ITU – NBTC Training
On

“Building Distributed Ledger Technologies (Blockchain) Projects”

5 – 8 November 2019,
Bangkok, Thailand

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Session 2: DLT based applications and an assessment framework

Objective: To provide an overview of DLT applications and an assessment framework

5 November 2019,
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Overview of this 90-minute session:

- **Use cases**
  - Key functions and benefits of DLT: 15 minutes
  - Use cases across vertical domains: 10 minutes
  - Use cases across horizontal domains: 10 minutes
  - Addressing the SDGs: 5 minutes
- **Flowchart for deciding if you need a blockchain and which type:** 5 minutes
- **Technological Assessment criteria for DLT:**
  - Applications: 5 minutes
  - Operation functions: 5 minutes
  - Performance: 5 minutes
  - Ecosystems: 5 minutes
- **Reviewing key terms and challenges:** 10 minutes
- **Question and answer:** 15 minutes

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Part 1.1

Key functions and benefits of DLT: 15 minutes

- General benefits
- Transparency and trust
- Security
- Economic and social incentives
- Efficiency and reduction of complexities
- Disintermediation
- Identity management

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Part 1.1 Key Functions & Benefits of DLT

The benefits gained from the use of DLT vary by use-case, environment, event, process and industry. While the financial sector, for example, may make use of the crypto-currency features associated with DLT, other sectors may make use of other features of the technology, such as distribution, disintermediation and others. This clause looks at common threads that are effective in multiple use cases, as well as unique features that are more specific to certain applications.

FG-DLT D2.1 is heavily referenced

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General benefits

DLT is considered as a tamper-resistant and auditable technology that is resistant to systemic failures. It is also an effective tool to detect and mitigate fraud.

DLT can be seen as a form of General Purpose Technology (GPT).

A GPT is a technology that on top of standing for itself – also brings gains to other technologies and sectors. It may take a long time to reach mass adoption, but once adopted GPT leads to productivity gains across multiple industries [ref-coa-1], [ref-coa-2], [ref-coa-3]. Classic examples of GPTs include the steam engine, electricity and the internet.

DLT revolutionizes the way we look at data in terms of trust, anonymity, storage, and processing. Being in the information era, where “data is everything”, DLT’s innovative approach to handling information and its agnosticism to the types of data it handles, make it a useful tool in many fields of business, administration, research and government – thus the designation as a GPT.

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General benefits

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Transparency and Trust

DLT is perceived as a canonical trusted and transparent shared resource that makes interactions and transactions understandable, traceable, certifiable, and accountable.

The major beneficiaries would be use-cases that include untrusted stakeholders seeking to build a trusted infrastructure where data can be shared in a secure and accountable manner.

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Security

There are multiple aspects of security that are related to DLT:

- **Encryption of data -** DLT allows data to be easily encrypted, which can be useful to many use cases.
- **Access control -** Albeit the fact that all records exist in many nodes of a DL, access to records can be restricted on a per-record-per-user basis.
- **Tamper-resistant data -** Once data is loaded into a DL, it would require extensive computational resources and/or massive collusion amongst voting stakeholders to modify the DL without being noticed by others, hence rendering it practically immutable.
- **Identity management -** Participants in a DL can be anonymous, pseudonymous, or fully identifiable.
- **Fault tolerance -** DLT consensus algorithms offer a means of redundancy to mitigate the risk of the overarching network being compromised if one or more components of the DL network fails.

More on this topic during the security session tomorrow!

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Economic and social incentives

The economic incentives for the adoption of DLT vary depending on the use-case, with some benefiting from cost-reductions, new revenue streams, or both.

Cost reductions are achieved through disintermediation and increased efficiency.

New revenue streams are generated through removal of technological and operational barriers, thus enabling new types of services or applications.

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Economic and social incentives

DLTs enable near real-time disbursement of money directly to its designated recipients through a decentralized network that, in the case of public DLTs, runs 24/7 and validates transactions across hundreds of computers simultaneously to ensure no individual node is cheating.

You no longer need to trust the transactions occurring behind closed doors at private banks to be fairly distributing funds or issuing dividends, instead, a public network of hundreds or thousands of computers cross-referencing one another can do this.

This can be of value to any industry domain that transacts money, either as part of an application (e.g., payment for goods or services) or as means to transfer value (e.g., transfer money).

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Economic and social incentives

The most prominent method of money disbursements using a DLT is in the form of a cryptocurrency.

On these public networks, people are incentivized to run a full block producing validating node (“miner” in PoW) to secure the network because they can receives rewards and/or fees in the form of additional cryptocurrency.

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Economic and social incentives

DLT can also be used to store and operate on information while using non- cryptocurrencies to settle transactions.

These types of DLTs are generally permissioned such that a consortium of validators, for example large shipping companies in TradeLens, join together to utilize a shared ledger to ensure data integrity across industry players.

The incentive in this case is that if you provide fake information, your competitors will be able to hold you accountable, so if enough of the major suppliers in the industry decide to share information in this way – it could enable a new level of accountability and transparency.

- On these purely private permissioned networks, collusion can still happen if the industry as a whole decides it is in their shared benefit to misrepresent historical data since they control the ledger history together!

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Efficiency and reduction of complexities

DLT allows for better tracking of assets and transactions. It can serve to significantly shorten timelines and automate paperwork laden manual tasks thus making processes rapid and simple. This is achieved through removal of data silos and establishing direct, traceable and secure interactions between stakeholders.

DLT enables the creation of digital platforms where the benefits from network effects and shared digital infrastructure do not come at the cost of increased market power and data access by an intermediary.

This reduction in the cost of networking has profound consequences for market structure, as it allows startups and open-source projects to directly compete with entrenched incumbents through the design of platforms where the rents from direct and indirect network effects are shared more widely among participants (e.g., developers, users, investors), and no single player has full control over the network.

