CHAIRE AgroTIC

BLOCKCHAIN AND AGRICULTURE

> UNDERSTANDING,
> EXPLORING, AND
> EVALUATING

An AgroTIC Business Chair Study - October 2017

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INTRODUCTION

Blockchain: Not a week goes by without this term appearing in the press. It is a trend, to say the least! This technology, which allows the creation of a distributed and forgery-proof record, or ledger, of transactions is even hailed as a "revolution", likely to be useful in many sectors. However, despite this surge in interest, blockchain remains a hard-to-understand technology.

In any case, this was the impression of members of the AgroTIC Digital Agriculture Business Chair, who were keen to know if and how this technology could affect the agricultural sector. The AgroTIC Chair decided to conduct its first feasibility study on the subject of blockchain.

The problem with blockchain is that a string pulled to find out more information quickly becomes a whole ball! We felt it was important to start with the fundamentals, to understand the basis of the technology and what makes it so innovative. Our goal here is nevertheless humble: to offer an overview of theory and practice so as to better understand the technology and new possibilities currently under study. Knowing more will clarify future horizons, both for users and developers of solutions. Tests and feedback will enrich this overview and provide a comprehensive vision of what the technology has to offer.

THIS DOCUMENT IS DIVIDED INTO 3 PARTS:

"UNDERSTANDING"
reviews the fundamental principles of blockchain from a technical perspective and identifies in detail its main properties.

"EXPLORING ITS POTENTIAL"
presents several ways the technology is used and focuses on potential applications in the agriculture sector.

"EVALUATING"
looks at issues surrounding the use of blockchain to reveal any barriers or shortcomings and identify future technological prospects.

PART I:
Understanding

1 | What is a blockchain?

A search for the meaning of 'blockchain' often turns up the following type of definition:

> "A blockchain is **a secure public ledger platform** shared by all parties through the Internet or an alternative distributed **network** of computers" (Pillington, 2015). **(5)**

> "A blockchain is an open and secure method of storing and distributing information which operates without a central server. By extension, a blockchain is a database containing a record of every transaction between users from its creation onward. It is a secure, distributed database that is shared by the different parties without an intermediary, allowing each user to verify the validity of the chain". (Blockchain France / Blockchain Partner). **(6)**

These definitions are clear, but additional information is useful.

FURTHER READING:

> *La blockchain décryptée : les clés d'une révolution* - Blockchain France **(1)**

> *Comprendre la blockchain - livre blanc* Uchange **(2)**

> *La blockchain pour les entreprises* - MEDEF **(3)**

> *Réalités industrielles - Blockchain et smart contracts : des technologies de la confiance ?* - Annales des Mines **(4)**

A distinction should be made between "the" blockchain and "a" blockchain: (2)

> "the" blockchain refers to a type of technology (or more accurately **an innovative combination of pre-existing technology**) developed by a certain Natoshi Sakamoto and revealed in 2008, based on cryptography, among other things.

> "a" specific blockchain refers to a given protocol and network that an individual or organisation can use. Bitcoin is a blockchain. Ethereum is another.

LET'S REVIEW THE TERMS IN THESE DEFINITIONS TO CLEARLY UNDERSTAND WHAT THE TECHNOLOGY ENTAILS:

LEDGER

DISTRIBUTED, WITHOUT A CENTRAL SERVER

SECURE

Ledger

> A record of transactions

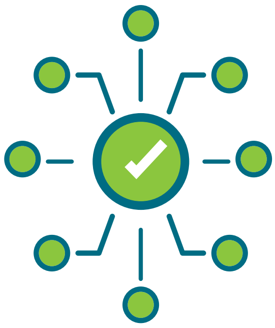
Blockchain: a "ledger" technology which stores a record of transactions

The 'blocks' in blockchain are batches of transactions. In computing, a transaction is an indivisible series of operations to go from State A to State B: a purchase, a payment, or to send a message, for example. A blockchain is therefore a database to which transactions, grouped together as blocks, are added in chronological order. It is similar to a ledger, where each line is a transaction. **A key feature of this ledger is that it is written in indelible ink:** every page can be consulted, lines can be added, but existing data cannot be deleted or changed. Users on the peer-to-peer network receive identical copies of this ledger.

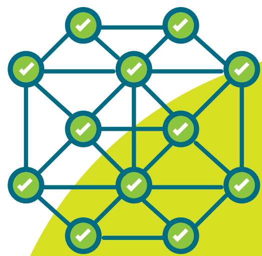
Blockchain: a technology based on distributed architecture and governance

» A PEER-TO-PEER (P2P) NETWORK...

Distributed computing is a computer system architecture in which resources are located in different places. These resources are not organised around a central server. A blockchain is therefore a network of computers (with each computer acting as both server and client) which exchange data directly across the network without going through a central server (similarly to the peer-to-peer tools used to share multimedia content, like eMule, for example). The blockchain eliminates the need for a **central authority**. The devices making up the network are called **nodes.** The ledger is replicated at the node level.



Centralised



Decentralised

» WHICH OPERATES BY DISTRIBUTED CONSENSUS

In a traditional, centralised system, central servers act as a trusted authority. They verify whether conditions are met to enable transactions, and then carry them out. However, centralised computing implies a high level of trust in the central unit and can be a source of risk (attacks are easier at a single location), infrastructure costs, and longer processing times. These intermediaries do not exist in a blockchain system. The nodes in the network perform verification and carry out tasks. To do so they – a majority, in any event – must concur, even if they do not know or trust one another. Blockchain operates according to a common set of rules based on consensus mechanisms (run by algorithms). This is a **distributed consensus,** the result of which is that trust is not limited to a single authority but spread over an entire network. Different consensus mechanisms exist. We will discuss them later.

Secure

Blockchain: a technology made secure by cryptography

The vast blockchain "ledger" is accessible to all users. This means that the list of transactions is visible to all. Cryptography, however, is used to:

> make the chain unalterable by linking each transaction block to the preceding one=> use of hash functions.

> guarantee the signature of transactions => the principle of authentication by public-key cryptography

Let's look at these two concepts:

» HASH FUNCTIONS

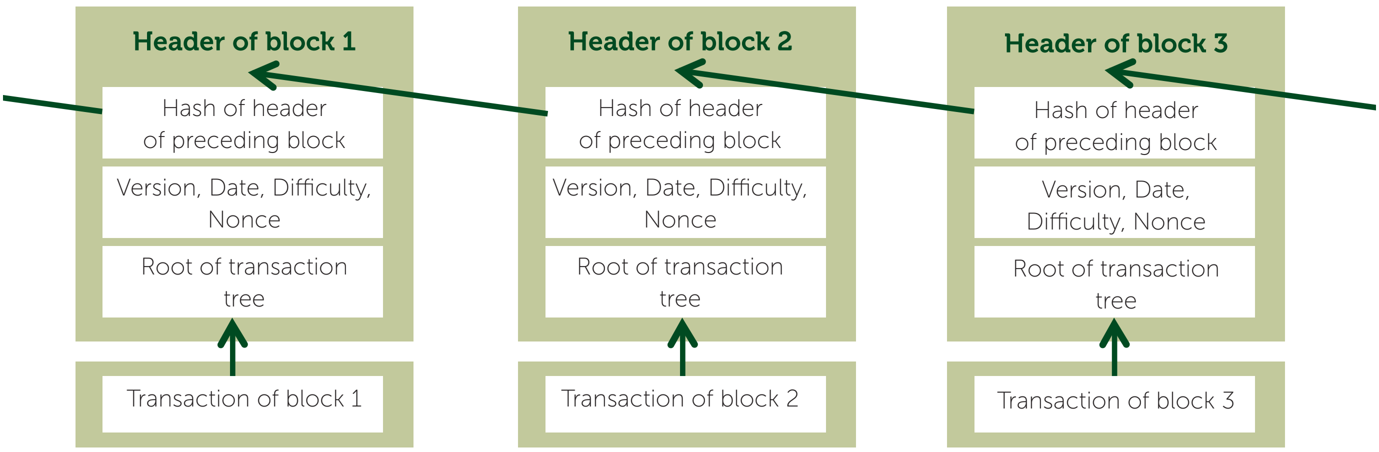
Hash functions, or hashes, are algorithms that generate a digital fingerprint from input data (an entire document, for example): just like a human fingerprint matches a single individual, a digital fingerprint identifies a single, unique unit of data. The slightest change to the input data will yield a completely different fingerprint.

Example: *Comparison of hashes (function SHA-256) for the word AgroTIC with and without an exclamation mark.*

AgroTIC => 842ef466771f1af6ea4c24824512cde129bf4c6281674424f0b0254b27d054ea
AgroTIC! => 5792a4c098aa14eac06d640fa333fe2a9ec719203bd8392e6851bec55acdf622

This hash function is one-directional. It is impossible to return to the original data from the obtained hash.

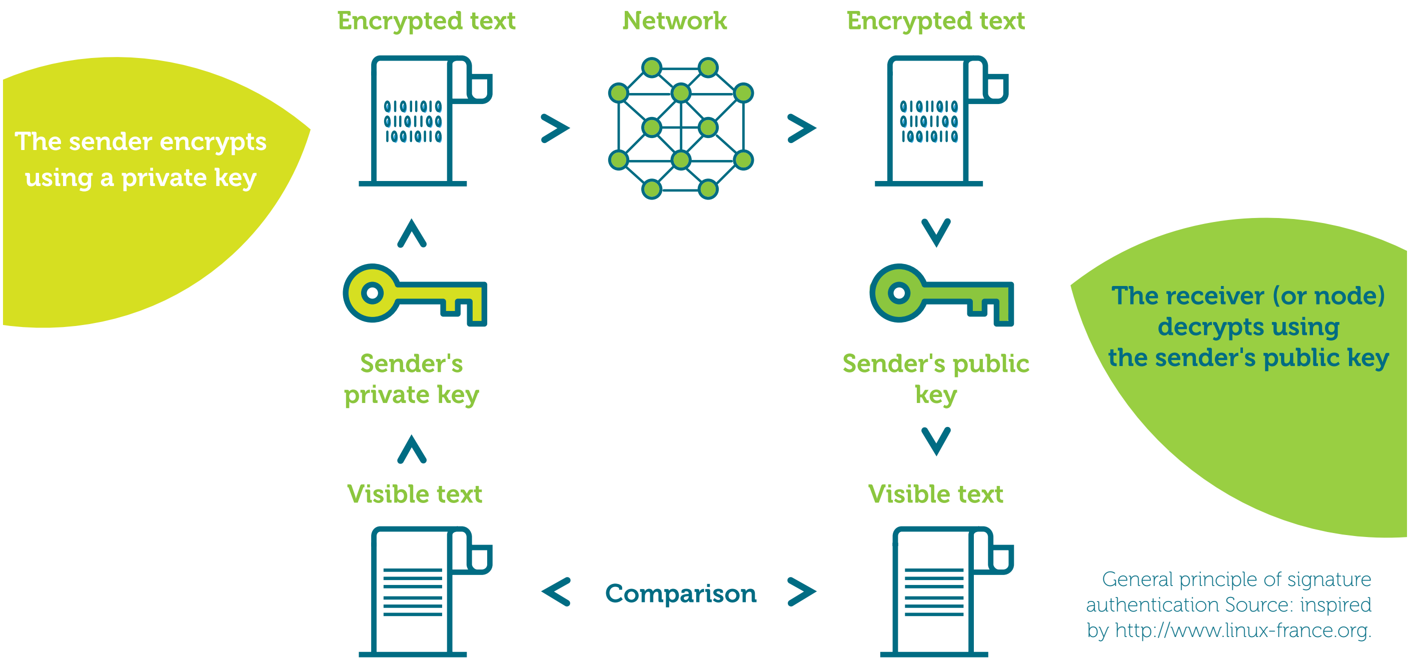
These functions ensure that the ledger cannot be altered.
Each block in the chain consists of a header and new transactions. The **header** of the block stores a **digital fingerprint** containing a "digest" of the transactions in the block (the root of the "hash tree" or "Merkle Tree"). Each block is linked to the preceding one via a hash derived from the header of the previous block: that way, every block contains a print of part of the previous block, so that even the slightest change made to a transaction after its consignment results in the entire chain being changed. Since the chain is duplicated in multiple copies, any modification is noticeable. And given the number of copies, and the principle of distributed consensus, it is difficult to pass any anomaly onto all the copies in the chain. Each newly-added block secures the chain a little bit more. This is what makes a blockchain appear tamper-proof.



