2ND GLOBAL ENTERPRISE BLOCKCHAIN BENCHMARKING STUDY

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Forewords

Cambridge
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Terms such as "blockchain" and "distributed ledger technology (DLT)" have established themselves in our daily lexicon. Yet, rarely do they relate to the same thing. Unfortunately, this conflation of terminology hampers a clear assessment of blockchain technology adoption in different industries. Our *2nd Global Enterprise Blockchain Benchmarking Study* seeks to shed light on the diverging interpretations of these terms and the potential confusion being created. The report delves into the granular detail of how the enterprise blockchain ecosystem has evolved since the publication of our first report in 2017, by using data collected from more than 160 entities and 67 live networks.

We believe this report is distinguished from other studies by its focus on the state of network deployment and its investigation of the different development stages of ongoing enterprise blockchain-based projects. This approach has revealed several patterns of development that provide both industry participants and the wider public with common points of reference to build upon. In multiple industries, enterprise blockchains are perceived as a solution to establish common data standards across organisations, eliminate organisational silos, and facilitate record reconciliation to help improve overall efficiency and enable the creation of new services.

Adoption of enterprise blockchains within the private sector has been increasing with several networks moving from ideation to production over the course of 2018 and 2019. However, the technology is not a panacea and comes with its share of trade-offs that industry adopters are experiencing first-hand. As empirically demonstrated in this report, blockchain adoption by incumbents is indeed a slow and challenging process that requires deep cross-organisational coordination and careful legal and organisational design choices. This may at least partly explain the dominance of centralised approaches to system design observed across the majority of deployed networks, albeit with an expectation of a gradual distribution of control over the course of time.

Our hope is that this analysis will make a critical contribution to deconstruct the enterprise blockchain ecosystem globally. As always, we recognise that our ability to produce high quality research is highly dependent on the cooperation of industry initiatives and entities and we extend our thanks to those that have contributed information and data to the co-authors of this report.

Dr. Robert Wardrop
Director
Cambridge Centre for Alternative Finance

The *2nd Global Enterprise Blockchain Benchmarking Study* is a straightforward and comprehensive look at the state of blockchain affairs across the financial services industry. It gives insight into the realities of how blockchain initiatives are structured, supported and moving to production with a special focus on private, permissioned Distributed Ledger Technology (DLT). The findings of the study can be corroborated by Invesco's own experiences in initiating blockchain and DLT proof-of-concepts (PoCs) to help people get more out of life through a superior investment experience.

The study looks at over 160 stakeholders from a global sample of 49 different countries and begins by setting context around defining blockchain projects. It dives into the terminologies surrounding blockchain initiatives distinguishing between true DLT projects from the "blockchain meme", a way of classifying projects that satisfy the blockchain hype as opposed to deploying truly transformational DLT networks. A few salient points shine through in the report: one being that the success of blockchain cannot and will not happen in isolation as the power is in the network, that true transformation of ecosystems takes time, and that new technologies must prove themselves to build trust in the new paradigm.

It has been noted in some places, that blockchain has entered the "Trough of Disillusionment" phase of the technology hype curve as defined by Gartner. This study shows that experimentation, adoption, and execution are still strong, but that most blockchain initiatives fall into the realm of the "blockchain meme", and "only 3% of analysed networks meet the criteria of full multi-party consensus systems, whereas one fifth of projects can be considered potential DLT systems that are gradually progressing towards removing single points of failure and control." There is also still a strong misconception of trust on the blockchain. Potential participants get wary about whether blockchain can be trusted; however, it is primarily the on / off ramps that are the vulnerable exposure points to malicious intent rather than the technology.

Blockchain has its roots in Bitcoin, a fit for purpose digital currency and transactional accounting ledger enabling trust among untrustworthy actors. Observers caught on that the concepts that make the blockchain whole could be applied elsewhere, thus, blockchain started as a utopian solution looking for a problem, which contributed to the adoption of "blockchain meme" initiatives. Blockchain is still in the early stages of providing real solutions for actual problems.

The financial services industry is a complex ecosystem, and we're all living through the blockchain/DLT transformation together. The true disruptive potential means that entire paradigms and operating models could be turned on their heads. Many players are exercising caution as they proceed in into unchartered territory as there are incumbents in positions of power who will be severely disrupted by blockchain's success. These players have a vested interest to ensure that the technology is not successful.

We'd like to thank all of the individuals and teams dedicated to creating this global study. As Invesco continues to move forward in our quest to deliver alpha generating performance and an elite client experience, we're undertaking multiple blockchain initiatives across various intersections of

our value chain. Our relationship with the CCAF and the access to reports such as this Global Benchmarking study serve to provide a glimpse into the overall trends occurring across financial services that help us calibrate our strategy and make informed decisions on the right pace at which to move in adopting blockchain/DLT technology.

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Executive Summary

Since the publication of the first *Global Blockchain Benchmarking Study* in September 2017, the enterprise blockchain ecosystem has undergone considerable changes: while two years ago, the industry landscape was mostly dominated by half-hearted experiments and short-lived proofs-of-concepts — often announced with great fanfare and publicity, the hype has gradually given way to genuine development of sustainable blockchain networks that are increasingly being deployed in production environments.

Between July and November 2018, the research team collected survey data from more than 160 start-ups, established companies, central banks, and other public-sector institutions from 49 different countries across the world. Additional data on 67 live enterprise blockchain networks was collected between April and June 2019 to provide new, empirical insights into the state of the ecosystem and capture major trends of the rapidly-evolving industry.

The analysis has revealed the following key findings:

- **The Banking, Financial Markets and Insurance industries are responsible for the largest share of live networks:**
  The trend indicated in 2017 has continued: 43% of enterprise blockchain networks deployed in production can be attributed to Financial Services, far ahead of any other sector and industry. The specific use case of a network can be at times difficult to identify, but supply chain tracking, trading infrastructure, and document certification seem to currently dominate.

- **Successful projects require a long-term perspective and commitment:**
  Transforming critical market infrastructure takes longer than simple application development: the median enterprise blockchain project takes 25 months between the first proof-of-concept and being deployed in production, with some large-scale networks taking more than four and a half years for the full launch.

- **Founder-led networks between partnering organisations are prevalent:**
  While much has been written about large-scale consortia developing new blockchain networks, 71% of live networks have been initiated by a single founder leading the initiative. 88% of deployed blockchains are designed for shared use between multiple independent entities, but the majority are restricting membership to partners: only 19% are jointly operated by direct competitors.

- **Cost reduction is the main value proposition of live networks, but increasing revenue generation is expected in a second phase:**
  72% of live networks are currently primarily used to reduce costs for participants through reduced reconciliation efforts. However, 69% of network participants indicate that the key motivation for joining the project is the potential of generating incremental revenues through the provision of new products and services.

- **Hyperledger Fabric appears to be the platform of choice across all industries:**
  48% of covered projects that are used in production have chosen Hyperledger Fabric as the core protocol framework underlying the network, followed by R3's Corda platform (15%) and Coin Sciences' MultiChain framework (10%).

- The majority of live networks retain a high degree of centralisation, but plan to gradually distribute control over time:
  81% of covered networks have a leader entity dominating the governance process (centralised *social consensus*), and many networks — at least in their current form — use third-party service providers to host and operate nodes on behalf of network participants (centralised *network consensus*).

- Unclear terminology and marketing hype have contributed to the "blockchain meme":
  77% of live enterprise blockchain networks have little in common with multi-party consensus systems apart from incorporating some of the same technology components (e.g. cryptography, peer-to-peer networking) and using similar nomenclature. The "blockchain meme" nevertheless acts as a powerful catalyst to overcome corporate inertia and spur wide-reaching organisational change, both within and across organisational boundaries.

The study also dives into major technological concepts of blockchain technology and lists the key characteristics that a blockchain network typically fulfills. Furthermore, the report introduces the various types of actors that populate the ecosystem and describes their activities and associated revenue models, while empirically demonstrating the development of the industry with employee growth figures. The main blockchain strategy drivers, activity assessments, and remaining key challenges to broader adoption are highlighted and potential future trajectories are explored.

Section 1: Blockchain 101 - Clearing up Common Misconceptions

Introducing key concepts

Terminology: "Blockchain" or "DLT"?

There are a multitude of terms floating around the industry that, depending on the discussant, may have either the same meaning, or refer to completely different concepts. Similarly, there are various conflicting definitions as to what constitutes a "blockchain" or a "distributed ledger". This situation frequently leads to misunderstandings and creates unnecessary confusion that hampers further development.

Whilst we have repeatedly suggested an alternative, more generic term — distributed ledger technology (DLT) systems — we recognise that "blockchain" and "DLT" both have established themselves as umbrella terms that are often used interchangeably. We will thus use them as such throughout the remainder of the report.

DLT is a subset of distributed systems

DLT can be considered a subset of distributed systems, i.e. systems that consist of multiple independent components (e.g. computers) that communicate with each other.[1] They are often based on a peer-to-peer (P2P) architecture where computers (*nodes*) exchange messages directly between each other without going through a central server.

<p align="center">DLT systems are designed to operate in an adversarial environment</p>

Most distributed systems consist of multiple nodes that collectively store and process data, but are owned or controlled by a single entity. What sets DLT apart from these systems is the lack of a central authority that coordinates how nodes reach agreement over the state of the system: DLT systems are specifically designed to operate under adversarial conditions so they can remain operational even in the presence of unreliable components (e.g. hardware failures, connectivity issues) and malicious actors who are trying to sabotage the system.

Key characteristics of a DLT system

A DLT system is a *multi-party consensus system* that enables multiple distrusting entities to reach agreement over the *ordering of transactions* in an *adversarial environment* without relying on a central trusted party.

A DLT system needs to be capable of ensuring the following four properties:

- **Shared recordkeeping:** enable multiple separate entities to provide data inputs and participate in the creation of new records.

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[1] See Figure 4, page 23 in Hileman, G., and Rauchs, M. (2017) *Global Blockchain Benchmarking Study*. Cambridge Centre for Alternative Finance. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3040224 [Last accessed: 29 July 2019].

- **Multi-party consensus:** require multiple separate entities to collectively reach agreement over the *ordering*[2] of transactions in the absence of a central authority.

- **Independent validation:** enable each participant to independently verify the state of their transactions and the integrity of the system. This also involves detecting unauthorised changes applied to records in a trivial way.

- **Tamper evidence:** allow each participant to detect on-consensual changes applied to records trivially.

- **Tamper resistance:** make it hard for a single party to unilaterally change past records (i.e. transaction history).

It is worth noting that DLT systems are dynamic and constantly evolving. This continuous transformation may affect system characteristics and thus potentially its core properties highlighted above. As we will see, a number of "DLT systems" currently operate in closed, safeguarded environments with no adversarial dynamics for a variety of reasons. More information can be found in the *Distributed Ledger Technology Systems: A Conceptual Framework* report from 2018.[3]

Permissioned vs. Permissionless

DLT systems can be **public and permissionless**: anyone is free to join, use, and leave the network as well as participate in the network consensus without having to ask for permission. Because these systems have dynamic membership (i.e. the number of peers on the network is unknown and subject to change), they rely on a combination of economic incentives via their native token and game theory in order to properly function and remain secure.

DLT systems can also be **private and permissioned**: access to the network is restricted to a limited number of participants, courtesy of a gatekeeper. Different levels of permissions (e.g. the right to participate in "network consensus") are assigned to network participants. These systems have fixed membership (i.e. the number of peers on the network is known): since all participants are identified, contractual agreements can be established between them to penalise misconduct.

The remainder of this report will exclusively focus on private and permissioned DLT systems that operate in an enterprise context.

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2   In some cases, there may be multiple valid but competing claims in the system of which only one can eventually get processed (e.g. someone trying to send the same token to two different recipients simultaneously).

3   Rauchs, M. et al. (2018) *Distributed Ledger Technology Systems: A Conceptual Framework.* Cambridge Centre for Alternative Finance. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3230013 [Last accessed: 18 July 2019].

Decomposing "consensus"

Common blockchain parlance often involves the notion of "consensus", but generally lacks a clear specification about the nature of agreement, i.e. what consensus is reached over. We introduce the concept of two related, but distinct types of consensus in Figure 1.

Figure 1: Every DLT system has two types of consensus

1. Social consensus:
Reaching agreement over what actually constitutes the system (incl. consensus rules, how network consensus is reached, etc.)

2. Network consensus:
Reaching agreement over the system state (i.e. latest ledger version) within the universally-accepted consensus rules
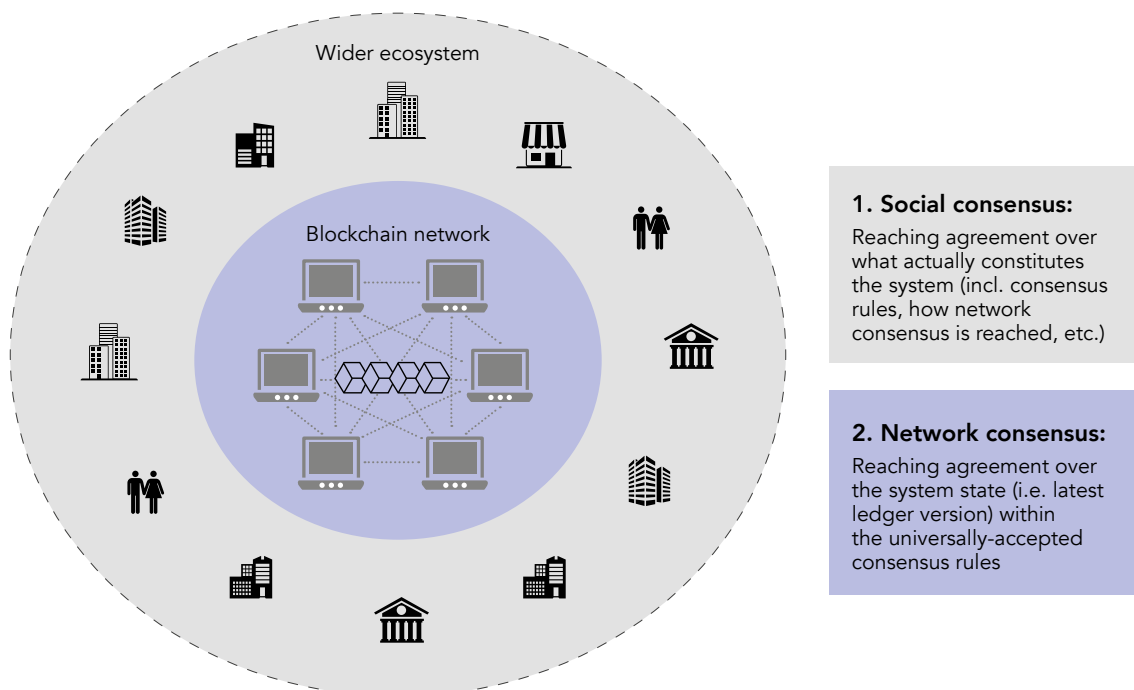
First, network participants and other stakeholders need to agree on the ruleset (expressed in the protocol via the consensus rules) that governs the system as well as an adequate process for applying changes to the rules. *Social consensus* goes beyond mere governance of the system: it also involves the implicit agreement between stakeholders over the very nature (and, thus, associated characteristics) of the system.[4] Any party remotely involved in the system — whether directly or indirectly — can potentially play a role in social consensus, although with varying degrees of influence over the process.

"Social consensus" sets the rules while "network consensus" enforces them

Once stakeholders have agreed on the nature of the system including its key properties, network participants need to establish agreement over the records produced by the system - i.e. the content itself. *Network consensus* refers to the process of resolving potential conflicts within the boundaries of the P2P network that may arise from multiple valid, but conflicting ledger entries. This type of consensus, which is performed by block producers, is limited to the ordering of transactions and operates within the socially-agreed ruleset.

Social consensus can always override network consensus

While different, both consensus types are closely linked. Social consensus implicitly includes network consensus, as the latter produces the latest system state that is universally accepted by all network participants and external stakeholders. It is, thus, important to point out that social

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4   For instance, Bitcoin's social consensus can be considered the implicit agreement between miners, developers, users, exchanges, wallets, and other stakeholders over essential properties (e.g. 21-million coin limit) that "define" what Bitcoin is in the first place.

consensus can always override network consensus, because changes to the rules can invalidate transaction ordering decisions taken by block producers such as miners.

A functional DLT system should have an appropriate system of checks and balances that prevents a single entity or colluding group of actors from dominating either social or network consensus, as this would create a single point of trust - and, thus, also failure. For instance, block producers are put in check by fully-validating nodes (*auditors*) that threaten to reject mined blocks that do not comply with protocol rules.

Mapping different interpretations

Unclear terminologies, fuzzy boundaries, and the lack of robust definitions have resulted in the terms "blockchain" and "DLT" effectively losing their meaning. This development does not only impact effective communication and understanding, but also risks the conflation of distinct concepts under a single umbrella term making it difficult to objectively assess and compare different projects.

<p style="text-align:center">The terms "blockchain" and "DLT" have effectively lost their meaning</p>

Introducing two major interpretations

In an attempt to make the terms meaningful again and to facilitate discussions, we suggest grouping all uses of self-labelled "blockchain" or "DLT" projects into one of two categories:

1. **Use of blockchain as multi-party consensus systems:**
   Federated business networks with no single entity in control; operating in adversarial environments and occasionally resolving conflicts around transaction ordering.
2. **Use of blockchain as a "meme":**
   No/limited notion of multi-party consensus nor potential disagreement over transaction ordering; often acting as a catalyst for transforming a variety of systems and processes.

Category 1: multi-party consensus systems

This category refers to DLT systems as defined on page 12. The key distinctive characteristic is the notion of *multi-party consensus*: several independent entities need to reach agreement over a shared set of data without relying on a central coordinator, with occasional disagreements over transaction ordering being resolved via *network consensus* (see page 14).

In a permissioned environment, these systems are best described as *federated business networks* that distribute control among network participants so that both *social consensus* and *network consensus* are not prone to be easily dominated by a single entity. However, as explained in the subsequent sections.[5] As a result, we suggest referring to these networks as *potential* DLT or enterprise blockchain systems as they do not meet the criteria at the time of analysis, but have a clear and committed roadmap on gradually distributing control over time as to effectively becoming "true" multi-party consensus systems.

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5   Section 3 provides an overview of the current degree of centralisation in live networks that have been deployed in production. Section 5 presents several explanations regarding the rationale behind this approach.

Category 2: the "blockchain meme"

This category comprises all projects and networks that, while identifying as "blockchain" or "DLT", do not constitute multi-party consensus systems as previously defined. Instead, they generally make use of several component technologies used by DLT systems in order to meet the requirements of a given business case. Figure 2 provides an overview of the key component technologies — cryptographic primitives and concepts from distributed systems — that are frequently used separately.

Figure 2: Component technologies used in "blockchain"

Component Technologies

DLT systems employ a set of component technologies that can – and are – used separately

Cryptographic primitives

Digital signatures: authentication

Cryptographic hashing functions: integrity checks

Merkle trees: data structure with specific features

Timestamping: proof-of-existence

Encryption: keep communications private

Distributed systems

P2P networking: no central server required

Message passing protocols: secure messaging

Consensus algorithms: (Byzantine) fault tolerance

Distributed databases: replication for robustness

"Blockchain meme" projects are designed to serve business cases in which a) the notion of multi-party consensus is either not required or feasible, and/or b) where disagreements over the ordering of transactions (e.g. events, facts) are not possible. This means that by definition, these projects cannot display the key characteristics that define a blockchain or DLT system.

What's the technical rationale behind the "blockchain meme"?

Projects and networks may use blockchain-related concepts and tools with no intent of supporting multi-party consensus for a variety of reasons:
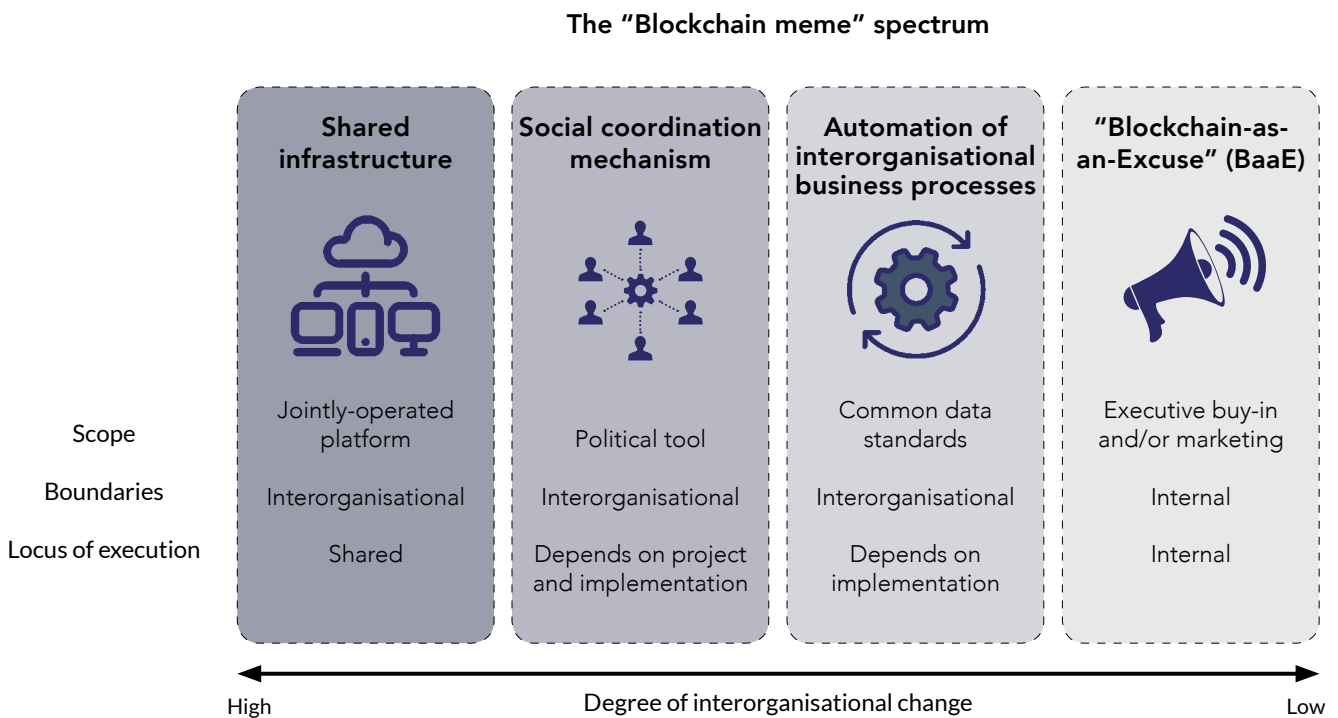
- **Single source of "truth":** an append-only log of events that produces a single, consistent source of "truth" available to all participants.[6]
- **Benefits of component technologies:** the application of some cryptographic primitives and the borrowing of specific concepts from distributed systems can provide significant benefits to existing offerings (e.g. more security, increased resilience, additional cryptographic assurance through independent validation, integrity checks and better authentication).
- **Readily-available blockchain protocol frameworks:** off-the-shelf blockchain software libraries and platforms that are readily available, often free and open-source, to rapidly build new systems and networks with different permissions configurations.
- **Fit-for-purpose architecture:** solving for a specific use case in practical terms may mean selecting elements that are distributed in some aspects but centralised in others. Enterprise blockchain deployment will usually force pragmatic rather than idealistic decisions.

