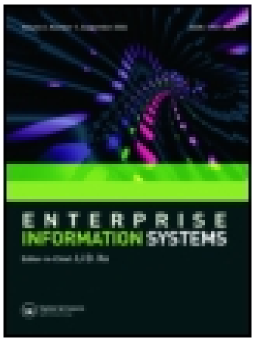

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Distributed Ledger and Decentralised Technology Adoption for Smart Digital Transition in Collaborative Enterprise

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ABSTRACT

Digital transformation of Collaborative Enterprise (CE), both in terms of planning and implementation, relies on new business models and innovative technologies. One of such technologies is Distributed Ledger Technology (DLT) which deploys a decentralised approach requiring no need for intermediaries, thereby facilitating decentralised enterprise operations. Accordingly, this article provides a systematic review and theoretical background of the current state and applications of DLTs within CEs by exploring how this disruptive technology can digitally transform CE practices. Grounded on the review of existing literature, a comprehensive characteristics, application, governance, stakeholders, and emerging security threats faced during DLT adoption and mitigation strategies are presented. More importantly, a model is proposed based on the factors that inhibit DLT adoption in CE. Findings from this study provide implications to support smart digital transition in CE for smart enterprise operations.

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Enterprise systems; digitalisation; disruptive technology; distributed ledger; collaborative enterprise; enterprise transition

1. Introduction

Collaborative Enterprise (CE) comprises of different enterprises that works together using digitalised platforms and data-driven solutions to accomplish common goals (Jnr, Majid, and Romli 2020). But, CEs' current business processes are evolving due to digitalisation and innovations with potential disruptive technologies (Serrano-Calle and Delarue 2018; Jnr and Petersen 2021). In this era of digitisation, CE aims to reduce cost incurred and increase their competitiveness in a globalised economy (Dobler, Ballandies, and Holzwarth 2019; Jnr 2020a). Nevertheless, management of enterprise operation is still a major issue due to complexity, decentralised governance, data privacy regulations, multiple stakeholders, lack of technological and data interoperability, unforeseen disruptions, etc. (Chatterjee, Parmar, and Pitroda 2019; Dobler, Ballandies, and Holzwarth 2019; Jnr 2021). Digital innovations, such as Distributed Ledger Technology (DLT), are now being adopted in collaborative enterprises for addressing issues related to traceability, anonymity, etc. (Red 2017; Poels et al. 2019; Centobelli et al. 2021).

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DLT offers a platform for smart contracts, thereby offering great potential for sustainable digital business ecosystems for collaborative enterprise transaction (Hrga, Capuder, and Žarko 2020). The digital transformation of CE and particularly the adoption of DLT can become a very useful tool to establish integrity of data sharing, trust, traceability and accountability (Ribitzky et al. 2018; Venkatesh et al. 2020). DLT is now widely known as one of the disruptive tools that have emerged in this new digital age, which plays a vital role in supporting cross-border payments and improving the digital payment ecosystem. DLT provides the central backbone for deploying decentralised systems on which different application transactions can be implemented in CE (Ølnes, Ubacht, and Janssen 2017). Thus, DLT is considered as one of the emerging digital technologies for the next generation of collaborative enterprise systems such as in energy systems, real estate, finances, governance, healthcare, etc.

DLT enables unprecedented traceability and efficient data decentralisation by associating linked records of cryptographically secured, propagated and validated across peers and nodes (Red 2017; Rückeshäuser 2017; Seok, Park, and Park 2019). DLT encompasses multiple areas of computer science (i.e., information systems, cryptography and databases) (Poels et al. 2019; Gräbe et al. 2020); however, this research is more aligned with the information system aspects of DLT. Presently, prior studies are mostly focused on the technological aspects and challenges of adopting DLT for peer to peer (P2P) enterprise operations (Ribitzky et al. 2018). Also, most studies examined the opportunities of DLTs offered towards information exchange and redesign of transaction in private and public domains (Ahi and Singh 2019; Zamani and Giaglis 2018; Hrga, Capuder, and Žarko 2020).

In contrast, hardly any studies are focused on DLT adoption in CE (Xu et al. 2019). Neither is the potential of applications based on DLT for CE investigated in a systematic way (Ølnes, Ubacht, and Janssen 2017). Moreover, academicians argued that DLT will modernise CE making businesses more economical and efficient. However, adoption of DLT in collaborative enterprise networks remains largely unexplored (Wu et al. 2017). Also, a model can be developed as a suitable approach to fully understand smart digital transition via DLT to support digital services in CE. Therefore, this current study argued that the information systems approached via enterprise modelling can contribute to deploying DLT in CE towards the development of new business models (Zamani and Giaglis 2018). Therefore, this study is motivated to identify the characteristics and application of DLT in CE. This study also examines the governance, stakeholders and DLT security threats and mitigation strategies in CE. Finally, this study investigates the factors that inhibit DLT adoption in CE.

Evidently, there are fewer studies that provides a concrete and systematic review of DLT adoption in CE. Accordingly, this study develops a model to support the adoption of DLT in CE towards smart digital transition. The model can serve as a guide for business developers, architect designers and researchers for achieving the requirements for implementing a sustainable DLT in CE. The remainder of this article is organised as follows. Section 2 explains literature review, and then section 3 explains the methodology. Findings are presented in section 4. Section 5 explains the discussions and section 6 presents the implications of the study. Finally, section 7 explains the conclusion, limitations and future works.

2. Literature review

DLTs ensure data integrity in a distributed network, and it is deployed in different sectors such as in finance, education, e-democracy, etc. Recently, DLT is gaining attention due to digitalisation in collaborative enterprise. Moreover, few studies have been carried out that proposed DLT approaches for efficient management and data integrity. Among these studies, Tsang et al. (2021) explored on the intellectual cores of the blockchain Internet of Things (IoT) termed as BIoT. The authors contributed towards the development of a knowledge structure for BIoT based on a structural framework. Jnr (2020a) investigated the role of green IT/IS initiatives in CE. The author designed a research model grounded on sustainable life cycle process and diffusion of innovation theory identified through secondary data after which survey questionnaires were carried out to analyse the model. Liu, Farahani, and Firouzi (2020) explored the prominent DLTs and their applications in different domains. The authors also discussed the role of IoT and DLT for enterprise-level DLT applications. Hrga, Capuder, and Žarko (2020) presented a systematic review of DLT background, principles, implementations and a technical in-depth analysis of DLT used cases in the energy sector. Their study provides an insight into the limitations, benefits and technical challenges that impacts the use of DLT in energy systems.

