A Survey on the Opportunities of Blockchain and UAVs in Agriculture

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***Abstract*—Unmanned Aerial Vehicles (UAVs) and blockchain Technologies are relevant systems that have a significant performance in numerous sectors. In particular, applying these emerging technologies will affect positively the agricultural ecosystem. In this paper, we investigate the opportunities offered by UAVs and blockchain (BC) in the agricultural sector. We review recent research efforts in the subject with a synthesis illustrated by a classification table. Finally, open challenges and future directions for IoT-based agriculture applications are discussed.**

***Index Terms*—Blockchain, UAV, IoT, Agriculture, survey**

I. Introduction

Challenges faced by agriculture sector are enormous. We are witnessing a climate change that has a major impact on food security. According to the Food and Agriculture Organization, the world needs to increase its food production by almost 50% by 2050 [1]. During the world government summit in 2018, authors [2] claim that roughly 800 million people worldwide suffer from hunger and 8% of the world population will still undernourished by 2030. Currently, we are witnessing a new era of agriculture, Precision Agriculture (PA) which "employs data from multiple sources to improve crop yields and increase the cost-effectiveness of crop management strategies" [3]. Basically, PA is based on modern technologies like wireless sensor networks, IoT, Cloud Computing, Artificial Intelligence, Big Data, etc.

Among the recent technologies that are expected to have a big impact on PA, we can identify Blockchain and UAVs. Indeed, many emerging applications are using these technologies such as supply chain management [4], livestock monitoring [5], smart watering system [6], etc. Thanks to the peer-to-peer (P2P) network, blockchain technology eliminates the need for a central authority and avoids the single point of failure problem. It is helpful when products tracking is needed as transactions are timestamped and the history is preserved. Added to that, it is adequate when integrated with data-driven applications thanks to its immutability characteristics that provide reliable information. Thus, blockchain integration in UAVs networks may be very effective in the agriculture for data acquisition for instance where data is gathered from IoT devices using drones acting as relay nodes. The research work of Castello et al. [7] is one of the earliest studies that investigates the integration of blockchain technology with robotic. It explains how blockchain technology can provide innovative solutions for security and decision making for swarm robotic. Blockchain can be seen as a platform that coordinates drone work in a transparent and secure manner as discussed in [8]. The two technologies complement each other perfectly, one greatly improves the ability to collect data, while the other preserves its quality, and both are ideal for the decentralized operation required for large-scale operations. Because the combination of those fields and PA is witnessing a flurry of activity, this paper aims to review recent work on this subject.

The reminder of this paper is structured as follows: Section II presents an overview about the background technologies. Section III focuses on UAVs-based applications in agriculture. Section IV deals with blockchain-based applications in agriculture. Section V reviews blockchain and UAV-based applications in agriculture. Section VI summarizes the previous presented applications and reveals some challenges and open issues. Section VII concludes the paper.

II. Background: Overview about Blockchain and UAVs Technologies

A. Blockchain Technology

The blockchain is a *distributed ledger* of similar information records. This information can be a list of financial transactions, a document, IoT collected data, or any kind of data [9]. For instance, the data unit on the blockchain is called a *transaction*, and a number of transactions are bundled into a *block*. The block header includes among others: a timestamp (time of block creation) and a hash of the previous block [10]. This hash permits to cryptographically link blocks together and make the blocks immutable. Blockchain nodes form a P2P network and can send and receive transactions within this network. A node initiates a transaction and then broadcasts it to the network to be validated by other participants. Valid transactions are grouped into a block created by special nodes called *miners*. Peers in the network *validate* this block, add it to the chain and finally broadcast it across the network [11] using a *consensus* protocol. Like that, all nodes will have the same copy of the ledger. A consensus algorithm is a procedure through which all the peers of the blockchain network reach a common agreement about the present state of the distributed ledger [12]. Blockchain technology paves the way to the materialization of the concept of smart contracts [11]. Technically speaking, smart contracts are self-executing programs which actuate the terms and conditions of a particular agreement using software codes [13]. Ethereum [14] was one of the pioneer blockchains to include smart contracts. Today smart contracts have been included in the majority of existing blockchain implementations, such as Hyperledger [15]. Originally, this technology was associated with Bitcoin and enabling the management of cryptocurrencies. It is pertinent to understand that the fundamental concept is to manage any transaction digitally. Blockchain, the underlying technology of the Bitcoin can be explored for other applications or domains, including healthcare [16], [17], [18], transportation [12], [19], and Internet of drones [20], [8].

