smart contracts on the Ethereum network and Solana, possibly associated with an enhanced FIPA-ACL communication protocol with blockchain tags and primitives. This could lead to a comparison of performance in terms of transactions speed and optimum function maximization as Key Performance Indicators. In such a testbed more specific languages and programming tools, such as DALI [Costantini and Tocchio, 2004], for example, may also be tested and enhanced to integrate blockchain and DAO functionalities. A second area of application may be the deployment of a DAO environment where agents act as components of the organization, using pre-determined voting procedures to resolve conflicts and to determine actions to take for maximizing the system goals. Another interesting solution to be investigated is MAS deployment on the permissioned ledger Corda. Despite its use being meant for financial and banking purposes Corda's particular way of node interaction and consensus determination, through special notary nodes that timestamp and certify transactions [Carare *et al.*, 2021 October], makes it interesting for field sensors and security networks applications where a limited level of information disclosure is requested. Lastly Microservices architectures for Internet-of-Things solutions could be another interesting paradigm of deployment. In particular we would like to focus on a network for meteorological, agricultural and seismic data collections. Monitoring parameters such as humidity, wind, solar radiation and seismo-acoustic signals in fact, would lead to structuring datasets of real data upon the results of which Artificial Intelligence solutions can be implemented for forecasting their behaviour (e.g through the training of neural networks with Machine Learning algorithms and Distributed Machine Learning). [De Gasperis *et al.*, 2021]

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