A characteristic common to all "blockchain meme" projects is the use of "blockchain" or "DLT" branding when promoting their business offerings. Moreover, these projects strive to produce a single, consistent source of records that stakeholders can access — even though the records may only be provided by a single controlling entity through a trusted application programming interface (API). The existence of a single, shared view of authoritative records opens up vast opportunities that can range from better data management and sharing, to the automation of cross-entity business processes and workflows.

There are, however, substantial differences between projects that fall into this category: as indicated by Figure 3, an entire spectrum of project types with different objectives, design requirements and implementations make this category rather large.

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6   "Truth" in this context refers to the computer science definition, in the sense that a particular piece of data in the shared ledger exists and does not conflict with other data in the system, but the data itself is not necessarily true in the objective sense. For example, a record saying that 'Alice reports that the sky is yellow' would be 'truth' only in that it confirms what Alice reported, not the truth of the statement itself.

Figure 3: The "Blockchain meme" spectrum

The "Blockchain meme" spectrum

	Shared infrastructure	Social coordination mechanism	Automation of interorganisational business processes	"Blockchain-as-an-Excuse" (BaaE)
Scope	Jointly-operated platform	Political tool	Common data standards	Executive buy-in and/or marketing
Boundaries	Interorganisational	Interorganisational	Interorganisational	Internal
Locus of execution	Shared	Depends on project and implementation	Depends on implementation	Internal

High ←——— Degree of interorganisational change ———→ Low

The "blockchain meme" is perhaps best understood as an influential driver of organisational change to promote the development of common data standards between entities, improving general data availability, and reducing the number of steps required to reconcile individual ledgers and bookkeeping systems between parties. It can, thus, be thought of as an effective coordination mechanism for aligning interests between different stakeholders that would otherwise not collaborate, on matters that would otherwise not be open to discussion.

The "blockchain meme" acts as an agent of behavioural change
- both internally and at the industry level

As a result, the "blockchain meme" can act as a powerful catalyst to first encourage entities to rethink existing infrastructure and business processes, and eventually move towards a new core industry infrastructure that is commonly owned, shared, and operated by distinct parties. The "blockchain meme" can help solve political roadblocks in the creation of industry utilities and drive behavioural change in industries that are generally resistant to change. Depending on design decisions and network configuration, these systems may also provide additional cryptographic assurance that is independently verifiable by network participants.

Why does the distinction matter?

An analysis of more than 60 live enterprise blockchain networks that have been deployed in production reveals that more than three quarters of all projects fall into the "blockchain meme" category (Figure 4). Only 3% of analysed networks meet the criteria of full multi-party consensus systems, whereas one fifth of projects can be considered potential DLT systems that are gradually progressing towards removing single points of failure and control.

Figure 4: The majority of live enterprise blockchain networks can be categorised as "blockchain meme"

Blockchain type

- Blockchain meme
- Potential multi-party consensus system
- Multi-party consensus system
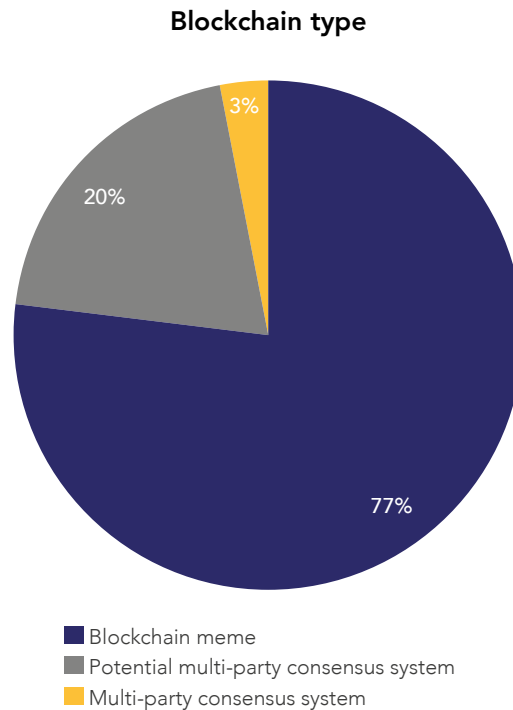
Note: based on CCAF dataset of 67 live enterprise blockchain networks.

Introducing the study samples

All empirical data presented in this report is based on one of the following data samples:

1. **Live network sample:** CCAF-curated list of 67 enterprise blockchain networks from 25 countries globally that have been deployed in production and are currently live.

2. **Survey samples:** in addition to the live network sample, the analysis is informed by data collected via a combination of three online surveys conducted by CCAF in 2018:

   a. **Vendors:** 60 respondents including start-ups and large corporations from 25 countries globally.

   b. **Network operators, participants, and end users:** 56 respondents including start-ups and large corporations from 22 countries globally.

   c. **Public sector:** 45 respondents including government agencies, public institutions, and central banks from 33 countries globally.

More information about the samples can be found in **Appendix I**. Data sources will be indicated appropriately below relevant figures and data points.

"Blockchain meme" projects generally have little in common with DLT systems as previously defined, yet they frequently tend to get conflated with actual multi-party consensus systems. This development has contributed to the widely-shared perception of "blockchain" as a magic bullet that overestimates the actual capabilities of the technology itself. If an internal accounting system operated by a single company can be branded as "blockchain", it becomes increasingly difficult for industry peers, regulators and policymakers, as well as other stakeholders to properly assess the properties (and associated trade-offs) that distinguish "true" DLT systems from "blockchain meme" projects. This, in turn, creates challenges for performance comparisons and evaluation of potential applicability and impact.

This is not to say that one category or the other is superior: in fact, it is very likely that the global impact of "blockchain meme" projects will be greater than that of multi-party consensus systems, simply because the emergence of common data standards for entire industries has the potential to unleash massive efficiency improvements and the creation of new services and business models. Applications of "true" multi-party consensus systems may remain niche and have little implications beyond their narrow use case.

<p style="text-align:center;color:blue;">The "blockchain meme" has the potential to
significantly shape the transformation of industries</p>

Nevertheless, it is worth pointing out that the classification is not set in stone and that one needs to be aware of the business operation and overall strategy constraints that would force networks to start either as a "meme" or potential DLT systems. As these systems are dynamic and constantly evolving, their respective analyses should, therefore, follow suit.
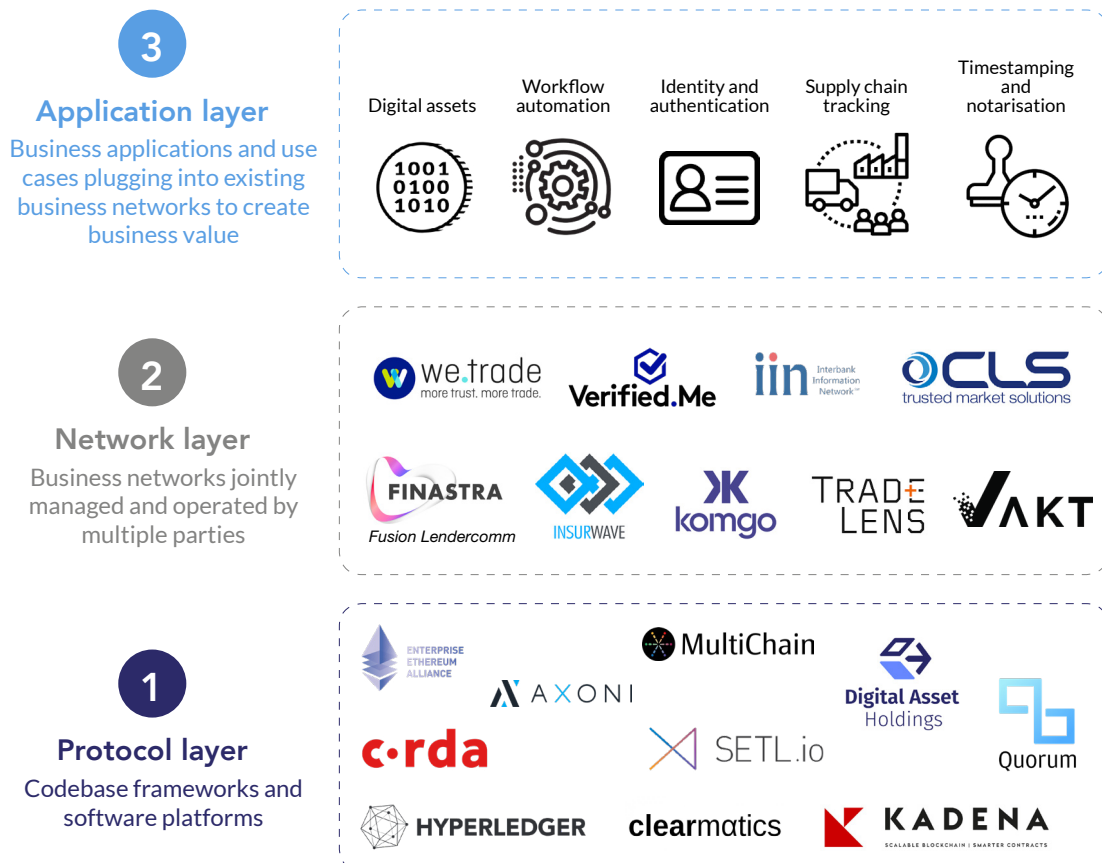
Section 2: Introducing the Enterprise Blockchain Ecosystem

Exploring the landscape

In recent years, the blockchain ecosystem has seen an explosion of new entrants that have introduced a plethora of new projects, products, and services at an astonishing pace. This can make it difficult for industry outsiders — and even insiders — to keep track of the proliferation of novel offerings that often span multiple market segments.

Figure 5 presents a useful lens to readers for exploring and navigating the changing blockchain landscape: the framework divides the landscape into three value-creating "layers" (protocol, network, and application) that are interconnected. It is worth noting that this mental model is not limited to enterprise DLT projects, but can also be applied to open and permissionless cryptoasset DLT systems.

Figure 5: A three-layer mental model for exploring the blockchain landscape

3

Application layer

Business applications and use cases plugging into existing business networks to create business value

Digital assets | Workflow automation | Identity and authentication | Supply chain tracking | Timestamping and notarisation

2

Network layer

Business networks jointly managed and operated by multiple parties

we.trade — more trust. more trade. | Verified.Me | iin Interbank Information Network | CLS trusted market solutions | FINASTRA Fusion Lendercomm | INSURWAVE | komgo | TRADE LENS | VAKT

1

Protocol layer

Codebase frameworks and software platforms

ENTERPRISE ETHEREUM ALLIANCE | MultiChain | Digital Asset Holdings | AXONI | corda | SETL.io | Quorum | HYPERLEDGER | clearmatics | KADENA SCALABLE BLOCKCHAIN | SMARTER CONTRACTS

Note: this model is based on a framework initially developed by Colin Platt (2016).[7]

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[7] Platt, C. (2016) *Of permissions and blockchains... A view for financial markets.* Available at: https://medium.com/@colin_/of-peDLrmissions-and-blockchains-a-view-for-financial-markets-bf6f2be0a62. [Last accessed: 05 August 2019].

1) Protocol layer: *the technological building blocks constituting the "back-end"*
The protocol layer is the collection of core protocol frameworks, i.e. the set of core technological building blocks that constitute the technological backbone of any blockchain system. The protocol layer includes the foundational infrastructure components upon which networks and applications are built. Given that protocols are merely code (either open-source or proprietary), the protocol layer itself does not deliver much value without a corresponding network.

2) Network layer: *the shared business networks producing a single source of "truth"*
The network layer consists of the actual P2P networks that bring a blockchain system to life by connecting participants to enable the sharing and verification of data. The network layer comprises all business networks that are jointly operated and maintained by multiple participants with the objective of producing a single consistent source of "truth" regarding a shared set of records. Networks can be built by either using a standard core protocol framework (e.g. Hyperledger Fabric), or by using a combination of modular core building blocks borrowed from multiple core protocol frameworks.

**3) Application layer:** *the products and services that create actual business value*
The application layer can be thought of as the primary user interface for blockchain networks: it comprises business applications that connect to existing networks to make use of the underlying set of data records that has been jointly produced and maintained by network members ("single source of truth"). The application layer is the main driver of business value as it provides tangible products and services to end customers and users. "Permissioned" applications that restrict usage to select parties can also exist on top of an open, permissionless blockchain network.[8] Applications can also be "blockchain-agnostic", meaning that they can plug into several separate networks depending on demand.[9]

Figure 6 uses the example of J.P. Morgan's *Interbank Information Network (IIN)* to illustrate how the three-layer framework can be used as a lens for assessing the different components of a given project. The first live application — *IIN Resolve* — uses the network to streamline compliance checks for correspondent banking in an attempt to speed up cross-border payments. Several more applications are in development to leverage the underlying IIN network.

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[8]   For example, the public and permissionless Bitcoin blockchain (main net) is used by permissioned applications for distributed timestamping and notarisation.

[9]   We apply a broad definition to the application concept presented in this model. From a technical perspective, many services labelled as "blockchain applications" correspond to simple plug-ins rather than veritable applications running directly on top of the blockchain network. In this context, any external system that interacts with a distributed ledger network can be considered an application.

Figure 6: Illustrating the landscape framework using J.P. Morgan's IIN
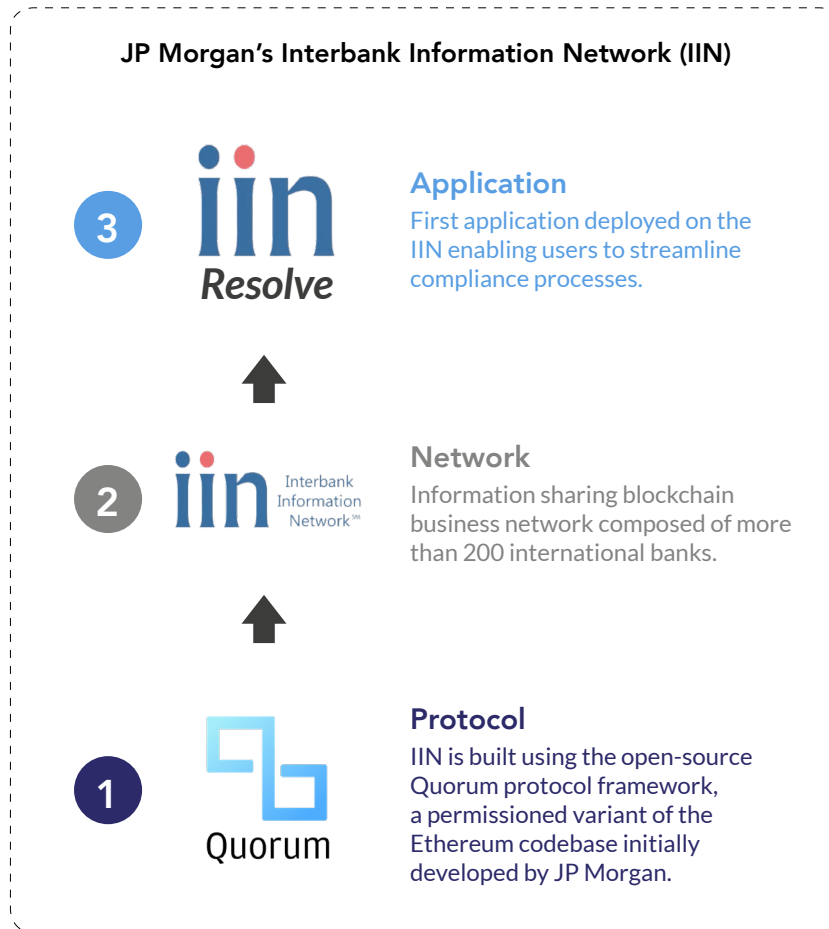
Meet the industry actors

Actors and activity types

The blockchain enterprise ecosystem is composed of a diverse set of actors that carry out distinct activities. Actors and activities can be grouped into six broad categories:

- **Vendors** design, develop, implement, and maintain the technical infrastructure powering blockchain networks and applications.

- **Network operators** are responsible for managing and governing blockchain networks, which are jointly run and maintained by **network participants**.

- **Application providers** offer interfaces for **end users** to plug into blockchain networks in order to achieve business objectives that leverage the utility of a shared single source of records.

- A variety of **other stakeholders** provide tangential services and insights that benefit the ecosystem as a whole.

Table 1 presents an overview of the major actor types of the ecosystem and their associated activities.

Table 1: Actors and activities in the enterprise blockchain ecosystem

	ACTOR TYPES	ACTIVITIES	DESCRIPTION
	Vendors Entities that design and build the technical infrastructures that power blockchain networks and applications	**Core protocol framework development:** design, development, and maintenance of one or more core protocol frameworks	• **Project lead:** originator and lead maintainer of a core protocol framework (can be open-source or proprietary) • **Project contribution:** one of several contributors to a core protocol framework project
		Solutions design: development and implementation of actual business networks for clients	• **Integration:** help clients build and implement blockchain networks by integrating elements from existing core protocol frameworks[10] • **Software development platform:** easy-to-use software environment for clients to develop their own blockchain networks
		Commercial application development	Design and develop business applications for clients that run on top of, or connect to, existing blockchain networks
		Consulting services	Ideation, business case, and roadmap development
	Network operators Entities that manage and operate blockchain networks	**Administration**	Govern network operations, set protocol rules, and manage change; generally also owning and managing intellectual property (*governing entity*)
		Permissions management	Assign different permission levels to network participants (e.g. right to initiate transactions or to participate in the network consensus process
		Gatekeeping	Onboard and offboard network participants in accordance with access restriction and onboarding policy (*gatekeeper*)
	Network participants Entities that directly participate in running blockchain networks	**Transaction validation**	Operate and run a fully-validating node to verify transactions and independently reconstruct the latest system state (*auditor*)
		Transaction processing	Participate in the network consensus process by proposing candidate records (e.g. blocks consisting of ordered, non-conflicting transactions) to be added to the ledger (*record producer*)
	Application providers Entities that create business value for end users by providing applications that make use of the underlying blockchain networks	**Use case servicing**	Operate and maintain specialised interfaces to existing blockchain networks that leverage the access to a single source of records to enable a specific set of use cases
	End users Entities that use blockchain applications to achieve a specific business objective	**(Application) usage**	Derive value from using applications and services enabled by a blockchain network's single source of records. End users can connect indirectly via intermediaries (e.g. API, application) or directly by participating in the network running nodes.

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10   Integrators are generally specialised in a suite of core protocol frameworks for which they have the relevant technical expertise and community support.

	ACTOR TYPES	ACTIVITIES	DESCRIPTION
	Other stakeholders Entities that provide tangential services and insights of commercial and/or non-commercial nature	Funding	Provide funding and/or facilitate access to funding (e.g. venture capital, incubators, strategic investors, etc.)
		Research	Collect, analyse, and present data on various aspects of the ecosystem, including the technology itself (e.g. academia, industry research, analytics platforms, etc.)
		Advocacy	Support the development of the ecosystem, and the industry in particular, through a variety of means including engagement with external parties (e.g. special interest groups, lobbying organisations, etc.)
		Regulation	Regulate and supervise activities in the ecosystem
		Legal	Provide legal opinion and advice to organisations before, during and after the technology adoption process (e.g. IP, tax, reporting, etc.)
		Miscellaneous	Includes all other activities that, either directly or indirectly, play a role in the ecosystem (e.g. industry associations, consortia, data services, legal and regulatory services, education, training and certification, etc.)

It should be noted that one entity can take multiple actor roles and engage in several activities. For instance, survey data indicates that the majority of vendors do not specialise in a single activity, but instead provide a broader range of services that sometimes go as far as acting as a network operator for client networks. Similarly, one activity can also be carried out jointly by multiple distinct entities (e.g. gatekeeping and administration of a blockchain network).

<p align="center">The lack of clarity around roles and positioning of
actors indicates the ecosystem is still maturing</p>

Given the (still) relatively early stage of the industry, the boundaries between different roles and activities are not always clearly delineated and significant overlap can be observed in some instances. Today, for example, the different roles of a network operator are in most cases performed by the same entity: in the future, one can imagine a potential unbundling of these roles across multiple entities that will lead to increased decentralisation in network governance.

Industry development

Entry points

The enterprise blockchain industry is composed of hundreds of entities providing products and services, which range from small start-ups to large, established corporations. Not all firms have entered the industry in the same manner, however: this study distinguishes between *blockchain-native* and *non-native* entities.

- **Blockchain-native:** entities that have been founded to, at least initially, exclusively serve the enterprise blockchain market.

- **Non-native:** existing entities that have expanded their business offering to include blockchain-related products and services.

  ° Expansion: begin offering blockchain-related products and services as a new vertical in addition to existing business lines.

° Full pivot: discontinue existing business offerings and undertake a complete pivot towards exclusively providing enterprise blockchain services.

With a few exceptions, blockchain-native firms tend to be relatively small start-ups, whereas non-native firms are generally larger-scale incumbents from other industries. An interesting observation relates to cryptocurrency-focused companies that have started to provide additional enterprise blockchain services, particularly during periods of stagnating or declining cryptocurrency prices.

Figure 7: While vendors are primarily blockchain-native, operators tend to come from existing backgrounds

Entry points

Share of vendors   *Share of network operators and participants*

■ Native ■ Non-native
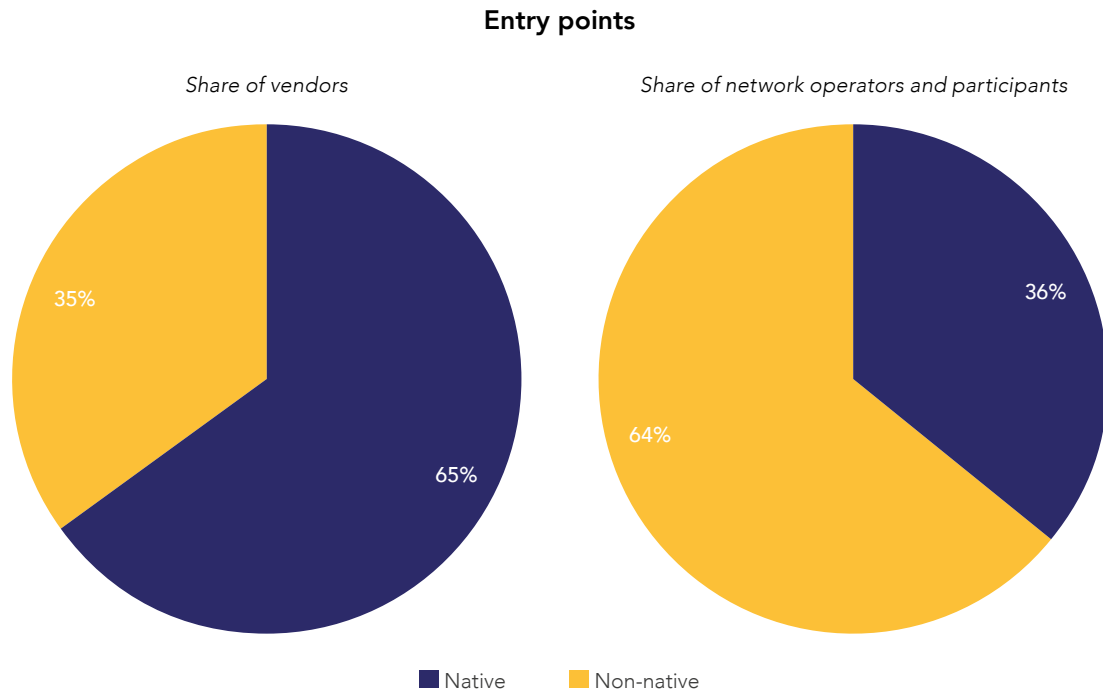
Note: based on CCAF survey data.