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Disintermediation

Novel digital platforms, in absence of a central ‘clearing house’ or market maker, can benefit from permissionless innovation. As long as an application is compatible with the established protocol and consensus rules, it can be deployed on the network without permission from other participants.

This reduces the expropriation risk application developers face when building on top of existing digital platforms (e.g., iOS, Facebook etc.).

Furthermore, since each contributor to a DLT-based platform can theoretically shape its evolution in a way that is proportional to its stake in the platform (e.g., in terms of computing power, storage, labor or capital dedicated to it), these new platforms can democratically evolve over time to accommodate changes in market design that are beneficial to the majority of contributors.

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Identity management

The process of identity verification is central to all economic transactions.

A well-functioning market and economy relies on robust identity management to verify the goods and services being exchanged (e.g., in terms of their provenance, how they moved through the supply chain, etc.) and the credentials of the parties involved (e.g., degrees on a curriculum vitae, professional licensing status, bad actor status, driving record, etc.). More in FG-DLT 2.1 Section 7.1.

Public key cryptography - cryptography in which a public key and a corresponding private key are used for encryption and decryption, where public key is disseminated, and private key is known only to the key owner.

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Part 1.2

Use cases across vertical domains: 10 minutes

- Finance
- Healthcare
- Information and Communication Technology (ICT)
- Government and public sector

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Finance

Some of the most mature use cases of DLT have been in the financial services industry [ref-fin-1]. From the obvious use in financial payments (e.g., Bitcoin) to the more complicated use in trade settlement (e.g., Digital Assets partnership with ASX), the financial industry has been testing the technology since its early days. While some banks have gone ahead with developing the technology in-house (e.g., J.P. Morgan's Quorum), others have made strategic investments (Goldman's investment in Circle), and many have joined industry consortiums (R3 CEV) to engage with the technology and test the proof-of-concepts.

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Finance

Table 1: How DLT can be applied to the subcategories

ID	Subcategories	How DLT can be applied
1	ID verification (KYC/AML)	DLTs can provide a trusted way to do customer verification to satisfy KYC (Know your Customer) and AML (Anti-Money Laundering) obligations, e.g., through past immutable data in the DLT.
2	Tokenization and stable coins	The digitization of regulated financial products and services such as security/asset tokens and utility tokens and create new ones, e.g., cryptocurrency/payment tokens through tokenisation.
3	Financial management (accounting and auditing)	Smart contracts can automate some accounting processes. Auditing costs can be reduced through cheaper verification of transactions in DLT [ref-coa-4].
4	Reduction in the risk of fraud	Real time data is decentralised and this can increase trust of the shared data, e.g., management of cash or financial controls, data of maritime industry for insurance purposes, etc.
5	Funding	DLT creates new revenue opportunities such as new models of funding and new types of markets such as equity crowdfunding, secondary market or new types of exchanges.
6	Investments	Tokenised assets can support the transformation of the regular investments model and promote accessibility to new asset investments.
7	Regulatory compliance and audit	DLTs can provide accurate and tamper-proof financial, audit and regulatory reports thereby improving speed and quality.
8	Clearing and settlement	Automation and improvement of the centralized clearing and settlement processes using DLT can result in increased efficiency and reduction of costs, time and agents involved.
9	Payments and P2P transactions	DLTs can bring new models and arrangements to make payments and transfers faster with lower costs and less or no intermediaries. E.g., remodelling correspondent banking, cross-border payments, etc.
10	New product models	New peer-to-peer insurance models can be secured with DLT. Credit: Decentralised financing.

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Healthcare

Technological advancements in healthcare have been documented, among others, at the use of data to record and analyze the behavior of individuals. This has become pervasive. The adoption of wearables and Internet of Things (IoT) connected devices has accelerated this expansion. Whether users consent to this analysis has been partially addressed by GDPR regulation in the EU, which requires transparency in the use of data.

In the health environment, data collection, recording and analysis is even more delicate since health data is considered as a special category of sensitive personal information. Health data is often organized into silos in order to preserve patients' data. However, silos contribute to information asymmetry, which generates:

1. An imbalance in market competition to provide services and
2. a lack of information sharing for proper patient diagnosis.

This lack of information sharing results in slower diagnosis, more expensive testing, insecure data transmissions between silos and incomplete records [ref-hea-2].

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Healthcare

Pharmaceuticals – securing supply chains and combatting fraudulent medicines
Biotechnology research – research requires sensitive genetic data being recorded and transmitted, which means data integrity and privacy are fundamental requirements
Medical records – putting patients at the center of controlling their electronic health records (EHCs)

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Information and Communication Technology (ICT)

Current DLT deployments in ICT can be broadly divided into three main categories:

a) **Retail services** - services where the end-user (typically mobile or fixed-line subscriber) would be the main beneficiary of the service.
b) **Wholesale services** - services where the ICT operators are the main beneficiaries of the services.
c) **Internet of Things (IoT)** - a fast-growing field of technology that involves a plentitude of devices (hence "Things") producing data that needs to be collected, analyzed and stored.

While services from these categories may involve multiple ICT providers, the differentiating factors are related to the users of the services, the types of services and the beneficiaries from the use of DLT.

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Retail services

DLT enables opening up mobile-operator services that were previously available only to full time subscribers while on their home network, to visiting users from other networks and to its own users roaming to other networks.

Another popular use case is establishing a **marketplace** [ref-ict-2] where vendors (or government offices) sign up with ICT which enables the selling and purchasing of goods (or payment for services) through applications installed on their ICT devices.

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Wholesale services

ICT operators live in a state of *mutual-suspicion* and in an environment of "*coopetition*" where ICT providers both compete and cooperate with each other on delivery of services. On one hand, ICT operators compete with each other by trying to win the consumer business. On the other hand, ICT operators often rely on complementing their own portfolio with certain elements of service that they acquire from their competitors.

This could be geographical coverage of a certain territory, computational or storage resources, specific applications or security features not available through the ICT provider's own resources.