B. *Unmanned Aerial Vehicles (UAVs)*

UAVs are aircraft systems that may be controlled by human commands or be entirely autonomous [21]. The UAV system includes the drone as the flying device that integrates (a card-sized computer, a battery, sensors like camera and an antenna), a Ground Control Station (GCS) which provides status information about the drone with a map that gives an overview of the covered area and real-time images as recorded during the flight. The last component is the Flight Control (piloted remotely or fully autonomous) [22]. However, the continuous advancement in UAVs manufacturing gives the system some exceptional capabilities such as fluent mobility and ease of deployment which allows it to be versatile, relevant and widely implemented in divergent domains. Thus, UAVs are being successfully employed in Search and Rescue operations [23], Aerial Inspection and patrolling [24] in military sector. In addition, UAVs offer the ability to provide network connectivity as flying stations or mounted base stations [25]. Last but not least, UAVs are widely applied in Precision Agriculture (PA) [22]. In section III, we present the major applications of UAVs in the agriculture sector.

III. UAVs-based Applications in Agriculture

Drones technologies have been deployed in the two pillars of the agriculture domain that is the vegetable farming and the livestock management as shown in Figure 1. The major applications of UAVs for vegetable farming are the following:

- **Imaging and video Taping:** Drones can be attached with different types of cameras RGB, Multi spectral and thermal cameras. Using these images several operations could be achieved:

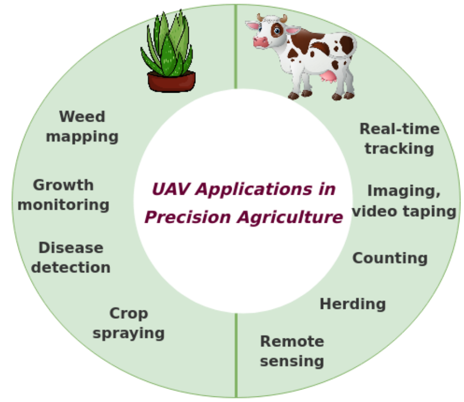

Fig. 1. UAV Applications in Precision Agriculture

  - *Disease Detection and Weed Mapping*: the captured images from the overall crop field can be leveraged to drive an accurate weed cover map outlining which locations chemicals are required. Hence, the map can be used as an input for the spraying system in the tractor and only the areas with weeds are sprayed. For instance, KerKerch et al., [26] implement a Convolutional Neural Network (CNN) and color information based model to detect symptoms in the vine yards and build a 2D map of the field.
  - *Yield Estimation*: having an insight about the crop production mass can help to decide when and where the harvest needs to be started. However, yield estimation is a tedious, time consuming and expensive task. Via UAVs images and computer vision algorithms we could have an accurate estimation of the production quantity and quality. Apolo et al., [27] propose a deep learning model in order to detect and count the number of apples in each individual tree.
  - *Plant Growth Monitoring*: is very relevant to have measurement estimation like the plant height, width and chlorophyll percentage to farmer or the decision maker, these measurement are significant for plant health, growth monitoring and disease detection in early stage [28].
- **Remote Sensing**: is the process of gathering some information remotely. The drone could gather data from IoT nodes such air quality, soil quality, temperature and water quality. Such information is relevant for decision making related to the agriculture activity [22].