Similarly, Casino, Dasaklis, and Patsakis (2019) conducted a systematic literature review and thematic content analysis of blockchain-based applications and identified the classification, status and open issues. In this study, the authors aimed to explore how detailed characteristics of DLT can revolutionise business practices. Chatterjee, Parmar, and Pitroda (2019) explored the production challenges associated with DLT-based applications in enterprises. The study provided a complete view of readiness challenges faced in decentralised application adopted for enterprise with ranking and alternative solutions. Dobler, Ballandies, and Holzwarth (2019) researched on innovations that impacts ICT enabled supply chain management in relation to smart custom management. The authors provided a list of potential trust-based innovations supply chain management in digital business ecosystems. Also, the authors provided a requirements analysis of existing DLTs system configuration, requirements and system governance. Additionally, Scuri et al. (2019) researched on how DLT can be employed to support peer-to-peer energy trading. The authors contributed by providing an understanding of the human characteristics impacting the adoption of DLT systems and technologies in a decentralised energy marketplace.

A recent study by Ahi and Singh (2019) examined the role of DLT to improve resiliency in IoT ecosystem towards a better security in blockchain based IoT system. Troncia et al. (2019) employed DLT to facilitate peer-to-peer local markets within a distribution network. A decentralised approach is proposed to bypass the need for a physical dominant authority, thus, performing the role of a virtual decentralised market authority in the administration of local energy community. Ferraro, King, and Shorten (2018) described how DLTs can be adopted to achieve social contracts and to manage the behaviour of agents accessing a shared resource. Accordingly, the authors proposed a set of delay equations to define the dynamical behaviour of the Tangle for the cryptocurrency IOTA. Giraldo (2018) examined significance of DLT in cross-border platforms. The author employed digital platform literature to conceptualise a cross-border payment approach for remittance organisations to assess the potential shapes of DLT within these platforms.

Another study by Rauchs et al. (2018) carried out a comprehensive study and developed a conceptual framework for DLT systems that can be used as a multi-dimensional tool for investigating and comparing existing DLT systems. In this study, the authors argued that a DLT system comprises of interrelated layers, processes, and components. Zamani and Giaglis (2018) examined the role of DLT in building novel business models including autonomous economic agents, machine money, and decentralised organisations. The study conceptually investigated how digital technologies and money embedding trust in decentralised eco-systems will impact markets and commerce in trusted peer-to-peer transaction ledger applications and systems. Wu et al. (2017) suggested the use of DLT to address visibility for supply chain physical distribution. The authors further introduced a framework that supports current enterprise-based supply chain management solutions. The framework comprises of a single blockchain public ledger and a set of private distributed ledgers.

Ølnes, Ubacht, and Janssen (2017) investigated blockchain in e-government domain and provided the benefits and significance of DLT for information sharing. Their study offered a road map for further research into the benefits of DLTs applications in e-government and the impact of governance of blockchain applications and architectures to conform with public values and societal needs. DLT has recently been adopted in different sectors to support businesses in providing value added services. However, none of the reviewed studies have investigated the adoption of DLT in CE context. Hence, this current study adds to the body of knowledge by carrying out a concrete and systematic review of DLT adoption in collaborative enterprise.

3. Methodology

A systematic review methodology was employed to present evidence similar to prior studies (Jnr 2021; Anthony Jnr 2021a). A systematic literature review aims to expediently assess prior studies that are appropriate to the specific research topic in order to present a fair assessment of an investigated topic using a rigorous and trustworthy approach. Therefore, the research flow for this study comprises of five phases, as shown in Figure 1.

Figure 1 depicts the research flow for this study, where each phase is discussed in the subsequent subsections.

3.1. Inclusion and exclusion criteria

The inclusion and exclusion criteria are the sampling methods employed to select articles to address the motivation of the study presented in the Introduction section. The inclusion and exclusion criteria are presented in Table 1. Thus, an article is included if it meets up to the inclusion criteria and is excluded if it satisfies any of the exclusion criteria.

Figure 1. Research flow.

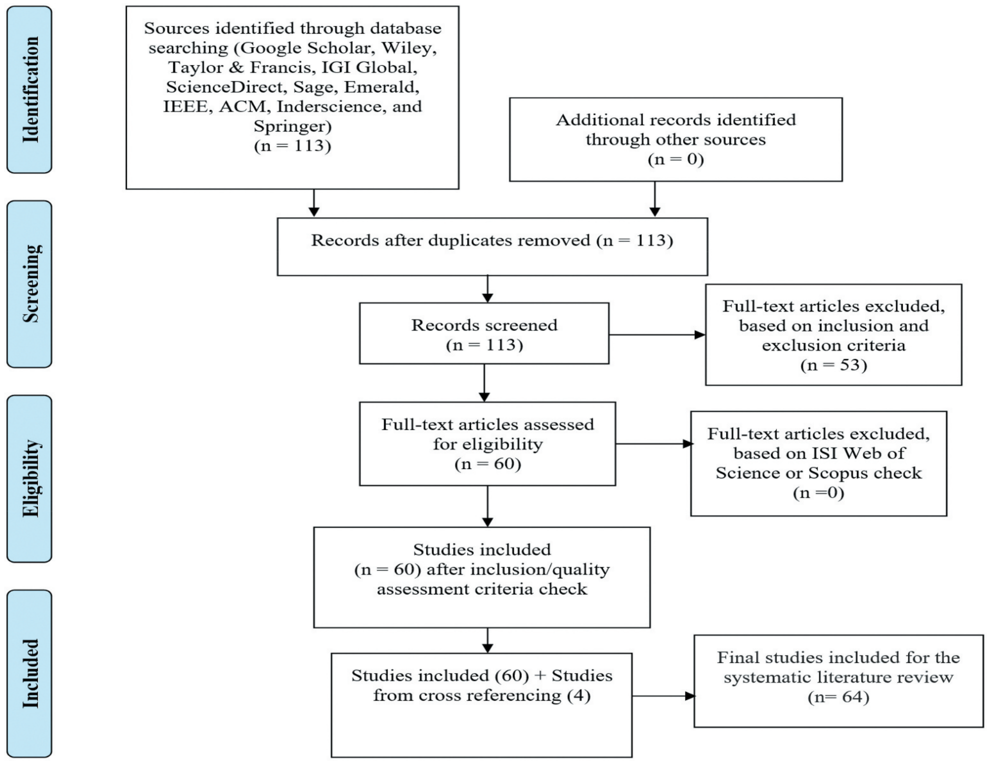

Figure 2. PRISMA flowchart for the selected articles.

3.2. Search strategies and data sources

The sources employed in this study were retrieved through a comprehensive search of prior DLT/blockchain adoption research through online databases which comprise Google Scholar, Wiley, Taylor & Francis, IGI Global, ScienceDirect, Sage, Emerald, IEEE, ACM, Inderscience and Springer. The search was undertaken within January 2021. The search terms include the keywords ((‘distributed ledger technology adoption’ OR ‘DLT adoption’ OR ‘blockchain adoption’) AND (‘model’ OR ‘architecture’ OR ‘framework’ OR ‘enterprise’ OR ‘smart cities’ OR ‘organizations’ OR ‘industries’) AND (‘factors’ OR ‘drivers’)). These keywords were employed to retrieve appropriate articles to provide empirical evidence regarding the aim of this study.