Broad potential when applied to:

- **Supply chain operators** - DLT allows all stakeholders to be linked together to ensure trusted transactions take place and information is correctly stored and retrieved by all parties.
- **Mobile and phone number porting** – as users move their phone number from mobile carrier to mobile carrier, an underlying DLT would allow mobile operators to avoid managing their own centralized number porting system or paying a third party to manage one.

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Government and public sector

Incomplete and inconsistent quality data makes effective decision making extremely difficult, especially in government.

The lack of digitization aggravates the problem.

With many records scattered across multiple departments and even existing only in paper form, people need to appear in person to register, update and retrieve their information and certificates.

Even in governments with a high level of digitization, **DLT can be used to prevent forgery and counterfeiting by presenting trusted data.**

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Government and public sector

Table 2 Summary of government DLT applications

Use Case	EU [ref-gov-6]	Dubai	New Zealand	China	Korea	US [ref-gov-12]
Government database	✓		✓ [ref-gov-9]			✓
Law	✓			✓ [ref-gov-8]		✓
Tax	✓ [ref-gov-15]			✓ [ref-gov-7]		
Citizen identity	✓	✓ [ref-gov-11]			✓ [ref-gov-10]	
Residency		✓				
Land registration	✓	✓				

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Part 1.3

Use cases across horizontal domains: 10 minutes

- Identity management
- Security management
- Data management
- Governance and DAOs
- Crypto-infrastructure

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Use cases across horizontal domains

As an emerging technology, DLT has the potential to be applied in many areas, not only for vertical use cases, but also throughout horizontal domains. The horizontal domain represents use cases that are applicable across multiple sectors of the economy.

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Identity management

A DLT-based digital identity solution could focus on three key challenges: security, privacy, and portability. DLT technology may offer a way to solve this problem with or without the need for a trusted central authority. More specifically, individuals and businesses could store and authenticate their identity on the DLT, giving them greater control over who has their personal information and how they access it.

By using a decentralized, open-source DLT and combining it with an identity management tool, we could create a digital ID which would act as an incorruptible watermark.

This watermark could be used to verify an identity for any transaction in real time. Once such a digital ID has been created, it could be used to verify an identity for any service and dispense with the need for clumsy and unreliable password/email combinations [ref-hor-1].

Scenarios may include securing medical records of patients, credit assessments of bank customers, access-management systems in secured locations and many others.

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Security management

Security management is the identification of an organization's assets (including people, buildings, machines, systems, and information assets) followed by the development, documentation and implementation of policies and procedures for protecting these assets.

An organization uses such security management procedures as asset and information classification, threat assessment, risk assessment and risk analysis to identify threats, categories assets, and rate system vulnerabilities so that they can implement effective controls.

DLT might address Confidentiality, Integrity and Availability; offering improved resilience, encryption, auditing and transparency. For example, DLT has the potential to enable safer IoT device networking including the prevention of DDoS attacks [ref-hor-3].

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Data management

Certain DLT implementations contain what everyone in data management, from data scientists to chief data officers (CDO), wants; information that comes with complete provenance. This is data which shows who did what, when and with a full tamper-proof history from day one verified by all parties participating in the network using the latest cryptography.

DLTs are authenticated records of the history of a network's activity distributed among the nodes of the network. DLT enables secure storage of arbitrary information (which, in some cases is a token balance and in other systems, more complex information) within the network simply by securing a set of private keys.

After some years of evolution, DLTs are now capable of storing arbitrary data and establishing permissions to modify that data through self-administering and self-executing scripts which are performed by a distributed virtual machine. These scripts are known as **smart contracts** and they allow platform operators to define complex and fully customizable rules which govern the DLT's interaction with its users.

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Governance and DAOs

DLT can be used to create new tools to realize governance for a decentralized global public utility for self-sovereign identity on the internet, for which a new term has been put forward, Decentralized Autonomous Organizations, or DAOs. A DAO is digital entity that manages assets and operates autonomously in a decentralized system but also relies on individuals tasked to perform certain functions that the automaton itself cannot. DAOs have automation at the center and humans at the edges [ref-hor-4].

A DAO is similar to a regular corporation in that it is a separate entity and has its own bank account (here it is cryptocurrency wallet) and ID number (the contact address). The main difference is that a DAO is autonomous. In contrast to regular corporations, a DAO is managed by itself (its code) rather than by humans (in the form of executive management, i.e., CEO) [ref-hor-5]. Updates to the DAO's code require social consensus amongst the human operators at the edge of the system.

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Crypto-infrastructure

The number of crypto-assets issued and traded now exceeds 1800 with a total market capitalization of more than $200 billion [ref-hor-6]. Behind this, a group of people are silently laying the groundwork for long-term crypto-infrastructure including individual block producers, pools of block producers, BaaS (Blockchain as a Service) providers, wallets, and exchanges.

Concretely speaking, individual block producers and pools of block producers provide consensus services that maintain network security for the DLT, BaaS provides cloud-like infrastructure to applications, wallets help users to hold crypto-assets in hardware or software both online and offline while exchanges provide trading platforms for the circulation of crypto-assets.