Differences between actor types can also be observed: while nearly two-thirds of surveyed vendors are considered blockchain-native, a similar proportion of network operators have been active in other industries before entering the enterprise blockchain ecosystem (Figure 7). This is hardly surprising given that most blockchain networks serve a particular use case or industry that has already existed before. Nevertheless, more than one third of network operators have specifically set up a new entity to deliver their value proposition.

Industry growth

While it can be difficult to quantify the growth of the enterprise blockchain industry due to a lack of reliable data sources, one can employ proxies to provide an approximate estimate. One such proxy is the number of full-time equivalent (FTE) staff employed by blockchain firms.[11]

Figure 8 shows that the number of total FTE employees in the enterprise blockchain industry has grown substantially since 2016, with vendors experiencing the largest growth rates of all actor types. However, survey takers also warn that the rapidly increasing demand for skilled blockchain talent is not met with an adequate growth of supply, leading to growing skilled labour shortage.

Figure 8: The total number of FTE staff active in the blockchain industry has grown substantially, with vendors recording the highest growth rates of all actor types

Total FTE growth rates

	2017 YoY	2018 Q1+Q2
Vendors	184%	165%
Network operators and participants	103%	62%
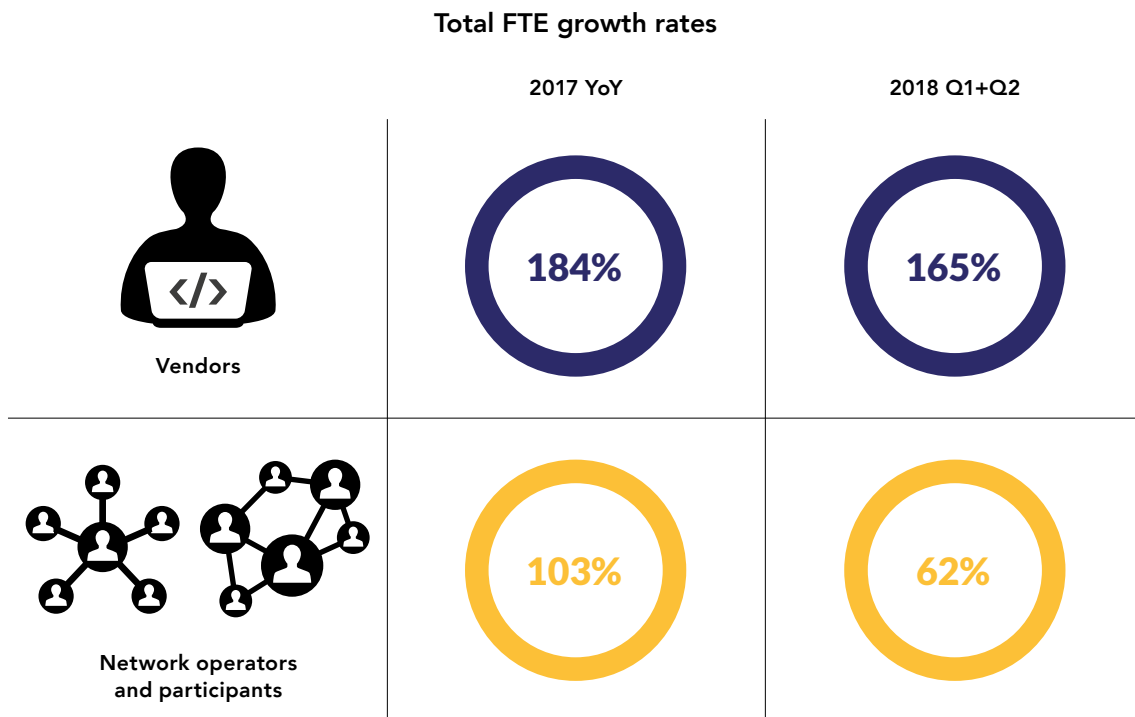
Note: based on CCAF survey data. FTE staff not exclusively focused on blockchain activities have been removed from the calculation.

Surprisingly, vendors have, in aggregate, grown at nearly the same rate in the first two quarters of 2018 than for the entire year in 2017. The total number of blockchain-focused FTE staff employed by network operators has also significantly increased during the covered period, which suggests that the industry is increasingly moving towards the adoption of actual business networks that are deployed in production.

A similar pattern can be observed at the firm level: the average blockchain company has grown considerably in size since 2016, with entities acting as vendors employing more people (median) and recording the highest growth rates (Figure 9).

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11 We only consider FTE staff that are exclusively involved in enterprise blockchain activities in order to remove noise from firms that also operate in other market segments. Moreover, not all employees of blockchain firms are directly involved in blockchain-related activities: some employees may be assigned to complementary business areas such as accounting and legal services. In fact, survey data shows that native blockchain vendors have on average 73% of their employees working exclusively on blockchain activities, compared to 28% of non-native companies.

Figure 9: Both vendor and network operator companies have significantly grown in size

Firm growth

Median FTE staff exclusively engaged in blockchain activities
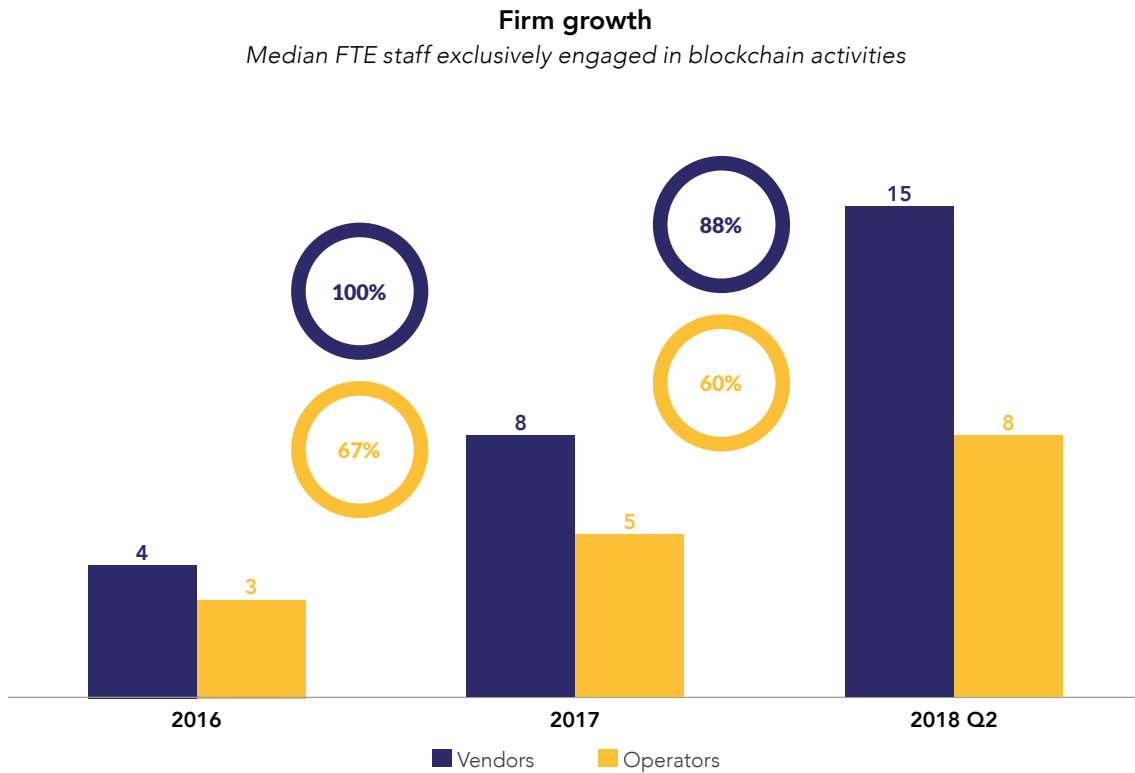
Note: based on CCAF survey data. Only takes into account firms that have been operating throughout the covered time period.

However, there are staggering differences between firm sizes within the same category: while some vendors have fewer than 5 employees dedicated to blockchain services, the largest organisations have more than two thousand blockchain-focused staff, up from 300 in 2016 and 800 in 2017. Network operators tend to be much smaller in size: the largest entity employed some 70 people at the end of Q2 2018, up from 35 in 2016 and 50 in 2017.

Consortia and ecosystem building

Blockchain networks require collaboration between distinct parties in order to develop their full potential. As a result, we can observe an explosion of new initiatives in recent years that attempt to pool attention and create joint efforts between interested parties to harness the technology and build network effects.

These initiatives can range from simple partnerships between companies and projects to strategic investments and the development of large-scale technology and industry consortia (Figure 10). Survey data suggests that partnerships between vendors and projects are the major type of collaborative activities, although more than 40% of vendors are also engaged in one or several consortia.

Figure 10: Direct partnerships are the preferred collaboration model for vendors

Collaborative initiatives
Share of vendors

Category	Share
Partnerships	81%
Consortia	43%
Government initiatives	41%
Joint ventures	32%
Strategic investment	24%
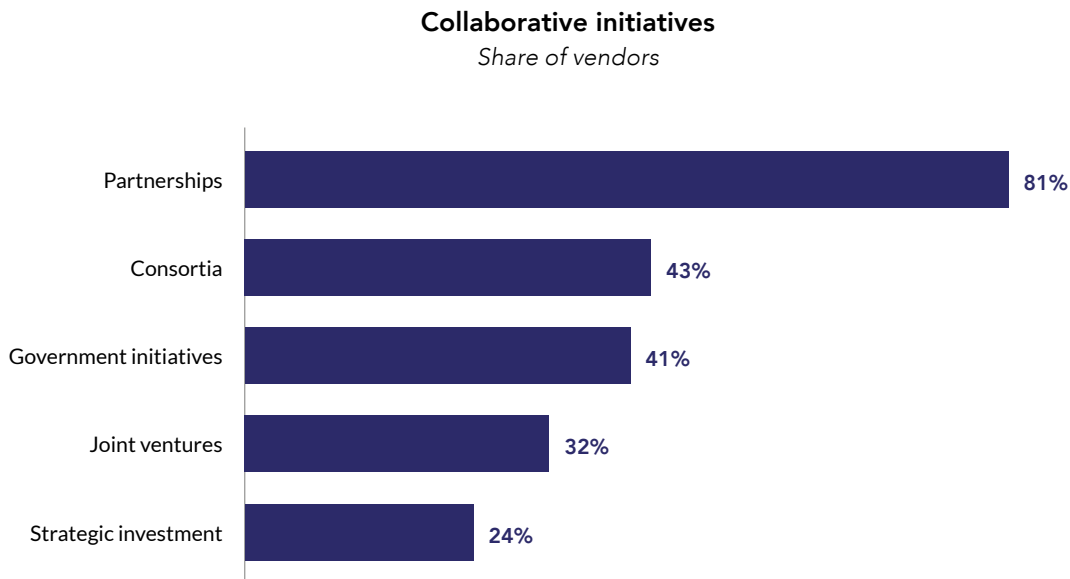
Note: based on CCAF survey data.

Another way of looking at the enterprise blockchain ecosystem is to consider it as a collection of smaller (sub)ecosystems that have formed around specific platforms, industries, geographies, and use cases. Most of these initiatives fall into one of the following three categories:

- **Technology-focused:** veritable ecosystems have developed around (primarily open-source) core protocol frameworks and related technology platforms that comprise vibrant developer communities with hundreds of active contributors. The Hyperledger ecosystem managed by the Linux Foundation and R3's Corda platform appear to be the most popular in terms of members and active contributors at the time of writing. Standard-setting bodies such as the Ethereum Enterprise Alliance may also fit in this category despite having no specific mandate to deliver technology solutions.

- **Industry-focused:** dozens if not hundreds of industry initiatives have emerged to provide a way for relevant industry actors to pool resources in order to explore blockchain-based use cases and establish common data standards and governance structures. One example of such an initiative is the B3i consortium of the insurance industry.

- **Geography-focused:** some initiatives are also focused on a specific geographic region or country to facilitate the local development and implementation of blockchain networks. These initiatives can apply at different levels: e.g. regional, national, state, and municipal. Examples include the Alastria network in Spain, the Blockchain Federal Argentina network, as well as several government-sponsored initiatives such as the Blockchain Roadmap launched by the Australian Ministry of Industry, Science and Technology and Ministry for Trade, Tourism, and Investment[12], and the Dubai Blockchain Strategy.[13]

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12   Ministry for Industry, Science and Technology (2019) *Advancing Australia's blockchain industry*. Available at: https://www.minister.industry.gov.au/ministers/karenandrews/media-releases/advancing-australias-blockchain-industry [Last accessed: 17 June 2019].

13   Smart Dubai (2019) *The Dubai Blockchain Strategy* Available at: https://www.smartdubai.ae/initiatives/blockchain [Last accessed: 21 June 2019].

Section 3: State of Adoption

Moving to production

The enterprise blockchain landscape has changed considerably since the publication of the first *Global Blockchain Benchmarking Study* in September 2017.[14] While over half of surveyed vendors had production-ready technology platforms two years ago, only 8% of surveyed operators indicated running a live network: the majority were involved in early testing, proofs-of-concept, and experimental projects.

The picture looks fundamentally different in 2019: while it is almost impossible to keep track of all production deployments globally, we estimate that there are hundreds of live blockchain networks that are being used in production environments across a variety of sectors and industries. As illustrated by Figure 11, the majority of covered blockchain networks have entered production over the course of 2018 and early 2019.

Figure 11: Live network deployments have taken off in mid-2018

Number of new deployments
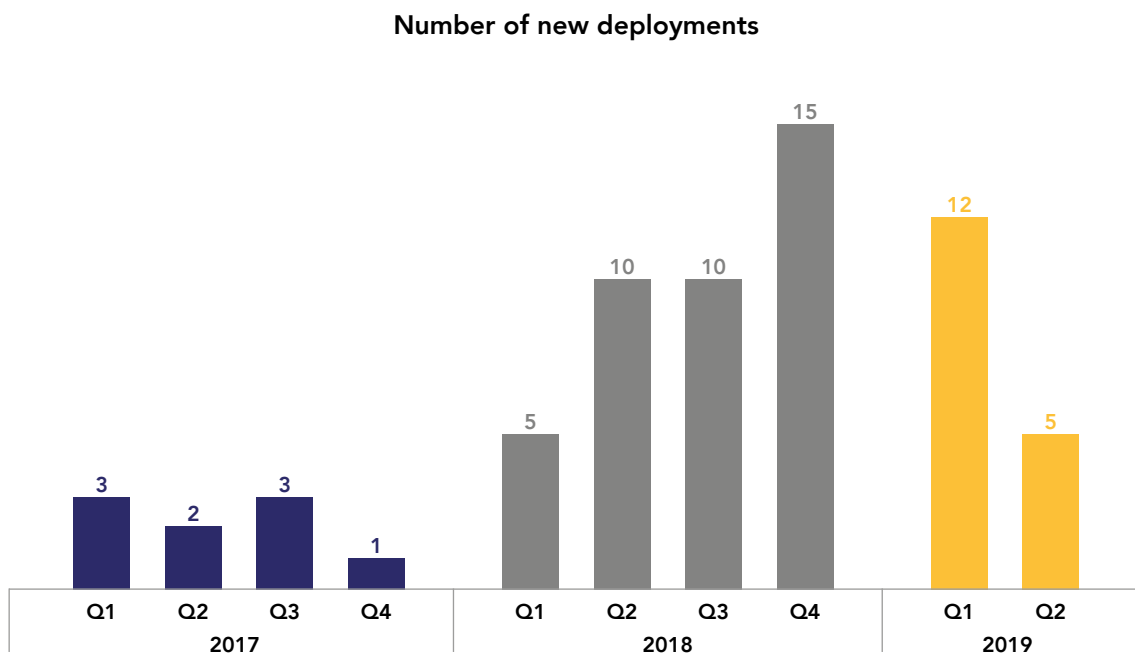
Note: based on CCAF dataset of 67 live enterprise blockchain networks.

It is, therefore, appropriate to say that DLT has, to a certain extent, moved away from the hype and experimentation phase, and is slowly entering the production phase. Nevertheless, substantial differences between networks can be observed, which will be covered in the remainder of this section.

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14 Hileman, G. and Rauchs, M. (2017) *Global Blockchain Benchmarking Study*. Cambridge Centre for Alternative Finance. Available at: https://www.jbs.cam.ac.uk/faculty-research/centres/alternative-finance/publications/global-blockchain/ [Last accessed: 15 July 2019].

Project lifecycle

One stage at a time

Blockchain networks and projects generally progress through several stages until they are equipped to run in a production environment. The typical lifecycle of a production network can be broken down into four main stages: initial exploration, proof-of-concept (PoC), pilot/trial, and production.

An empirical analysis of more than 60 live networks suggests that the median time between launching a PoC and eventually deploying a network in production amounts to 25 months, i.e. roughly two years (Figure 12). The transition from PoC to an a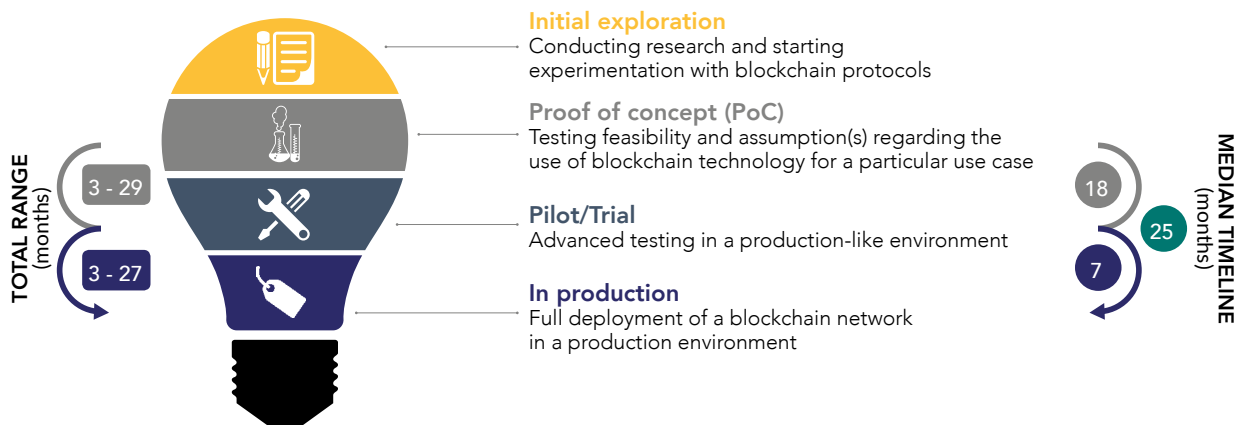dvanced trial stage takes up more than two-thirds of the time, whereas moving from pilot to production is generally completed in about half a year (median).

Figure 12: Enterprise blockchain projects typically undergo four main stages

Initial exploration
Conducting research and starting experimentation with blockchain protocols

Proof of concept (PoC)
Testing feasibility and assumption(s) regarding the use of blockchain technology for a particular use case

Pilot/Trial
Advanced testing in a production-like environment

In production
Full deployment of a blockchain network in a production environment

TOTAL RANGE (months): 3 - 29, 3 - 27

MEDIAN TIMELINE (months): 18, 25, 7

Note: based on CCAF dataset of 67 live enterprise blockchain networks.

A closer look at the total range reveals major discrepancies between projects: while some enterprise blockchain networks took merely three months to complete each of the aforementioned stages, others spent more than two years within each phase. Scale and ambition plays an important role here: small-scale projects with a limited number of participants and a relatively simple use case have been capable of launching within six months after initialising a PoC, whereas larger-scale projects that involve complex use cases with multiple participants and riddled with regulatory and legal obstacles have taken more than four and a half years to go live.

Blockchain projects are a journey requiring a long time frame

This supports the view that enterprise blockchain projects are journeys that involve the transformation of core market infrastructure, which naturally require a longer time frame and more patience than simple application development. Moreover, successful network launches do not immediately translate into commercial benefit: most live networks have yet to see extensive usage after being deployed in production. It will likely take years before significant impact can be observed.

Origination

DLT is often said to be a "team sport" requiring collaboration and cooperation between multiple parties. However, it can be difficult to launch an initiative that gathers sufficient momentum among participants without strong leadership support and significant efforts of persuasion, i.e. effective coordination. Our empirical analysis identifies three major origination models: founder-led, consortium-led, and government-led. Given the aforementioned challenges, it is not surprising to see that more than 70% of blockchain networks have originated from the initiative of a single entity (founder-led) that effectively assumes leadership of the project (Figure 13).

Figure 13: The vast majority of live networks originated from the initiative of a single entity

71% **Founder-led**
A single entity, often with a dominant market position, takes the lead in setting up an initiative

22% **Consortium-led**
A collection of entities cooperate to jointly set up an initiative

6% **Government-led**
A government-related institution brings together a set of entities to launch an initiative

1% **Other**
Unclear which party initiated the project
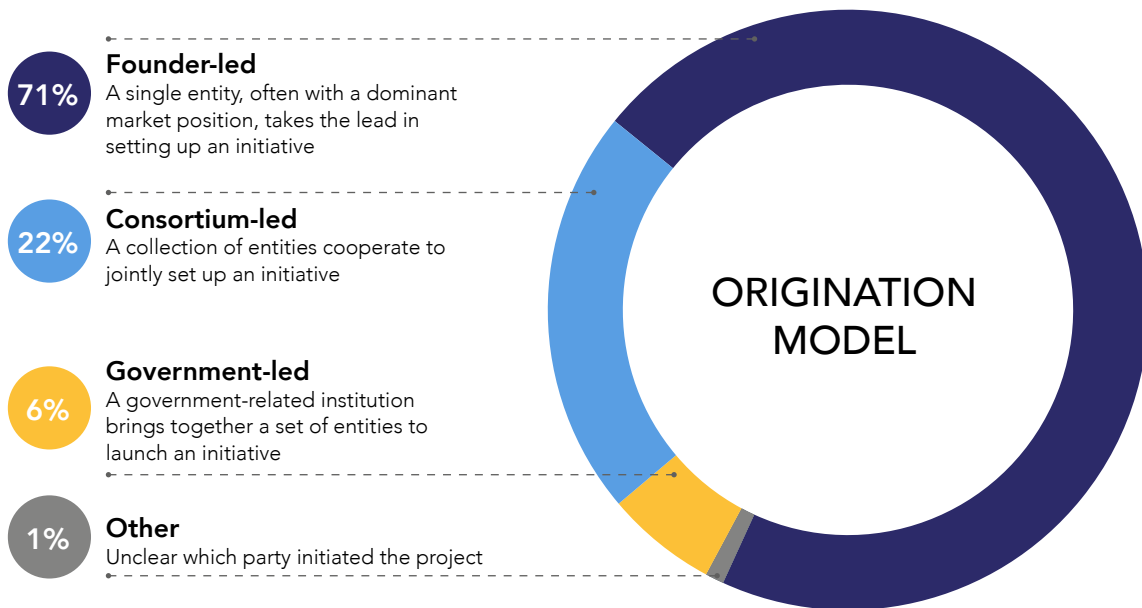
ORIGINATION MODEL

Note: based on CCAF dataset of 67 live enterprise blockchain networks.

However, the boundaries between origination models can be somewhat fluid: as these projects undergo multiple stages, different models may apply at different stages, with new actors joining. For instance, some projects are initially founder-led, but as competitors join the initiative, a new structure may evolve moving to a broader-based consortium and possibly a full equity-based joint venture. Similarly, a government agency can set the ball rolling by bringing together multiple national entities that eventually take over to turn the project into a corporate-managed venture. The benefits and limitations of each origination model are discussed in greater detail in Section 4.