Simplified blockchain diagram (for something like Bitcoin) (Source: www.ethereum-france.com)

» PUBLIC-KEY, OR ASYMMETRICAL CRYPTOGRAPHY

This cryptography method is used to ensure the confidentiality of a data transfer between 2 parties or ensure the authenticity of a message signature without sharing a secret code between the 2 parties. The method involves 2 connected keys: one private, and one public. The private key is a strictly personal one that is not to be shared. The public key is shared with the entire network (the 'address' of a party to which transactions can be sent is determined using the party's public key).



General principle of signature authentication Source: inspired by http://www.linux-france.org.

In the case of blockchain, this mechanism is used to authenticate a signature.
To initiate a transaction between Alice and Bob, Alice must use her private key to "digitally sign" her message (e.g. "I hereby send 200 monetary units to Bob"):

> *> To her open message she adds a signature that matches the "digital fingerprint" of the open message. This print is then encrypted using a private key.*

Nodes in the network are sure the message comes from Alice if they are able to decrypt its signature using the public key.

> *> The transaction is authenticated if the parties are able to decrypt the digital signature of Alice using her public key and establish that this decrypted signature and the fingerprint of the open message are identical.*

2 | How does it work?

To understand how this actually works, take the example of the first blockchain put into use at world level: **Bitcoin**.

1. Sender/party A uses his private key to initiate a transaction with receiver B, identified with a public key.

2. This transaction is sent to the nodes in the network.

3. Nodes, called "miners" in the case of Bitcoin, encode and verify the transaction. It is important to check whether concerned parties in the transaction have authorised it, and whether the transaction is feasible. For example, does the receiver have sufficient funds?

4. If approved, the transaction is added to a block of other pending transactions. Each miner prepares its own block from a list of pending transactions (blocks are pre-defined in size and the number of transactions in a block varies). In order to be added to the chain, the block itself must be verified and approved by consensus: the miners must provide proof that the block has, in fact, been checked (see box). This solves syncing and logging problems by establishing priority rules.

5. When a block is approved, it is timestamped and each node adds it to its own copy of the chain. (*)

6. The transaction can reach its receiver and is visible to the entire network. For Bitcoin, the operation takes around ten minutes, the time needed for the proof mechanism.

Created in 2009, Bitcoin is a digital currency, or "cryptocurrency" for peer-to-peer payments (for purchases of goods and services, but also now exchanged for 'real' currencies). Bitcoin operates according to an open protocol (open source code) which allows users to issue Bitcoins and manage transactions in a collective and automatic manner thanks to the interoperability of the software and services involved. Bitcoin is both a payment intermediary and a store of value limited to 21 million units ('Bitcoin' is also the name of the unit) **(7)**. The Bitcoin blockchain tracks every transaction carried out since its creation. Like all cryptocurrency, Bitcoin has no real underlying value: it is only valuable on the internet and relies on a speculative mechanism.

(*) Note: Sometimes, due to the time it takes to synchronise nodes, two nodes transmit their version of the block simultaneously. In this case, the chain can temporarily have two different branches. Each node continues to operate according to the block it received first, but keeps the other pending. When the next block is added, the longest branch becomes the valid one and the other is discarded.

PROOF OF WORK AND OTHER CONSENSUS MECHANISMS

In a decentralised system without a trusted third party, and where, in theory, there is no trust between individuals, consensus **mechanisms** are essential. To work together, network users must abide by universally accepted rules, allowing as many users as possible to concur, and ensuring that those who take part in decisions are legitimate (and are not malicious).

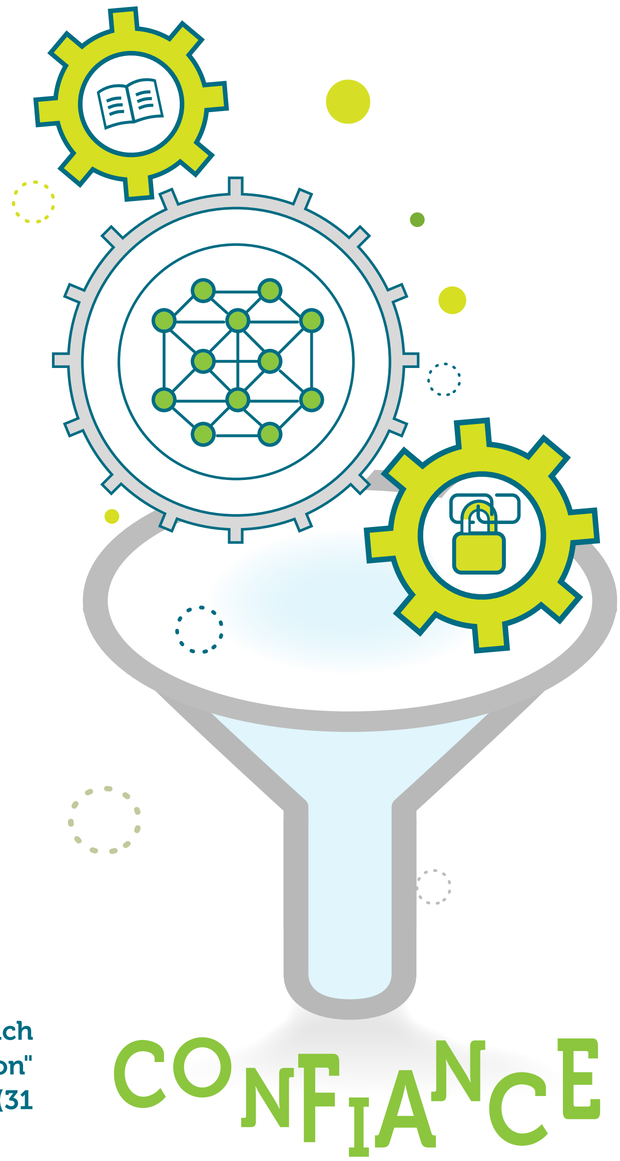
In the Bitcoin network, blocks are approved using a form of consensus called **Proof-of-Work**: evidence that effort has been made to verify a transaction **(8)**. This mechanism requires such a level of computing power to approve each block that it deters malicious attacks and makes it nearly impossible to re-write the chronology of the chain.

Since each miner prepares a block, it is necessary to select which one will be added to the chain. The following rule applies: the miner that solves a complex math problem first is allowed to add his block. For example, parties could be asked to add (or concatenate) a random value to the preceding header to obtain a hash below a certain threshold (the hash must begin with a series of 0s for this to work, which requires several attempts). Problems get increasingly complex as the blockchain evolves, but the solution is always easy to check. As a result, the block is approved if more than 50% of the nodes approve the result. Given the high level of computing power required, this is handled by specialists. In exchange for this work, miners receive **tokens** (worth a fraction of the cryptocurrency), which act as an incentive to keep the network running smoothly. This is where the term "**mining**" originated, in reference to gold miners who earned money from their work...

The Proof of Work mechanism was the first to be used in blockchains, but other consensus protocols are also now common **(see (9))**. One option frequently mentioned is "**Proof-of-State**", a protocol that requires far less computing power and energy, in which miners (called "**minters**") earn the right to approve, or sign, blocks by betting cryptocurrency units. The more they have, the greater their chance of being selected by the algorithms.

It should be noted, however, that not all blockchains require these relatively complex mechanisms. We will see that certain chains are private, or managed by a limited number of parties. Where trust is less of an issue, approval mechanisms are far more simple and use little energy. Sometimes a block can be approved simply by X number of N nodes to be considered valid (e.g. a simple voting system). Or certain nodes can be deemed contractually responsible for approving blocks.

As seen above, blockchains have the following characteristics:



☑ LOGGING
Transactions are added chronologically: they are timestamped and inter-linked.

☑ UNALTERABILITY OF RECORDED DATA
The record is replicated multiple times and the slightest modification changes the entire chain.

☑ DISINTERMEDIATION AND DECENTRALISATION
The peer-to-peer nature of the network makes a central server unnecessary.

☑ SECURITY
The distributed consensus nature of the system makes attacks more difficult. A digital signature guarantees the origin of the transactions.

☑ TRANSPARENCY
Nodes contain the entire chain and can access transactions.

Blockchains are first and foremost a technology which "ensures the sincerity and validity of any kind of transaction" (10): a "trust machine", in the words of The Economist (31 Oct/6 Nov 2015).

Summary:

- Blockchains make it possible to keep a secure and shared ledger of transactions. They are based on two major technologies: cryptography and peer-to-peer architecture, which ensure that data is highly secured and tamper-proof.
- They operate on the principle of collective governance based on a consensus mechanism, and have the potential to remove the need for intermediaries and a central authority.
- Because of the mechanisms involved, based on sharing and data transparency, blockchains can be seen as 'trust machines'.

3 | From blockchain to blockchains (distributed ledger technology - DLT)

As seen above, the blockchain is a shared and secure database.
As such, it records (ledger) and exchanges data (such as payments). Other protocols have rapidly appeared to meet new needs. These protocols have added new functions, as well as new ways to view governance.

Where once there was "the blockchain", now there are many. Original blockchain 'purists' refer to the technology in general as: "Distributed Ledger Technologies" (DLT).

» SMART CONTRACTS: A MAJOR FUNCTIONAL SHIFT

Smart contracts are stand-alone programs which automatically carry out the terms and conditions of a contract according to predetermined parameters, without the need for human intervention once implemented (Blockchain France, 2015). The contract's terms and modalities are embedded in the blockchain and therefore cannot be altered.