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Part 1.4

Addressing the SDGs: 5 minutes

Table 3: DLT Solutions for Key Challenges [ref-SDG-8] in the 17 SDGs SDG #	Challenge	Solution (one example)	Example use cases included in the ITU-T Focus Group DLT
1	One in ten people in Low- Middle-Income Countries (LMCs) are living with their families on less than the international poverty line of US$1.90 per day.	DLT can automatically record transactions on a secure ledger with near-instantaneous financial settlement. This means there are shorter payment cycles in comparison to traditional banking and third-party payment methods. Such efficiencies could be harnessed to help address poverty, as they promote more transparent and equitable trade, which, in turn, helps to ensure that all men and women – particularly the poor and vulnerable – have equal rights to economic resources.	HLC-004
2	Not all people (and especially children) have access to sufficient and	DLT could strengthen the supply side, particularly for small-scale food producers and family farmers, thus enabling them to better	IND-005 IND-007

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Table 3: DLT Solutions for Key Challenges [ref-SDG-8] in the 17 SDGs

SDG	Challenge	Solution (one example)	Example use cases included in the ITU-T Focus Group DLT
	nutritious food all year round.	access markets and receive equal treatment in the supply chain.	
3	Non-communicable diseases and mental health have been attracting new attention and funding; competing with the traditional focus on infectious diseases such as HIV, TB and Malaria.	DLT can support enhanced prevention and treatment outcomes through, for example, breaking down data silos across medical providers and enabling the tokenization and incentivization of physically or mentally beneficial activities.	HLC-002 HLC-003 HLC-005 HLC-006
4	Access to inclusive education	DLT-based platforms could connect students, educators, and service providers where, together, they develop and engage in personal and group online sessions, as well as in-person educational programs where progress, attendance, and completion are automatically tracked.	GOV-006
5	Discrimination against women and girls globally	DLT could help women earn and retain control over additional income. DLT also has the potential to mitigate on-line harassment.	IDM-002
6	Clean water is an essential resource for life, yet its distribution is globally unbalanced.	DLT combined with IoT sensors enables households, industries, water managers, and policymakers to all access the same data on water quality and quantity in order to make more informed decisions.	
7	Increasing the share of renewable energy and doubling the efficiency of energy production.	DLT enables the ability to tokenize energy trading platforms, allowing consumers to trade the energy from solar panels and batteries in a peer-to-peer network, incentivizing the introduction of new devices to local microgrids.	IND-002
8	1) Government access to domestic financing at a reasonable cost and 2) Access to interest bearing savings instruments for the poor and emerging middle class with an emphasis on the emerging middle class because the really poor have no money to invest at all.	DLT can allow the sale of small value mobile retail bonds and promote inclusive growth in an economy by democratizing sovereign debt.	GOV-001 FIN-004 FIN-006
9	Economic development	Trading with a DLT-based regulatory-compliant global currency can enable micro-transactions which are an important enabler of services and particularly services tailored for the poor.	FIN-004

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Table 3: DLT Solutions for Key Challenges [ref-SDG-8] in the 17 SDGs

SDG	Challenge	Solution (one example)	Example use cases included in the ITU-T Focus Group DLT
10	Reducing inequalities in the economy, governance, rights and decision making.	DLT can enable better economic equality by reducing the costs of remittances. It can also open new avenues for citizens to get involved in decision-making through secure voting initiatives.	GOV-003 FIN-007
11	Two thirds of the world's population will be living in cities by 2050 (2.5 billion more than today) and by 2030 the world is expected to have 43 megacities with more than 10 million inhabitants compared with 31 today	DLT can provide a cost effective and trustworthy enhancement for local democracy within cities, allowing neighborhoods and large housing developments, to have a voice, through voting, on decisions that affect them.	GOV-003
12	Transparency and visibility of value chains and production processes are key steps for gaining a better understanding of social, environmental and health risks and ensuring due diligence.	Tracing of products in supply chains relates closely to consumers awareness of the origins of products, sustainable production methods, and health implications.	IND-005 IND-006 IND-007
13	Challenges to the ability of the world to meet climate change goals, creating the risk of irreversible ecological disaster	DLT can be implemented to support the development of carbon marketplaces. While traditional technologies are subject to accounting flaws and fraud – which have held back the development of such marketplaces in the past, DLT platforms for trading assets which represent carbon could guarantee immutability and transparency.	IND-004
14	Protect marine and coastal ecosystems from pollution, as well as address the impacts of ocean acidification and other negative practices such as over-fishing.	DLT can combat overfishing and wildlife trafficking by providing the baseline architecture for interoperable data collection, allowing better management of ecosystems, more informed decision making across organizations, and increased accountability around catch types and quantities since competing organizations must share the same ledger.	IND-011
15	Reversing the effects of land degradation and desertification through sustainable land management	DLT can be used to incentivize organizations and individuals to increase the scale and efficiency of conservation protection by offering small cash payments in exchange for conserving nature.	GOV-002 FIN-007
16	Strengthening the rule of law is the fundamental key for success in this process of achieving peace.	Smart contracts executed on DLT platforms can be used to automate and enforce agreements between business entities.	GOV-004
17	Coordinating policies to help developing countries manage their debt, as well as promoting investment for the least developed, is vital to achieving sustainable growth and development	DLT can be used to facilitate partnerships and collaboration between governments, companies, academia, civil society and individuals where trustworthy information and value transfers are needed. Bridging the digital divide and increasing digital literacy with enhanced use of DLT can support the empowerment and capacity building of communities and regions on both the domestic and international level.	GOV-002