Project scope

Industries and use cases

Companies and institutions from nearly every sector and industry of the global economy have been exploring the potential of blockchain technology in recent years. However, no other sector has come close to the Finance and Insurance sector with regard to the deployment of live enterprise blockchain networks: nearly half of all covered networks have been launched by financial institutions (Figure 14).[15] The Accommodation and Food Services as well as the Healthcare and Social Assistance sectors come at a distant second place with 6% of all networks each.

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15   Sectors have been categorised in accordance with the North American Industry Classification System (NAICS). The complete NAICS code list is available at: https://www.naics.com/search/ [Last accessed: 15 July 2019].

Figure 14: Nearly half of live blockchain networks have been launched by the Finance and Insurance sector

Live networks by sectors

Finance and Insurance
Cross-industry
Other
Accommodation and Food Services
Health Care and Social Assistance
Retail Trade
Mining, Quarrying, and Oil and Gas Extraction
Transportation and Warehousing
Arts, Entertainment, and Recreation
Wholesale Trade
Public Administration
Real Estate and Rental and Leasing
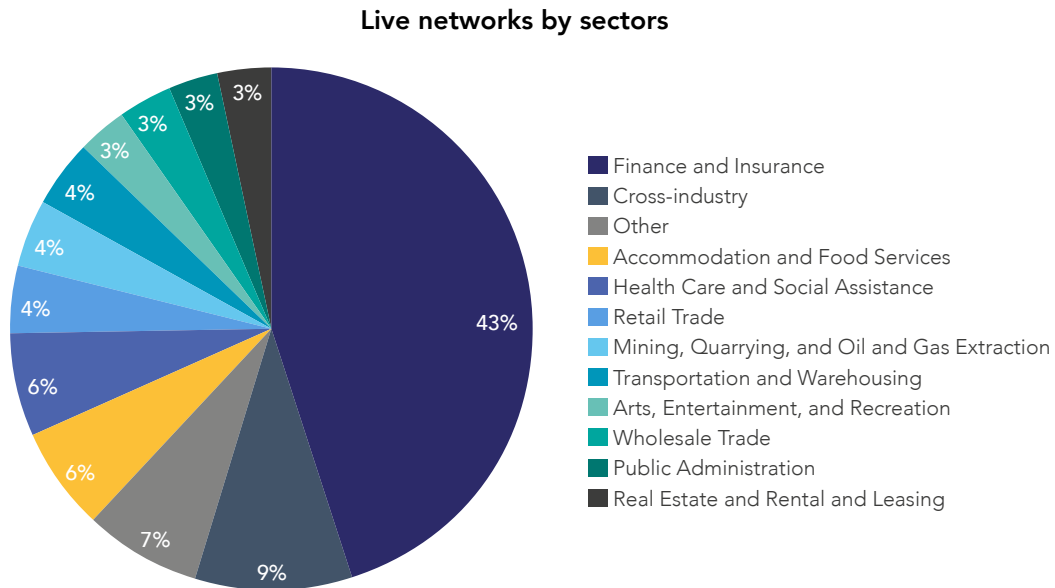
Note: based on CCAF dataset of 67 live enterprise blockchain networks. Sectors have been categorised in accordance with the North American Industry Classification System (NAICS).

These findings are mostly consistent with the conclusions from our 2017 study, which revealed that the Banking and Finance industries in combination with the Insurance sector were responsible for 42% of all explored use cases.[16] An interesting discrepancy arises with regards to the public sector: while 13% of explored use cases in 2017 were attributable to the public sector, only 3% of live blockchain networks are government-related in 2019. This suggests that some projects may have been discontinued, or are still under development.
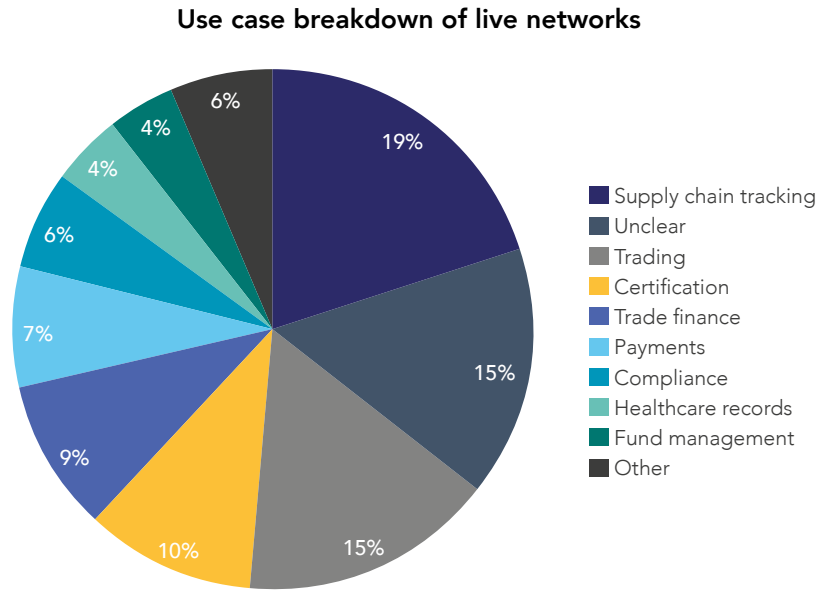
<div align="center">

Identifying use cases of a given blockchain network is not always straightforward

</div>

Blockchain networks facilitate the secure exchange of information between a set of participants and enable data verification and integrity checks via a consistent audit trail. The specific use case of a blockchain network, thus, corresponds to the business area(s) from which the shared data is generated. Interestingly, it can be surprisingly difficult to identify a particular use case of a live blockchain network whose mission statement has remained relatively vague and/or broad. Moreover, blockchain networks can also function as shared data platforms that support a wide range of use cases.

Data suggests that the majority of live networks have launched with a narrow focus on a specific use case, although the intention to gradually broaden the scope to include other industry-related usages is often highlighted in the official roadmap. Figure 15 presents the use cases supported by the covered production networks: tracking items in large and complex supply chains (e.g. food, gemstones, shipping containers) emerges as the most prominent use case of live networks, followed by market infrastructures for trading tokenised assets.

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16   Hileman, G. and Rauchs, M. (2017) *Global Blockchain Benchmarking Study*. Cambridge Centre for Alternative Finance, p. 37. Available at: https://www.jbs.cam.ac.uk/faculty-research/centres/alternative-finance/publications/global-blockchain/ [Last accessed: 15 July 2019]. It should be noted that a different industry categorisation framework was used in 2017, which nevertheless allows an indirect comparison.

Figure 15: Supply chain tracking is the dominant use case for one in every five live networks

Use case breakdown of live networks

■	Supply chain tracking
■	Unclear
■	Trading
■	Certification
■	Trade finance
■	Payments
■	Compliance
■	Healthcare records
■	Fund management
■	Other

Note: based on CCAF dataset of 67 live enterprise blockchain networks.

Key value propositions

Network participants and application providers use enterprise blockchain networks to extract business value for their operations. Blockchain networks can provide value to enterprises in three ways: (1) reduce costs by removing avoidable reconciliation steps between company ledgers, (2) generate revenues through the provision of new services enabled by the access to shared data, and (3) create new market models and types uniquely enabled by the shared network that did not previously exist.

Data shows that currently, more than two-thirds of live networks are primarily designed to reduce costs for network participants and end users (Figure 16). Interestingly, differences can be observed between founder-led and consortium-led models: while 84% of the former are predominantly focused on cost reduction, only 40% of the latter have been set up with the primary objective to reduce operational costs — 20% have been launched to set the foundation for a new industry utility that creates new market models.

Figure 16: Cost reduction is the predominant objective of current enterprise blockchain networks

72% **Cost reduction**
Improved reconciliation efforts lead to efficiency gains that translate into lower operational costs

6% **(Incremental) revenue generation**
New services and business models emerge as a result of having access to a single shared source of records

8% **New market models**
A shared (industry) utility enables the development of entirely new market types and models that did not previously exist

14% **Hybrid**
A combination of cost reduction and revenue generation objectives

VALUE PROPOSITION

Note: based on CCAF dataset of 67 live enterprise blockchain networks.

This situation is a testament to the early days of the enterprise DLT ecosystem: most production networks are still in the phase of eliminating reconciliation efforts to streamline the exchange of information between participants and optimise existing workflows. It is likely that the value proposition of these networks will evolve over time to gradually move the focus from mere cost reduction to incremental revenue generation as the systems mature. Eventually, we may see the emergence of entirely new products, services, and business models.

Network usage

It may come as a surprise to some readers that enterprise blockchain networks can be limited to internal use: in fact, 5% of production networks are exclusively employed within the boundaries of a company or conglomerate, with different departments or subsidiaries participating in the network (Figure 17).[17] Nonetheless, the vast majority of networks are designed for shared use between different, non-affiliated entities in order to cross organisational boundaries.

Figure 17: The majority of live networks are designed for shared use between partners

88% **Shared use**
The network is jointly used by separate, non-affiliated entities

5% **Internal use**
The network is used internally within a company conglomerate where participants can be separate subsidiaries or departments

7% **Unclear**
The participation model is not explicitly disclosed

NETWORK USAGE

Other 24% Competitors 19% Partners 57%
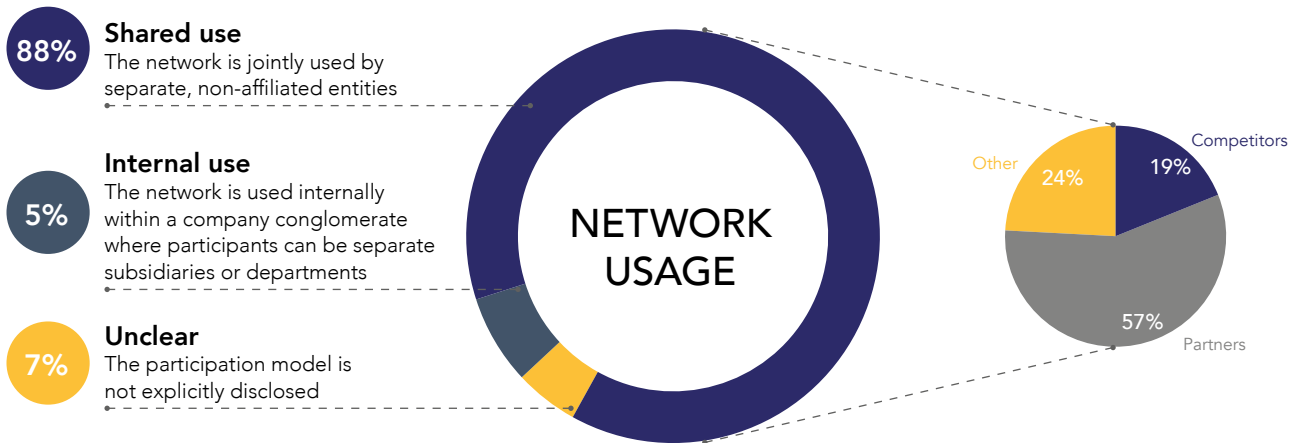
Note: based on CCAF dataset of 67 live enterprise blockchain networks.

A look at the type of participants for shared-use networks reveals interesting insights: in their current form, more than half of production networks have been set up between business *partners*, whereas only 19% have launched with the participation of direct *competitors*. A quarter of covered networks have a combination of competitors and partners that are less straightforward to categorise given that they occupy different positions in the value chain (downstream and upstream).

In their current form, most networks are set up between business partners rather than competitors

A typical example of competing entities joining forces to develop a shared industry utility is the financial institutions that are looking for the secure exchange of relevant information and the automation of existing workflows. In contrast, networks run between business partners are generally found in supply chains that involve an existing web of collaborating manufacturers, suppliers, and distributors.

The types of participants also differ depending on the origination model: in founder-led networks, a leader entity with a dominant market position primarily onboards business partners (65%). In contrast, consortium-led networks tend to predominantly engage competitors (73% divided between direct and indirect competitors - see "Other"). A common approach for consortium-led networks run by direct competitors is to establish a joint-venture between participating entities.

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17   There are a variety of reasons for companies to use an internal blockchain-based network: for instance, in some countries, legal and regulatory considerations mandate that data cannot be held by a single entity in one place. Furthermore, increased robustness and resilience with regard to data storage, verification, and sharing can be operational motives.

Network design

Market share of protocol frameworks

Businesses and institutions can choose from a wide range of core protocol frameworks as the technological foundation of their networks. However, data suggests that only four protocol frameworks dominate the market: Hyperledger Fabric takes the lion's share, supported by nearly half of live networks deployed in production, followed by R3's Corda and Coin Science's MultiChain (Figure 18).

Figure 18: Hyperledger Fabric is the dominant protocol framework for deployed enterprise networks

Supported protocol frameworks
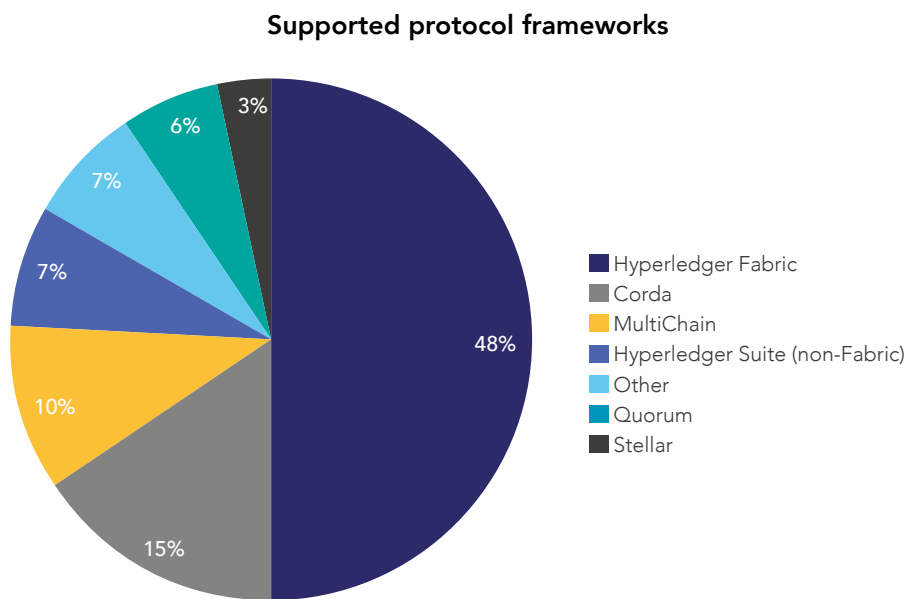
Note: based on CCAF dataset of 67 live enterprise blockchain networks.

Survey data based on responses from software vendors that integrate existing protocol frameworks confirm this picture: the Hyperledger suite (with Fabric as the flagship protocol) is the most frequently supported protocol framework by integrators and software development platforms (53%), followed by Corda (35%), MultiChain (32%), and Quorum (26%). This distribution also indicates that many integrators specialise in a set of protocol frameworks, rather than a single codebase.

<p align="center">The Hyperledger protocol suite is the most frequently supported
framework set by integrators and software platforms</p>

Network operators and participants usually experiment with multiple protocol frameworks before choosing a particular platform to build their network on. In fact, survey data shows that 26% of operators have switched protocol frameworks at the PoC stage when conducting several tests.[18] However, more than half of surveyed entities also indicated to continue working with the framework initially chosen.

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[18] For example the WeTrade PoC was originally developed on an Ethereum fork, but ultimately moved to Hyperledger Fabric. Similarly the B3i insurance consortium started working on Hyperledger Fabric, but subsequently switched to the Corda platform.

Figure 19: Vendor maturity is considered the most important protocol framework selection criteria

Core protocol framework selection criteria
Share of network operators and participants
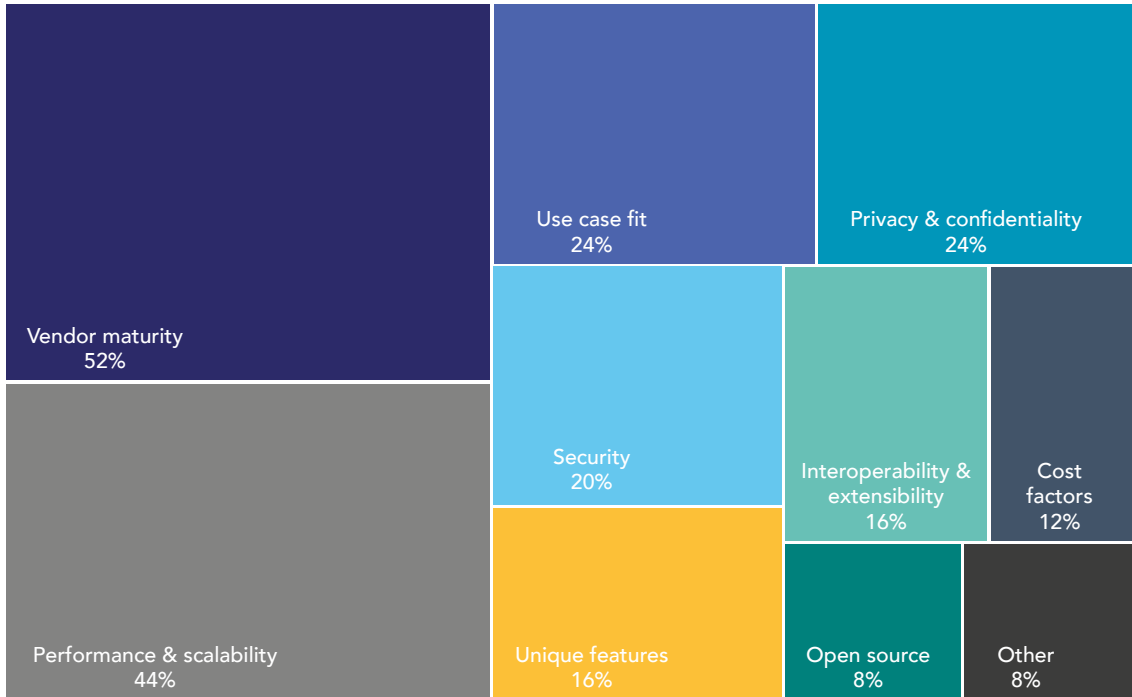
Note: based on CCAF survey data.

Network operators and participants choose the right core protocol framework on the basis of a set of selection criteria. As illustrated by Figure 19, the maturity and product readiness of enterprise blockchain vendors are considered the most important factors in the decision process. Performance and scalability are also ranked as key criteria by surveyed network operators, although these are often the result of trade-offs and, thus, difficult to directly compare (see call-out box). The selection criteria ranking largely mirrors the sentiment of ecosystem actors with regard to the remaining key challenges to broader blockchain adoption (see Appendix III).

Beware the trade-offs

Each network is based on a unique set of architecture and design choices optimised for the delivery of a specific business objective. Every design configuration is a conscious trade-off between a variety of properties, with the most common trade-off being the achievement of performance gains at the expense of "decentralisation". Some properties may be more desirable than others in a specific context or environment, but it is important to understand that they are always achieved at the expense of another property. This makes it difficult to directly compare the performance and scalability of blockchain networks as they generally choose different trade-offs that result in distinct characteristics.

Decentralisation and distribution of control

Blockchains are tools for distributing control over a shared record system across multiple participants so that, in theory, no single entity can unilaterally exert full authority over the system. In practice, however, traditional business environments require a certain level of safeguards and protection measures in place to ensure that potential issues can be quickly resolved without severely impacting operations. This notion generally presumes the existence of an entity — or small set of entities — vested with certain powers.

The remainder of this section will explore the degree of decentralisation in existing enterprise blockchain networks by considering both network consensus (automated agreement on transaction ordering) and social consensus (governance).

a) Network consensus

There are two main actors involved in network consensus:

- **Auditors:** full nodes that independently verify transactions and the system state[19]

- **Block producers:** entities that commit transactions to the global ledger by establishing a fixed ordering to avoid double-spending[20]

Determining the network resilience of a blockchain system requires evaluating two dimensions: first, which entity operates the nodes (*control*), and second, where these nodes are hosted (*hosting*). Figure 20 provides a visual representation of this mental model.

Figure 20: Various options are available for the control and hosting of full nodes
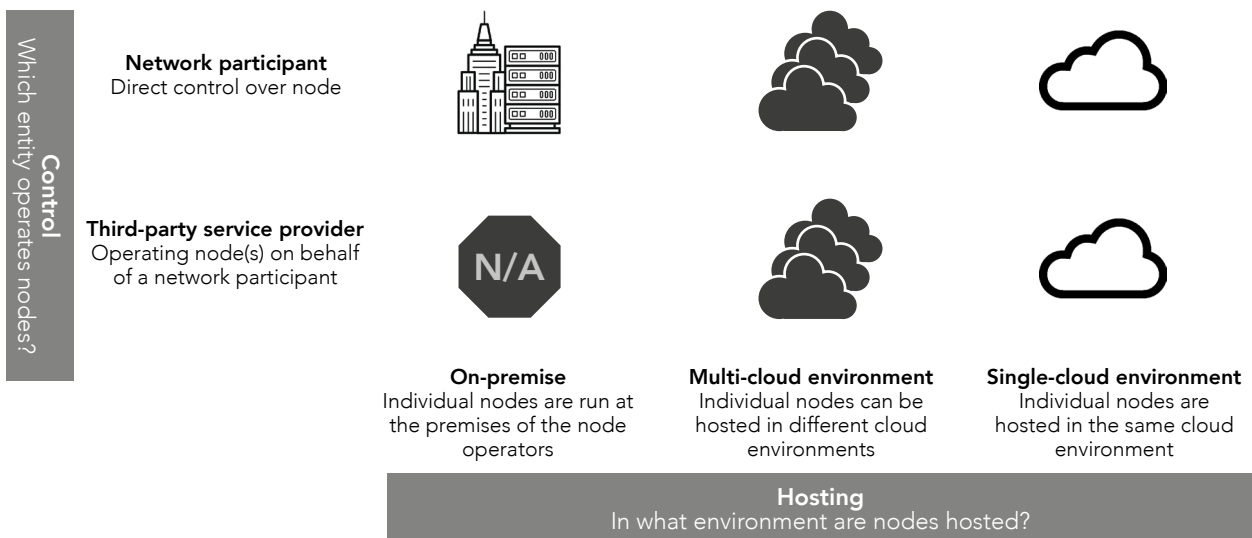
Network participants only benefit from the ability to independently verify transactions and the system state if they operate a full node themselves (i.e. have full control and access to the node); otherwise they are fully dependent on a third-party service provider to whom the auditing

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19 Full nodes are software programs run by network participants that enable them to connect to other network participants in a peer-to-peer fashion, i.e. directly exchanging messages between each other. Full nodes are an essential component of any blockchain system as they provide each network participant with the ability to individually check submitted transactions and records for validity and reject invalid submissions. In essence, a network participant running a full node has the capacity to perform an independent audit of the entire system state without having to trust a third party — hence, sometimes being referred to as *auditors*.

20 Block producers are sometimes also referred to as *miners, bakers, stakers,* or *validators.* The term "validator" can lead to confusion as it may suggest that only block producers are validating submitted transactions and records. In practice, full nodes do validate transactions as to independently reconstruct and verify the latest state of the system. Block producers can - and should - run full nodes as well so they can be sure of the validity of the transactions they are ordering.

function has been delegated.[21] The network can be more resilient against failures and external attacks when nodes are either hosted on-premise by network participants or in multiple cloud environments, although the individual configurations and settings do play an important role as they can widely differ from one organisation to another.[22]

It is surprisingly difficult to get reliable data on the network composition of live networks

It is important to note that limited information is available with regard to the exact network composition of the covered live networks: few disclose the number and hosting environment of full nodes and block producers. In addition, unclear terminology often leads to confusion, such as the conflation of "users" with "participants" or "nodes". For networks where data is available, it turns out that the number of nodes can range from a single node to more than 70, all while having more than 200 members in specific cases.