Once again, this is not a new concept. The term "smart contract" was used for the first time in 1993 by computer scientist Nick Szabo. The development of the Ethereum network took the technology to another level by associating it with a cryptocurrency (Ether, in the case of Ethereum), allowing a completely automatic and secure exchange of assets.

Smart contracts pave the way for new developments: **in combination with connected objects, for example, they can establish a secure link between virtual and physical spheres.** A sensor can collect data which, when sent, triggers a series of automatic transactions stipulated in a smart contract (e.g. a payment triggered when geolocation provides proof that a parcel has reached its destination).

» PRIVATE BLOCKCHAINS: A SHIFT IN GOVERNANCE

As a completely open and transparent technology (e.g. Bitcoin), blockchains are very original. However, the concept quickly attracted criticism from those less eager to share or make decisions together. Less open blockchains were quick to appear.

Three main kinds of blockchains exist. **(11)**

> Public, or "permissionless" blockchains:

Anyone can approve transactions and take part in the consensus process.
Anyone can send transactions for approval and integration in the blockchain if the transactions are valid.
Anyone can consult transactions.
This type of blockchain is truly decentralised, which allows for lower infrastructure costs for any given party since these are shared across the entire network (no servers to maintain, for example). A cryptocurrency is closely linked, as a financial incentive, to ensure the network is well maintained. This type of blockchain is not easy to change because all parties must agree.

Examples: Bitcoin, Ethereum, Litecoin, etc.

> Consortium blockchains

The consensus process is handled by pre-selected nodes (similarly to a consortium of banking establishments that agrees to a set of common rules). Transactions are either open to all, restricted to network participants, or only partially accessible.

These blockchains are considered to be partially decentralised.

> Private, or "permissioned" blockchains

These chains are owned by a given organisation which has complete control over permission to write and consult. In practice, they are regulated, subverting the original idea behind Bitcoin. Purists refuse to call these types of chains blockchains. This type of chain does not rely on a cryptocurrency or on proof-of-work, or proof-of-stake mechanisms. They are still blockchains in that they are distributed and secured by encrypted authentication.

There are pros and cons to each type of chain, and some are better suited to certain contexts than others. For example, public blockchains work well for consumer-to-consumer (CtoC) applications, while private chains are better for business-to-business (BtoB) uses.
Private blockchains are still often a means for companies to test the technology with less impact, but eventually it is likely that the different kinds of blockchains will co-exist and operate together. This is already the case: **sidechains** can be used to create linkages between different blockchains.

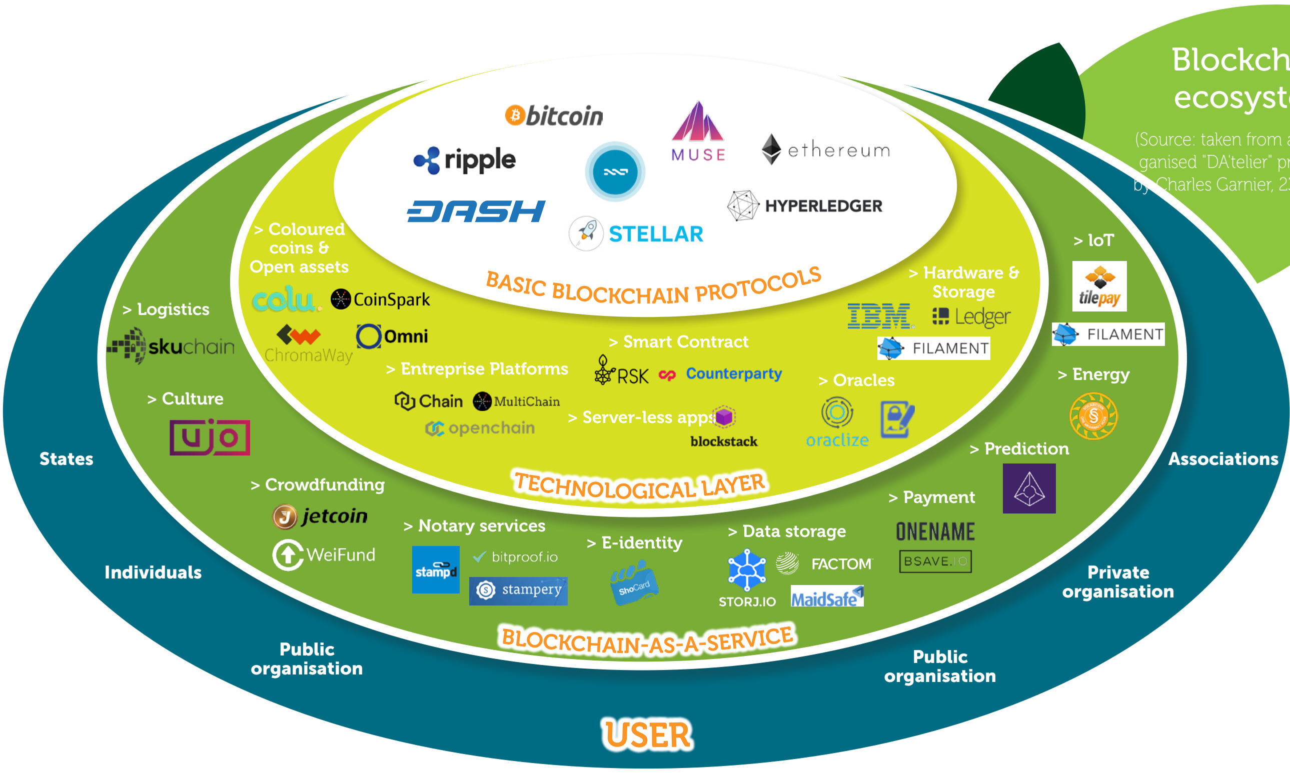
» THE BLOCKCHAIN ECOSYSTEM: A SHIFT IN SERVICE DEVELOPMENT

> A blockchain is built in layers, exactly like the internet:

The **"infrastructure" layer** is the distributed "database", the actual chain of blocks, and the network in which it is replicated.
This layer of infrastructure is topped by a **"protocol" level**: a set of rules followed by the blockchain, such as verification and transaction approval rules...

The **"technological" layer** is the intermediate layer offering services used to process blockchain data and make it available to applications.

The **application layer** is composed of applications which interact with users. At this level, the blockchain is transparent to the user. This is the "blockchain-as-a-service" level (Baas).



Blockchain ecosystem

(Source: taken from a CATIE-organised "DA'telier" presentation by Charles Garnier, 23 May 2017)

Depending on their needs, a company has several options for implementing blockchain technology (**see (12), chart below**), including the use of a development platform.

APPROACH	HOW IT IS DONE	EXAMPLE
Computer services	We do it for you	Major digital services firms
Blockchain first	You work directly with blockchain tools and services	Bitcoin, Ethereum
Development platforms	Tools for IT professionals	BlockApps, Blockstream, Eris, EthCore, Hyperledger, Tendermint
Vertical solutions	For industry	Axoni, Chain, Cleamatics, DAH, itBit, R3
API and specific sub-layers	"Do-it-yourself" building blocks	Blockstack, Factom, open Assets, Tierion

Source: William Mougayar, 2016, www.coindesk.com

In the long-term, the ecosystem will likely be built around service providers that develop the technological layer on one hand, and companies that develop sector-specific applications on the other.

Service providers, including majors like IBM and Microsoft, will need to successfully impose their service environments to allow companies to create, launch, operate and monitor blockchain-based applications. To this end, IBM is developing services based on Linux Foundation's *HyperLedger*. Microsoft is focusing on its *Azure* platform, and Orange on *Chain*.

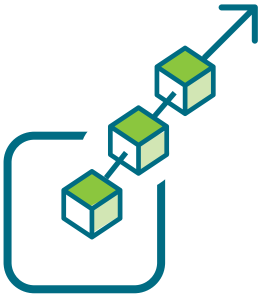
Companies developing sector-specific applications need to be the one to offer the "killer app", the one which will make the massive adoption of blockchain technology possible.

Summary:

- There are not one, but many types of blockchains, each with different characteristics and functions.
- Smart contracts and self-executing computer code, add value to the simple principle of a distributed database: they offer the possibility of connecting the physical and the virtual.
- Private blockchains exist now. They move away from the original philosophy of a system managed entirely by its users.
- Blockchains already enrich a veritable ecosystem of participants and solutions.

4 | Why do blockchains generate so much interest?

BLOCKCHAINS ARE OF PARTICULAR INTEREST BECAUSE THEY ARE A TECHNOLOGY DESCRIBED AS BEING **DISRUPTIVE**.



Blockchains – public blockchains in particular – have enormous potential to transform and imply paradigm shifts:

> **They reinvent trust.** By eliminating the need for a central authority, And because they are based on transparency and distributed consensus, they change the way trust is granted (see "**educational talk**" by Claire Balva at TEDxLyon on this topic **(13)**).
Until now, the common modus operandi has been to delegate trust to a third party: a banker, a notary, a certification body, or a state. However, such third parties are fallible, and may be subject to security breaches. They can also arbitrarily decide to change the rules. Blockchains "re-invent trust" by distributing it: transactions are approved and carried out not only by one person or entity, but by a whole community. Instead of trusting an authority, trust is placed in a technology (and mathematics!).

> **This allows risk to be pooled:** once again, risk is not concentrated on an intermediary but shared by all.

> Blockchains imply sharing tools, transparency, decentralisation, and establishing functions specific to **a collaborative or sharing economy.** Cryptocurrencies, which exist independently of states and banks, are one form of this, but not the only one. Because they are based on a peer-to-peer network, blockchains open the door even further to "uberisation", the phenomenon of putting professionals and clients in direct contact. Blockchain makes it possible to sidestep this type of service platform. Parties trade units of value of any kind securely: this is called "tokenisation", from the term "token", where a token can be an asset, a production unit, or something immaterial like time, a voting right, a reputation, etc.**(14)**

>This new technology re-invents the power balance between parties and how they interact... In private or consortium-based blockchains, power sharing between parties that propose the technology and partners who adopt it will probably have to be based on a subtle balance. "A joint form of coordination is needed, based on power without abuse and trust without blindness. This type of system is difficult to implement". **(15)** In public blockchains, community members have enormous power, but also responsibilities. "If there is no central authority capable of enforcing the law, the blockchain community has a moral obligation to intervene to ensure that the law (or code, in this case) is respected, as well as uphold public order and ethics. This is exactly what is implied by 'distributed governance'". (Primavera de Filippi, quoted by Blockchain France, 2016) **(16)**

Evidently, this raises many questions for researchers from a range of disciplines: technological issues, of course, as well as legal ones (regarding responsibility and regulation), political ones (the role of states), societal and ecological issues, etc.