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Part 2

Flowchart for deciding if you need a DLT

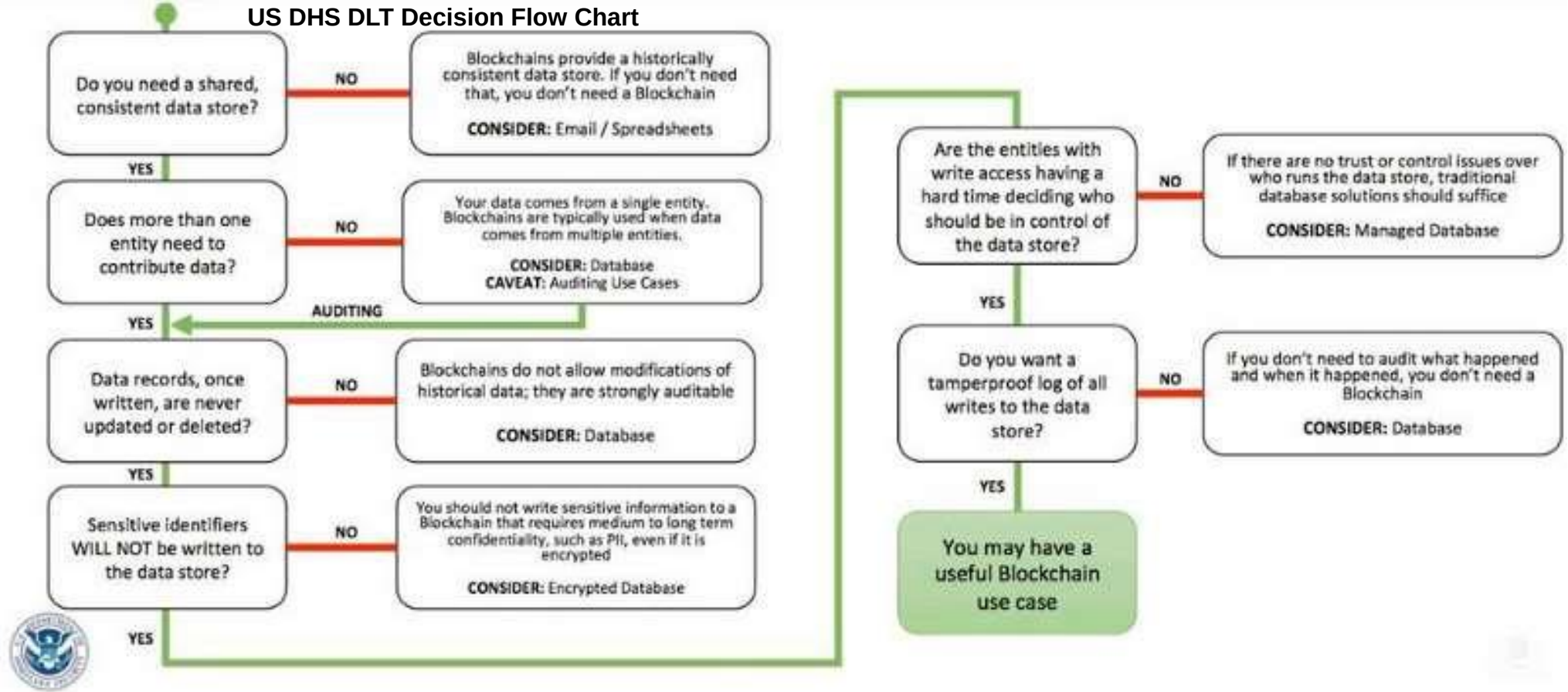

Image: Creative Commons/World Economic Forum

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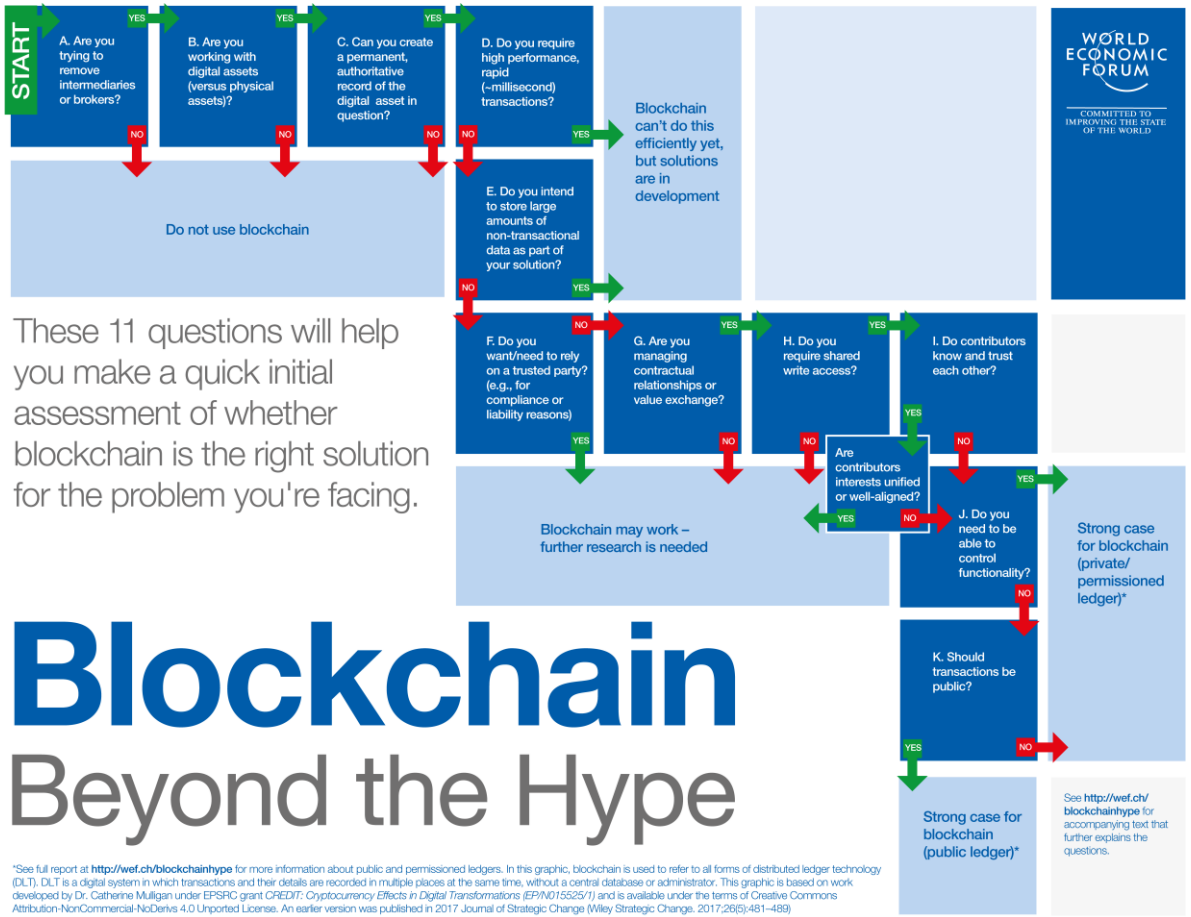
Flowchart for deciding if you need a DLT