UAVs are also used in livestock management applications as shown in Figure 1:

- **Imaging and Video Taping**: the images and videos captured are treated by the appropriate computer vision algorithms. They present a significant source of information and support decision making:
  - *Disease Detection*: estimating vital health parameters like temperature from thermal scanners, weight, size, and visual ailments aid in the diagnosis and the

treatment of affected animals in a preventive way.
  - *Real-time Tracking*: tracking cattle behavior and activity are crucial in livestock management as they give insights about cattle state (health, rumination, movement, etc). In [5], authors propose an approach for drone imaging processing to detect goats and predict the animal activity grazing or sleeping.
  - *Counting*: in [29] authors introduced an approach for counting cattle in pasture using animal geolocations and a graph-based algorithm.
- **Data Harvesting**: or in another word remote sensing. The drones are equipped with an antenna which capture data emitted from the RFID tags or electronic collar tags attached to cattle. Webb et al. [30] describe the drone tethered to a RFID repeater to capture temperature data released from the RFID tags linked to the livestock.
- **Herding**: is the process of rounding up livestock, preventing them from splitting up and straying (wandering). It can be conducted for a wide variety of situations, such as routine health controls and livestock treatments, marking, shearing, lamb marking, selling, feeding and transporting or leading them to a new area. Li et al., [31] present an approach that aims to navigate a network of barkers drones to gather a herd of livestock by adopting boids model to imitate the animal behavior.

IV. Blockchain-based Applications in Agriculture

Blockchain has emerged as the ultimate solution to many sectors, such as agriculture. In this section, we discuss some of the possible applications of blockchain technology in agricultural and food sectors.

- **Food Supply Chain**: have become longer and more complex due to globalization and intense competition in the market. Blockchain has shown efficiency as discussed in [4]. In this reference, authors propose a system to help supply chain actors to benefit from advanced technologies such as IoT, blockchain and advanced deep learning. It gives end users access to check their food before consumption. They can verify the origin and the supply chain of the food on their table. It will also help the industry to develop policies based on food demand forecasts and trends and manage their assets on the immutable ledger. Authors in [32] proposed a blockchain–IoT-based food traceability system (BIFTS) to integrate BC and IoT technology for effective and efficient traceability, they use fuzzy logic to determine adjustment of shelf life, rate, and order of quality decay evaluation. The blockchain is modified as a lightweight solution as it is associated with cloud computing to support IoT monitoring. Authors believe that existent consensus algorithms are not appropriate for supply chain applications. They propose PoSCS (proof of supply chain share) to select validators in a probabilistic way to forge and validate the new blocks into the blockchain.
- **Smart Farming**: in [33] authors propose a permissioned blockchain-based fish farm platform that provides fish farmers with secure and reliable agriculture data that cannot be tampered with. They develop two smart contracts to reduce the risk of error or manipulation. The first is a ”Fish farm contract” to provide various functions related to device monitoring and management. The second is a ”Policy contract” to define a specific rule list to manage access to resources, whether the user is permitted to access or manipulate a given resources of the blockchain network. In [34], authors propose an intelligent Smart Watering System (SWS) based on blockchain to provide safe channels for transmission of data between users (gardeners), smart devices, sensors, actuators and cloud storage. Blockchain plays an important role by providing privacy, and reliability in the proposed IoT base smart system. The proposed decision support system is based on fuzzy logic. It makes decisions based on sensors data. The results show that the proposed system is efficient and enable secured applications to handle the watering process of plants. The reference [6] proposed a water control system to efficiently manage and coordinate the use of water based on blockchain technology and electronic devices. Blockchain is used to support trust among community members and commercial resource constrained communicating devices. Smart contract implements irrigation and management policies.
- **Monitoring Systems**: for crops monitoring, animal welfare, etc. In this paper [35], a permissionned blockchain-based livestock farm platform is presented to improve scalability, security and performance challenges of livestock. It provides distributed data storage with an animal disease tracking service and an access control security mechanism. The proposed blockchain platform is composed of two smart contracts. First the farm environment smart contract supports environment data tracking, animal data tracking and management. Second, a user permissions smart contract handles documents and operations permission. In this paper [36], the authors propose a cloud-based livestock monitoring system to improve food safety by collecting data using a subsystem of RFID sensors (movement, moisture, CO_2, etc). Cloud servers are used to solve RFID inherent computational capacity limitations. Blockchain technology is adopted to govern access control for multiple groups in the food industry (producer, processor, distributor, retailer and customer). For surveillance purposes blockchain technology is used as well. For instance, in [37] authors propose a blockchain framework where the Repelling and Notifying System (RNS) is available as a service to ensure the protection of the crops from animal attacks during all stages of the harvest, even if farmers are not available in their fields.
- **Administrative Services**: to manage business and protect data from falsification and manipulation blockchain technology has proven to be effective. In [38] the authors discuss the benefits and risks associated to the use of blockchain technology in agricultural insurance. The analysis shows that blockchain-based solutions can