It is even more difficult to get reliable data on the number of separate block producers in live enterprise networks, suggesting that many networks rely on a single block producer to date. It should be mentioned that this would be in line with an examination of use case specifics, which have revealed that disagreements over the ordering of transactions are rarely the case — or even possible. This explains the absence of multiple block producers.

Most live networks barely distribute control across participants and are effectively controlled by a small set of parties

Our findings suggest that the majority of enterprise blockchain networks in production are currently hosted in a single-cloud environment where nodes are all administered and operated by a single third-party service provider (platform host) who is also responsible for producing blocks.[23] Project members can then connect to the platform host via a trusted API connection. It turns out that in 69% of these cases, the platform host is also the technology partner (i.e. software vendor) of the network.

However, there are also exceptions: some networks do provide members with the option to run their own nodes (on-premise or in the cloud), although interestingly, most participants choose to delegate their auditing power to a third-party service provider. While this may seem to miss the purpose of a blockchain, there are valid business reasons for doing so at an initial stage.[24]

b) Social consensus

While a diversified network structure and composition ensures that no single participant can take control over the transaction ordering process, it is worth recalling from Section 1 that social consensus can always override network consensus by changing the rules of the system. It is therefore important to take into account the governance of blockchain networks as well when assessing the degree of decentralisation.

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21   This may be an implication of the use case that doesn't require specific participants to validate transactions themselves.

22   For instance, cloud providers would argue that their services are more secure than self-hosted alternatives. Moreover, a network is often only as secure as its weakest point, which means that cloud-based node owners would need to trust that other network participants hosting nodes on-premise have implemented similarly high security standards.

23   It is important to note that administration in this context can refer to different functions: cloud administration (e.g. compute and storage capacity), blockchain network administration (e.g. onboarding new members, peer management), and/or application administration (e.g. application function by user). A cloud provider may facilitate the former but not necessarily the latter two.

24   Members may have a lack of technical expertise when it comes to manage complex infrastructure components in-house. Furthermore, they may not feel comfortable with the idea of operating their own infrastructure at an early stage given that they are used to third-party outsourcing. Managing nodes on-premise can also involve complexities related to security and interoperability issues that most companies are unfamiliar with.

Our empirical analysis shows that more than 80% of live enterprise blockchain networks are currently governed by a leader entity (Figure 21). This leader entity is responsible for coordinating protocol changes, permissions management, and onboarding policy. The governance structure may be different from one project to another, with other participants having various degrees of decision-making power.

Figure 21: Four in five live networks are governed by a leading participant entity

Enterprise blockchain network governance
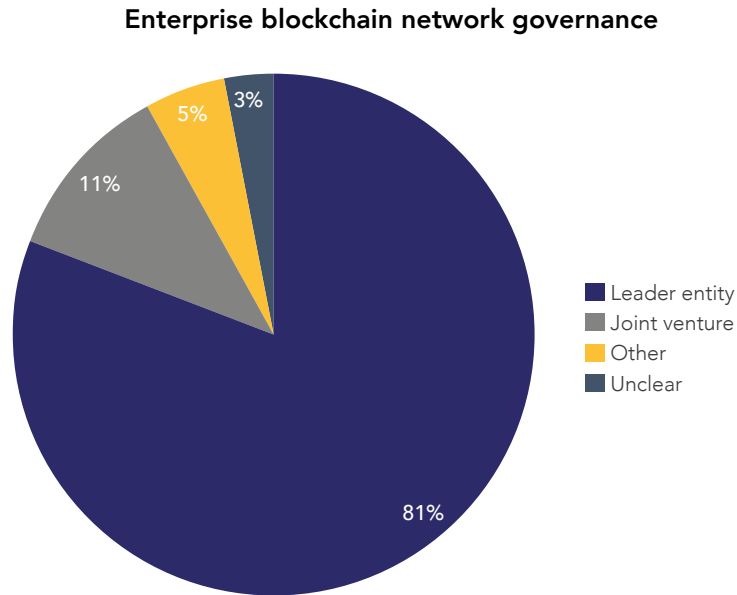
Note: based on CCAF dataset of 67 live enterprise blockchain networks. For further information about the difference between social and network consensus, please refer to Figure 1 on page 14.

The leader entity generally takes the lead in setting up the network: in fact, 96% of founder-led networks are governed by the same entity that launched the initiative. In contrast, networks that originate from a consortium of organisations tend to be governed more often through joint ventures (33%), although one consortium member is still leading network governance for more than half of the covered networks.

Case study: We.Trade

Overview

We.Trade is a blockchain network launched by a consortium of international banks to support open account trade finance for small and medium enterprises (SMEs), initially across Europe.

Project lifecycle

The formal We.Trade project was launched on October 17, 2017, having originally started as *the Digital Trade Chain*, a consortium of seven international banks (Deutsche Bank, KBC, Rabobank, Societe Generale, Natixis, Unicredit, and HSBC) in 2016. The first production transactions were announced on July 3, 2018, after two more banks (Santander and Nordea) subsequently joined the consortium and joint venture. In October 2018, 3 banks (UBS, Erste Group, and CaixaBank) from the rival UBS-led BATAVIA consortium joined, in addition to Eurobank that allowed We.Trade to expand to Greece and take the total number of banks to 13.

Project scope

We.Trade is an open account trade finance project directed towards European SMEs: each of the thirteen participating banks provides access to their SME clients via their commercial banking platforms. The network enables SMEs to discover trusted trading partners in other countries who have already been vetted and verified locally by participating banks. Since all steps of the transaction are committed to the blockchain ledger and payment notifications are automated via smart contracts, SMEs can have more confidence that they will get paid at a pre-agreed time. The We.Trade motto "More Trust More Trade" is a fitting indication of the revenue generation objective of the network: the more trust there is between SMEs, the more trade will ensue, which will lead to more wealth creation, and, in turn, generate additional revenues for the participating banks.

Network design and composition

The We.Trade network is built on the Hyperledger Fabric core protocol framework and operated by software and services vendor IBM on behalf of the We.Trade Joint Venture. Initially, it was expected that individual banks could choose whether to run their nodes on premise or deployed on cloud. In the early stages of planning, two of the original seven banks were planning to run their nodes on-premises; however, all banks subsequently decided to run their nodes in a cloud environment, with the core infrastructure running on the IBM Blockchain Platform. The original Digital Trade Chain PoC, led by KBC in 2016, was based on Ethereum. Hyperledger Fabric was eventually chosen for the production implementation as a result of the selection of IBM as the platform developer.

Workflow

Only banks that are party to a transaction have the ability to endorse that transaction. Each bank has its peer node(s), supported by IBM's Blockchain Platform and cloud services. The bank nodes are integrated into each bank's commercial banking, payments and KYC processes. When a purchase transaction is committed by a buying SME, their platform processes the transaction in both bank's ledgers, which is in turn validated by the selling SME and committed to the ledgers by their bank. All steps of the transaction are reflected on the ledger, including the optional physical movement of goods (via a Track and Trace API), and payment notifications, which are automatically triggered by smart contract code, based on the meeting of predetermined settlement criteria. Buying SMEs are able to request a Bank Payment Undertaking to give the seller confidence of payment, and selling SMEs are able to request invoice financing from their bank — all through the We.Trade platform.

Social consensus and governance

With each bank having stakeholders for requirements, architecture, security, compliance, and more, design meetings rapidly became very large. This and other considerations such as governance and commercialisation models led to the formation of We.Trade as a Dublin-based Joint Venture with 12 of the 13 banks as shareholders. Interestingly, Eurobank, the latest member to join the network, was on-boarded as a licensee of the We.Trade platform rather than as a We.Trade shareholder. The We.Trade network now has some functions such as marketing, bank sales, business development and product management centralised within the We.Trade Joint Venture, with day-to-day operations distributed across the member banks, and an overseeing governance model through the We.Trade Joint Venture and platform licensees.

A note on blockchain activities in the public sector

In recent years, central banks and other public-sector institutions (OPSIs), which include local municipalities and governments, national ministries and agencies, as well as international bodies and multilateral organisations, have increasingly expressed interest in the potential of blockchain technology. More recently, however, it appears that initial enthusiasm has cooled down and made way to the sobering realisation that the journey to practical implementation takes time and is often riddled with obstacles and challenges.

Compared to data from the 2017 survey, the number of institutions that are still in the early stages of exploring the technology and conducting research studies has substantially declined, but has not translated into a meaningful increase in PoCs or actual trials. This observation applies equally to central banks and OPSIs, although findings confirm survey results from the 2017 study about central banks being more conservative than OPSIs and less "adventurous" regarding experimentation and advanced testing. Only a small number of projects have been actively advanced and made significant progress over the last two years, which suggests that the experiments have been largely completed and only the more committed and serious efforts have moved ahead.

Figure 22: The focus on explored use cases has slightly shifted since 2017

Explored blockchain use cases

Share of central banks

Use case	2018	2017
Central bank-issued digital currency (CBDC)	56%	82%
Real-time gross settlement (RTGS) systems	50%	
Payment networks	50%	55%
Other clearing/settlement systems	44%	
Regulatory compliance	38%	36%
Ownership records management	25%	14%
Other	19%	41%

Share of other public-sector institutions (OPSIs)

Use case	2018	2017
New payment and value transfer systems	57%	13%
Regulatory compliance	52%	25%
Personal records management	43%	31%
Ownership records management	35%	50%
Shared government infrastructure	26%	
Business records management	22%	31%
Voting	22%	25%
Taxation	17%	6%
Public procurement	4%	
Other	39%	63%

■ 2018 ■ 2017

Note: based on CCAF survey data.

A comparison with 2017 survey data reveals that the focus on explored use cases has slightly shifted (**Figure 22**). For instance, the interest of central banks in using blockchain networks for the issuance and management of central bank-issued digital currency (CBDC) has significantly declined.[25]

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25 Other studies have shown that motivations for developing a CBDC, independent of the underlying technology, may vary across central banks. However, surveyed central banks from our sample share similar reasons: in particular, assessing the potential impact of CBDC on financial stability and the growing trend toward a cashless society are mentioned as the key drivers behind the exploration of CBDC. Interestingly, the potential ability of CBDC to preserve central bank seigniorage revenue, to facilitate tax collection and impede tax evasion, as well as to better enforce capital controls are not considered primary incentives.

This finding suggests that internal research and initial experiments have shown that alternative technologies may be better suited, but also confirms the recent announcement of a number of central banks to abandon initiated CBDC projects. In contrast, blockchain technology remains a popular candidate tool for increasing the resilience and robustness of critical payment infrastructure such as RTGS systems.

Meanwhile, surveyed OPSIs have shifted the focus of their blockchain activities from ownership and business records management to personal records management (e.g. birth and death certificates). Moreover, blockchain technology is increasingly explored as a potential tool for the development of new payment and value transfer systems that would increase transparency — and thus facilitate regulatory compliance for companies and institutions alike by providing an auditable log of verified records.
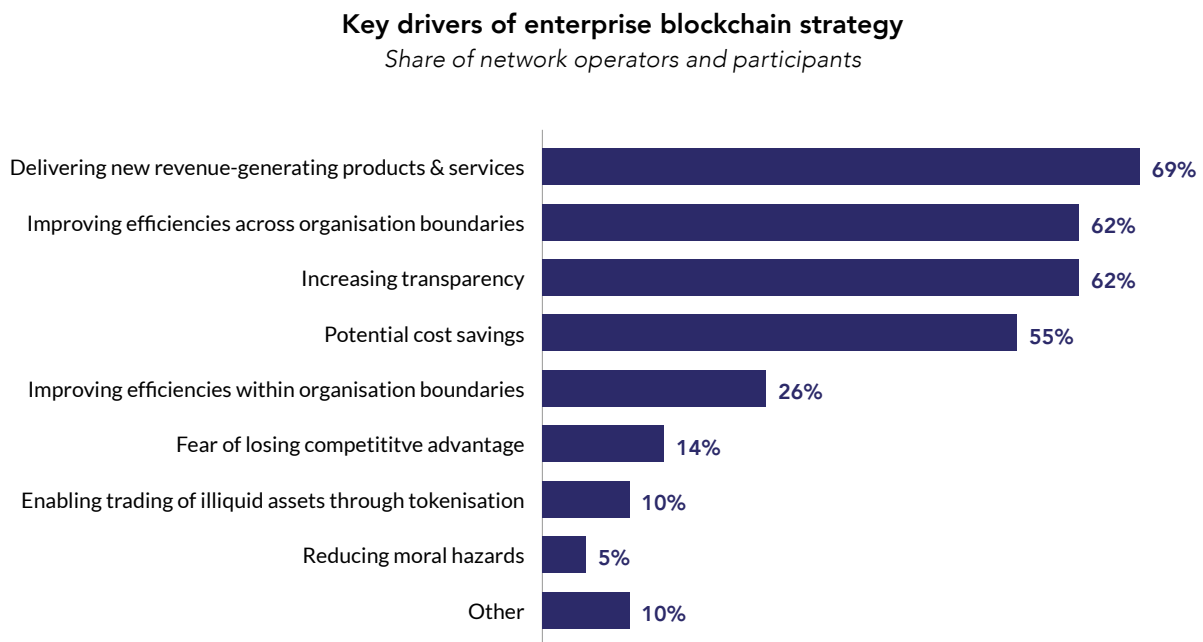
Section 4: Blockchain Strategy and Business Models

User motivations

Expected benefits

Since early 2015, the ubiquitous blockchain hype has touted innumerable benefits that organisations could expect when adopting blockchain technology. But are there any real drivers of corporate and institutional interest in exploring blockchains as a new tool for their operations? According to survey data, the key motivation is the potential of generating revenues through the provision of new products and services (Figure 23). The prospect of increased process efficiency and the associated cost savings also encourage organisations to start exploring blockchains.

Figure 23: The potential of new revenue generation is the key driver of corporate blockchain strategies

Key drivers of enterprise blockchain strategy
Share of network operators and participants

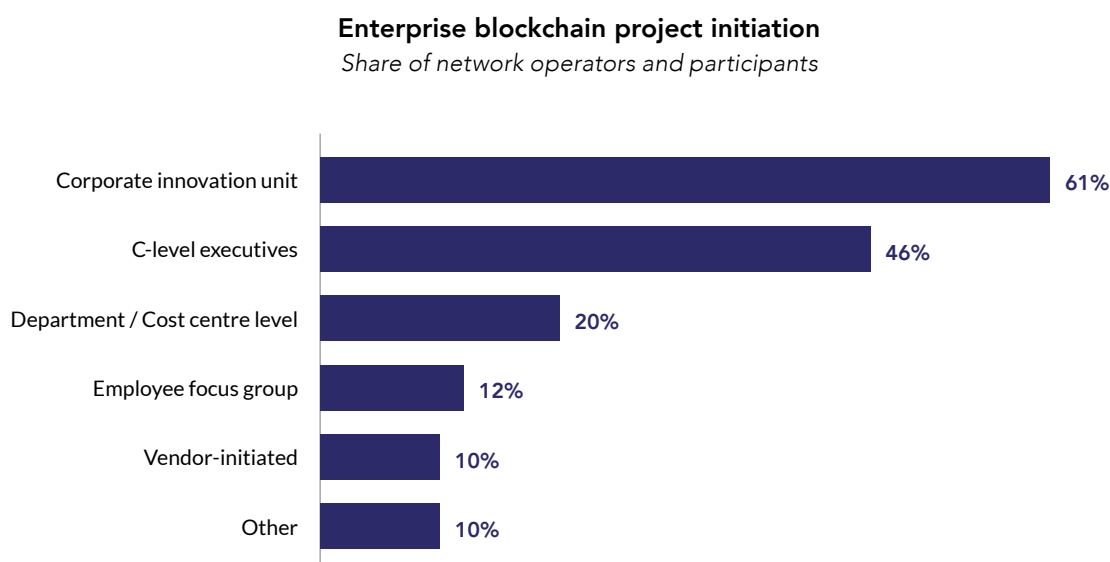|	
Delivering new revenue-generating products & services	69%
Improving efficiencies across organisation boundaries	62%
Increasing transparency	62%
Potential cost savings	55%
Improving efficiencies within organisation boundaries	26%
Fear of losing competititve advantage	14%
Enabling trading of illiquid assets through tokenisation	10%
Reducing moral hazards	5%
Other	10%

Note: based on CCAF survey data.

This is in line with the findings from Section 3 that showed how the initial focus of live networks primarily lies on cost reduction, but will gradually shift towards the provision of new products and services that promise to generate additional revenues. Furthermore, the data confirms our initial assessment that blockchain technology is considered a "team sport" that develops its full potential through collaboration between multiple parties beyond organisational boundaries. Interestingly, network operators and participants report that general reluctance to change established business processes remains the key challenge to broader blockchain adoption (see Appendix III), indirectly confirming the view that "blockchain" is more of a powerful catalyst that is driving organisational change than a new technology.

Finally, it is noteworthy that one in seven respondents indicated to have launched a blockchain strategy for fear of losing competitive advantage. However, it is unclear whether this refers to a genuine concern over missing the train with regards to a potentially groundbreaking new innovation, or if it can be interpreted as corporate "innovation theatre" for marketing purposes to influence external perceptions.

Internal decision-making

Blockchain strategies and projects can originate from various levels of the corporate hierarchy. Perhaps unsurprisingly, the majority of surveyed organisations indicate that internal innovation units have been playing a major part in crafting an organisational blueprint for incorporating blockchain technology into their operations (Figure 24).

Figure 24: Enterprise blockchain projects primarily originate from internal corporate innovation units

Enterprise blockchain project initiation

Share of network operators and participants

Corporate innovation unit	61%
C-level executives	46%
Department / Cost centre level	20%
Employee focus group	12%
Vendor-initiated	10%
Other	10%

Note: based on CCAF survey data.

Notably, nearly half of respondents also mention that chief executives have been paving the way for their companies to get involved in blockchain activities, which suggests that the technology is increasingly considered a priority that benefits from executive buy-in. This confirms findings from another study observing that 53% of top management executives from companies across all industries assign a high priority to blockchain activities.[26] Interestingly, 10% of respondents point out that internal blockchain activities were launched at the initiative of external vendors.

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26   Deloitte (2019) *Deloitte's 2019 Global Blockchain Survey*. Available at: https://media.licdn.com/dms/document/ C4E1FAQEDQciR9s2Jow/feedshare-document-pdf-analyzed/0?e=1563868800&v=beta&t=2LCmCNUYCVEe3aU6pI0Hhn9E563n Gz2mz98xyFmKIN8 [Last accessed: 22 July 2019].

Strategy implementation

Market approaches

After organisations have identified a viable business case that can be appropriately delivered by way of a blockchain solution, two major market approaches are at their disposal: they can either take the lead and launch a new network, or join an existing blockchain initiative and network. Each approach has different advantages and opportunities, but also drawbacks and challenges, as illustrated by Table 2.

Table 2: Pros and cons of different blockchain market approaches for new entrants

MARKET APPROACH	POTENTIAL ADVANTAGES	POTENTIAL DRAWBACKS
A) JOIN EXISTING NETWORK	• **Speed:** faster go-to-market • **Cost-effective:** limited to no coordination costs and development costs • **Reduced complexity:** technological infrastructure has already been set up and workflows have been tested • **Business case validation:** use case fit has already been tested and validated, and potential network effects may already in place • **Accelerated learning:** lessons learnt by other network members	• **Fees:** on-boarding and/or licensing fees • **Existing terms and conditions:** limited influence over decision-making process, technical standards, and commercial mode • **Limited flexibility:** subject to potential technical and operational debt originating from existing architecture • **Reduced commercial opportunity:** depending on the project stage, the commercial benefit for revenue-generating use cases may potentially be less obvious
B) CREATE NEW NETWORK	• **Influence:** retain influence over use case fit, technical architecture and standards, as well as governance and commercial model • **Flexibility:** create new system from scratch free from technical debt • **Relevance:** potential to create a new industry-leading utility • **Commercial up-side:** taking a founders' premium for revenue-generating use cases	• **Costs:** coordination, development, governance, and operations • **Time:** gathering support as well as internal and external buy-in is time-consuming • **Lack of critical mass:** potentially no network effects - project becomes just another isolated network • **Regulatory uncertainty:** taking the initiative (and costs) for regulatory and legal approvals

Choosing the right approach depends on a variety of factors, both internal (e.g. business case, resource requirements and availability, acceptable time horizon) and external (e.g. industry context, presence of competing platform). Moreover, the stage of existing projects an organisation is pondering to join plays an important role: the earlier the project, the more flexibility and decision-making power can be granted to the new entrant; however, also the more costs are likely to be incurred in terms of network development and governance arrangements.

Incentives: allocating costs and benefits

Like other major technology and infrastructure upgrades, the launch and maintenance of enterprise blockchain networks can involve considerable costs. What are these costs and who has to bear them?

The cost factors can be grouped into four categories that are closely linked to the project stage: the initiative launch, project development, governance arrangements and operational activities. Depending on the origination model, the cost levels and allocation can vary significantly: for instance, costs tend to be mutualised and shared between consortium members, whereas in founder-led networks, the initial investment and project-related expenses are generally borne by the leader entity (Figure 25).

Figure 25: Cost factors and allocation are dependent on the network model

Cost and incentive factors

	① Initiative launch	**②** Development	**③** Governance	**④** Operation
Founder-led	• Costs exclusively borne by the leading entity • Opportunity to drive early critical mass if founder has significant market share in the target market	• Costs borne by the leading entity • Leading entity may hold intellectual property (IP)	• Rulebook set by the founder • Option to make a level-playing field to create incentives for adoption, or compromise on level-playing field to extract early revenue opportunity	• Operating model defined by the founder - may need to adjust as others join • Founder may operate the network or encourage joint maintenance by participants – impact on cost allocation
Consortium-led	• Long gestation period to agree on proposition detail, business case(s), and signoffs – all of which increase launch cost • Cost can be shared across founding members	• Shared build cost • Individual member objectives on approach, technology, and architecture may slow down the build phase • IP ownership needs to be agreed	• Can take a long time to agree on the rules, from commercial model to operations and IT governance • Option to avoid favouring early adopters and founding members	• Operation more likely to be outsourced to a neutral party, or setting up a joint venture to own operational responsibility • Maintenance and operational costs generally mutualised among participants

Network model (vertical axis label)

Project stage and maturity →

A major consideration linked to both cost factors and eventual commercial benefits are network effects: blockchain projects unlock their full potential only if all relevant parties to a trade reside on the same network. Choosing the right incentives in accordance with the network model is crucial to encourage other organisations to join the initiative. Founder-led networks can create network effects relatively easily, if the leading entity has a dominant market position that can be leveraged to onboard downstream and upstream members of the value chain. Consortium-led networks should adopt a suitable commercial model that avoids favouring founding members and early adopters too much if others are to be encouraged to join.