Blockchains rapidly caught the attention of the financial sector due to their cryptocurrency component and their ability to transfer assets, and they are likely to be of interest to all business sectors.

After this overview of the technology, let's now look at examples of how it is used and specifically at applications in the agricultural world.

Summary:

- Blockchain technology is 'disruptive' due to the paradigm shifts it involves in terms of trust, user interaction, and power.
- It raises technological, economic, social, political, legal, and ecological questions to do with research.

PART II:
Exploring the potential

1 From potential to use

As seen above, the main characteristics of a blockchain are:

- ✔ LOGGING
- ✔ UNALTERABILITY OF RECORDED DATA
- ✔ DISINTERMEDIATION AND DECENTRALISATION
- ✔ SECURITY
- ✔ TRANSPARENCY

A blockchain can represent added value when the goal is to:

> protect the reliability of data, secure the system, or ensure its transparency,

> gain time and money by decentralising infrastructure*, as well as by automating and simplifying procedures.

* Combined with a cryptocurrency, a blockchain functions on a stand-alone basis: as with Bitcoins, costs are shared across nodes in the network and participants are remunerated by internally created value. This can potentially lower infrastructure costs.

Currently, uses can be classified into three main categories (6) (17):

Record keeping

Storing data and information for which proof of existence, logging, ownership, origin, etc. need to be guaranteed.

Digital transactions

Transfer of units of value: cryptocurrencies, real estate transactions, co-financing, purchases/sales, votes, etc.

Smart contracts

Development and storage of smart contracts which automatically execute terms and conditions that are permanently written into the blockchain.

However, this conception of the technology is probably simplistic and it would be unfortunate to limit its potential...

2 | Examples from all sectors

The financial sector took an early interest in the potential of blockchains and is without a doubt the one which has invested the most in proofs of concept (progress rarely advances past this stage) for asset management, international trade financing, and private financing. However, the financial sector is by no means alone: according to a study by the French employers' association (MEDEF), in May 2017, 66% of decision-makers at 302 French companies of all sizes and in all business sectors were interested in blockchains**(3)**. In 2016, international investments in this technology reached $694 million (Source: baromètre blockchain, TNP & Largillière Finance). Below is a brief overview of how blockchain is used, to show the variety of fields and applications involved...

CERTIFICATION OF DIPLOMAS

Two engineering schools, Léonard de Vinci (Paris) and the Ecole Supérieure des Sciences Economiques et Sociales (ESSEC) created a partnership with a company called Paymium to offer "diploma.report", a service that certifies the degrees awarded by the two schools. The school makes a digital copy of the degree, a digital fingerprint of the degree is made, and a transaction is recorded in the blockchain to attest that the degree was indeed issued by the school. That way, a company can receive the digital version of the degree, check that it has not been modified by comparing the hash, and explore the blockchain to verify that it was indeed the school that issued the degree.

ENERGY PRODUCTION

Solar Coin is a cryptocurrency that allows energy self-producers to be paid in SolarCoins based on the electricity generated by their solar power installation. For example, 1 SolarCoin rewards the production of 1 MWh and can be converted into most currencies. In France, ekWateur, a green energy distributor, accepts SolarCoin in exchange for energy.

Neighbourhood-level experiments are under way to develop direct solar energy trade between neighbours: examples include the TransActiveGrid project in Brooklyn or the Bouygues Immobilier project with Microsoft, Energisme and Stratum, in the Confluences district of Lyon, France.

COPYRIGHT / INTELLECTUAL PROPERTY

Several applications use blockchain to protect the authorship of a work and/or pay the authors directly (Monegraph, Verisart, Muse Blockchain). In May 2017, music streaming platform Spotify, regularly found guilty of poorly paying rights holders, announced it had purchased Mediachain, a startup specialised in the development of digital on-line protection solutions. Mediachain uses the Ethereum blockchain to authenticate authors of works.

A COOPERATIVE FOR APPLICATION DEVELOPMENT

The Digiculteurs (or 'digital growers') are a group of companies in the digital sector launched by Crédit Agricole. Crédit Agricole releases its data – including banking information, which is, of course sensitive – to the companies in this group to help spur the development of innovative applications. Digital growers are paid via an original system; remuneration depends on the monthly rate of usage of applications. This provides long-term income to "digi-growers" and encourages them to continually improve applications. Because small sums are involved, the system relies on payment in Bitcoins, allowing Crédit Agricole to improve its expertise in this technology. **(18)**

CARPOOLING

LaZooz offers a carpooling ride service based on a self-managed platform. Drivers are paid in Zooz, a cryptocurrency modelled on Bitcoin.

ELECTRONIC VOTING

FollowMyVote, an American start-up, offers a vote recording service, using a ledger and verification by nodes that a given voter has the right to vote, and hasn't voted more than once.

STORAGE CLOUD

Filecoin is a Dropbox style data storage solution which uses data centres.
File storage is decentralised: data is encrypted and distributed across the nodes of the network. Miners earn Filecoins by providing disk space. Clients can personalise data replication settings according to the security level, access speed, and desired cost.

THE INTERNET OF OBJECTS

Slock-it: Their slogan: "Rent, sell or share anything". Slock-it connects physical objects with the Ethereum blockchain to provide interaction with regard to smart contracts. The company cites the example of an apartment rental: the front door lock can be connected to the blockchain and a smart contract can open it if the payment conditions of the contract are fulfilled. Slock-it highlights the added value of the blockchain by comparing it to other systems: it can't break down or fall under the control of a third party. Cost reduction is another argument used **(19).**

Filament is working on a long-distance wireless network of connected objects based on the blockchain concept. The goal is to develop a protocol (Blocklet) thanks to which connected objects can interact. The blockchain simply verifies inputs and outputs.

Iota: this application, which promises a solution to link connected objects, is in fact a '2.0' extension of the blockchain principle in that transaction blocks are not in a chain, but a tree. The system is not driven by a monetary incentive, resulting in lower costs. Nodes are not paid in exchange for approving transactions: instead, they approve two to be allowed to send one.

3 | Examples in agriculture

Below is a (non-exhaustive) overview of blockchain uses in agriculture as seen in the press and scientific publications. These examples illustrate current opportunities and fields in which the blockchain can be a technology of interest and a solution to certain challenges. This will also allow us to grasp related questions. It is important to note, however, that these examples are not exempt from a "buzz effect"; almost all of them are pilot projects or simply proofs-of-concept.

FURTHER READING:

"Agriculture, agroalimentaire et blockchain", a study by Blockchain Partner - **(20)**

EXAMPLE 1: **TRACEABILITY AND TRANSPARENCY IN THE SUPPLY CHAIN**

THE CONTEXT:

Food scandals and health crises which have made the headlines since the 1980s, along with an increase in certain health problems – those linked to obesity, for example – have weakened consumer trust in producers and the agribusiness sector. Consumers complain of a lack of transparency with regard to food products, their origin, their ingredients, and, increasingly the social and environmental conditions in which they are produced **(21)**. Companies therefore need to reassure them.

Similarly, producers and industry stakeholders must adhere to strict standards for which they are obliged to provide field-to-plate traceability. These are complex and expensive processes. Despite this, it sometimes takes weeks to find the source of a problem by comparing dissimilar (and sometimes paper-based) information systems: up to three months in the case of Fipronil-contaminated eggs last summer **(22)**. The challenge in such instances lies in achieving effective traceability.

BLOCKCHAIN TECHNOLOGY CAN HELP TO:

- **find the source of a problem:** the blockchain can record every step in an item's production chain. Malfunctions can be quickly identified. Data is tamper-proof, ensuring that no changes are made to records (thus clearing a company of responsibility).
- **report a malfunction:** incorporating connected objects and smart contracts makes it possible to report problems in real time (when a temperature is not properly maintained, for example).
- **restore trust via transparency:** traceability via blockchains can provide proof to the end consumer of origin, adherence to specifications, or manufacturing conditions (in regard to health, ethics or environmental concerns). The decentralised and distributed nature of the technology makes information accessible to every link in the chain, which can work in synergy.
- **facilitate audits and inspections:** the use of a ledger and/or smart contracts which independently verify that criteria are met reduces wait times and audit/inspection processing costs, and can be applied to a wider range of products. The blockchain is therefore compatible with certification processes.
- **reduce food waste:** by speeding up administrative procedures and identifying the source of malfunctions more accurately, it can prevent food waste caused by entire batches spoiling or being destroyed.

EXAMPLES:

> IBM SOLUTIONS FOR TRACEABILITY WITH MAJOR FOOD PROCESSING GROUPS:

The news received extensive media coverage: food giants such as Dole, Driscoll's, Golden State Foods, Kroger, McCormick and Company, McLane Company, Nestlé, Tyson Foods, Unilever, and Walmart have joined forces with IBM to explore the potential of blockchains in new traceability solutions. The consortium follows in the wake of two proofs of concept deemed conclusive, carried out by Walmart and IBM and based on Hyperledger technology: one for the traceability of pork in China **(23)** and the other for mangoes in Mexico **(24)**.

For the food industry, the goal is to store and track forgery-proof information about where animals were born, raised, and slaughtered; lot number, factory data, expiry dates, storage temperatures, transportation and delivery information – with the ultimate goal of total traceability. The blockchain as a service offered by IBM, which makes use of Linux Foundation HyperLedger innovations **(25)** and allows each party on the network to add data regarding its own activity (its link in the supply chain), and access the data of other members without giving any single party exclusivity. The roles and access of each party are monitored.

> CARREFOUR AND ITS ANIMAL QUALITY LINE

In France, **Carrefour** also announced in February 2017 that it had implemented blockchain technology for the traceability of its animal products **(26).** The initiative is part of its Carrefour Quality Lines (in this case its IGP, Label Rouge certified chickens, fed with French GM-free grain and not treated with antibiotics). The chain tracks events from birth to sale (approximately 90 days).

" The blockchain alone cannot ensure traceability. We have analysed the traceability process in depth to pinpoint what needs to be recorded in a blockchain, and when".

Emmanuel Delerm,
Project Director, Carrefour

The group chose to develop a private blockchain based on Ethereum technology (though other approaches are "under observation"), in which the network is composed of those parties included on the production and sales chain: chick consignment teams, breeders, grain suppliers, slaughterhouses, etc. Nodes in the network are hosted by Carrefour in a private cloud or by partners with the necessary IT resources.

Of course this system relies on each party effectively contributing. Chronological order is less important than ensuring processes are recorded at every stage. If needed, mechanisms such as smart contracts can report shortages/missing information.

A private network was chosen thanks to the simplicity in implementing the economic model and governance structure (initial contribution from each party according to a number of Ethers, predetermined by the consortium) and a desire to be able to control the dissemination (or not) of certain information, particularly expertise or data that is useful to producers (tracking the weight of chickens, for example). Some information recorded on the chain can be shared with the consumer via QR codes on products. Upward communication towards farmers is also being explored to keep them better informed on the repercussions of their production.