significantly enhance insurance protection and risk management in agriculture, as reliable data is available. The study [39] uses smart contracts to automate insurance policies and thereby reduce administrative management costs. The authors highlight the benefits of smart contracts in insurance, particularly in parametric insurance, which relies not only on damage inspection but also on objective measures.

V. Blockchain and UAVs in Agriculture

Authors in [40] proposed a new security scheme, named AKMS-AgriIoT, an authentication and key agreement in IoT-enabled agriculture environment using drones. A private blockchain has been adopted in the proposed system in order to support the authentication and key management design to provide an effective way to store data. It allows the authenticated credentials to be tamper-proof due to immutability property of the blockchain. [41] provided a deep and through analytical study to inspect the development of the schemes that provide information security using blockchain technology. After identifying the core requirements in smart agriculture, and discuss several security requirements and security attacks that are associated to an IoT-based smart agriculture environment, a generalized blockchain-based security architecture has been proposed. Framework of UAVs and IoT sensors in the agricultural farm using blockchain technology is presented in [42]. Authors used a private permissioned blockchain to manage the IoT devices and drones communications to prevent any intrusion into the network. They argue that the proposed system will not only help the farmer on how to better manage the farm, but also other parties, such as suppliers and traders, who can also be part of the network on an ongoing basis to add value to the farmer and keep the farm viable. Drones proved to be very useful in monitoring IoT sensors in agricultural areas where it is hard for humans to arrive and repair faulty sensors. In [43], authors proposed a blockchain platform and a Z-score algorithm integrated into a smart contract, to dynamically detect erroneous information and launch UAVs maintenance operations to replace malfunctioning devices without the need for human interventions. Farmers widely appreciate the use of UAVs to capture real-time data regarding crop health to detect weeds.

VI. Discussion

A. Summary of Reviewed Applications

Table I summarizes the reviewed applications. As the table shows, blockchain, as well as UAVs, are widely used in the field of agriculture. But, the above two technologies are not used very often together.

B. Challenges and Open Issues

Despite the potential of integrating blockchain and UAVs technologies in agriculture, key limitations and open issues remain:

- **Lightweight Solutions**: it is always a big concern to realize a lightweight blockchain solution as IoT devices have limited computational power. UAV can be an intermediary part that transmits collected data from IoT sensors to the blockchain network or can be integrated as a full blockchain node in the application. Offloading data from connected peers to more powerful servers can help to reduce storage overload. It is called archiving or vaporisation process. Edge, Fog and Cloud computing are used as computation offloading options to enhance the limitations of computation capabilities of IoT devices. InterPlanetary File System (IPFS) is adopted to enhance storage limitation. Generally, it is used to store data and generates a hash that is the only staff stored in blockchain nodes.
- **Blockchain Framework**: further research is needed to satisfy agricultural requirement (stakeholders with conflicting interests, heterogeneous IoT devices, ..). A framework that enables the integration of blockchain with an existing system will reduce time and can easily extend the actual services to the new blockchain based system.
- **A Consensus Algorithm**: The choice of the appropriate consensus algorithm for a specific use case is always a challenge. Literature reveals different algorithms like PoW, PoS, DPoS, PoET, PoA, PoB, etc. It is judicious to propose a consensus algorithm adapted to the application and to the hardware used. Also, we could introduce the artificial intelligence to determine a model for node profiling to predict the next miner.
- **Smart Contract Vulnerability**: Smart contracts security is of vital importance. It impacts the functionality of the entire blockchain network. Many attacks may occur in smart contract context such as re-entrency vulnerability, double spending attacks, sybil attack, etc. [13] describe the DAO attack on Ethereum, where 50M US dollars were stolen due to vulnerabilities in its code base. Attacks may happen due to numerous reasons like programming errors, security loophole and restrictions in programming languages. Deeper research on smart contract vulnerability will improve their usability.
- **Blockchain Interoperability**: using different blockchains together to exchange data between each other enables better collaboration, improves scalability and increases security and privacy [44]. A range of cross-blockchain interoperability solutions has been proposed but this is still an area of research as there is no mature solution so far.
- **Lack of Regulation and Legal Requirements**: regulations need to be proposed to support the deployment of blockchain-based applications [45].
- **Scalability**: is always a concern when dealing with real time data transmitted from IoT sensors and managed via blockchain technology [46].
- **UAVs**: one major issue with drone technology is the short flight duration. Due to its light weight, a drone cannot be equipped with large batteries. For that reason the UAVs motion and path must be optimized to extend the battery lifetime.