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Flowchart for deciding which type of blockchain

[Wüst and Gervais]	Permissionless Blockchain	Permissioned Blockchain	Central Database
Throughput	Low	High	Very High
Latency	Slow	Medium	Fast
Number of readers	High	High	High
Number of writers	High	Low	High
Number of untrusted writers	High	Low	0
Consensus mechanism	Mainly PoW, some PoS	BFT protocols (e.g. PBFT [5])	None
Centrally managed	No	Yes	Yes

https://www.wipo.int/edocs/mdocs/classifications/en/wipo_ip_cws_bc_ge_19/wipo_ip_cws_bc_session_2_seigneur.pdf

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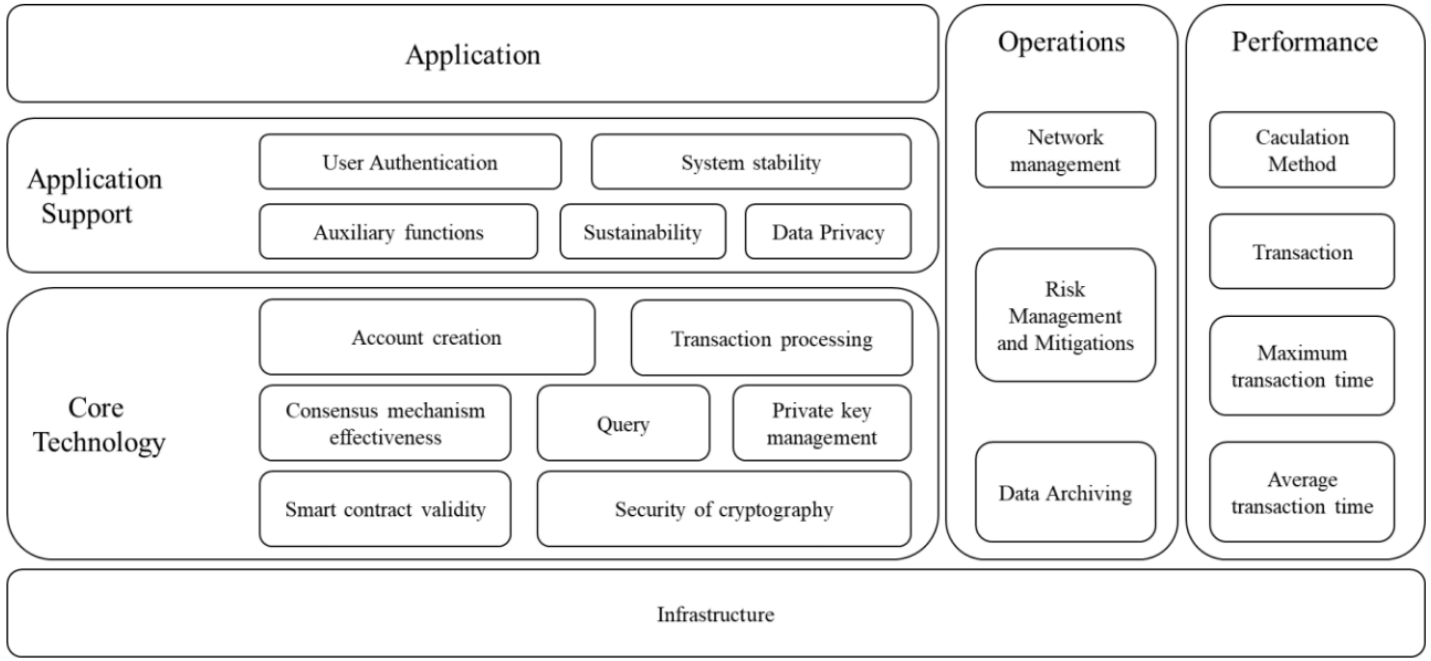
➢ Technological Assessment criteria for DLT

- Core functions: 5 minutes
- Application functions: 5 minutes
- Operation function: 5 minutes
- Performance and ecosystem: 5 minutes



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Assessment framework

Assessment criteria concerning the economic mechanism (clause 7.3) and ecosystem (clause 10) should be tested through disclosure information. The tester must conduct a comprehensive assessment of DLT system information and market information.

DLT core function criteria (clause 6) should be assessed in a test environment. These tests may affect normal operation of a DLT platform.

Criteria related to application (clause 7) and operation (clause 8) functions should be tested in DLT platforms in a production environment.

Performance criteria (clause 9) should be assessed in a laboratory environment, i.e., a “quality assurance environment”, which should be stable and controllable [b-SQuaRE].

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- **Technological Assessment criteria for DLT**
  - **Core functions: 5 minutes**
  - Application functions: 5 minutes
  - Operation function: 5 minutes
  - Performance and ecosystem: 5 minutes

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Core functions

Account creation - This refers to the ability to create user accounts. Accounts contain public and private key pairs. The create action can be launched by a client or by a smart contract. The private key shall be kept by the client only. If an account name can be customized, the account name must be unique in the system.

Transaction processing - This refers to the ability to process transaction(s). There are two types of transactions. It is not necessary for the DLT platform to support both types of transactions. Asset transfer transaction refers to the transfer of certain amount of an asset between accounts, ensuring the asset in the ledger is balanced. Non-asset transfer transaction (such as changing the configuration parameter of an account, modifying the status of a smart contract and other status modification operation within an account) refers to any transactions without any asset being transferred. Users could check the result from any of the nodes in the DLT system after a transaction has been successfully committed.

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Core functions

Query (balance/conditional) - A user can get result(s) by information request(s).