The experimental phase has been completed, and operational implementation could take place by the end of this year. For Emmanuel Delerm, a project director at Carrefour, the main advantage of this technology is the pooling of information within a circle of stakeholders committed to common quality goals. He believes the approach is essentially worthwhile for high added-value products, or where there is a need to demonstrate good practices, such as tuna fishing, another sector explored by Carrefour.

He highlighted two aspects which require caution. Care must be taken to:

// Ensure that the 'recorded information meets quality standards (since an entry is not modifiable, but enriched by another entry)'; to this end, he predicts that trusted authorities will maintain an important role, even if the technology will change this role.

// Support change by 'explaining the advantages, the rights and responsibilities of a blockchain (i.e. it is open, forgery-proof, publishable, involves commitment etc.).

> TRACEABILITY FOR CONSUMERS VIA TAGS ON PRODUCTS

A firm called **Provenance** has developed a service platform to inform consumers of the origin of a product and whether it was made in ethically/ environmentally responsible conditions. One of the blockchain-based proofs-of-concept focused on monitoring tuna fishing in Indonesia, using traditional methods rather than nets. The entire procedure is well-described on Provenance's website (www.provenance.org) **(27).** Fishermen send text messages detailing every catch; this information builds Provenance's Ethereum blockchain. Every fish is given a special serial number – a digital "tag" that it keeps as it moves along the supply chain. This example is interesting because it highlights the difficulty, at the beginning of the processing chain, of interfacing blockchain with enterprise research planning (ERP) integrated management tools in factories. In this case, only ERPs which are compatible with interoperability standards (GS1 standards) have been able to continue recording processing stages in the blockchain.

> *" Using a blockchain only makes sense if everyone works together. Its distributed and decentralised nature is essential".*

At the end of the chain, an electronic NFC tag placed on the product provides the user with background information on the product via smartphone. The tag of course cannot be copied, forged or moved, in order for the system to work. This is a challenge in making sure the solution is reliable, even though it is based on a blockchain...

The **wine industry** is also concerned: **Dartess**, a subsidiary of Tesson group, specialised in wine logistics, also announced the development of a POC. The goal is to be able to: "trace the background of a bottle of wine, so as to reduce fraud and theft, as well as simplify trade and customs processing" **(28).** Again, the link between the physical and digital is established using "smart tags". Similar initiatives have been launched in other countries, like Italy. **(29)**

>CERTIFICATION: CONNECTING FOOD AND OTHERS

Connecting Food is a French start-up with a slightly different approach to transparency: its service focuses on the notion of "real-time certification". As things now stand, brands which rely on suppliers can only verify whether specifications are followed by audits and occasional monitoring. *"Brands and distributors who outsource production audit their producers once or twice a year. This means only some 10% products sold on the market are verified and certified". (Stefano Volpi, co-founder of Connecting Food)* **(30)**. One result is that the brand image of the final product is impacted by any problems. The start-up offers a service to compare client specifications with what suppliers actually provide at every stage of production and in real time, so as to prevent an intermediary product that is unsuitable from being finished. The solution is based on a combination of technology implemented with support from IBM and CEA Tech LIST: blockchain, but also connected objects, cloud, cryptography and artificial intelligence. The economic model is based on a service approach ("Software-as-a-Service" or SaaS) with a subscription paid by the client whose specifications need to be followed **(31)**. The company also supports the work of farmers by offering financial compensation for their participation in the Connecting Food scheme.

Another example with regard to certification **is a pilot project developed by Dutch researchers** and presented at the EFITA Conference held at Montpellier SupAgro on 3–5 July 2017. The demonstrator uses Hyperledger technology in a private blockchain that manages, in real time, the creation, monitoring, and approval of certificates of conformity with specifications for the production of table grapes. This project has also appeared on the Agrotic blog: **click here**. Here again, the decentralisation of information – i.e. the 'non-monopolisation' of information – and transparency have been identified as the biggest advantages in the experiment, but with scalability issues as technical limitations.

Other studies are under way, including by key players in today's certification market – trusted third parties – such as **Bureau Véritas** which launched a POC on the certification of a logistics chain for tuna, based on "Proof-of-Process", a technology developed by Stratumn, a start-up combining blockchain and cryptography to secure communication between companies. (32) (33)

Summary:

In terms of traceability, reliable data sharing is viewed as a real 'plus' for working effectively and in confidence with partners. But:

- Blockchains only work if all parties update it;
- Information which enters and leaves the chain is not secured by the blockchain;
- The notion of a trusted third party remains in cases where the validity of information from outside the system or specific practices needs to be certified;
- Interoperability can be an issue when a blockchain is incorporated into existing information systems.

EXAMPLE 2: **BLOCKCHAIN AND AGRICULTURAL INSURANCE (AGAINST NATURAL HAZARDS)**

THE CONTEXT:

> In general, farmers are under-insured against natural hazards.

> In France, only 25% of commercialised crops (major crops and wine production) are insured against natural hazards. Farmers view available coverage as poorly adapted to their needs and only purchase insurance if they think they will recover at least the premium they paid **(36).** In the case of major incidents, governments must step in to cover losses as a result. It is in their interest, and that of insurance companies, to ensure that risk coverage is better planned.

> In developing countries, 357 million small-scale farmers with less than a hectare of land are not insured, and yet nearly 80% of all food consumed [...] is produced by these farmers. Production incidents of any kind can lead to food shortages. **(37)** The spread of risk areas across the globe, or on the contrary, the concentration of risk on a single type of crop in an area subject to the same hazards, is a source of administrative and operational costs for insurance companies. Because insurance is expensive, few farmers can afford it or are even well-informed.

FURTHER READING:

"*Blockchain et assurances*" Blockchain France website **(34)**

"*La blockchain dans le secteur de l'assurance*" on the Wolters Kluwer France website - Actualités du droit **(35)**

BLOCKCHAIN TECHNOLOGY CAN HELP TO:

- **Lower costs:** a decentralised and self-operating system can result in lower management and structural costs for insurance companies and potentially lower premiums for clients, particularly in countries where agricultural insurance is uncommon.
- **Anticipate and better assess risk:** shared access to reliable information can improve knowledge about situations and be used to develop more suitable and even more personalised insurance options (the "know your customer" principle).
- **Speed up processes:** automatic feedback in real time from connected objects or by searching a shared database can trigger stand-alone programs (smart contracts) managed by blockchain technology. An insurance policy can be paid out, for example, in the event of damage, without the need for a statement or review by an expert. The disbursement process can be sped up. "Bulk" processing can be made easier.
- **Develop new types of insurance:** collective ones, for example, by mobilising the potential of a peer-to-peer network (person-to-person insurance schemes, or involving common interest groups).

EXAMPLES:

Examples of how these possibilities are applied exist in other sectors (AXA, for example, launched "Fizzy", a travel insurance product that pays out automatically if a flight is delayed or cancelled **(38)**), but are still rare in agriculture.

> INDEX-BASED INSURANCE

A fictitious case proposed in the context of a challenge (2017 Swiss Re Hackathon: **(39)**) although theoretical, helps demonstrate the role of blockchain in **index-based insurance** (i.e. according to indexes or objective indicators such as average temperatures, rainfall, etc.) and **micro-insurance**.

The Hackathon example was developed for Kenyan farmers and describes a joint initiative, within a blockchain, of small-scale producers, aid organisations (cooperatives, micro-credit and technical assistance organisations), insurance companies, satellite weather index providers, and re-insurance companies (to whom principle insurers transfer a percentage of the risk). The insurance service is made available to farmers on their mobile phones, as most own one. The example is based on a system of indexed micro-insurance policies which take into account specific parameters for a given geographical area, a period in time, and a specific crop. Conditions and effects are noted in a smart contract. When the threshold of a parameter is reached (for example a sum of degrees, or a sum of millimetres of rain as recorded by satellite weather data), insured farmers are automatically paid. All policy holders in a given geographical zone receive payments based on the same contract, without the need for on-site inspection.

> PEER-TO-PEER INSURANCE

The idea is not new, and other platforms without blockchain already exist, like **Otherwise** in France and **Friendsurance** in Germany **(40)**: 1 insured parties form a community. 2 They declare assets and pay a premium to insure them. Most of the money is placed in an escrow account and the rest is invested in a re-insurance policy; 3 in the event of a claim, the customer is paid with the money from the escrow account and then by the re-insurance company when the escrow account is empty 4 the following year. Members of the community only pay the amount required to top up the escrow account and finance the re-insurance policy. The goal is to re-shape insurance by making customers responsible and eliminating the feeling of paying without ever getting anything in return.

The start-up Wekeep promised "a tool to store money digitally in escrow accounts as a smart contract in the blockchain", based on Bitcoin and Ethereum, but which no longer appears to be active **(41)**. However, the idea remains: a farmers' union or other association, for example, could programme a pay-out triggered automatically according to parameters such as weather data. It is similar to the concept of micro-insurance, but in this case is peer-to-peer.

NOTE:

Though few examples are specific to the agriculture sector, the insurance sector is actively exploring the potential of the blockchain. As in the financial sector, however, specific legal questions must be considered. The Norton Rose Fulbright and R3 study examined:

- "the need to create framework contracts to define relationships between participants in a blockchain;
- the need for new systems to conform with applicable regulations,
- the designation of the legally responsible party in a blockchain;
- risks of discrimination related to the storage and sharing of insurance customers' information;
- the collection and management of personal data, in particular sensitive data"

EXAMPLE 3: **MANAGING CONSENT FOR THE USE OF FARM DATA (SMART FARMS).**

THE CONTEXT

Farmers can choose to run their farms with the help of decision-making tools (DMT). Based on agricultural models, these tools incorporate an increasing amount of digital technology, for the collection, processing and use of data. The use of sensors and other connected objects on farms is growing. This increases the amount of data produced and creates agricultural "Big Data". "Over 12 million connected objects existed in the agricultural and environmental sectors in 2014. In 8 years, there will be nearly 100 million". **(42).** For increased efficiency, tools and systems must communicate and interoperate. The French government's Agriculture-Innovation 2025 mission recommends that an agricultural data portal be created to facilitate access to heterogeneous data from multiple sources. This raises real questions regarding the ownership and use of this data: farmers worry they will not control the use of their data, and digital tool and service suppliers are having a hard time determining the legality of making available and re-using the data they store. The issue of trust is central: what becomes of my data, who uses it, and what for? Can it be used against me (by competitors, for example)? Can it be sold? Can it be modified?

BLOCKCHAIN TECHNOLOGY CAN HELP:

- by providing a solution that builds confidence regarding the protection of entrusted data (in this case, consent to use data), the protection of anonymity, and confidentiality of data
- by providing a decentralised and secure solution that prevents intermediaries such as Google or Facebook from holding data for their own use

EXAMPLES:

This type of use will be explored as part of the CASDAR "Multipass" Project, launched in November 2017 and bringing together 7 partners: **ARVALIS - Institut du végétal** (project oversight), **ACTA**, **IDELE**, **ORANGE** (technological partner), **SMAG**, **FIEA** (agricultural data exchange) and **IRSTEA**.