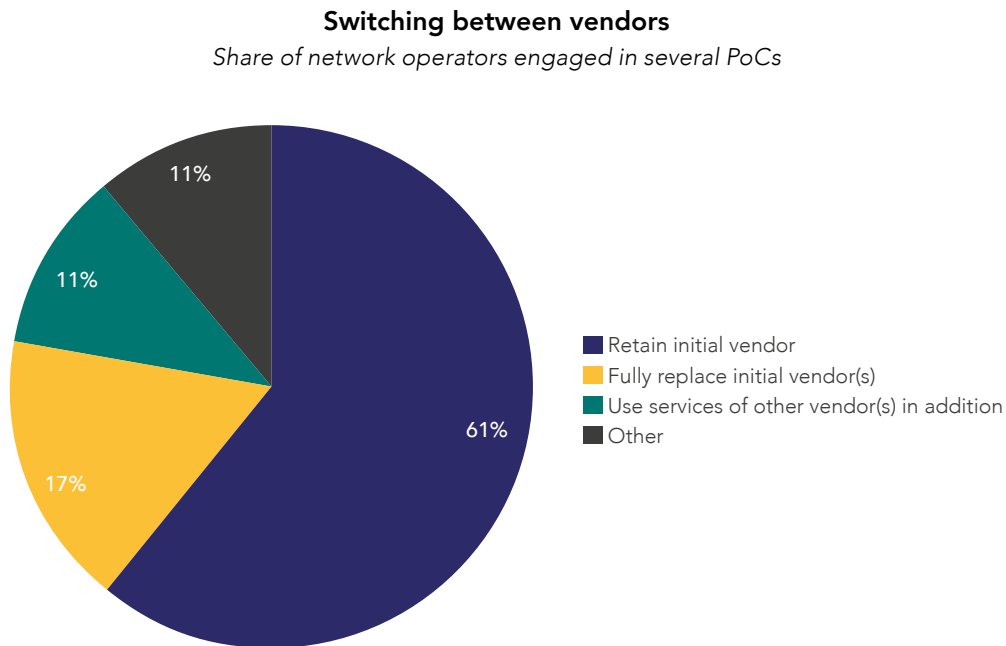**Case study: TradeLens**   TRADELENS

Announced in January 2018, TradeLens is a blockchain-based network started by Danish logistics and transport giant Maersk and software and services vendor IBM to transform ship-based supply chains. Given that Maersk controls some 25% of the world's container traffic, the TradeLens initiative represents an example of a founder-led network that uses its significant market share and power to achieve a minimal viable ecosystem without needing to form a consortium first. Press reports then followed at the end of 2018 indicating resistance from other major ocean carriers to join a network led by their major competitor. However, in May 2019, MSC and CMA CGM announced they were joining TradeLens, thereby taking the proportion of container traffic supported by the network to just under 50%. In July 2019, Hapag-Lloyd and Ocean Network Express — the 5th and 6th largest ocean carriers — also joined the network, further accelerating TradeLens adoption.

This case study illustrates the challenges of building critical mass for founder-led business models and the time required to get to the tipping point in multi-party networks where participants are also competitors. It also shows that there are incentives for organisations to join existing initiatives, even if led and managed by a key competitor, rather than to create their own projects that may fail to reach critical mass.

Vendor relationships

Network operators and participants have several options regarding network development and maintenance from a technical perspective. While some prefer developing the expertise in-house and reduce the dependency on third-party vendors, the majority of surveyed entities opt for a relationship with a third-party software or services vendor: in fact, about 60% indicate that their PoCs have resulted from a combination of in-house and outsourced developments, with the exception of the year 2016, where most organisations were experimenting internally with freely accessible open-source protocol frameworks.

Network operators and participants tend to retain the services of the vendor they initially contracted. Survey data shows that 61% of organisations engaged in multiple PoCs and/or other tests and trials chose to continue working with the same vendor, whereas only 17% opted for a complete switch to another vendor (Figure 26). These findings highlight the importance for vendors to build and maintain good relationships with potential clients from the start as customer retention appears to be relatively high. One explanation can be found in the specialisation of certain vendors on a specific protocol framework (e.g. IBM primarily working with Hyperledger Fabric, ConsenSys working with Ethereum variants) as well as existing trust in the capacities of these vendors who have successfully delivered first projects and PoCs.

Figure 26: Customer retention appears to be relatively high for blockchain vendors

Switching between vendors

Share of network operators engaged in several PoCs

■ Retain initial vendor
■ Fully replace initial vendor(s)
■ Use services of other vendor(s) in addition
■ Other

Note: based on CCAF survey data.

The relationship between network operators and software vendors is also closely linked to the project stage: the more advanced the project, the more likely a third-party software vendor is involved. Survey respondents mention that less than one third of pilots and trials have been exclusively conducted in-house with no technical assistance or support from external parties. This is akin to traditional software-based projects where businesses contract external software vendors.
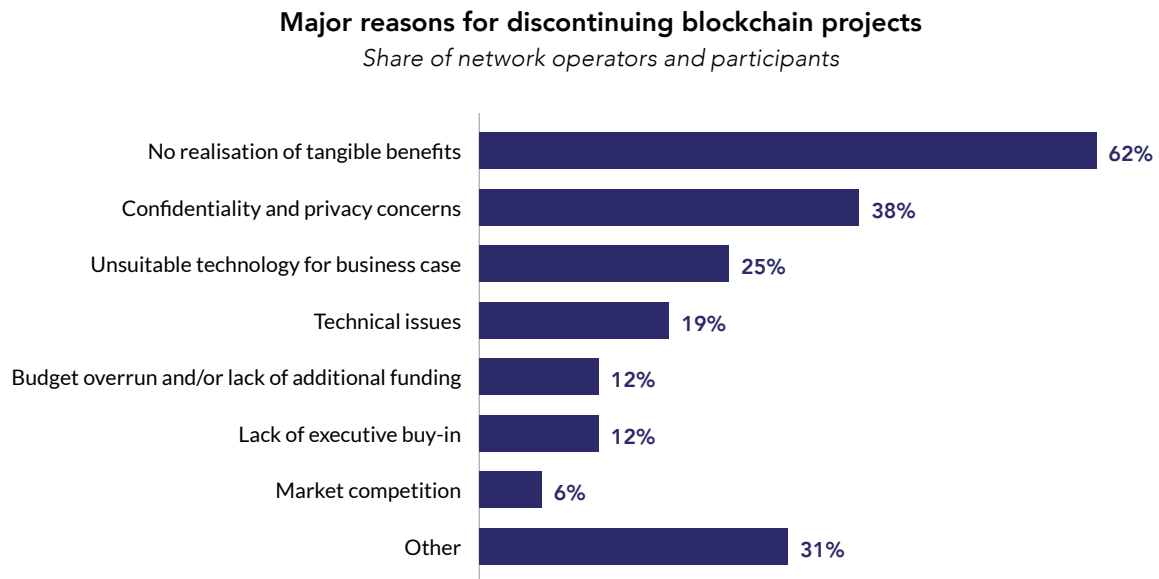
Internal evaluation of activities

Project discontinuation

The vast majority of blockchain experiments, PoCs, and trials do not pass to the next stage. While projects launches are generally announced with great fanfare including press releases, blog posts and news articles, many end up being quietly abandoned with little to no public acknowledgment. This further fuels the hype by creating an artificial perception that blockchain technology has been widely adopted.

Survey data from network operators and participants who have discontinued at least one enterprise blockchain project clearly highlights the primary reason: the application of blockchain technology to a specific business case failing to realise tangible benefits (Figure 27). This is hardly surprising given that many indicate to have misidentified suitable use cases in the first place. Moreover, regulatory barriers and the difficulty of collaboratively developing a business case across network participants are often cited when explaining the absence of realised benefits.

Figure 27: Failure to realise tangible benefits is cited as the major reason for discontinuing blockchain projects

Major reasons for discontinuing blockchain projects

Share of network operators and participants

No realisation of tangible benefits	62%
Confidentiality and privacy concerns	38%
Unsuitable technology for business case	25%
Technical issues	19%
Budget overrun and/or lack of additional funding	12%
Lack of executive buy-in	12%
Market competition	6%
Other	31%

Note: based on CCAF survey data.

It appears that a considerable number of projects are shut down before they have had the opportunity to realise their full potential: with many live networks, tangible commercial benefits are often only observed after the network has been running for a while. This is the result of business model innovation depending on many yet unknown parameters and circumstances. The uncertainty of returns on blockchain-related investments is largely acknowledged by industry actors as a key challenge to broader adoption (see Appendix III).

Some projects are discontinued before tangible benefits have the chance to manifest

Interestingly, more than a third of respondents indicate that concerns over confidentiality and privacy led to the conclusion of projects, which is in line with comments from surveyed entities on the difficulty of reconciling key blockchain attributes (e.g. difficult to rewrite history) with regulatory compliance requirements (e.g. GDPR). However, it is likely that the sentiment has slightly shifted in recent months after an increasing number of national and regional legislators have issued favourable legislations.[27]

Overall satisfaction

The majority of projects launched by surveyed network operators and participants are still in the early stages, waiting to unlock their transformative potential after completing the testing phase and achieving extensive usage. Nevertheless, survey data suggests that two-thirds of organisations engaged in blockchain activities are either satisfied or very satisfied with the overall performance and outcome of their projects (Figure 28).

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[27] See for instance, Chambre des députés du Grand Duché de Luxembourg (2019) *Bill of Law 7363*. Available at: https://www.chd.lu/wps/portal/public/Accueil/TravailALaChambre/Recherche/RoleDesAffaires?action=doDocpaDetails&backto=/wps/portal/public/Accueil/Actualite&id=7363 [Last accessed: 06 August 2019]; State of Wyoming (2019) *House Bill 185*. Available at: https://www.wyoleg.gov/Legislation/2019/HB0185 [Last accessed: 06 August 2019]; State of Nevada (2019) SB 163. Available at: https://www.leg.state.nv.us/App/NELIS/REL/80th2019/Bill/6234/Overview [Last accessed: 06 August 2019].

Figure 28: Network operators and participants generally tend to be satisfied with the outcome of their blockchain projects and activities

Degree of satisfaction regarding the outcome of blockchain activities

Share of network operators and participants
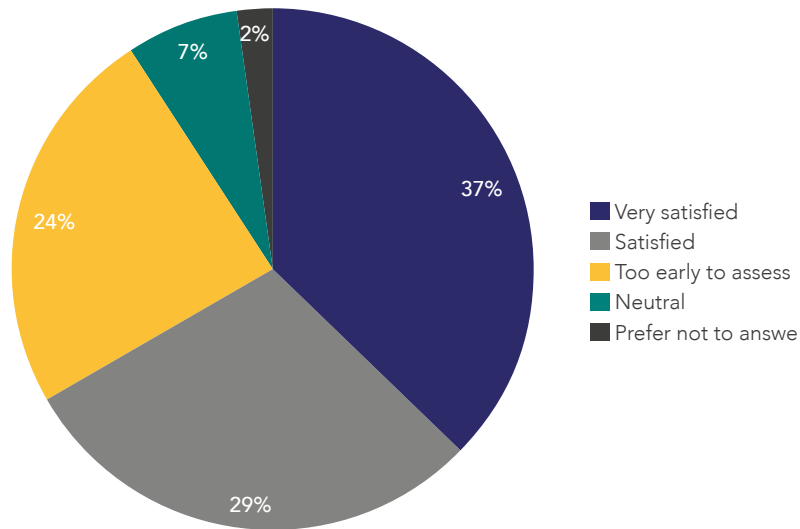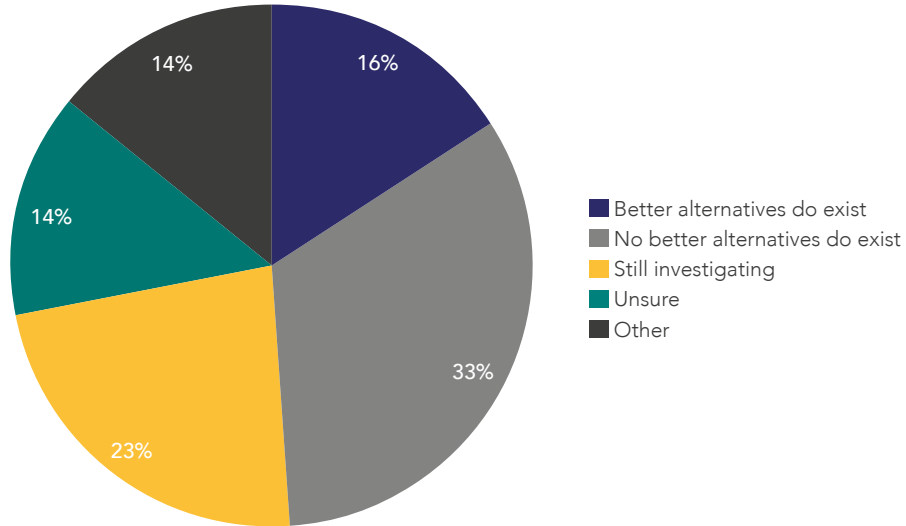

Note: based on CCAF survey data.

This self-assessment may initially seem surprising given the high rate of project failure. However, it may also reflect the valuable lessons learnt from negative outcomes and the growing realisation that blockchain technology is not a panacea for every enterprise problem, despite being frequently portrayed as such by the hype. Gaining these insights through self-experimentation and hands-on experience can add exceptional value to the organisation's overall strategy and avoid malinvestment.

Alternative technologies

Figure 27 suggested that one in four network operators discontinued a blockchain project on the basis that the technology turned out to be unsuitable for the aimed business case. When asked whether they were aware of alternative technologies such as cloud computing or traditional distributed databases that may be better suited to deliver the same business case, only 16% acknowledged that this was the case (Figure 29).

Figure 29: One third of network operators believe that blockchain technology is the best option to address their business case

Awareness of alternative technologies for delivering the same business case
Share of network operators and participants

■ Better alternatives do exist
■ No better alternatives do exist
■ Still investigating
■ Unsure
■ Other

Note: based on CCAF survey data.

One third responded that they do not believe an alternative technology could deliver the same benefits, demonstrating great confidence in the technology's effective capabilities. 37% of respondents are either still investigating alternatives or remain unsure about the existence of potential substitutes that would provide greater advantages.

Vendor strategies

Platform openness

Vendors that provide software services face an important strategic decision regarding the degree to which their platforms are open to third-party developers: the underlying codebases can be either *open-source* (i.e. outside developers are free to use or modify the code) or *proprietary* (i.e. closed-source and not accessible for outside developers).[28] Interestingly, survey data reveals that half of covered platforms are open-source, whereas the other half are proprietary (**Figure 30**).[29]

Figure 30: Half of vendor platforms are open to third-party developers, with the majority licensed under Apache 2.0
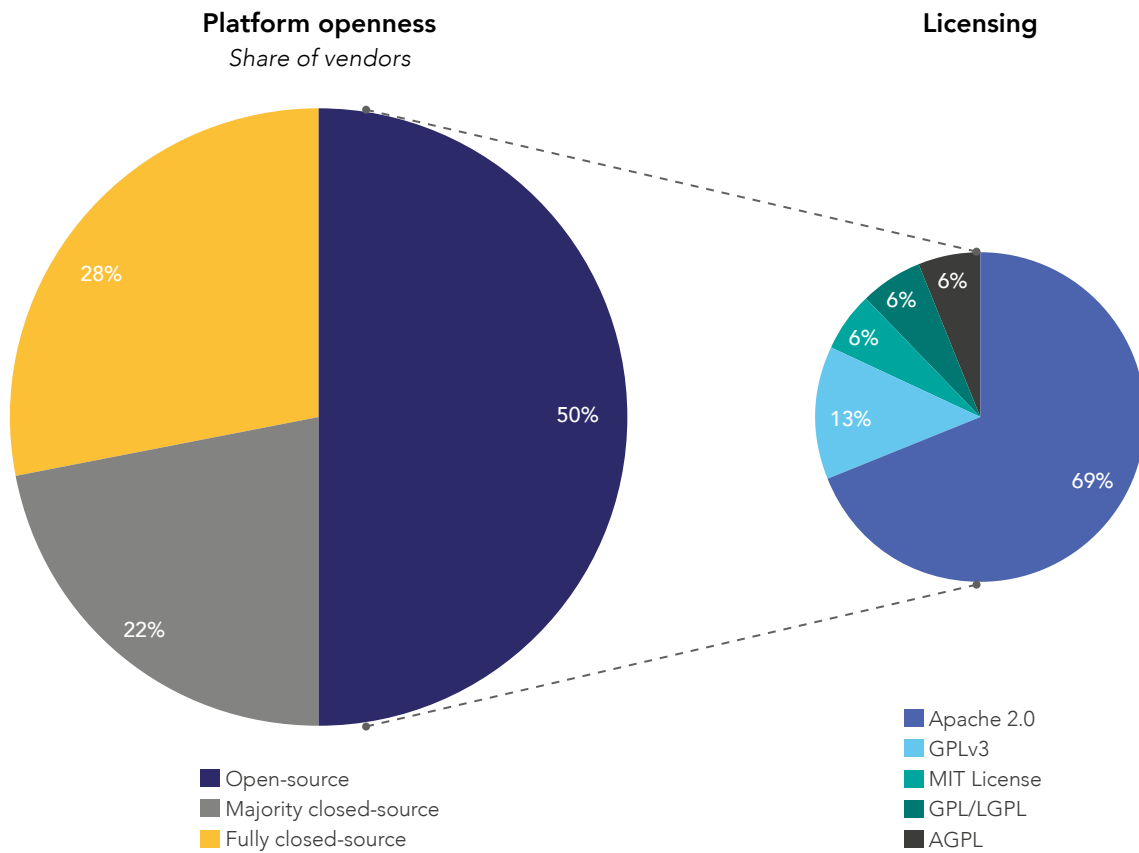
Note: platform openness based on survey data. Licensing breakdown based on a list of 17 blockchain software platforms.

Either decision has its advantages and downsides from the perspective of a vendor's business model and monetisation strategy: an open platform favours the emergence of a community and ecosystem around the software project, encourages experimentation, and facilitates integration into legacy systems, but cannot be directly monetised. In contrast, a proprietary offering enables direct monetisation via licensing fees and protects the company's IP, but may also deter potential users wanting to avoid vendor lock-in.

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28   In this context, we consider a codebase to be open-source when at least the majority of the code has been open-sourced. Similarly, a codebase is considered proprietary when the majority (or the entirety) of the code is close-sourced.

29   However, it is worth distinguishing between software platforms and execution environments: many live blockchain networks are based on open-source core protocol frameworks but are operated and maintained in closed-source environments. Similarly, vendors may license proprietary software development platforms that are based on open-source frameworks.

There are a variety of licenses available that determine permissions and rights around the use and modification of open-source codebases.[30] Open enterprise blockchain protocol frameworks and software platforms are predominantly licensed under the Apache 2.0 license (69% of covered protocols).

Industry targeting

From a technical perspective, a blockchain platform is a shared recordkeeping system that can be applied to any type of information. Given the broad applicability of data management and sharing tools, it is unsurprising to see that 41% of surveyed blockchain vendors adopt a cross-industry perspective and position their technology platform as a general-purpose tool applicable to all industries (Figure 30).

Figure 31: More than half of vendors are targeting specific industries with their platforms

Platform targeting
Share of vendors

General-purpose
Industry-focused but repurposable
Industry-specific
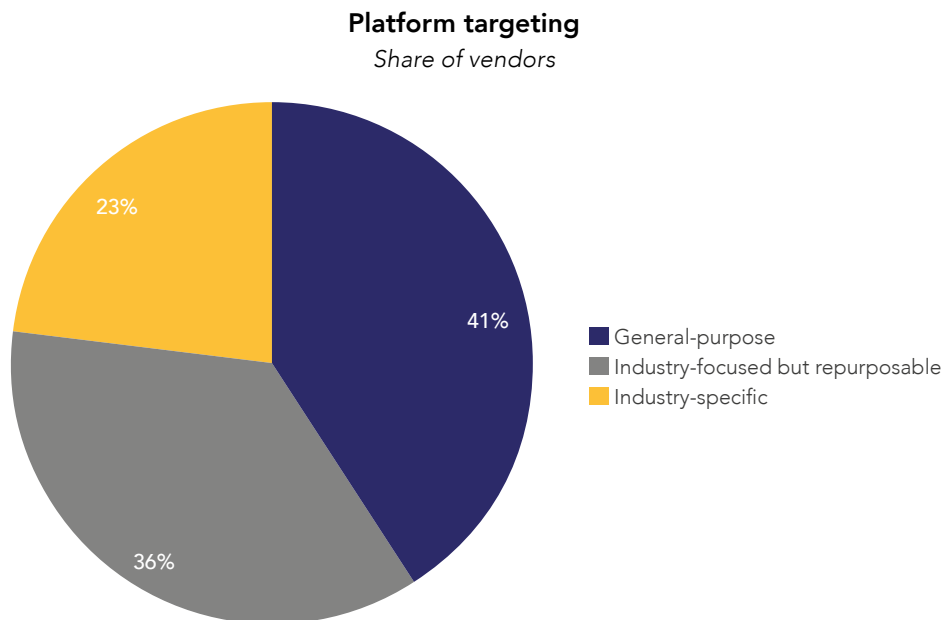
Note: based on CCAF survey data.

Nevertheless, the development of some platforms and core protocol frameworks has been primarily driven by industry requirements, that include the introduction of specialised features and functionality to meet the needs of specific business cases or industries. For instance, more than one in five vendors indicate that their platform has been specifically tailored to a particular industry, with Banking, Financial Markets, and Insurance being the predominantly targeted industries.
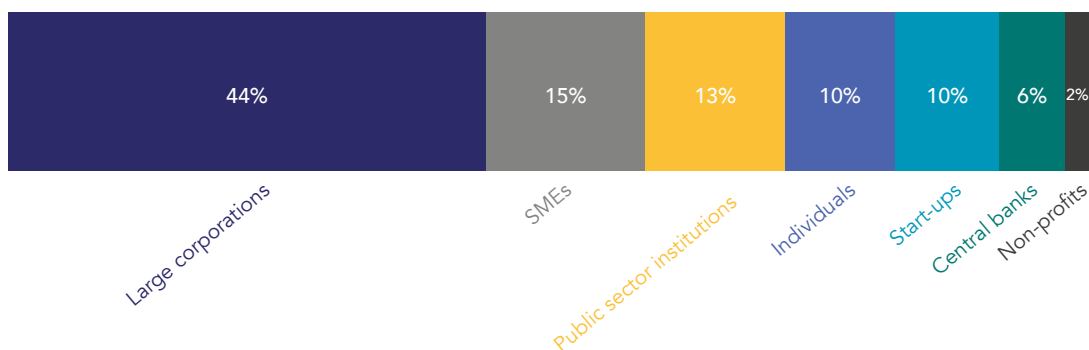
Furthermore, one third of vendors claim to have developed their platform with a specific industry in mind while keeping the design sufficiently flexible to cater to the needs of other industries as well. A good example of this strategic change is R3's Corda framework, which was initially customised to serve the needs of the financial and banking industries, but has since been repurposed to accommodate unrelated industries and use cases (e.g. supply chain tracking).

---

30   The MIT license is known as the most permissive open-source license that allows, for instance, commercial use of the code and only requires crediting original contributors when redistributing software (which can even become proprietary once modified). The Apache license is only slightly more restrictive in that it offers users additional protection from patent claims. GPL licenses are more restrictive, requiring derivative works to be made available on the same terms ("share-alike"/"viral licensing").

Customer types

Big, established corporations have not only dominated news headlines on enterprise blockchain initiatives and deployments to date, but also the customer base of blockchain vendors. In fact, surveyed vendors report that, on average, 44% of their total customer base is composed of large corporations, compared to only 15% of small and medium enterprises (SMEs) (Figure 32). The market pressure on large established companies to constantly innovate and look for new solutions may be one explanation for this discrepancy, a situation that SMEs do not generally face to the same extent.