Consensus mechanism effectiveness - A consensus mechanism is a set of rules and procedures by which consensus is reached. It is a data consistency mechanism that is used in DLT platform to achieve the necessary agreement on a single data value or a single state of the network among distributed processes or multi-agent systems. To ensure the effectiveness of the consensus mechanism, there should be enough nodes participating in the consensus process, aligned with the objectives of the blockchain platform. E.g., some blockchain platforms only requires a specific number of masternode participants, while others require all token holders.

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Core functions

Private key management - Public-key cryptography is a cryptographic system that uses pairs of keys: public keys (which may be disseminated widely), and private keys (which are known only to the owner). Private key management for use of DLT is an important function for user experience and security measures. It provides a reliable and safe way to keep users' private keys. Storage and usage of private keys may be separated. User should have full control of their private key usage. There are two common methods to store private keys: software wallet method and hardware wallet method.

Smart contract mechanism - DLT can support more complex transactions as technology evolves. Some complex transactions are stored in DLT systems in the form of source code/bytecode programs, and can be executed to deal with different business logics. These programs are called smart contracts. Smart contract mechanism includes language definition, compilation and execution of the code. Smart contracts for different DLT systems can be implemented using simple interpreted scripts or programming languages.

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Core functions

Security of cryptography - Security includes encryption, cryptography, crash tolerance, hack tolerance, etc. A DLT system should ensure the highest security for the system and disclose its security measures.

Encryption declaration A DLT platform should specify where the encryption is derived; open-source encryption or regulatory compliance encryption.

Pluggable encryption algorithm A DLT platform can use pluggable modular encryption and switch to a specified encryption algorithm online or offline as required.

Efficiency of encryption algorithm A DLT platform should use and make available to use secure, strong enough encryption with acceptable efficiency, depending on the objectives of the system.

Strength of encryption A DLT platform should declare the security level of the used cryptographic schemas. Category and cipher strength of the encryption could be taken as metrics. In addition, quantum-resistant encryption algorithms could be taken into account.

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Application functions

User authentication A DLT platform should have user authentication modules and user access control management modules. Electronic signature is an effective way to authenticate user. The platform may allow the creation of smart contracts that can authenticate and control the access of users.

- **User account verification** This is the validation of information, such as keystore and password, or 2-step verification.
- **Login state management** The platform should update the user login-state after user login.
- **User classification and user management** This is to assign users into one of several types and manage their permissions.
- **Authorization** Users can grant authority to others to access or modify their private data.
- **Smart contract data access control** Smart contract data should be shared among participants of the smart contract, all relevant participants should have access to this information, for example, interfaces to represent smart contracts and query them.

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Application functions

System stability The platform is required to satisfy at least, but not limited to, the following requirements

- **Stability for node management** - The system should grant normal operations when some nodes join, leave or upgrade.
- **Stability for cross-chain operation** The system should grant normal operations when cooperating with other DLT system or cloud system.
- **Network latency** The system should remain stable after running 7x24 hours with latency of network. The tolerable extent of latency is based on design of system.
- **Memory utilization** The system should remain stable after running 7x24 hours without memory exceptions
- **CPU utilization** The system should remain stable after running 7x24 hours without CPU exceptions.
- **Stability for concurrency** The system should remain stable with bursts of concurrent transactions

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Application functions

Economic mechanism design economic mechanisms should be in place to incentivize user participation. This includes, but not limited to, consensus protocol, resolution mechanisms, voting protocol, allocation mechanism, bargaining protocol, monetary policy of the token, transaction fees. Economics design focuses on both the economics of the blockchain platform, as well as the economics the tokens that is produced in the blockchain system (when applicable).

- **Incentive mechanisms** Incentive mechanisms includes both financial incentives and non-financial incentives.
  - Non-financial incentives can include voting protocol, reputation mechanism, and allocation mechanisms.
  - Financial incentives are a more direct form of rewards like monetary policy of the token, transaction fees, platform activities (i.e., block rewards when a block is mined). The latter is more applicable in the permissionless blockchains.

Incentives mechanisms are ways to coordinate activities amongst the decentralized participants, to achieve the objectives of the DLT system. E.g., Bitcoin's Proof-of-Work mechanism rewards users in financial ways (diminishing returns of block rewards and transaction fees) in return for the investment of electricity usage and special ASICs. This incentive mechanism should be detailed and be made known.

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Application functions

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- **Token economics disclosure** The token is a digital representation of value. They can be fungible or non-fungible in nature. Fungible tokens can have different functions, namely security, utility and money. Depending on the token function, a tokenomics report detailing the token economics should be publicly released. This should include, but not limited to, token policy (monetary policy of the token), valuation policy (for security tokens), platform activities (e.g., block rewards for miners), transaction fees, property rights and distribution of tokens.
- **Token transfer** A DLT platform should use a standard protocol for its tokens. The system should have functionalities to facilitate cross-chain or cross-DLT system operations, when applicable or required by regulations.

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Application functions

Information privacy Information privacy is a key requirement for DLT platforms, useful in some industries like finance and healthcare. It refers to the generation, storage and transmission of data in a DLT system being confidential and user private information being safely stored.

- **Secure transmission** Confidential or proprietary information should be transferred over a secure channel, which is achievable by a specified secure transmission protocol.
- **Secure transmission** Confidential or proprietary information should be transferred over a secure channel, which is achievable by a specified secure transmission protocol.
- **Privacy protection** A DLT platform may use privacy protection algorithm(s) such as zero knowledge proofs, ring signature, secure multi-party computation and homomorphic encryption to avoid privacy disclosure.

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Application functions

Application support functions A DLT platform may implement application support functions to improve user-friendliness (i.e., user experience and user interface).

- **User interface** for query A DLT platform may provide a functionality (web page, app, browser plug-in, etc.) to perform a query, visualize the query result and show the status of ledger.
- **User interface for smart contract** A DLT platform may provide functionalities to visualize the deployment and invocation of smart contracts, and queries to smart contract data.
- **Multi-language software development kits (SDKs)** A DLT platform should provide at least one SDK and may translate it into other programming languages.