" The goal is to give producers a "data passport" solution to protect shared data that is collected on their farms. ".

"Multipass" Project documentation

This project aims to develop new services for farmers in a confidence chain that manages consent to access farm data. The project will first identify farmers' needs in terms of a consent management tool (factors in establishing trust, barriers to remove in data sharing, and responses to legal obligations). These needs will be reformulated as functional specifications to adapt existing consent management tools. Concrete examples in major crops and livestock farming will then be studied. This will provide insight into operability between these tools and existing or future systems and the conditions needed for sustainable governance.

The blockchain will be only one of the technical avenues explored, and compared with a centralised solution which relies on a trusted authority. For this part, "development will be handled by Orange teams and primarily aim to transpose an Orange prototype to the context of agriculture [...]. This prototype, designed by innovation teams at Orange, was aimed at managing consent for accessing patients' medical data". **(42)**

Concretely, the medical prototype in question illustrates the possibility for a patient to decide with whom and why he or she wishes to share their medical information. The patient fills out a form stipulating the type of data they are willing to share, with whom (what category of medical professional), the duration of the consent and the type of authorisation given (reading access or writing). After, the data is included in the blockchain. That way, one day if he or she is away from home and needs to see someone other than their regular doctor, that professional can access their file. The patient can withdraw their consent when they return: this case is described by Sajida Zouarhi, a doctorate student at Orange Labs: **(43)**.

"The technical method used to carry out the project is based on the Hyperledger open source solution and provides a consortium-type blockchain [...] on which only pre-authorised parties (users or those who approve transactions) can intervene. Such a solution does not require the use of a resource-hungry consensus mechanism (i.e. proof-of-work), but rather a majority consensus, which also delivers good performance in terms of the number of approved transactions. Arvalis, FIEA and SMAG will each host a node in the blockchain network with support from the teams at Orange. Initially, nodes will be controlled by project partners, but are expected to be managed by the consortium in the long term". **(42)**

> *" Blockchain is not an end in itself. It is seen as a way to create confidence. "*
>
> Bruno Lauga, Arvalis, Multipass Project Manager

FURTHER READING:

"How blockchain will finally convert you: Control over your own data" **(44)**

EXAMPLE 4:
FOODSTUFF SALES AND PAYMENTS TO PRODUCERS

THE CONTEXT:

> In the agricultural sector, significant delays often occur between the sale of foodstuffs and the moment a producer is paid. Extended payment processing times can create situations where a producer is dependent on a client. A power imbalance can therefore result between individual producers and influential client companies.

> In developing countries, cooperatives help farmers retain a bigger percentage of the value of their crops, but rely on printed documents or oral promises to do so. Serious problems and corruption can result from a lack of transparency and restricted access to price data. **(45)**

> In developing countries, crops are sometimes sold too soon out of fear that they will not sell later, leading to a significant drop in the quality of the food and, possibly, waste. **(46)**

BLOCKCHAIN TECHNOLOGY CAN HELP:

- **By building trust** between buyers and sellers through the use of an open register which records who sells what, who buys what, and at what price.
- By providing **access to accurate information**, even to very small producers, so as to better ascertain the value of foodstuffs on local and international markets, and enable good planning.
- Through the use of **smart contracts**: general and payment terms and conditions can be recorded and impossible to change, and carried out automatically.
- Because a peer-to-peer network **enables direct producer-to-purchaser sales,** eliminating intermediaries and commission fees.

EXAMPLES:

> BEXT360: FOR A MORE FAIR REMUNERATION OF COFFEE GROWERS

Bext360 has decided to use blockchain technology to improve the lives of coffee growers. The company has developed an artificially intelligent and vision-equipped robot to sort coffee beans into three categories – A, B and C grade. Ratings are reported to purchasers and farmers, who can negotiate fair prices using the bext360 phone app. The app and software are cloud-based and use Stellar.org blockchain technology to create a record of where the beans come from and who paid how much for them. Processing plants, distributors, wholesalers and other stakeholders along the supply chain can use the platform's traceability feature. In the long term, this will enable customers to know the origin of a product and how it was made.

> AGRILEDGER: HELPING SMALL-SCALE FARMERS AND THEIR COOPERATIVES

AgriLedger is a philanthropic initiative that uses blockchain technology to create a 'framework of trust' for cooperatives and small-scale farmers. The company offers: a mobile app, connected to a blockchain, which records transactions (smartphones are provided via partnerships with telecommunications companies); a service bundle which provides a better vision of market conditions and allows users to improve product distribution; secure digital identity management and a value 'safe' which allows small-scale farmers access to the world of banking services, micro-payments, and loans.

> AGRIDIGITAL: INTEGRATED MANAGEMENT IN THE GRAIN INDUSTRY

The Australian firm **Fullprofile** is testing the use of Ethereum blockchain for AgriDigital, an integrated platform for the grain industry which brings together producers, buyers and agents managing contracts, invoices and payments. The solution uses smart contracts to ensure that sellers are paid immediately upon delivery to the buyer. After the transaction is approved, payment is made by traditional methods (e.g. an automatic payment order via a bank), thus eliminating the need for cryptocurrency.

OTHER EXAMPLES IN **AGRICULTURE...**

> Ensuring ownership of farm land:

// In Africa, 90% of rural areas are not listed on a land register, which is a real barrier to economic development: it is hard to run a company when one does not even have an address to receive supplies. *Bitland*, a start-up in Ghana, is trying to solve this problem by creating a record of real estate transactions using blockchain. Similarly, in 2015, the Honduran government registered its entire land registry on a blockchain with help from Epigraph and Factom to resolve frequent problems with fraud: certain people were entering databases and attributing themselves land ownership.

> Crowdfunding insurance:

// Crowdfunding, where a community co-finances a project, is developing in agriculture. Two examples are **Miimosa** and **Blue Bees**. Blockchain can extend (or transform?) this trend by offering a secure solution for transferring funds directly to an entrepreneur using cryptocurrency.

Blockchain is receiving a lot of attention in the press for its potential in venture fund raising. A term has been designated for the concept: Initial Coin Offering (ICO). Digital assets ('tokens') are issued by the company behind the ICO, and are sold to project backers in exchange for cryptocurrency. The tokens represent rights to use the company's future services. They can be re-sold, but their value depends on the value attributed to the service or product (i.e. based on speculation).

> And more indirectly:

// **Pur Projet** uses blockchain to support agroforestry projects in developing countries. In one project, Nespresso has committed to planting 10 million trees according to an agroforestry model, in partnership with Nespresso coffee growers in Colombia, Guatemala, and Ethiopia. Agroforestry is seen as a way towards a more sustainable production model for local populations. In exchange, the evidence of a company's commitment, equal to a carbon offset, is certified and the company can include this in its value chain. "Thanks to blockchain [...] all of a company's commitments to ecosystems can now be certified and recorded in a transparent, decentralised, and tamper-proof manner — without a financial intermediary, and therefore at a reduced cost", explains Tristan Lecomte, co-founder of Pur Projet and the International Platform for Insetting (IPI). **(47)**

Summary:

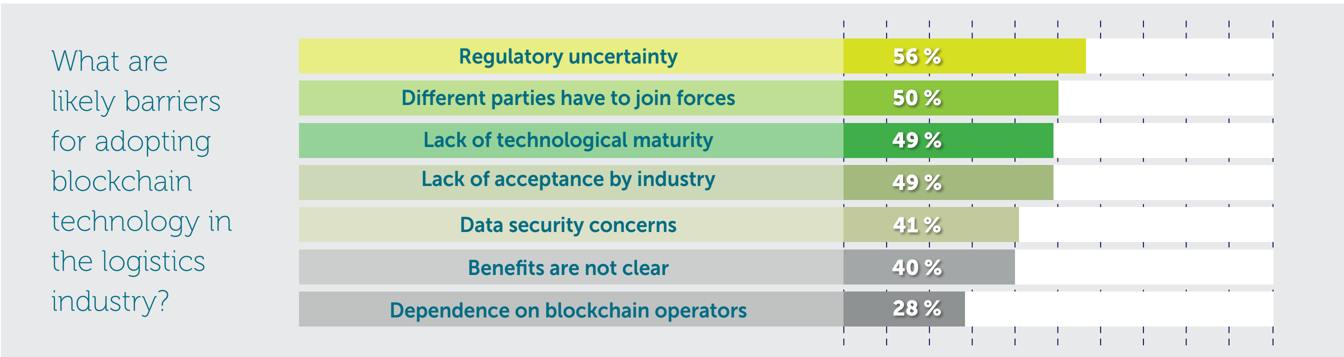
- The use of blockchain for traceability and supply chain management is one of the most promising – and probably best explored – uses so far.
- Blockchain is a promising concept in agriculture, particularly for its potential to deliver peer-to-peer solutions to small-scale producers.
- A wide range of applications are possible in agriculture, from traceability and payments for produced foodstuffs, to the piloting of smart farms. Others remain to be invented.

PART III:
Evaluating

As we have seen, distributed ledger technology holds a great deal of promise, in agriculture and elsewhere. However, several steps remain in making these promises a reality: most of the examples described are still at the PoC stage and it is sometimes difficult to obtain feedback from those who implement the solution.

We thought it interesting to review the various questions surrounding blockchain and the responses available today to better understand possible obstacles and find a better positioning in relation to individual needs.

In an October 2017 conference paper entitled *("Blockchain in Logistics and Supply Chain: Trick or Treat?")* **(48)**, researchers Niels Hackius and Moritz Petersen share the results of a study conducted on social media between April and June 2017 to gain insight into blockchain use in logistics chains and identify likely obstacles to the adoption of the technology. One hundred fifty-two participants answered the following question: "What are likely barriers for blockchain adoption in the logistics industry?"



Even if these results are specific to the logistics industry, they raise the following issues:

"Benefits are not clear"

> The blockchain is heralded as a revolution, but **is it all it is chalked up to be**? We know that a technology must prove it can satisfy a given set of needs before it is accepted. When is it suitable?

"Data security concerns"

> The main selling point of the blockchain is its ability to build trust, particularly in relation to security. Is this trust warranted? **Are there security risks?**

"Lack of technological maturity"

> Can blockchain technology be used today? **Is it mature enough?** If not, why?