Table 1. Inclusion and exclusion criteria.

Inclusion	Exclusion
• Should involve background of DLT/blockchain adoption and factors that influence DLT/blockchain adoption	• Studies that do not present background of DLT/blockchain adoption and factors that influence DLT/blockchain adoption
• Should be based on an approach, model, theory and framework for exploring DLT/blockchain adoption	• Models, approach, frameworks or theories used in contexts other than DLT/blockchain adoption
• Should be mainly written in English and published between 2000 to 2021 as this is the duration of the cryptocurrency and bitcoin	• Studies not within 2000 to 2021 and are not written in English
• Studied on DLT/blockchain architectures	• Studies not on DLT/blockchain architecture

Figure 2 shows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart which was used for screening of articles as previously used by Anthony Jnr (2021b). The final search resulted to 113 articles using the keywords above. No articles were established as duplicates. The articles were checked against the inclusion and exclusion criteria (see Table 1) and 53 sources were removed since they were not related to DLT/blockchain adoption and factors that impacts DLT/blockchain adoption resulting to 60 articles. The remaining articles was checked for quality assessment. A check was carried out to verify if the articles were indexed in Scopus or/and ISI Web of Science databases. The findings as discussed in the quality assessment section suggest that the selected studies meet the inclusion and quality assessment criteria. Finally, four articles were included via cross referencing, as seen in Figure 2. All included sources are presented in the reference section of this paper totalling to 64 articles.

3.3. Quality assessment

One of the important benchmarks that is required to be checked with the inclusion and exclusion criteria is the quality assessment check, as recommended by Anthony Jnr (2021a). Therefore, quality assessment check was employed for all selected papers to confirm if the papers are indexed in Scopus or/and ISI Web of Science database. This criterion helped to evaluate the quality of the selected studies used to provide secondary data for this study. Figure 3 depicts the journal articles, conference proceedings and book/book chapters

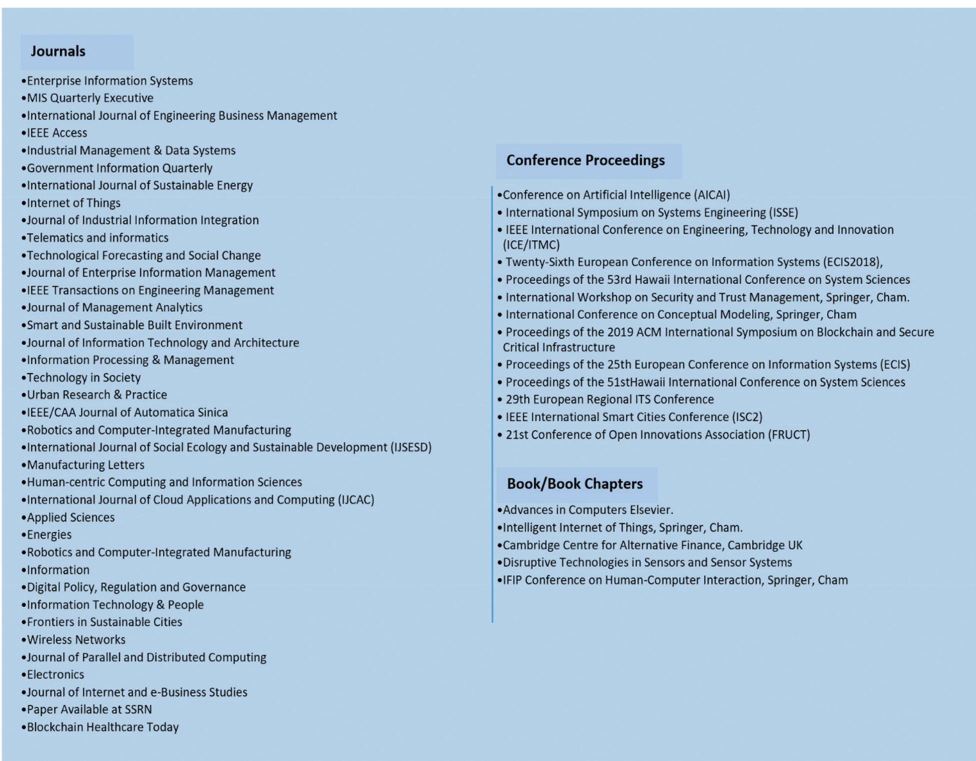

Figure 3. Selected studies journals, conference proceeding and book chapter articles.

employed for this study. Most of the articles included are indexed in Scopus or/and ISI Web of Science database suggesting that the articles are peer reviewed. Hence, findings from these articles can be regarded as credible to provide secondary data needed for this study.

3.4. Data coding and analysis

The final 64 studies are utilised to provide evidence in response to the aim of this study. This helps to provide secondary data on DLT adoption in collaborative enterprise. Thus, secondary data is extracted, synthesised, coded and examined in detail as evidence from these sources as related to the objectives presented in the Introduction section of this paper.

4. Findings

With respect to the selected studies regarding distributed ledger and decentralised technology for smart digital transition of collaborative enterprises, the findings of this study are presented based on the objectives of this study.

4.1. Characteristics of DLT

Distributed ledgers are replicated, and immutable synchronised data structures (or databases) shared and managed by the equally untrusted network of peers or nodes (Gräbe et al. 2020). Commonly, DLT platforms comprise first of peer-to-peer network for network maintenance and peer interaction with the aim of sharing distributed ledger transactions amongst all peers within the network (Lee et al. 2020). Thus, a distributed ledger has some characteristics that makes it suitable to be adopted in collaborative enterprise. These characteristics are presented in Table 2.

Overall, based on the characteristics described in Table 2, DLTs can be adopted in collaborative enterprises for the transaction and exchange of assets amongst a limited number of actors. It also provides provenance tracking which focuses on the trace of origin and movement of assets across the entire collaborative enterprise using digitalised or virtual certificates of authenticity. More importantly, for record keeping within the collaborative enterprise, DLT can be employed as a transaction log mechanism for notarising and recording all types of data of high prominence while providing redundancy and ensuring recording of data in a jointly managed data ledger/record (Xu et al. 2019).

4.2. Background of DLT in Collaborative Enterprise

Collaborative enterprise is derived from the word 'collaboration' which is a process that comprises two or more stakeholders in organisations working collectively to achieve a shared goal towards their organisational visions (Jnr 2020a). To this end, a CE is any organisations that implement activities where two or more people contribute distinct skill, resources and know-how to towards the development of both establishments involved (Jnr, Majid, and Romli 2020). Accordingly, the goal of CEs is multifaceted hence different from other ordinary enterprises (Jnr 2020b). Presently, CEs are increasingly

Table 2. Characteristics of DLT.