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Operation functions

Network management The management and monitoring of nodes within a DLT system, including status, configuration, node type and behavior.

- **Node status monitoring** A DLT system should have ability to monitor nodes statuses, such as number of nodes online/offline, synchronization status, client version and so on
- **Multi type nodes** A DLT system should have ability to classify nodes. For instance, node can be classified into two categories, full node and lightweight node, according to whether a complete ledger copy is stored in the node. With lightweight nodes, SPV method should be applied to verify the correctness of the shared ledgers.
- **Node configuration modification** A DLT system should have the ability to support hot or cold modification of the node's configuration parameter, such as the block size, node type and so on.

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Operation functions

Risk management and mitigation A DLT system should have the ability to resist DDoS attack, Sybil attack or dishonest node(s). If failure exists under an attack, the DLT system should have ability to recover to its previous known state.

- **Recovery mechanisms** A DLT system should be able to recover from failure by downgrading recovery, security service, etc. Recovery solution should be flexible and problem-oriented.
- **Trouble shooting** A DLT system should have ability to execute rapid trouble shooting, automatically send failure notifications.
- **Avoid single point of failure** The DLT system should not depend on any centralized system, which might cause a single point of failure.

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Operation functions

Data archiving A DLT system is an append-only trusted ledger. However, mass data stored in DLT systems may degrade the query performance. It is essential to move data that is no longer actively used to a separate storage device for long-term retention, especially for a permissioned DLT system.

- **Data archiving** A DLT system should have ability to archive data that is no longer used or activity level under a threshold to independent storage and migrate the archived data from a node.
- **Data query** A DLT system should have ability to query archived data by providing APIs or tools.
- **Data recovery** A DLT system should have ability to recover archived data in some ways, and the ledger(s) should keep the same status as before it was archived.

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Performance and ecosystem

Performance The throughput and resource usage of processing standard transactions. Environment and deployment reasons may affect performance, such as network topology and test environment (CPU, memory, disk, network). Transactions per Second (TPS) is a standard performance indicator. When evaluating performance with TPS, topology deployment and test environment must be indicated.

A lack of standardization in testing environments has made it nearly impossible to directly compare any two DLT protocols.

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Performance and ecosystem

Criteria for evaluating a DLT ecosystem:

- Platform maturity
- Open or closed source code
- Maintenance requirements
- Availability of skilled professionals
- Running cost of DLT systems
- Avoiding vendor lock-in

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Performance and ecosystem

Platform maturity

Platform maturity of DLT includes many factors such as year of creation, launch of production version, deploying networks (mainnet/testnet), numbers of production networks, numbers of applications, and expertise of team. Whether permissioned network or permissionless network, DLT vendor should disclose this information to all consumers.

Open or closed source

DLT platforms should be open sourced (to its users) and announce the license it is using.

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Performance and ecosystem

Maintenance

DLT platforms should be well maintained by either individuals, companies or non-profit organizations. This can include regular updates on source repository, active discussion by the community regarding the platform and ease of updating the DLT platform with respect to the decentralized applications and DAOs that exists on it.

Availability of skilled professionals

Different DLT platforms require compound technical backgrounds. This indirectly limits the number of professionals available in the market. Sufficient talent supply is an important factor to evaluate DLT platforms.

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Performance and ecosystem

Running cost of DLT systems

It is an essential factor for DLT systems to evaluate the running cost. It includes transaction fees payable, transaction confirmation time and cost of writing, reading and executing smart contracts. In the future, with the importance of smart contract security, audit fee of smart contract and code review and many other intermediate fees should also be taken into consideration.

Avoid vendor lock-in

DLT system should have standardized APIs, such as, service access, data dictionary, communication protocol, encryption algorithm and system testing, so that there can be multiple vendors that provide similar services for the customers to avoid vendor lock-in.

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Overview of this 90-minute session:

- **Use cases**
  - Key functions and benefits of DLT: 15 minutes
  - Use cases across vertical domains: 10 minutes
  - Use cases across horizontal domains: 10 minutes
  - Addressing the SDGs: 5 minutes
- **Flowchart for deciding if you need a blockchain and which type:** 5 minutes
- **Technological Assessment criteria for DLT:**
  - Applications: 5 minutes
  - Operation functions: 5 minutes
  - Performance: 5 minutes
  - Ecosystems: 5 minutes
- **Reviewing key terms and challenges:** 10 minutes
- **Question and answer:** 15 minutes

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Reviewing key terms

- **Smart contract –** program written on the distributed ledger system which encodes the rules for specific types of distributed ledger system transactions in a way that can be validated, and triggered by specific conditions.
- **Decentralized application (dapp)** – application that runs in a distributed and decentralized computing environment.
- **Blockchain as a service (BaaS)** – a cloud service category in which the capabilities provided to the cloud service customer are to deploy and manage a blockchain network enabling the ability of consensus, smart contract, transaction, crypto engine, block record storage, peer-to-peer connectivity and management using blockchain.

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Reviewing key terms

- **DLT Oracles -** service that supplies information to a distributed ledger using data from outside of a distributed ledger system.
- **Block producing full validating node -** participates in a consensus process and contains an entire replica of the distributed ledger, including every transaction that has been executed since its inception (miners in POW).
- **Non-block producing full validating node -** does not participate in a consensus process and contains an entire replica of the distributed ledger, including every transaction that has been executed since its inception.

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Reviewing key challenges

- **General technological risks** - privacy risks, connecting new and legacy infrastructure
- **Knowledge risks** – private key management, lack of implementation know-how, new proprietary coding languages
- **Ecosystem barriers** – many alternative DLT platform solutions with under-developed front ends and interoperability problems across other DLT protocols
- **Intrinsic features and interoperability** – intellectual property concerns, immutability, high energy demand and difficulties upgrading public networks
- **Legal considerations** – regulatory uncertainty around new asset classes and business models

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Thank You