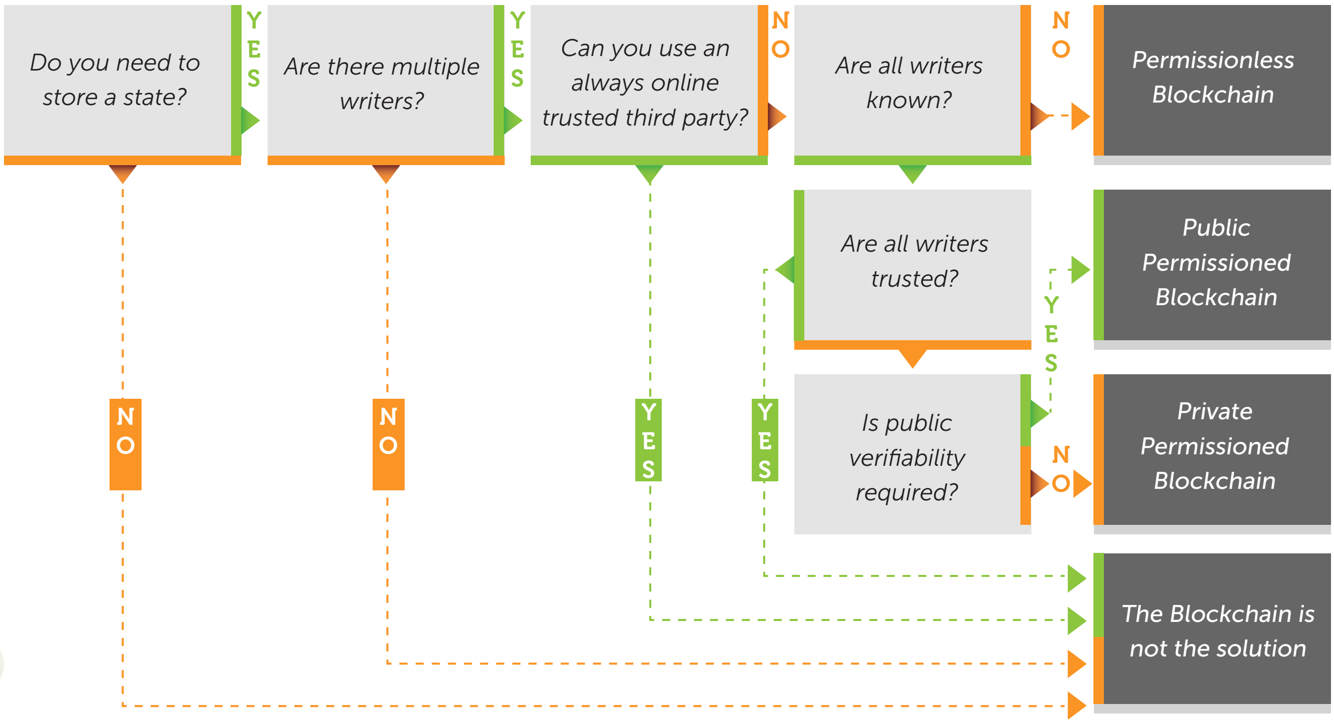
"Regulatory uncertainty"

> Blockchains – public blockchains in particular – represent a complete paradigm shift in terms of governance and the way transactions are carried out. However companies must show they adhere to a legal framework to convince people that their project is sustainable. **How are legal aspects currently addressed in blockchain technology?**

1 | Is blockchain technology all it is chalked up to be?

NO, of course not: as with any technology, there are pros and cons which must be understood in order to avoid disappointment. In particular, there are cases where blockchain technology is simply not relevant.

Gidéon Greensplan addressed this topic in 2015 in an article published on the site Multichain **(49)**. In it, he stated that to generate a blockchain, it was first necessary to determine whether a shared database was useful; whether there were, in fact, among different contributors some who had trust issues; whether it was really necessary to do without a trusted third party, and whether enough was known about those entrusted with approval roles. These ideas were echoed in a 2017 article by Karl Wüst and Arthur Gervais, in which they propose a method for identifying cases where the use of blockchain makes sense (see figure below).



It is important, then, to view blockchain in relation to a set of needs and not expect more than it can deliver.

"Blockchain alone can't do it all," explained Alexandre Stachtchenko, a co-founder of Blockchain France, in an article published in *Usine Nouvelle* magazine **(28)**. *"The blockchain manages digital assets wonderfully; when you throw physical elements into the mix, you need QR codes, connected objects, and sensors. The blockchain is simply an architecture that acts as a catalyst for all these technologies".*

In light of this, let us examine what the blockchain makes possible and what it does not. In theory, information is tamper-proof once it is consigned to the chain. However, if consigned data were incorrect when entered, the information will remain incorrect forever (another transaction will eventually be needed to correct it).

This raises the question of the disappearance of the trusted authority, highlighted as being one advantage of this technology. As seen above, especially in the case of traceability, it is still necessary to make sure that information added to the blockchain is consistent with reality and that data leaving the blockchain will not be corrupted. **The need for a third party, or "trusted authority" therefore moves to the periphery of the system. (3)**

Smart contracts pose a special problem when it comes to this issue of peripheral trust: they require input data to automatically trigger actions based on pre-determined conditions. This data comes from real or virtual sources outside the blockchain (databases, connected objects, etc.).

However a blockchain is "blind" to the outside world by design **(50)**. It cannot rely on outside services to recover data; if it did, the request would be included in the transaction and re-initiated every time the blockchain is replicated. The data must be 'injected' into the blockchain, and its integrity ensured beforehand.

To resolve this problem, blockchains are integrating a new component, similar to a trusted authority: an Oracle (this term originated with Ethereum).

Oracles are "agents" tasked with connecting the chain to the real world to allow secure, reliable data to be added to the blockchain. These agents can be physical trusted authorities, as before; in this case, however, the issue of whether the technology is useful arises. Oracles can also be applications that check whether data is compliant with its source (**Oraclize** offers this type of solution). A peer-to-peer network can approve data by consensus (platforms like **Augur** offers these types of services). Connected objects can also carry out this task; in this case the objects themselves are connected to solutions that transmit or receive secure data.

Summary:

- A blockchain should be implemented as a solution to specific problems. It is not a miracle solution.

- The blockchain only ensures data integrity and security from the moment it is written into the blockchain. Erroneous data can be written into the chain, and data can be tampered with when it exits said chain. The notion of trusted authority can arise with the chain's periphery.

- A new type of trusted agent is needed to connect the chain to the 'real' world: the oracle.

2 I Is blockchain technology 100% trustworthy?

NO. It increases trust compared with other systems but there is no such thing as 'zero risk'.

A paper by Igor Kabashkin, published for the "Network and System Security 11th International Conference" held in Helsinki in August 2017 **(51)**, lists the different risks that may arise, including:

> **Private key loss:** private keys are personal and allow owners to send and receive transactions. If it is lost or stolen, there is no way for the transaction to be recovered.

> **Loss of anonymity** (or pseudonymity): the system itself is not as anonymous as promised. The same user can carry out bulk transactions with public keys connected to one another. If their real identity is unveiled, all of the dealings can be traced.

> **Program glitches:** by definition, the data recorded in a blockchain cannot be altered. However, all this is performed by algorithms. If there is a glitch in the program (in a smart contract, for example), both the glitch and its outcome are 'sealed' in the chain and a security breach could be exploited. The "TheDAO" hack is a well-known example of this: a glitch in the code made it possible for one network member to steal 50 million dollars.
If the glitch is in the blockchain, the protocol must be updated, which may create chronological discrepancies (i.e. a risk of creating a second 'fork' in the chain). If the source of the problem is a smart contract, a second program is needed to correct the first, which itself cannot be modified. In this sense, a blockchain is considered as being adverse to change.

> **Sustainability of cryptographic algorithms**. The blockchain is secured by these algorithms. If a new process capable of attacking them were developed, the entire system would collapse. Currently, no malfunction of this kind has been found.

> **A takeover of the blockchain:** blockchains are built on protocols which are highly resistant to attacks – consensus protocols in particular. However, if nodes were to take over more than 50% of the computing power (in the case of a PoW), or collude to approve blocks, they can take control of the chain by creating the longest one possible (as seen above, one rule in Bitcoin, for example, is that if two competing branches are created, the longest one becomes the valid one). Control measures must be put in place to prevent such attacks.

> **Blockchain neglect:** "maintenance" of the blockchain depends on the good will of its participants (i.e. nodes). If they decide to no longer work on the blockchain, it dies.

According to Primavera de Philippi, a researcher at CERSA interviewed by **Blockchain France** in the wake of the "TheDAO" affair: *"There is no truly "trustless" system, in which the issue of trust is completely eliminated. While the concept can work as a rhetorical tool, the ideal of a perfectly trustless technology is just that: an ideal"* (20 July 2016)

Summary:

• The blockchain is secured at different levels: through the use of cryptography, through duplication by network nodes, through the implementation of approval protocols, etc. As such, it is a technology that inspires trust where security is concerned, more so than other technologies.

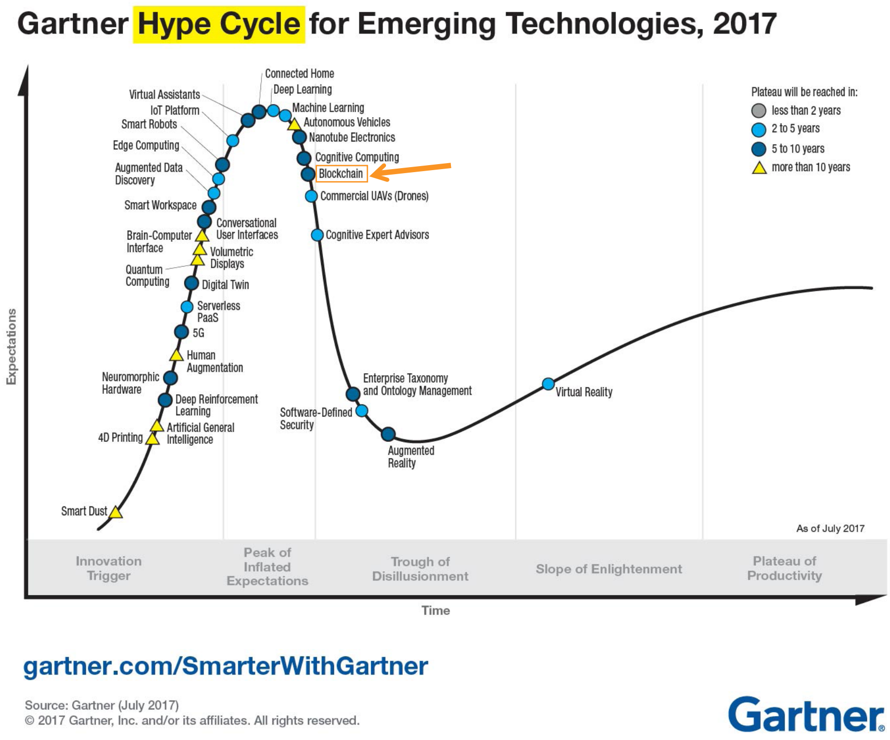
• As with any system, however, security breaches can always be found. Some have already caused malfunctions. Others remain hypothetical.

• The first to be implemented show that trust cannot be completely handed over to technology: it remains an ideal.