Characteristics	Description
Immutable	Uses an advanced hash functions cryptography as such once data have been written, it cannot be deleted or changed without noticing (Lee, Azamfar, and Singh 2019; Gräbe et al. 2020), as same data are stored in several ledgers (Ølnes, Ubacht, and Janssen 2017)
Flexibility	Involves the options offered by a DLT design for further development and maintenance (Gräbe et al. 2020)
Institutionalisation	DLT is defined based on the embedding of artefacts and concepts in social structures (Gräbe et al. 2020)
No intermediaries	DLT employs a self-executable algorithm such as smart contract (Rahmadika and Rhee 2018; Lee, Azamfar, and Singh 2019)
Traceability	DLTs have the capability for employing traceability as such it guarantees the time traceability of transactions since they are arranged in immutable blocks (Arslan et al. 2020; Hrga, Capuder, and Žarko 2020)
Authentic	All involved stakeholders in the transaction have consistent, timely, accurate and complete data (Lee, Azamfar, and Singh 2019)
Anonymous	Anonymity defines the extent to which entities are not recognisable within a set of users (Grover et al., 2019). DLT anonymous users by employing an encryption public and private access or keys which ensures that the information of stakeholders is private (Ølnes, Ubacht, and Janssen 2017; Lee, Azamfar, and Singh 2019)
Performance	This comprises DLT characteristics regarding the achievement of a given task assessed against standards of completeness, accuracy and speed (scalability, confirmation latency and throughput) (Gräbe et al. 2020)
Security	DLT ensures the preservation of availability, integrity and confidentiality of information (Lee et al. 2020). In DLT the security of data for all participants are verified via public-key cryptography using a pseudonym for each member (Seebacher and Maleshkova 2018; Grover et al., 2019)
Trust	Trust in DLTs is increased due to immutable record keeping in the block which helps for verification of the data via multiple nodes (Ølnes, Ubacht, and Janssen 2017)
Auditability	DLT can track transaction history and generate an audit trail increasing the predictive ability. Also, DLTs have several ledgers which help to ensure consistency (Ølnes, Ubacht, and Janssen 2017)
Avoids manipulation and fraud	Unauthorised changes and hacks are difficult to enforce without being unnoticed, as data are stored in multiple distributed ledgers (Ølnes, Ubacht, and Janssen 2017)
Consistency	Refers to storing of identical copy of the ledger at the same time on each node. The consistency can be measured based on the transaction latency which is the period for a new transaction to be available on all nodes (Gräbe et al. 2020)
Fault tolerance	DLT possesses the capability to correctly operate in the likelihood of system failures (Gräbe et al. 2020)
Network size	Defines the number of nodes in a distributed ledger that retains a complete replication of the ledger. Thus, the network size is operationalised as the number of complete nodes within a distributed ledger (Gräbe et al. 2020)
Reliability	Denotes the period during which a distributed ledger is functioning properly. In DLT, the operationalisation produces a likelihood that the system generates a correct output within a time interval 't' (Seebacher and Maleshkova 2018). Reliability is attained through a code-based design and redundancy with possibility for automation (Seebacher and Maleshkova 2018)
Decentralised	The main benefit of DLT is that there is no single autonomous controlling body (Ølnes, Ubacht, and Janssen 2017; Lee, Azamfar, and Singh 2019)
Supports multiple writers	DLTs are appropriate when each party depend on others to complete a particular transaction. Thus, it supports the involvement of multiple stakeholders or actors (Lacity 2018)
Usability	Refers to the degree to which a DLT design can be utilised by different users to realise specified goals with respect to satisfaction, efficiency and effectiveness in the context of use (Gräbe et al. 2020)
Censorship resistance	This defines the probability that an entity can strongly influence the refusal or acceptance of transactions with a rational effort (Gräbe et al. 2020)
Distributed	DLTs are dispersed over different enterprises and/or location (Lee, Azamfar, and Singh 2019). As data are stored in multiple ledgers employing encryption manipulation is much difficult. Hacking of all the data at the same time is less possible (Ølnes, Ubacht, and Janssen 2017)
Aids data sharing	Since DLTs supports multiple writers in a transaction, some procedures may also require organisations to share data with observers such as regulators (Lacity 2018)

(*Continued*)

Table 2. (Continued).

Characteristics	Description
Aids data permanency	DLTs are appropriate when all actors need to depend on a shared historical audit trail of transactions that will not be altered. This creates data provenance which help to keep track of enterprise assets (Lacity 2018)
Cost	This relates to the deployment and use of an existing DLT design. It entails hardware and energy cost (which include hardware cost needed to set up all required components to join in the distributed ledger as well as the accumulated electricity and resource costs) and servicing and maintenance cost which includes all maintenance costs required to deploy network-based services within or outside the distributed ledger) (Lee, Azamfar, and Singh 2019). Besides, the costs of carrying out and validating a transaction can be lessened as no human are involved (Ølnes, Ubacht, and Janssen 2017)
Open	DLT offers a platform in which every actor can present and distribute their own source code and programs, thus offering a versatile and open setting (Seebacher and Maleshkova 2018). This make DLT platforms compliant with the EU General Data Protection Regulation (GDPR). Hence, every partner controls their personal data on their private node and the consensus nodes retains data that is visible to all actors (Mattke et al. 2019; Morelli et al. 2019)
Transparent view	Each participating computer in the distributed network has a replica of the ledger (Lee, Azamfar, and Singh 2019), thus providing a transparent view of the important data to all stakeholders (Grover et al., 2019). Hence, guaranteeing the democratising access to data (Seebacher and Maleshkova 2018), as history of transactions remains evident and every node has whole overview of transactions (Ølnes, Ubacht, and Janssen 2017)
Aids data storage	With DLT, all types of data can be referenced or stored. Conceivably, a DLT-enabled platform provides innovative opportunities to use smart contracts to ensure data minimisation and optimisation of on-chain as well as off-chain data storage (Ribitzky et al. 2018)

interested in DLTs because of the promise of significant competitive advantage and business value. A typical example of a centralised CE and a DLT-based CE is shown in Figure 4.

Figure 4 depicts a centralised collaborative enterprise and a DLT-based collaborative enterprise. In the centralised collaborative enterprise, all enterprises involved are linked to a centralised ledger managed by a third party who manages the ledgers of all individual enterprise. Whereas, in the DLT-based collaborative enterprise, all participating enterprises are connected to the decentralised block which comprises the node of each enterprise (Tsang et al. 2021). Thus, in CE, DLT can support organisations, which involve to directly transact with each other quickly and ensure the provenance of data (Lacity 2018). With DLT implementation, CEs are provided with a security model that is resilient, fault tolerant and available to all partners (Xu et al. 2019) and are provided with novel opportunities neither previously deemed practical nor feasible (Ribitzky et al. 2018). Evidently, findings from the literature (Ribitzky et al. 2018; Viriyasitavat, Anuphaptrirong, and Hoonsopon 2019) suggest that DLTs are attracting tremendous attention and resources from investors to entrepreneurs, policy makers, economic buyers and consumers around the world. DLT has the potential to improve the quality of services provided by CE, as well as the efficiency and economics of enterprise operations, mainly considering the increased data volumes from digital platforms deployed in businesses (Lacity 2018; Ribitzky et al. 2018).