Figure 32: Vendors have a diversified customer base dominated by large corporations

Average vendor customer base

Large corporations	SMEs	Public sector institutions	Individuals	Start-ups	Central banks	Non-profits
44%	15%	13%	10%	10%	6%	2%

Note: based on CCAF survey data.

An interesting observation is the absence of statistical differences between small, medium-size and large-scale vendors, which suggests that vendor size has little impact on the type and nature of customers. This is an encouraging sign for smaller service providers that do not seem to have a disadvantage relative to larger, established competitors when it comes to attracting large corporations as potential clients.

Blockchain revenue models

Given the relatively early stage of the enterprise blockchain industry, innovative new business models leveraging the unique characteristics of blockchain networks and related services are yet to emerge. Instead, traditional revenue models found in software development and maintenance are commonly encountered: Table 3 provides an overview of different revenue models that are currently applied in the enterprise blockchain industry to monetise services, categorised by the blockchain layers at which they occur.

Table 3: Overview of different enterprise blockchain revenue models

LEVEL OF HIERARCHY	REVENUE LEVER	REVENUE TYPE	ACTOR(S) INVOLVED
Application layer	Application usage: fees paid by users for using blockchain-based applications and services	• Access fees • Transaction fees • Licensing fees	End users, application providers
	Application development	• Application build cost • Licensing cost	Vendors, application providers
	Network operations: initial triage of user queries/problems (Level 1) and problem/application problem resolution (Level 2/3) support of the network service to end users	Regular fees	Various
	Third-party complementary services to end users	Various fee models	Application providers, third-party entities, other
Network layer	Network operations: participants running nodes (auditing) and processing transactions (consensus services)	• Data services (commercial API) • Transaction fees (by volume or value)	Network participants
	Gatekeeping and governance	• Onboarding fees • IP licensing	Network operators
	Cloud delivery services	Usage fees based on compute, storage, etc.	Vendors
	Network servicing: fully-managed blockchain network on behalf of participants	Fees based on the number of nodes and activity levels per member	Network operators, Vendors
Protocol layer	Provision of underlying technological building blocks, either through open-source or commercialised enterprise versions	• Commercial enterprise version (subscription fee) • Support packages	Vendors
Full stack	Blockchain-as-a-service (BaaS): fully-managed blockchain services (e.g. DLT software support, node management, application development)	Various fee models	Vendors
	Solutions design: education and training, ideation, consulting, and implementation	Various fee models	Vendors

For instance, vendors provide sophisticated enterprise versions of open-source protocol frameworks and offer service level agreements and premium support packages to customers. A popular model is the provision of "Blockchain-as-a-Service" (BaaS), which corresponds to a full-stack blockchain service package ranging from project ideation to full deployment, including a managed cloud environment and active platform maintenance. This model enables customers to configure and deploy a full network within minutes, to rapidly prototype and test applications in a sandboxed environment without needing to dedicate significant time, talent and R&D costs.

Services can be monetised across all blockchain layers

Network operators can monetise access to their networks via onboarding fees and IP licensing, while also potentially charging for platform maintenance, upgrades, and operational support. Network participants can charge transaction fees for processing transactions and setting up commercial APIs to external parties to provide network insights and data services, but also broadcasting transactions to the network. Application providers can charge end users for accessing network functionality via a third-party interface.
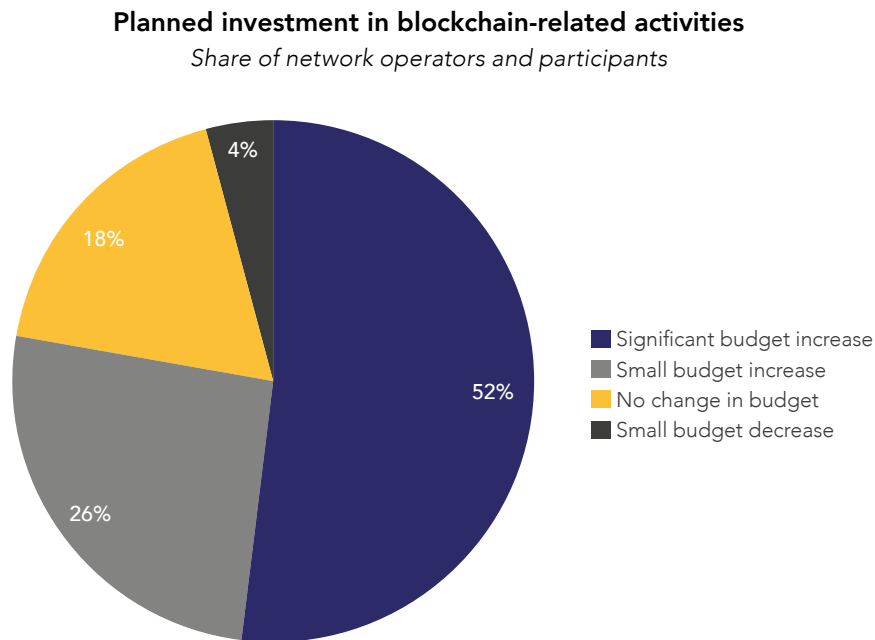
Section 5: Looking Ahead - What does the Future Hold?

Since the publication of the first benchmarking study in late 2017, the enterprise blockchain industry has slowly moved beyond the hype cycle and entered the production phase — although many deployed networks in their current form have little in common with blockchain systems initially envisaged as fully distributed multi-party consensus systems (see Sections 1 and 3).

Planned investment

Nevertheless, half-hearted experiments and short-lived PoCs have given way to more serious initiatives that involve well-specified implementation roadmaps and benefit from long-term executive commitment. This development is reflected in the projected budgeting of surveyed network operators and participants: only 4% indicated to moderately cut the budget allocated to their blockchain activities, whereas more than half planned to significantly raise the blockchain budget in the medium term to extend operations (Figure 33). This observation mirrors the sentiment of company executives in a recent *Deloitte* survey that found that the majority of organisations were planning to allocate a substantial amount to their blockchain strategy.[31]

Figure 33: The majority of network operators and participants plan to increase their blockchain-related budget

Planned investment in blockchain-related activities

Share of network operators and participants

Legend:
- ■ Significant budget increase
- ■ Small budget increase
- ■ No change in budget
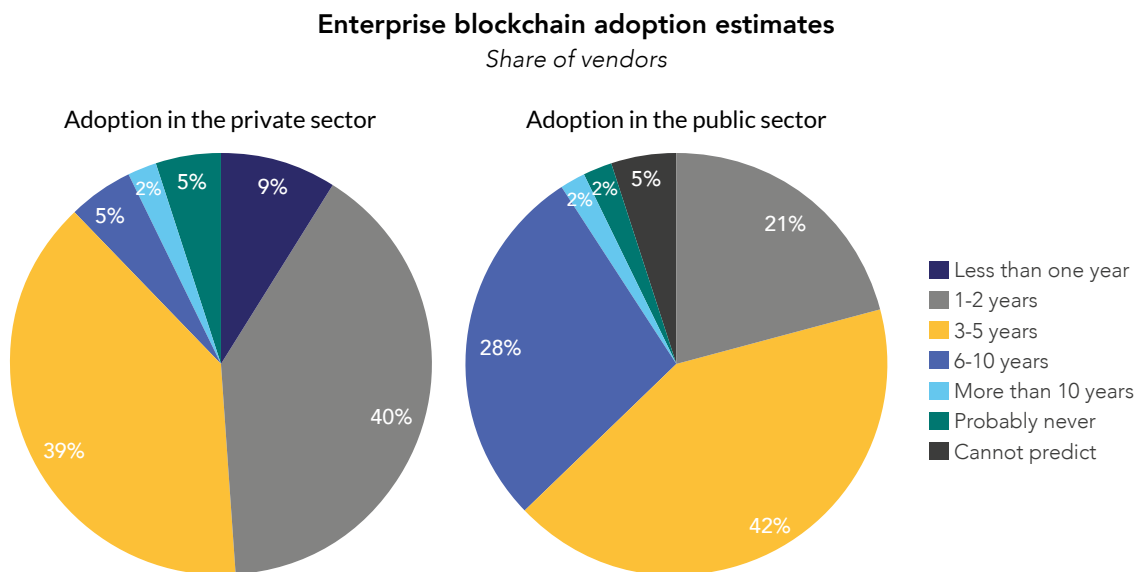- ■ Small budget decrease

Note: based on CCAF survey data.

31   Deloitte (2019) *Deloitte's 2019 Global Blockchain Survey*. Available at: https://media.licdn.com/dms/document/C4E1FAQEDQciR9s2Jow/feedshare-document-pdf-analyzed/0?e=1563868800&v=beta&t=2LCmCNUYCVEe3aU6pI0Hhn9E563nGz2mz98xyFmKIN8 [Last accessed: 22 July 2019].

Adoption estimates

Despite the prospect of substantial budget increases and planned investment from potential customers, blockchain vendors have become more cautious and have revised their optimistic adoption estimates from 2017. In fact, more than half of surveyed entities believed that broader enterprise blockchain adoption in the private sector will take at least three more years, with 5% even mentioning the possibility that it might never become a mainstream technology (Figure 34). Perhaps less surprisingly, estimates regarding broader blockchain adoption in the public sector are more conservative, perhaps based on the premise that the private sector generally precedes the public sector in terms of the adoption of new technologies.
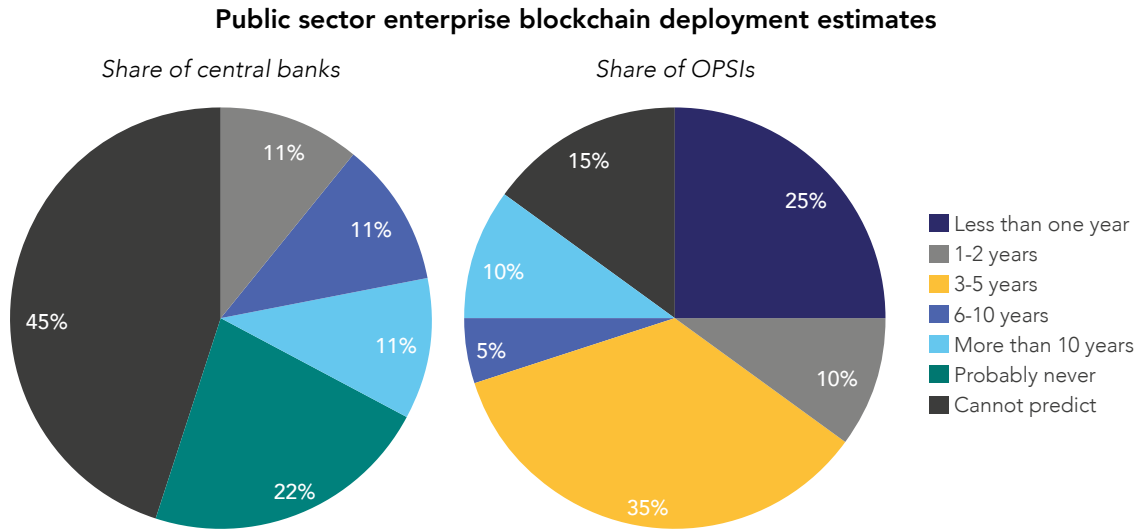
Figure 34: Blockchain vendors expect broader adoption within the next five years in both private and public sectors

Enterprise blockchain adoption estimates
Share of vendors

Adoption in the private sector | Adoption in the public sector

Less than one year
1-2 years
3-5 years
6-10 years
More than 10 years
Probably never
Cannot predict

Note: based on CCAF survey data.

Interestingly, the vendor view is remarkably in line with the estimates of other public-sector institutions (OPSIs) themselves, with the latter appearing to be even more optimistic regarding broader adoption of enterprise blockchains in the public sector (Figure 35). In contrast, central banks live up to their name as conservative and prudent institutions that are reluctant to engage in short-term technology worshipping: only a third of surveyed central banks believe that blockchain technology will ever play a larger role in the public sector, although the estimated timelines vary significantly from one institution to another.

Figure 35: Public sector estimates of broad blockchain adoption are significantly more conservative

Public sector enterprise blockchain deployment estimates

Share of central banks   *Share of OPSIs*

Legend:
- Less than one year
- 1-2 years
- 3-5 years
- 6-10 years
- More than 10 years
- Probably never
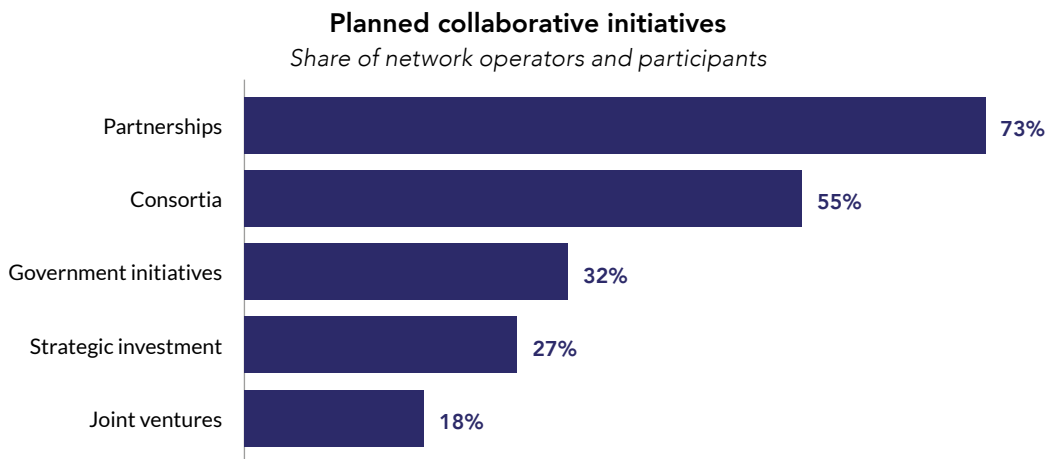- Cannot predict

Expected developments

It is worth repeating that despite achieving considerable progress in recent years, the enterprise blockchain ecosystem and industry remains in the early stages. We list below a set of potential developments that are likely to occur in the medium to long-term future.

Increased collaboration between competitors

Blockchain technology is a team sport that requires broad participation from diverse actors to build network effects and eventually unlock its full potential. While the level of collaboration appears to be relatively high at present, it is often limited to entities within the same trust boundary: i.e. existing partners, suppliers, and customers.

We expect to see increasing collaboration across trust boundaries (i.e. between directly competing entities) in various forms: survey data suggests that partnerships will remain the preferred method in the foreseeable future, although more than half of surveyed network operators and participants have also revealed plans to join an existing consortium or start a new initiative (Figure 36).

Figure 36: Network operators and participants plan to increase collaborative initiatives by entering more partnerships and joining consortia

Planned collaborative initiatives
Share of network operators and participants

Partnerships	73%
Consortia	55%
Government initiatives	32%
Strategic investment	27%
Joint ventures	18%

Note: based on CCAF survey data.

The "blockchain meme" hype will cool off

As the hype slowly fades and the industry matures, it is likely that terminology will be adapted to reflect the practical realities: a spade will be called a spade. This means that "true" multi-party consensus systems will be semantically distinguished from systems that use component technologies and/or elements of the blockchain toolkit.

This development will bring long-awaited clarity to the discussion and drastically reduce the unintended misinterpretations and confusion. This will lead to a more realistic appreciation of the technological limitations and, to some extent, prevent malinvestment of resources into expensive projects that are doomed to fail from the start.

Live networks will gradually distribute control

Many live networks are initially highly centralised, but plan to gradually distribute control over different network functions to multiple participants over time, citing "decentralisation" as a long-term objective from the outset. The main reason for this approach is the regulated enterprise setting in which these networks operate: participating entities generally opt for a conservative approach in the bootstrapping phase that involves the presence of safeguards, such as a central coordinator, who can intervene in the event of unforeseen circumstances.

In fact, many operators report that participating entities first need to get used to the new architecture and familiarise themselves with abstract concepts (e.g. key management, self-hosted infrastructure), until they feel sufficiently comfortable with the idea of gradually distributing control and assuming greater responsibilities. This approach enables network participants and end users to gain a better understanding of a system's functions and properties while operating in a safe environment. This results in invaluable experience that can then be used to move forward until all responsibilities related to both social consensus and network consensus are sufficiently distributed among participants such that no single entity can unilaterally impose decisions.

Network of networks will emerge

Given the number of blockchain networks already in production, a logical extension besides growth in the user base is to leverage the network and infrastructure for other business applications that are of value to the same community (e.g. the addition of supply chain financing applications to an existing supply chain tracking network).

Separate blockchain networks will increasingly be required to connect and interact in order to provide new services — i.e. form a "network of networks". Recent examples[32] of this development show a trend to connect networks built on the same blockchain technology (albeit with potentially different implementations) to facilitate interoperability, but this also points to the subsequent need for differing technologies to also facilitate interoperability.[33]

Focus will increasingly shift to the application layer

Since the publication of our first study in 2017, the focus has already shifted from the protocol layer to the network layer. The industry has consolidated around a relatively small number of core protocol frameworks (see Section 3) and is now actively deploying hundreds of live blockchain networks. Once major large-scale networks have been established, a rapidly-increasing number of business applications will be built on top to leverage network data. It is also reasonable to assume that applications will increasingly become "ledger-agnostic", i.e. connect to different enterprise networks depending on their requirements, rather than limit themselves to a single network.
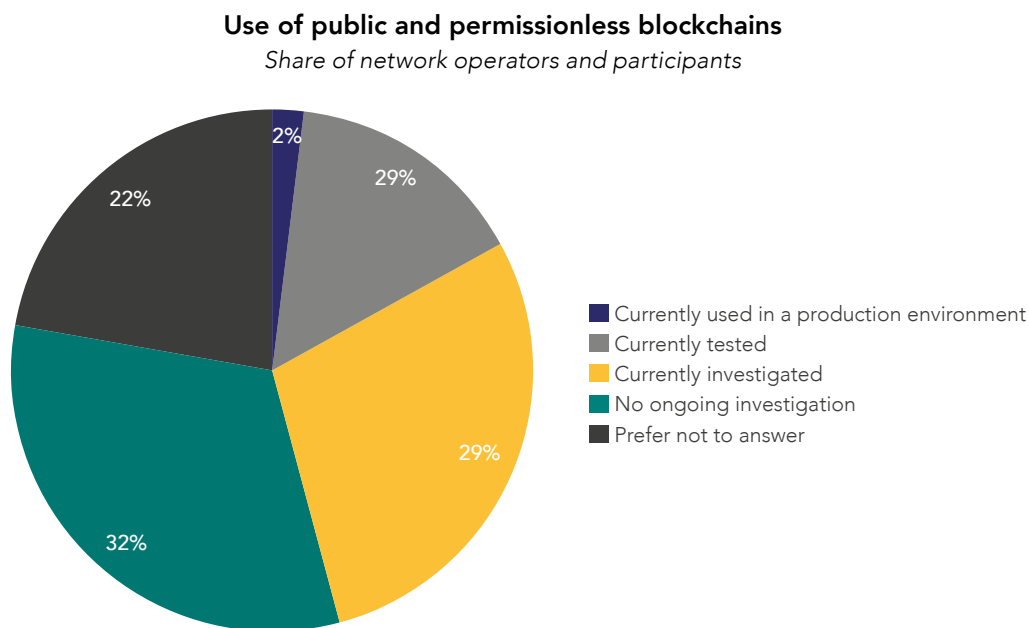
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32 For instance, see the Memorandum of Understanding signed between the Hyperledger Fabric-based Hong Kong's eTradeConnect and Europe's We.Trade networks to facilitate West/East trade. Similarly, comments have been made on the Corda-based Voltron network connecting with the Marco Polo trade finance network in the future.

33 Early signs of interoperability efforts already exist (e.g. the mutual memberships of EEA and Hyperledger), but much work remains to be done to facilitate full interoperability across all major enterprise blockchain technologies.

Increased convergence between private and public blockchains

While this report has exclusively focused on private, permissioned "enterprise" blockchains, one should not dismiss public, permissionless blockchains that function on the basis of complex socio-economic mechanisms. Some overlap between these two types of systems can already be observed: for instance, some enterprise blockchain vendors have developed core protocol frameworks based on open-source public blockchain protocols (e.g. Quorum is a fork of the Ethereum codebase, the initial Multichain version was a fork of the Bitcoin codebase).

Figure 37: Nearly half of network operators and participants have already been involved in public blockchain activities

Use of public and permissionless blockchains
Share of network operators and participants

- Currently used in a production environment
- Currently tested
- Currently investigated
- No ongoing investigation
- Prefer not to answer

Note: based on CCAF survey data.

Moreover, an increasing number of network operators and participants are experimenting with public, permissionless blockchain networks to investigate how enterprise use cases may benefit from an integration (Figure 37). A small number of established corporations already use the public Ethereum network as a new market infrastructure for the issuance, recording, and trading of financial instruments.[34] Other companies have been using the Bitcoin blockchain as a censorship-resistant public notary for securely timestamping documents, in order to prove their existence and integrity.

Similarly, enterprise blockchains may find it useful to periodically anchor the latest system state into a public blockchain for additional tamper resistance and independent third-party auditing. It is thus likely that in the foreseeable future, the enterprise blockchain and cryptoasset worlds will converge to the extent that cross-chain communications and asset transfers will become commonplace.

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34   See for instance Societe Generale's bond issuance on Ethereum. Societe General (2019), *Societe Generale issued the first covered bond as a security token on a public blockchain*. Available at:https://www.societegenerale.com/en/newsroom/first-covered-bond-as-a-security-token-on-a-public-blockchain [Last accessed: 11 July 2019].

Rise of asset tokenisation

Tokenisation is already underway for assets ranging from traditional financial instruments to real estate and art. For some assets, tokenisation can fractionalise ownership, which may facilitate a larger investor base and hence potentially increase market liquidity. For other uses, tokenisation can introduce new economic incentive mechanisms to influence consumer and business behaviour on digital platforms. Tokenisation allows logic to be embedded into the security, facilitating automation of tasks such as regulatory compliance. As noted by industry actors, tokenisation will drive significant future usages of enterprise blockchain platforms by banks, exchanges, asset managers and custodians.[35]

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35   See for instance R3 (2019) *Digital Asset Working Group Report.* Available at: https://www.r3.com/reports/digital-asset-working-group-report-july-2019/ [Last accessed: 05 August 2019].

Appendix I: Study Sample

Survey data

The Cambridge Centre for Alternative Finance carried out three online surveys between July 2018 and November 2018 via secure web-based questionnaires. Surveys were written in English and distributed via three main channels: (a) directly to prospective survey participants via email invitations, (b) through the sharing of public survey links in relevant social networks (e.g. Twitter, LinkedIn), and (c) with support from blockchain consortia R3 and the Hyperledger project, who were instrumental in assisting with survey dissemination within their network.