3 I Is blockchain technology mature?

NO if you believe the Gartner group:

Every year, the group publishes the "Hype Cycle", which positions various emerging technologies on a curve and describes 5 phases in their adoption: the "innovation trigger", the "peak of inflated expectations" (buzz in the press, appearance of multiple start-ups), the "trough of disillusionment" (criticism in the press, failure of initial trials), the "slope of enlightenment" (identification of real interests), and the "plateau of productivity" (the technology is mature). These 5 phases can occur over several years because of technologies reaching maturity at different times.



The 2017 curve placed blockchain as still being in the "peak of inflated expectations" phase and nearly entering the "disillusionment phase". The report also indicated that the blockchain would arrive at maturity in five years or more...

This is also the analysis of Christine Hennebert, a researcher at CEA LETI in Grenoble who studies the security of Internet of Things protocols and the implementation of security functions in connected objects. Ms Hennebert was interviewed for this study:

"There is a lot in the press about blockchains, but in the vast majority of cases, there is little behind this buzz. This technology is in its early stages and at the experimental phase. I think it has enormous potential, but it needs to prove its effectiveness via initial projects and feedback.
Much needs to be done. I think some (robust) solutions will be ready for the public in four years' time, but probably not before".

C. Hennebert, September 2017

What are the main problems which prevent the technology from reaching a sufficient stage of maturity today?

Problems are essentially linked to the "scaling up" phase (the transition to real use from the experimental phase). Limitations, primarily technical, are particularly observed in public blockchains (like cryptocurrency), and involve:

> **the size of the blockchain** and its ability to support growth in the number of users: according to statistics, available at **https://blockchain.info/fr/**, the size of the Bitcoin chain increased 58% in a year and reached 137,000 MB in October 2017. Given that the number of users is currently still very limited and that the computing power required for mining increases considerably with the size of the chain, the system is viewed as not being easily "scalable". Energy costs are also criticized (in early 2017, the cost of powering the PoW was estimated to be 3.8 billion kWh per year, according to Bitcoin.fr).

> **The volume of transactions**: currently, Ethereum and Bitcoin handle, respectively, 25 and 7 transactions per second, while VISA handles 20,000 transactions in the same amount of time. This is due to the time taken by mining: as mentioned earlier, around 10 minutes pass between the addition of two new blocks in a Bitcoin chain.

> **Storage capacity**: a blockchain is not a database in the traditional sense. Its data storage capacities are limited: a blockchain is designed to store the fingerprint of data – the proof of its existence – rather than the data itself. As discussed in the paragraph on oracle systems, this therefore involves maintaining an additional infrastructure.

> **Interoperability** between blockchain and other systems is also a point to be monitored. According to Nicolas Pauvre, Project Manager at GS1 France, interviewed for this study, the blockchain does not eliminate the problem of standards, structuring, and the coding of transactions. "The short-term challenge is to ensure interoperability with existing systems on which the blockchain is an additional layer. Different blockchains must also be able to work together".

Solutions to these different problems are being developed, but still require serious testing. For example:

> Concerning scaling up and the fluidity of transactions, possible improvements are under study in the main blockchains in operation (gradual improvements to protocols, increasing the size of blocks, etc.).

In the case of the internet of objects, the decentralisation and system availability offered by blockchain appear to offer a plus compared to other systems. A project manager at Atos interviewed for this study explained that "Blockchains are interesting for IoT because they remove the need for single units of certification, which creates conflict given the volume of exchanges with connected objects".

> Concerning energy costs, the issue arises differently depending on the blockchain (public or private, for example) and the systems for approving blocks, which differ significantly. However, the CEA-LETI in Grenoble is working on quantifying the energy needed to achieve a given level of security.

> Concerning harmonisation and interoperability problems: GS1 has announced a partnership with IBM and Microsoft to make progress on establishing interoperability standards. French standards body AFNOR has also created a standardisation committee on the subject of blockchain, but work has only just begun.

Scaling issues also raise questions about governance. The more chains grow, the more stakeholders they involve, and the harder it is to see eye to eye. Efforts to improve performance, for example, have divided the Bitcoin community – and the blockchain as a result – into two camps: some favour gradual improvements (a "soft fork" consisting of a protocol update, i.e. the "Segwit" camp), and others want a radical update (a "hard fork, in which block sizes are increased significantly, the "Bitcoin cash" camp).

Summary:

- Blockchain is not a mature technology.
- Technically speaking, uncertainties persist as to its ability to integrate larger numbers of users. Solutions for interoperability with other information system components are also needed.
- In terms of governance, a balance must be struck: a growing chain means more stakeholders who need to agree with one another.

4 | Will legal uncertainty be a concern?

YES and NO... The legal framework of blockchains is, indeed, far from complete. On one hand, this could be a good thing, as too much legislation can curb creativity and innovation. However, on the other, it could be a significant obstacle to its adoption. Legal uncertainty implies taking risks A simple oversight or error of interpretation can lead a party to breach a regulation (and expose them to fines) and lose credibility by making promises that cannot be kept.

FURTHER READING:

"*Panorama des enjeux juridiques de la blockchain*", Blockchain Partner (52)

Until now, blockchain technology has not violated regulations which apply to specific sectors (finance, insurance, healthcare, gaming, etc.) in regard to identity (Know Your Customer rules, for example) or the collection of personal data.

However, some people defend the idea of "blockchain law", which would completely revolutionise operating rules in the legal field, as it promises to change other fields, based on the argument that "a large percentage of the obligations established on blockchains are incompatible with the requirements of traditional law" (See the Blockchain France article on the subject:
"*Blockchain et Droit : Code is Deeply Law*") **(53)**. Blockchains have no borders, for example: the Bitcoin is a worldwide blockchain. As such, when a problem occurs, which laws apply?

Let's review the main examples of blockchain uses to identify some of the legal issues that exist today:

» RECORD KEEPING

Currently, blockchain is not recognized as a legally valid form of proof of the ownership or a transaction to that effect. As with any other digital medium, there is an obligation to show a judge that a record is admissible (which amounts to explaining that blockchain guarantees the authenticity and integrity of data, etc.).

The legal framework is evolving quickly, however, with a focus on financial aspects: In France, the following changes have been made:

> **French official decree no. 2016-520 of 28 April 2016 on saving certificates,** Article L223-12, states that "the issuance and transfer of mini-certificates can also be consigned to a shared electronic recording system which allows the authentication of these transactions [...]".

> French Law no. **2016-1691 of 9 December 2016 ("Sapin II")**, on transparency, the fight against corruption and the modernisation of the economy, allows the French government to change the legislative framework to facilitate the transfer of certain financial instruments using "blockchain" technology.

> The French Treasury conducted preliminary consultations prior to drafting a text, **(54)** and then, from September to October 2017, consultations on a draft **decree** on blockchains and financial instruments.

Other issues do remain:

> The **burden of** certification: while blockchains eliminate the need for certain trusted authorities such as lawyers or banks, it remains to be seen who will assume responsibility in the event of a malfunction. A private blockchain poses less of an issue, but in the case of a public blockchain, which by definition belongs to no one, who will be held accountable in the event of prejudice to a party? Is the system reliable enough to resolve these issues?

> The right **to be forgotten:** This issue is central to the unalterable nature of the data recorded on a blockchain. In principle, once recorded, data cannot be erased or modified, and yet parties other than the individual concerned have access to this data.

DIGITAL TRANSACTIONS

Questions regarding this issue focus for the most part on the status given to "tokens", the unit of currency used in a blockchain. A token can be a variety of things: a product, the traceability of which is tracked; a 'reputation' token, a loyalty coupon, a voting right, a cryptocurrency unit, etc. but has no intrinsic value itself. Its value is derived from how it is used or evaluated, which results in speculation. That raises legal questions because, if a single, blanket definition is established through regulation, this could lead to the application of a specific set of regulations (the Monetary and Financial Code, Commercial Code) or make certain tax law provisions apply (VAT, etc.) In France, for example, tokens are currently identified as simple movable assets, more by elimination compared with other definitions. The status of cryptocurrency is attributed differently depending on the country. Most accept it as a "payment method", at least, but few have attributed a legal value to it.

SMART CONTRACTS

It is important to understand that, contrary to what the term suggests, smart contracts are not actual contracts. They are sets of computer code that carry out contractual obligations. The same provisions therefore apply to an agreement between parties; to enter into a contract, they must be aware of applicable regulation. However the issue of legal security arises. Like any computer code, a smart contract can be subject to glitches even if, in theory, smart contracts are unalterable. Who is held responsible if a contract cannot be executed? The developers who created it? However, knowing who they are may not be possible. The parties to the agreement who have not made sure that all the clauses in the contract were properly translated into computer code? Not everyone can read computer code, however. These issues have not been resolved.

Summary:

- The legal framework surrounding blockchain remains unclear.
- Waiting to enact laws allows room for experimentation. Excessively coercive regulation is anathema to the philosophy behind public blockchains, which by definition are independent of central authorities.
- Legal uncertainties create risks for those who launch solutions and those who use them (i.e. an inability to determine liability, non-recognition of prejudice, non-recognition of the "proof" provided by the blockchain, etc.).
- The legislative and regulatory framework evolves in tandem with developments and uses. Financial uses are currently the most frequently observed ones.

CONCLUSION

The term blockchain represents many things:

- an innovative combination of pre-existing technologies which enable the distributed and secure management of a transaction ledger,
- a form of peer-to-peer governance that re-invents the concept of trust without a trusted third party,
- a structured ecosystem of parties,
- a paradigm shift in a variety of fields

The blockchain disrupts existing frameworks – legal ones in particular – and encourages the emergence of new and relevant applications to fully achieve the potential that many, in all sectors, see in this technology.

The agricultural sector is of course directly affected. Blockchains create interesting opportunities, in terms of traceability, adding value to farmers' work, improving the working conditions of small-scale farmers, and enhancing the operation of smart farms. One future challenge is to create a chain of trust on which a farmer can control his or her data. The rapid development of connected objects in agriculture will necessarily benefit from the advantages offered by blockchain technology and smart contracts: stand-alone programs that link the digital to the real world.

Several challenges remain, including the need to secure data that exists on the periphery of a blockchain. Today, however, distributed ledger technology – in its various forms – is still in its early stages, and it would be unreasonable, in agriculture or elsewhere, to place excessive hope in its potential. A number of technical, legal, and social issues must still be addressed. It will likely be another five years before robust examples of blockchain become available.

This summary, intended as an introduction to the subject, is based on an already wide body of literature. It should be expanded to include more experiments and feedback. A wide range of possibilities exist: public and private blockchains, the use or not of the tools and services of "major" digital players, interfacing with existing and future information systems, etc. The return on investment must also be assessed, but even without clear performance targets, testing is the only way to develop infrastructure and skills within companies. This is key to adopting a technology which, even when well understood, remains difficult to implement.

The AgroTIC Business Chair will naturally be monitoring developments until the blockchain reaches technological maturity.

CHAIRE AgroTIC

FEASABILITY STUDIES

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