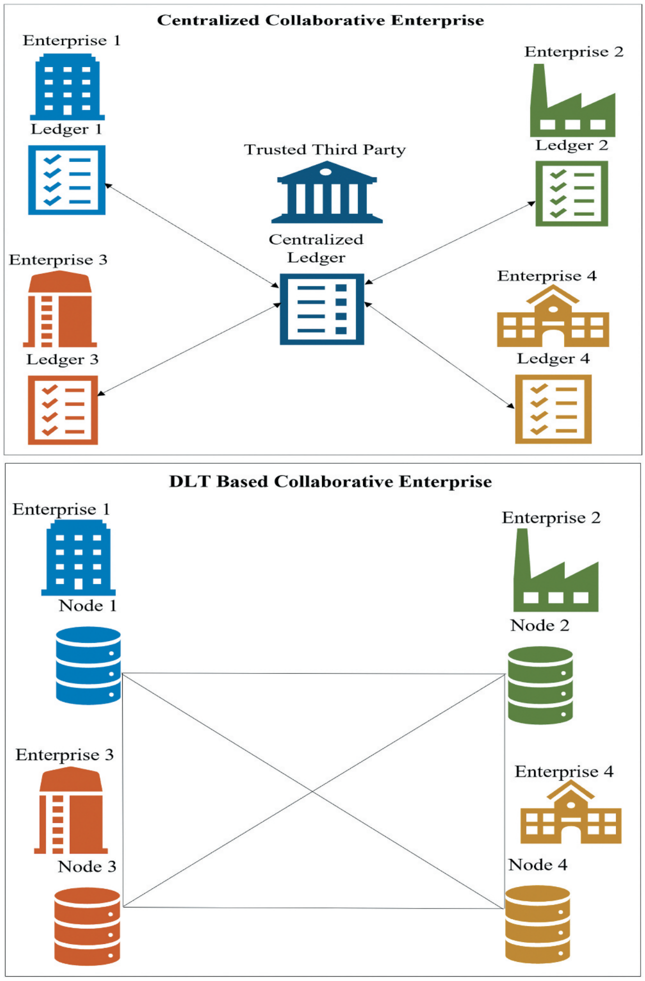

Figure 4. Centralised CE and a DLT based CE.

4.2.1. DLT adoption in collaborative enterprise

Distributed ledger is one of the main decentralised technologies under the fourth industrial revolution and is seen as an emerging disruptive technology in many sectors including collaborative enterprises (Erdenebold, Rho, and Hwang 2019; Liu, Farahani, and Firouzi 2020). DLT adoption has introduced great disruptions to the traditional enterprise processes since the applications and transactions which required trusted third parties or centralised architectures to verify transactions are now deployed in a decentralised approach with the similar level of certainty. Therefore, DLTs are not just a hype as such collaborative enterprise are now investing in this technology since they see the potential of making their business model decentralised thereby reducing transactional costs as they become intrinsically safer, transparent, and faster in some cases (Casino, Dasaklis, and Patsakis 2019). Many practitioners, developers and leading tech firms such as Walmart, Facebook, Microsoft Azure, IBM, Amazon, Hewlett Packard, SAP and Oracle are vastly focused on development, pilot and trial adoption of DLTs such as blockchain into their back-end enterprise operations for increased benefit (Ferraro, King, and Shorten 2018; Erdenebold, Rho, and Hwang 2019; Kaczmarczyk and Sitarska-Buba 2020).

The most famous applications of DLTs are related to cryptocurrencies (Helo and Shamsuzzoha 2020). Cryptocurrencies offer the payment mechanism for transactions, whereas DLT provides validation and verification of these transactions, while smart contracts triggers transactions, basically setting the entire business in motion when pre-defined conditions are met (Zamani and Giaglis 2018). In a DLT-based platform, data are stored in the distributed ledger. The process of storing data is referred to as a transaction and every transaction is assessed by a group of actors in the network known as miners, before the data are stored in the distributed ledger. The DLT networks have the capability to reject an unauthorised transaction which attempts to modify data in the distributed ledger (Li et al. 2019; Esposito, Ficco, and Gupta 2021). As mentioned by Hrga, Capuder, and Žarko (2020,) there are presently over 5000 active types of cryptocurrencies which mainly keep record of account balances and transactions of all participating actors. Hence, in the distributed ledgers, cryptocurrencies are used as a store of value which are verified and eventually linked to actors' digital wallets stored until exchange is needed. The value of cryptocurrencies stored are portable, divisible into nano-units and identifiable by all actors/peers within the network (Zamani and Giaglis 2018; Dobler, Ballandies, and Holzwarth 2019).

Deploying distributed ledger and decentralised technologies enable CEs to transact directly with each other as every participating enterprise has an exact copy of the same digital ledger (Lacity 2018). Additionally, transactions among the enterprises on the common ledger are immutable and transparent to all partners involved. With DLTs, consumers and the enterprises control their own data with cryptographic digital signatures, thus minimising the risks of identity theft and data leakage (Lacity 2018; Gräbe et al. 2020). Furthermore, when CE deploy DLTs smart contracts apply pre-defined rules to intelligently execute contracts based on pre-agreed conditions. Hence, the need for contract monitoring is not required by all enterprises involved (Lacity 2018). But, despite these growing interest towards the integration of DLTs into enterprise process, little attention has been devoted in the literature, specifically by means of theoretical and systematic approach, inter and intra enterprise collaboration known as CE adoption of distributed ledger and decentralised technology. Likewise, there are fewer studies that holistically investigate the governance and security of DLTs adoption more specifically in collaborative enterprise domain.

4.2.2. Application of DLTs in collaborative enterprises across the world

Due to the ubiquity and potential of DLT, countries such as Singapore and Switzerland are exploiting these potentials, whereas adoption of DLT is mostly regulated in other countries, such as India and China (Ferraro, King, and Shorten 2018). As mentioned by Hrga, Capuder, and Žarko (2020,) DLTs are mostly adopted for the following, as shown in Figure 5.