Paper	Year	Contribution	Tools/BC platform	IoT	Cloud	AI	UAV
[4]	2020	A private blockchain platform for supplychain management and hybrid deep learning model to make policies according to the predictions	Hyperledger Fabric	X	X	X	-
[32]	2019	A blockchain–IoT-based food traceability system and a fuzzy logic module as a shelf life management system	MATLAB	X	X	-	-
[33]	2020	A platform based on blockchain for fish farm data management	Hyperledger Fabric	X	X	-	-
[34]	2019	A blockchain-based IoT smart watering system using fuzzy logic based on the sensed values	implemented in Java	X	X	-	-
[6]	2019	A blockchain-based system to efficiently manage and coordinate the use of water for irrigation communities	Ethereum	X	-	-	-
[37]	2020	A blockchain-based supply chain management and a safe farming as a service prevention system	Not mentioned	X	-	-	-
[35]	2021	A blockchain-based system for livestock farm management in Sri Lanka	Hyperledger Fabric		X	-	-
[36]	2020	A blockchain-based architecture for livestock monitoring using RFID technology	-	X	X	-	-
[40]	2022	A blockchain-based drones-assisted authentication scheme	Node JS	X	X	-	X
[41]	2020	Survey	-		X	-	X
[42]	2020	A blockchain-based framework for drones and IoT sensors security	Multichain, Ethereum	X	-	-	X
[43]	2020	A blockchain-based platform for autonomous IoT management by drones	Ethereum	X	X	-	X
[38]	2021	Survey	-	X	-	X	X
[?]	2016	A blockchain-based smart contract system to automate insurance policies	-	X	-	-	-
[26]	2018	A CNN model to address the problem of identifying the infected areas of grapevines using drone imagery	-	X	-	X	X
[27]	2020	A R-CNN Model was trained to detect and count the number of apple fruit based on images taken by UAV	-	X	X	X	X
[28]	2020	A UAV-based solution for estimating leaf nitrogen content in rice crops while presenting a novel trajectory control strategy to reduce the wind perturbations that affect image sampling	-	X	-	X	X
[22]	2021	Survey	-	X	X	X	X
[5]	2019	A tracking of animal activities method based on images taken by drones	-	X	-	X	X
[29]	2021	A CNN and a graph-based optimization models to detect and count cattle in images obtained by UAVs	-	X	-	X	X
[30]	2017	A livestock health monitoring system based on UAVs that capture temperature data released from RFID tags	-	X	-	X	X
[31]	2022	A novel motion control for a robotic livestock herding system based on a network of autonomous barking drones	-	X	-	X	X

TABLE I
SUMMARY OF BLOCKCHAIN AND UAV-BASED APPLICATIONS IN AGRICULTURE

VII. CONCLUSION

Potential benefits in integrating blockchain and UAVs technologies in PA are the major contribution of this research study. Blockchain is a secure infrastructure to manage UAVs work and it performs well in many areas, especially when talking about swarm of UAVs. In this paper we reviewed applications based on blockchain and UAVs in agriculture and compare them. Finally, detailed analysis of the literature has revealed research axes and future directions.

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