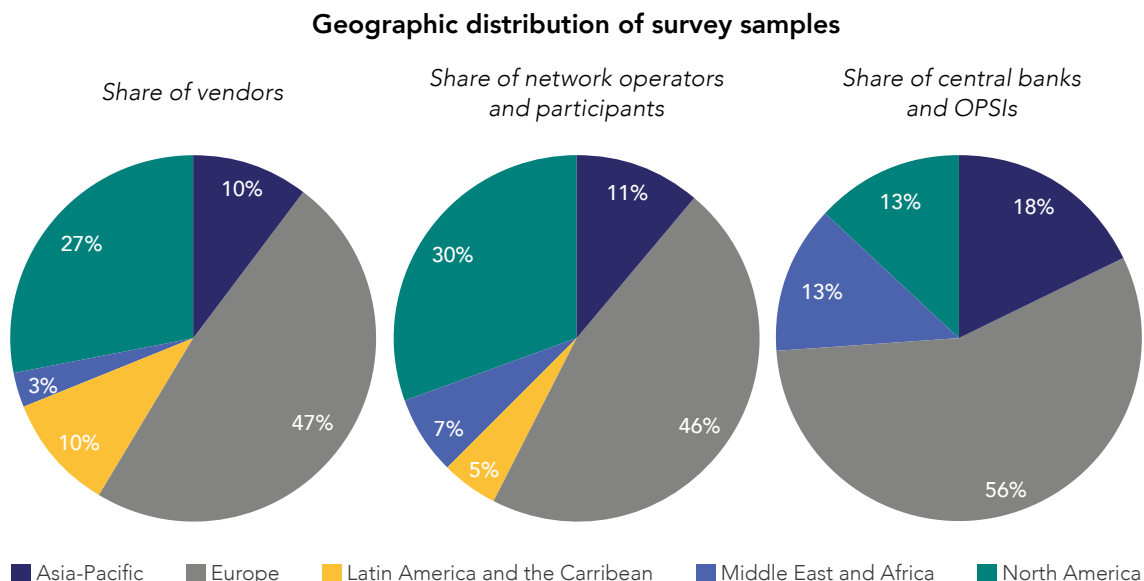<p align="center">Data was collected from more than 160 entities across 49 countries</p>

During the survey process the research team communicated directly with individual organisations to explain the study's objectives. The research team collected data from enterprise blockchain start-ups, established corporations, central banks and other public-sector institutions ("OPSIs"). The collected data was encrypted and safely stored, and was only accessible to the authors of this study. All individual, entity-specific data was anonymised and analysed in aggregate.

In total, survey data was collected from more than 160 entities across 49 countries and five world regions:

- **Blockchain Vendors Survey:** 60 firms including start-ups and established software vendors from 25 countries providing blockchain development services to third parties.

- **Blockchain Operators and Users Survey:** 56 companies from 22 countries engaged in blockchain activities involving the operation and/or usage of a network.

- **Central Banks and Public Sector Blockchain Survey:** 45 institutions from 33 jurisdictions engaged in blockchain-related activities; composed of 17 central banks and 28 OPSIs including government agencies (e.g. ministries, municipalities, regulators), multilateral institutions, and state-owned enterprises.

Figure 38: All three survey samples are dominated by European entities

Geographic distribution of survey samples

Share of vendors

Share of network operators and participants

Share of central banks and OPSIs

■ Asia-Pacific ■ Europe ■ Latin America and the Carribean ■ Middle East and Africa ■ North America
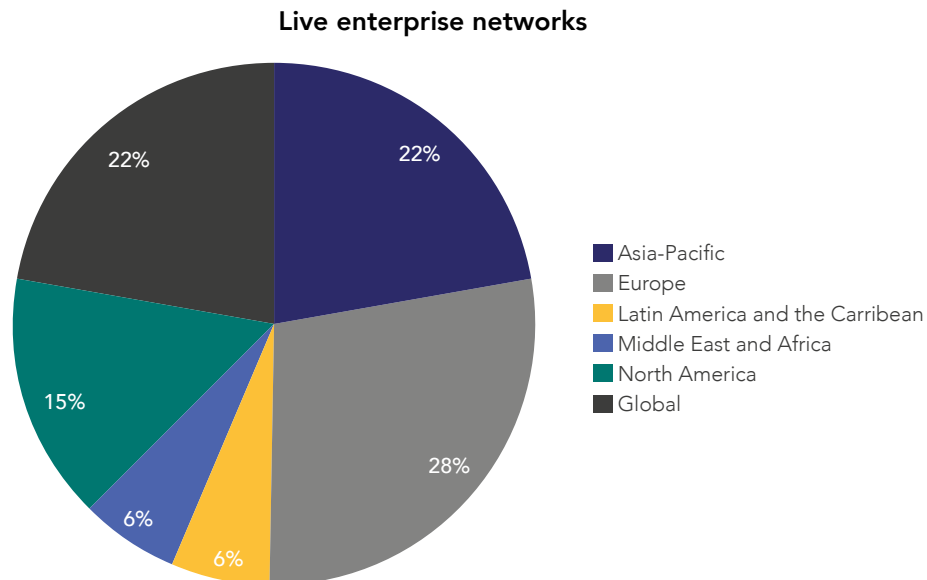
Follow-up phone calls, emails, and in-person interviews with industry participants were used to clarify survey responses if needed, with further quality assurance provided by comparing results to available public data if feasible. The datasets from online surveys were supplemented with additional desktop research using commonly applied methodologies. Despite best efforts to ensure a geographically diverse distribution, European-based entities dominate all three survey samples (Figure 38).

Live network data

The research team built an additional dataset of 67 live enterprise blockchain networks that have been deployed in production. Data was collected via desktop research between April 2019 and June 2019 and included primary data sources (official documents and statements from company websites) as well as secondary data sources (e.g. news articles, blog posts, podcasts). Moreover, the research team conducted phone-based interviews with representatives from several projects to cross-check public data sources.

Live networks were identified through a variety of channels that included routinely screening press releases and news articles, trawling project and ecosystem directories from various organisations, attending industry events and practitioner conferences, and publicly requesting information via social media and the networks of supporting organisations, among others. The resulting dataset covers enterprise blockchain networks from all five world regions (Figure 39) and a wide range of distinct industries (see Section 3).

Figure 39: Geographic distribution of covered live blockchain networks

Live enterprise networks

- Asia-Pacific
- Europe
- Latin America and the Carribean
- Middle East and Africa
- North America
- Global

Appendix II: Technology Platforms
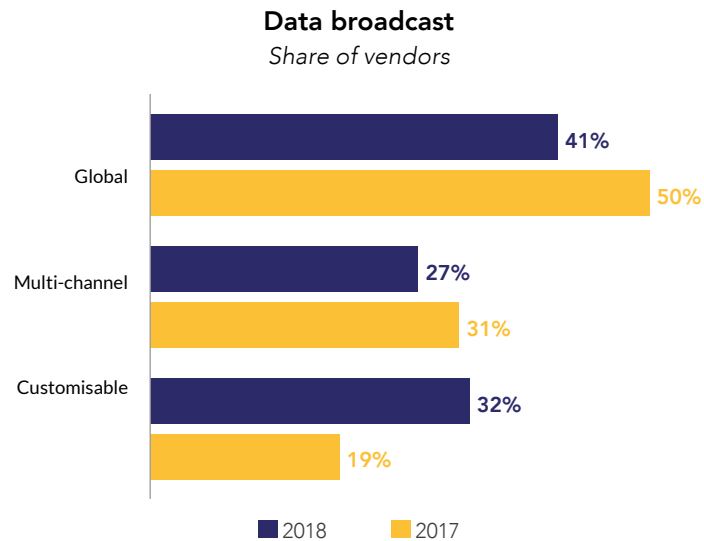
Codebase

Figure 40: The majority of core protocol frameworks are based on existing protocols
Is the codebase substantially based on (or derived from) an existing blockchain core protocol framework (e.g. Ethereum)?

Origin of core protocol framework

Share of vendors

- Substantially based on existing protocol framework
- Loosely based on existing protocol framework
- Completely written from scratch

36%

5%

59%
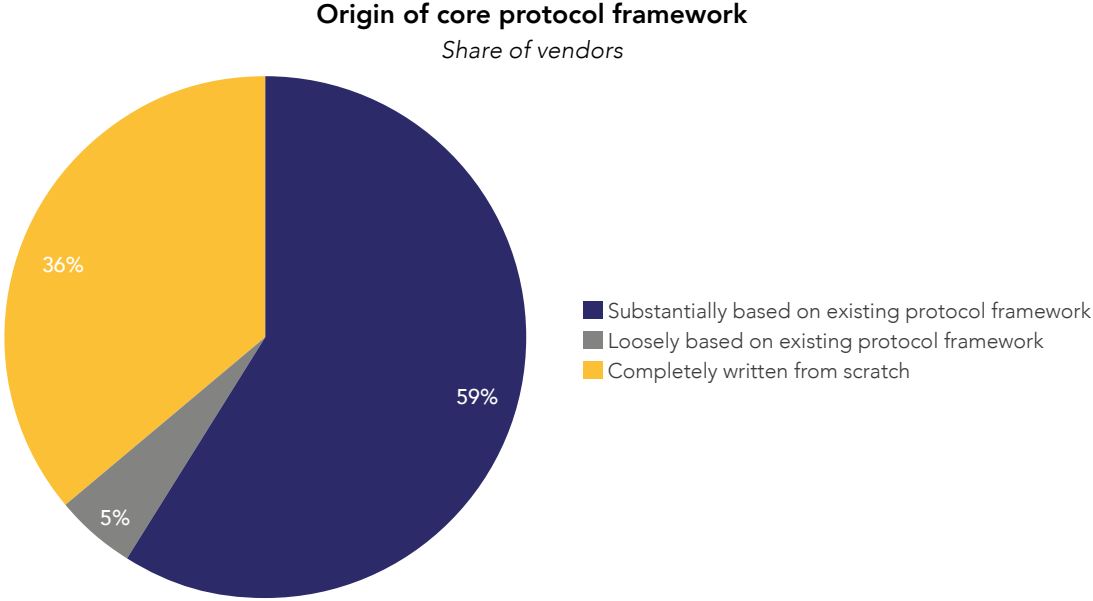
Note: based on CCAF survey data

Data Broadcast

Figure 41: Platforms increasingly support a more flexible approach to data broadcasting
How is data broadcast across the network?

Data broadcast
Share of vendors

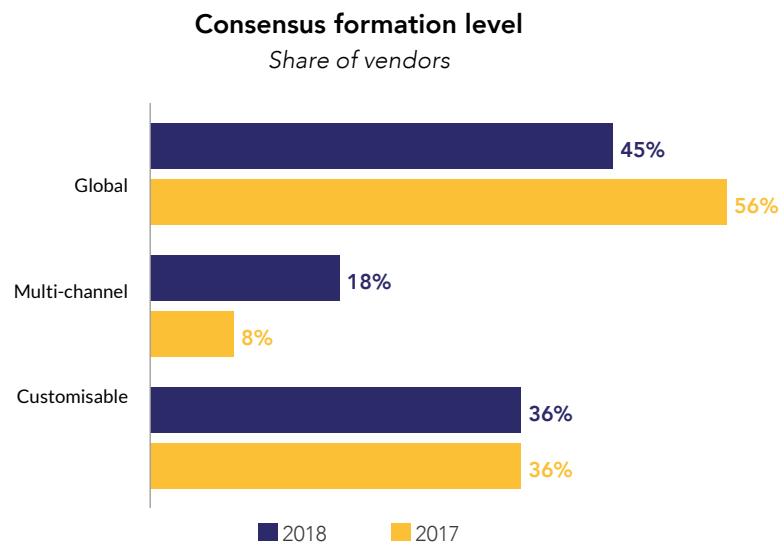|	
Global	41% (2018) / 50% (2017)
Multi-channel	27% (2018) / 31% (2017)
Customisable	32% (2018) / 19% (2017)

■ 2018 ■ 2017

Note: based on CCAF survey data. "Global": every node receives, validates, and broadcasts all data to each connected peer. "Multi-channel": transaction data is only shared between parties involved in the trade. "Customisable": various options are available to network participants, including hybrids.

Network consensus

Scope

Figure 42: While still dominant, reaching consensus at the global network level increasingly gives way to local consensus
At what level is network consensus reached?

Consensus formation level
Share of vendors

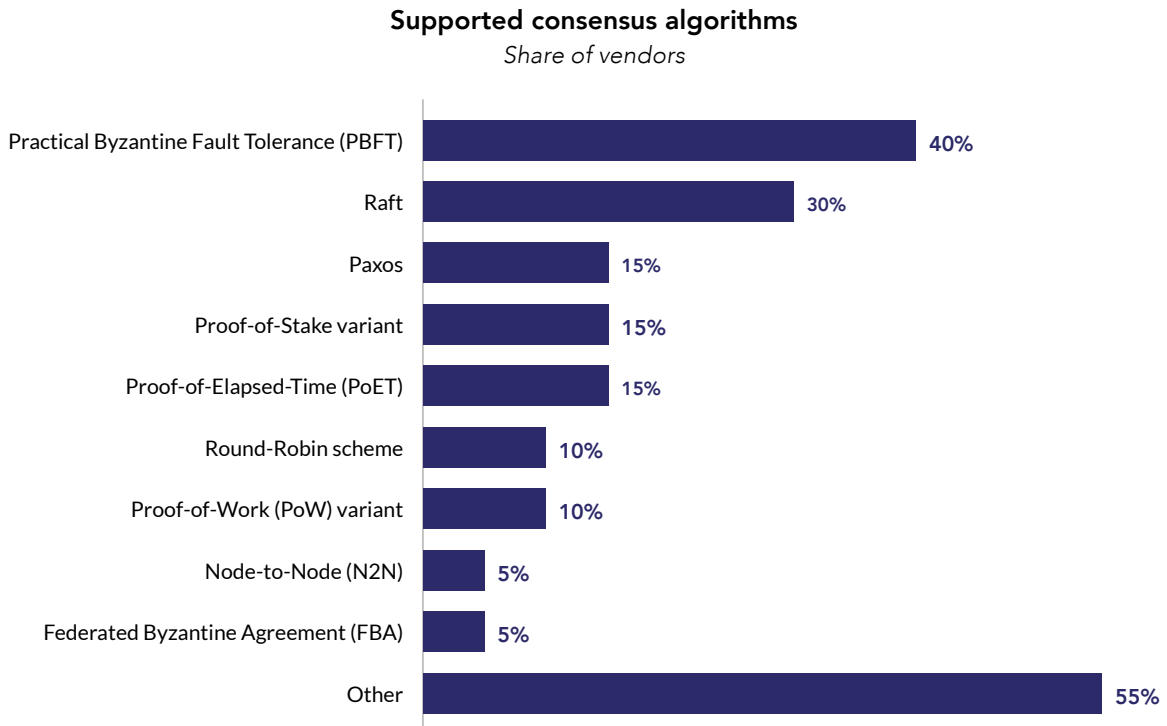|	
Global	45% (2018) / 56% (2017)
Multi-channel	18% (2018) / 8% (2017)
Customisable	36% (2018) / 36% (2017)

■ 2018 ■ 2017

Note: based on CCAF survey data. "Global": consensus reached over the entire state of the system. "Local": consensus reached exclusively between parties involved in the transaction. "Customisable": various options available to participants, including hybrids.

Consensus algorithm

Figure 43: Core protocol frameworks support a variety of consensus algorithms
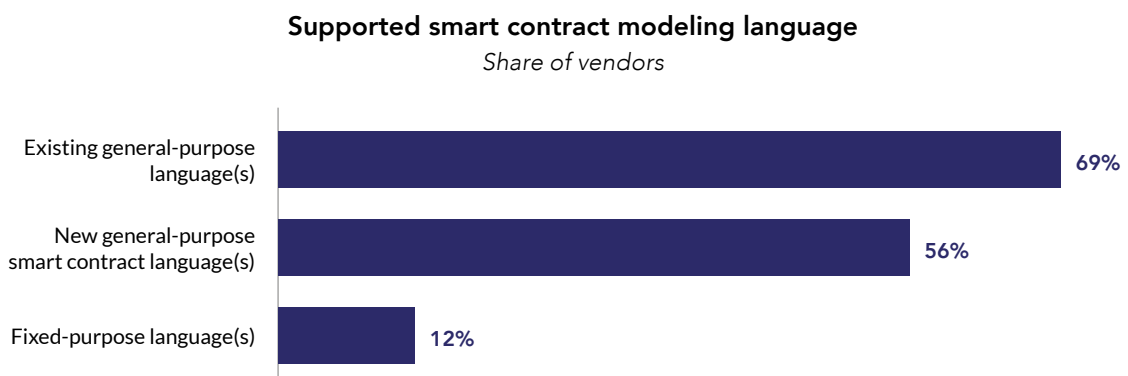*What consensus algorithm(s) are supported by the core protocol framework?*

Supported consensus algorithms
Share of vendors

Algorithm	Share
Practical Byzantine Fault Tolerance (PBFT)	40%
Raft	30%
Paxos	15%
Proof-of-Stake variant	15%
Proof-of-Elapsed-Time (PoET)	15%
Round-Robin scheme	10%
Proof-of-Work (PoW) variant	10%
Node-to-Node (N2N)	5%
Federated Byzantine Agreement (FBA)	5%
Other	55%

Note: based on CCAF survey data

Smart contracts

Figure 44: General-purpose languages (e.g. Java, Solidity) dominate smart contracting platforms
What smart contract modeling language(s) are natively supported at the base layer?

Supported smart contract modeling language
Share of vendors

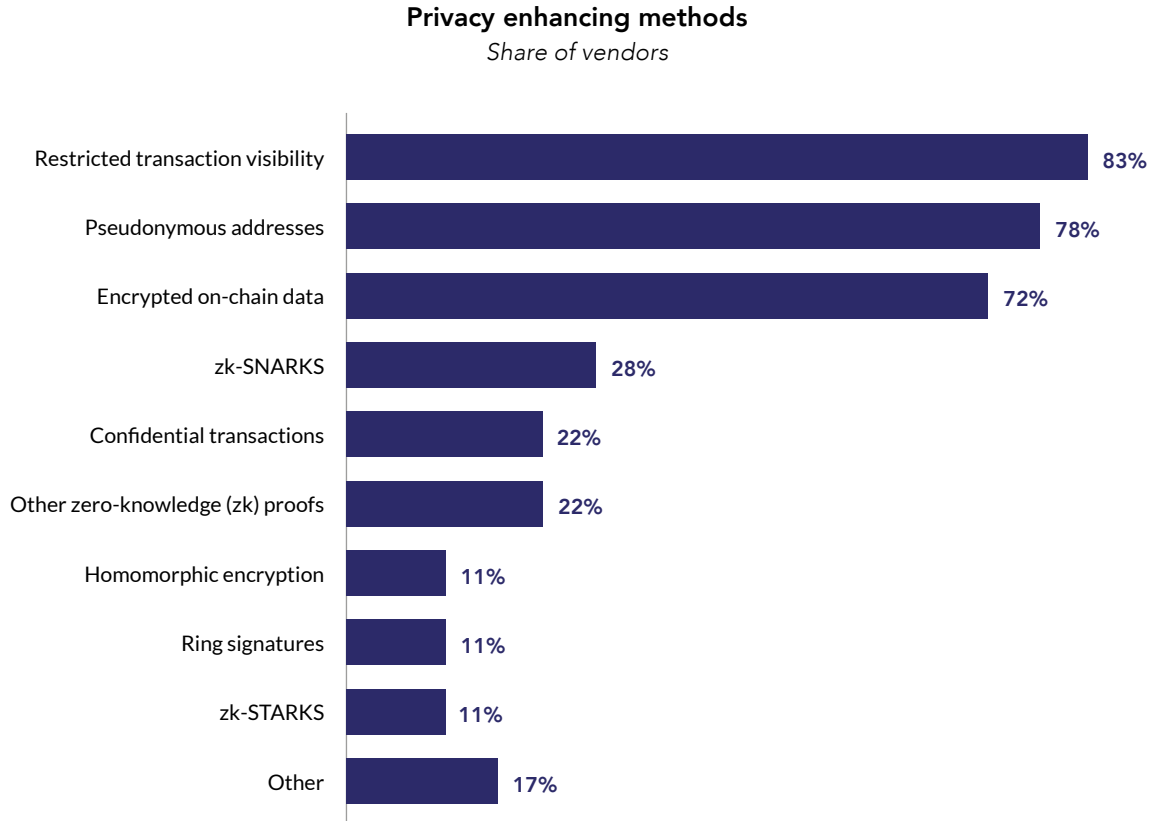| Language	Share
Existing general-purpose language(s)	69%
New general-purpose smart contract language(s)	56%
Fixed-purpose language(s)	12%

Note: based on CCAF survey data. "General-purpose" refers to expressive languages that are Turing-complete, whereas "fixed-purpose" refers to simple script languages that enable a limited range of operations.

Privacy and confidentiality

Figure 45: Zero-knowledge proofs remain experimental

Which of the following potentially privacy-enhancing methods are supported by your core protocol framework?

Privacy enhancing methods

Share of vendors

Method	Share
Restricted transaction visibility	83%
Pseudonymous addresses	78%
Encrypted on-chain data	72%
zk-SNARKS	28%
Confidential transactions	22%
Other zero-knowledge (zk) proofs	22%
Homomorphic encryption	11%
Ring signatures	11%
zk-STARKS	11%
Other	17%

Note: based on CCAF survey data. "Transaction visibility" refers to restricting visibility counterparties involved in the corresponding trades.

Appendix III: Challenges

Operational challenges

Private sector

Table 4: What are the main operational challenges limiting mainstream enterprise blockchain adoption?

Respondents scored these categories on a 1-5 scale:

1: Not important at all   2: Not important   3: Neutral   4: Somewhat important   5: Very important

Lowest average score ▬▬▬▬▬▬▬▬▬ Highest average score

	Vendors	Network operators and participants
Unknown cost-benefits (uncertain ROI)	4.14	4.02
Knowledge gap: poor understanding of the technology	4.22	4.05
Reluctance of changing established processes	4.18	4.22
Reputational risk associated with "blockchain"	2.60	2.93
Hype associated with unrealistic expectations	3.71	3.67
No compelling use case	2.80	2.93
Legal risks/regulatory uncertainty	3.76	3.75
Difficulty of building business networks	3.59	3.52
Vendor immaturity	3.11	3.80
Lack of standardisation/interoperability	3.39	3.89
Doubts about technological durability	3.11	3.49
Lack of deployed large-scale networks upon which application can be built	3.48	3.70
Lack of user friendliness/ease of use	3.52	3.11
Shortage of skilled blockchain engineers/developers	3.93	3.53

Note: based on CCAF survey data.

Public sector

Table 5: What are the major challenges inhibiting broader blockchain adoption in the public sector?

Respondents scored these categories on a 1-5 scale:

1: Not important at all   2: Not important   3: Neutral   4: Somewhat important   5: Very important

Lowest average score ▬▬▬▬▬ Highest average score

	Central banks	OPSIs
No compelling use case	3.93	2.88
Knowledge gap: poor understanding of the technology	4.00	4.29
Reluctance of changing established processes	3.79	4.08
Hype associated with unrealistic expectations	4.21	3.75
Lack of institutional support/buy-in	3.43	3.63
Public sector inertia	3.07	3.63
Lack of harmonised regulatory framework	3.27	3.50
Vendor immaturity	3.93	3.54
Lack of standardisation/interoperability	4.14	3.46
Doubts about technological durability	3.50	3.29
Shortage of skilled blockchain engineers/developers	3.93	3.83

Note: based on CCAF survey data.

Technical challenges

Table 6: What are the main technical challenges that enterprise blockchain networks currently face?

Respondents scored these categories on a 1-5 scale:

1: Not important at all   2: Not important   3: Neutral   4: Somewhat important   5: Very important

Lowest average score ▬▬▬▬▬ Highest average score

	Vendors
Security risks	3.20
Scalability issues	3.93
Performance concerns	3.71
Insufficient privacy and confidentiality guarantees	3.09
Immature technology that is not fit-for-purpose	3.00
Interoperatibility issues between DLT systems	3.40
Interoperatibility issues with legacy enterprise systems	3.19

Note: based on CCAF survey data.

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