Figure 5 depicts the applications of DLT in collaborative enterprise. Each of which is discussed below;

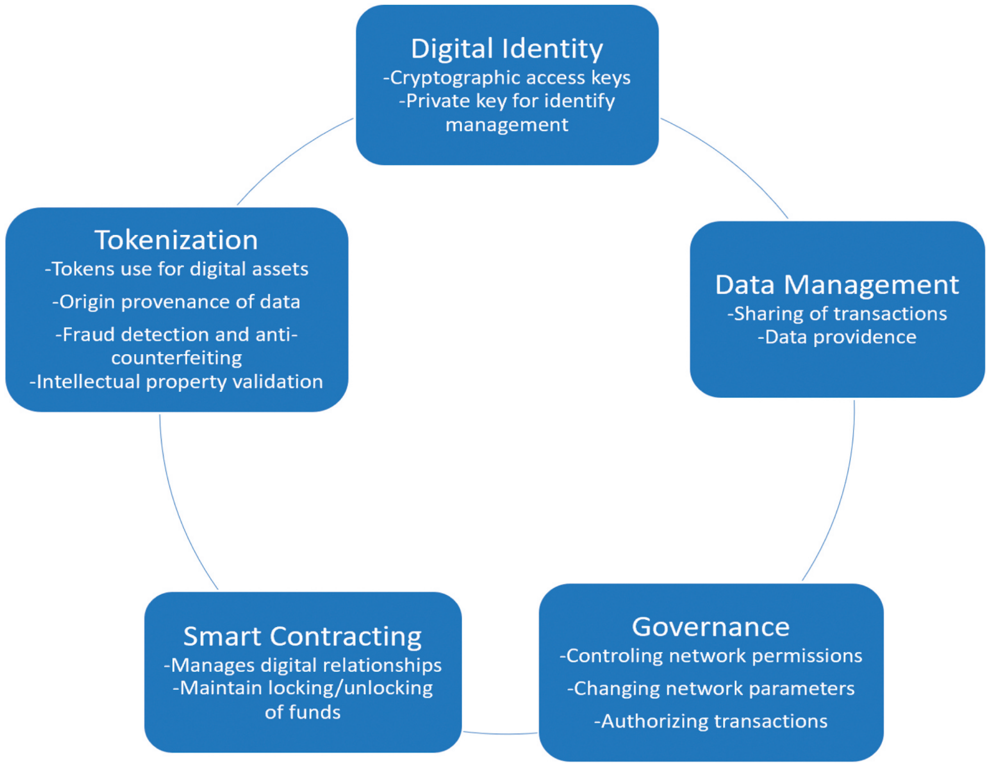

Figure 5. Typical applications of DLT in collaborative enterprise.

- **Digital Identity**: Cryptographic access keys employed user identification in a DLT platform. This enables owner of a digital asset to validate his/her identity, and this enables the user to control his/her private keys.
- **Tokenisation**: Tokens denote digital assets linked to existing physical items for purposes of intellectual property, origin provenance, supply chain management, fraud detection and anti-counterfeiting. Tokens can also be digital bearer bonds for confirming ownership of access rights in a digital platform.
- **Data Management**: DLT are used for sharing of records between organisations such as virtual or collaborative enterprises in a decentralised way, thus ensuring inter/intra organisational data management.
- **Governance**: DLTs is used in managing and invoking network permissions, changing network parameters and authorising transactions in a decentralised manner.
- **Smart Contracting**: DLT is used in providing a mechanism for setting up digital relationships and locking/unlocking funds.

DLT is an attractive digital solution which provides trade ability, proof of ownership and trust among the active actors aimed at achieving resilience to external threats, increased reliability and real time transactions (Zamani and Giaglis 2018). Findings from Hrga, Capuder, and Žarko (2020) mentioned that DLT has been used in managing data, where there are sensitive data that must be shared among regulating institutions or collaborative enterprises. Recent studies highlighted that DLT has been piloted in energy sector using cryptocurrencies for energy tokenisation, P2P trading, solar trading in the United States, energy investment, e-mobility, electricity billing, energy exchange in Austria and Electric Vehicle (EV) charging in countries such as in Germany (Xu et al. 2019; Hrga, Capuder, and Žarko 2020). Additionally, DLT tokens have been utilised in crowdfunding campaigns referred to as Initial Coin Offerings (ICO), which is a process analogous to crowdfunding, where organisations and startups get funds from potential investors who in return receive a kind of digital asset or token. ICOs are often utilised for raising funds because the traditional regulated and rigorous capital-raising procedures can be bypassed and simplified (Hrga, Capuder, and Žarko 2020).

Findings from Hrga, Capuder, and Žarko (2020) stated that about 28% of energy firms have used ICO or analogous type of token sale. As stockholders can utilise tokens to receive special discounts and products mostly made available through token payments and the token can later be sold in a market (Hrga, Capuder, and Žarko 2020). Likewise, the Swedish government has already begun pilot testing the adoption of DLT, where DLT is used to time-stamped transactions and in documenting assets ownership to be validated and verified by node of trusted peers. Similarly, the Estonian government employs DLT for implementing a keyless signature platform which is transparent and secure and further aid citizens to confirm that government records regarding them are correct promoting digital governance (Zamani and Giaglis 2018). As pointed out by Giraldo (2018), the World Economic Forum has reviewed the possible of adopting DLTs to support diverse financial services such as in global payments. Also, the Bank of England has considered deploying DLTs within its novel real time gross settlement system blueprint. Other entities such as SWIFT has lately implemented a proof of concept to test the use of DLT based platforms such as Ripple for inter-bank and cross-border market payment (Giraldo 2018).

For instance, in Germany and Europe RWE, a large renewable electric utility firm has developed BlockCharge which is a hardware-software unified application links to a blockchain-rooted network, allowing EV owners to charge their vehicles via any electric charging station network and autonomously billed for the electricity consumed (Xu et al. 2019). Besides, in Finland, a blockchain system for digitalisation of housing trade is under development to stimulate policy discussion for open and more decentralised market (Xu et al. 2019). Researchers such as Tekeoglu and Ahmed (2019) mentioned that DLT can be applied for real estate management, where property records are saved on distributed ledger as temper-resistant trusted data without any third-party involvement. Findings from the literature (Lee, Azamfar, and Singh 2019) suggest that distributed ledger has been applied in several industries, such as for machine-to-machine interaction in the electrical grid system, enterprise traceability system, enterprise logistic operation, data sharing and financial industry (Lee, Azamfar, and Singh 2019). However, there is no systematic study that examines the adoption of DLT in collaborative enterprise.

4.2.3. Types of DLTs adopted in collaborative enterprise

With the development in digitalisation, new DLT systems such as Blockchain, IOTA, Ethereum, and Hyperledger have emerged as the main distributed ledgers adopted in collaborative enterprises. These DLTs comprises complex mathematics which forms the basis of distributed ledger for ensuring secure transactions (Ahi and Singh 2019).

4.2.3.1. Blockchain. Several distributed digital ledgers are formed by blockchain which was a concept introduced by Nakamoto originally Bitcoin for offering security to online transactions without any third-party involvement. The core of blockchain is a data structure which stores records in an ordered way and connected to the previous block, achieving a distributed system of records (Demirkan, Demirkan, and McKee 2020; Nguyen et al. 2021). This structure mainly comprises two parts, i.e. the header and content (record or transaction) (Red 2017; Ahi and Singh 2019). Each block of blockchain is recognised by a unique ID produced from a cryptographic method. The header comprises a field that stores the hash of the immediately earlier block for creating a connection or link among the blocks (Teslya and Ryabchikov 2017; Rahman et al. 2019).

All transactions are assured of nonrepudiation via asymmetric cryptography in which the transaction's sender digitally signs the preceding hash with the sender's private key and includes the receiver's public key (Gupta et al. 2021). The receiver, in turn, authenticates the received transaction with the sender's public key and uses the receiver's private key to digitally sign a succeeding transaction. The storage of the data is achieved by using a root hash which representing a Merkle Tree (Mohan and Gladston, 2020), such that all completed transactions can be safely excepted from the last block propagating between peers (Red 2017; Scuri et al. 2019).

4.2.3.2. IOTA Tangle. IOTA which is the first cryptocurrency is another DLT that founded on blockchain protocol standards. It is deployed based on a blockless blockchain method. It is based on Tangle instead of blockchain which employs directed acyclic graphs to connect transactions instead of grouping them into blocks thus managing all security transactions (Red 2017; Scuri et al. 2019). While blockchain generates blocks of data and chains or link them together, IOTA Tangle uses Directed Acyclic Graph (DAG) to produce a digital ledger for storing transactions in public distributed database with P2P functionalities (Red 2017). The main objectives of IOTA Tangle are similar as blockchain, as it eliminates the cost of energy ineffective mining procedure required by many Bitcoins based crypto currencies and it develops via nodes involved in transactions, not miners, thus eliminating centralisation (Ahi and Singh 2019).

As seen in Figure 6, the Tangle transactions are represented as a vertex of the graph (T0 which is regarded as the genesis block). Any new transaction or data is added to the Tangle, by choosing two preceding transactions to approve, which creates two new edges to the Graph. In Figure 6, transaction number T5 approves transactions number T2 and T3. Specifically, each block can trace back to the original first block or genesis block in the Tangle as in Figure 6 (Red 2017). IOTA tangle is mostly lightweight as consensus does not need several peers intercommunicating or using computational effort for validation instead, two transactions can be authenticated by single peers committing a transaction themselves (Ferraro, King, and Shorten 2018), as seen in Figure 6. This reduces transaction overhead and time. IOTA employs an inbuilt smart contract mechanism which ensures the lightweight of Tangle to achieve offline transactions, infinite scalability and zero-cost transactions where transaction settlement is deployed in parallel ensuring scalability (Ahi and Singh 2019).

IOTA mainly uses Quantum resilient cryptographic algorithms, which are resistant to brute force attack. Also, IOTA has no transaction fees and miners, or external validations are not required as the computation for validating transaction are done by network users.

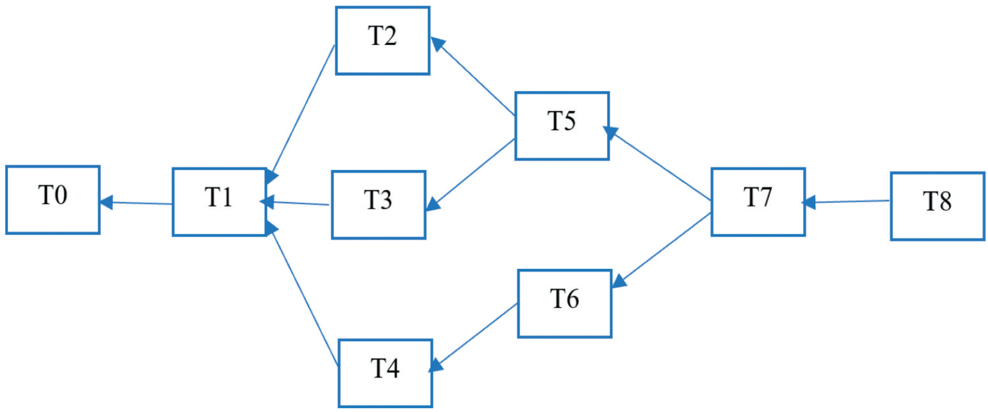

Figure 6. A cyclic graph implementation of a distributed ledger.

The blockless nature of Tangle aids multiple Tangles to exist in disconnected DLT platforms. It can temporarily create offline transactions and then publish the data in the network when there is Internet connectivity. Resulting in higher number of transactions in relation to existing blockchain solutions (Ahi and Singh 2019). Researchers such as Red (2017) highlighted that IOTA is the future backbone for IoT ecosystem in enterprises. IOTA was used by prior study (Oktian, Lee, and Lee 2020) as their payment engine to manage micropayments in ensuring real time machine-to-machine transactions.

4.2.3.3. Ethereum. Ethereum is a distributed ledger that started as a blockchain cryptocurrency and later integrated directed acyclic graph features for additional security for applying cryptocurrency features to other potential domains, such as in IoT (Red 2017). It is an adaptable blockchain with smart contracts features based on derivative of proof-of-work consensus termed as Ethash. Moreover, Ethereum deploys smart contracts which aids the storage of custom data (Tekeoglu and Ahmed 2019). This enhances the potential for immutability and auditability of enterprise data beyond cryptocurrency transactions supporting robust extensibility for enterprise systems. Ethereum provides full visibility of all data or transactions on the public ledger (Kuperberg 2019).

Using Ethash based upon proof-of-work, Ethereum may need between 10 to 20 s to generate a block within the network. In Ethereum, all peers are store within a blockchain in the order of tens of gigabytes large (Red 2017) and any enterprise can join as Ethereum main network is unrestricted, public and free; thus, enterprises can create a free pseudonymous account (also referred to as 'wallet'), which is a technically asymmetric keypair (Kuperberg 2019). Researchers such as Oktian, Lee, and Lee (2020) adopted Ethereum as their Compute Engine because the smart contract in Ethereum is more expressive as compared with those in other DLTs.

4.2.4. Hyperledger

Hyperledger consists of several open source blockchain platforms variably backed by many enterprises across industries (Red 2017). Hyperledger is a permissioned blockchain that distinctively applies variable consensus, smart contracts and access control. It employs a trust to root certificate as an enhancement to digital signature features and the asymmetric cryptography with Elliptic Curve Digital Signature Algorithm (ECDSA) and

SHA3 secure hash function. Hyperledger platforms prevents the computationally and probabilistic expensive mining of hashes as in PoW (Red 2017). Although Hyperledger have more advance smart contracts similar to Ethereum. It is inefficient since it depends on mainly on the key-value store (Oktian, Lee, and Lee 2020).

4.3. Governance of DLT Platforms Adoption

A distributed ledger employs a spreadsheet where account information and other record of transactions are accessible, transcribed and possibly owned by every node within a P2P network with an intrinsic mechanism to implement agreement among its users (Ferraro, King, and Shorten 2018). DLT is an evolving smart technology that can be used to effectively achieve process integrity, security, transparency and durability of enterprise process. DLT is a decentralised, digital and disruptive innovation in which transactions are saved in a chronological format aimed at creating permanent tamper-proof records (Venkatesh et al. 2020). DLT facilitates decentralisation, process disintermediation and global level transactions amongst several stakeholders to deliver timely services (Venkatesh et al. 2020). The governance structure of DLTs are transparent, with clear responsibilities and roles (Venkatesh et al. 2020). It is governed by no one since it is owned by no one and the software is mostly proprietary to a single controlling entity (Howell, Potgieter, and Sadowski 2019). Additionally, the governance of DLT is supported by smart contract governance which enables actors in collaborative enterprise to automate their certification processes and contracts (Venkatesh et al. 2020).

Therefore, governance of DLTs deals with how diverse actors come together to produce, change or maintain the inputs that make up the distributed ledger network (Casino, Dasaklis, and Patsakis 2019). Also, governance also clearly defines how information can be managed or changed within the nodes (Ølnes, Ubacht, and Janssen 2017). The software code for DLT is open source, and any node user is permitted at any time to modify the code used for themselves without faced with the shortcoming of a centralised system (Howell, Potgieter, and Sadowski 2019). All the systems deployed in distributed ledger operate within an architype of rules, either derived implicitly from the cultures and norms of the parties or explicitly specified in formal agreements (such as contracts and constitutions) (Howell, Potgieter, and Sadowski 2019). Regarding accountability DLT may face an immense centralisation issue due to the concentration of mining autonomy within a small group of early members. However, the concept of Proof of Stake (PoS) and Proof of Work (PoW) are employed which helps to address the problem where partners are given greater elective power as compared to those who have lower stake in the network (Howell, Potgieter, and Sadowski 2019). Generally, the governance rules of DLTs comprise of memorandum under in which a systemic interaction is employed to co-ordinate users and restructure decision-making rights for detailed subsets of system users (Howell, Potgieter, and Sadowski 2019).

As seen in Figure 7, the governance of DLT can be categorised according to the current network permissions and management as either 'federated', 'private/close (permissioned)' and 'public/open (permissionless)' (Ølnes, Ubacht, and Janssen 2017; Casino, Dasaklis, and Patsakis 2019). The main differences between both private and public types of governance are based on the level of openness and the allocation of permissions. The access to the copies of the distributed ledger is based on either it is public or whereas

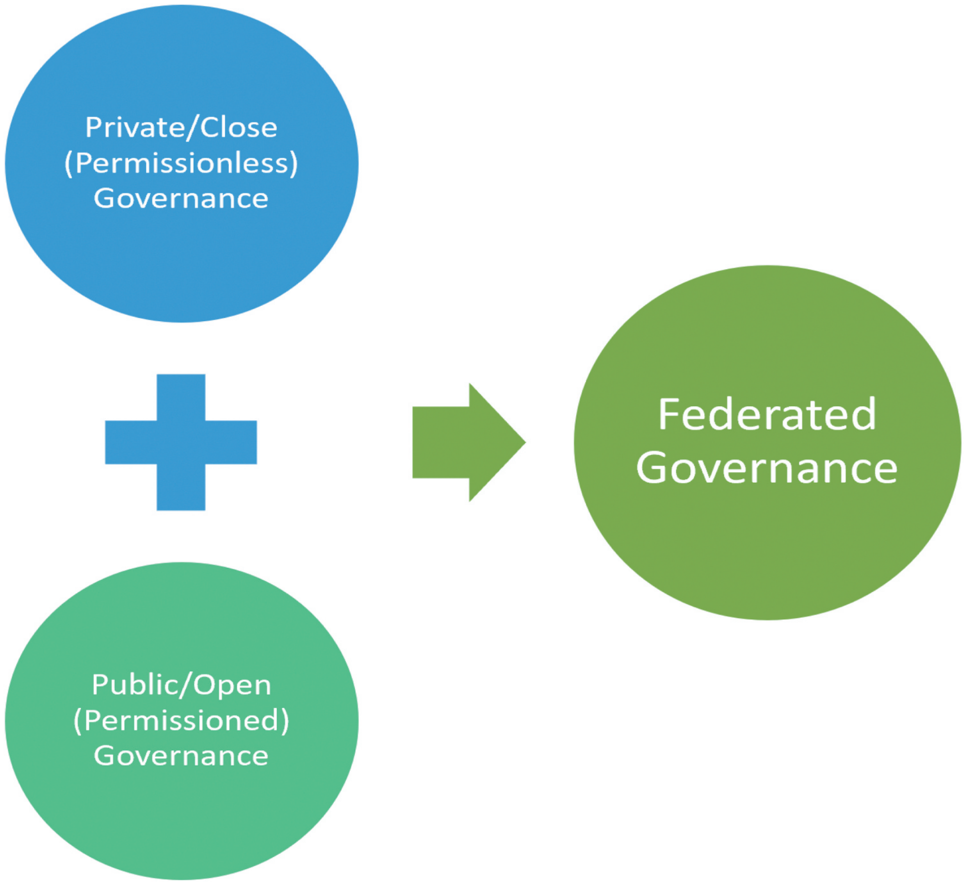

Figure 7. DLT governance categories.

the feature of permissioned versus permissionless assess who maintains the distributed ledger. In public or permissionless DLT, anyone can join as a new node miner or user (Casino, Dasaklis, and Patsakis 2019). Also, permissioned DLTs are solely managed by the owners as they only have the prospect to provide access and assign new nodes to the DLT ecosystem. Commonly, when a private DLT is set up, a permissioned network is instantiated and then participating partners need permission to be included into the network. Whereas a federated DLT is a hybrid combination of private and public (Casino, Dasaklis, and Patsakis 2019). The governance policy can also be endogenously modified over time as new requirements emerge such as new nodes. Although, there is also a risk that new participants are often discriminated by incumbent partners or may be excluded altogether. Moreover, incumbent partners have incentives to exploit their monopoly influence or restrict admission of new partners (Howell, Potgieter, and Sadowski 2019).

Collaborative enterprise can also choose to implement a public DLT, which can be viewed and used by all the partners involved in the alliance (Ølnes, Ubacht, and Janssen 2017). The roles of enterprises in distribute ledger applications vary dependent on their read and write rights. Some stakeholders might only possess the permission to read data, whereas others will only be able to create data and only conduct transactions. In permissioned DLTs, only the enterprises involve in the alliance or collaboration can add new blocks and transactions to the network. Thus, only trusted enterprises can operate within the node and be involved in the decision-making process for adding new data to the blocks (Ølnes, Ubacht, and Janssen 2017). Collaborative enterprises need to come to a consensus on what type of DLTs is best since there are trade-offs and benefits for every type of DLT. Collaborative enterprises understanding of the types of DLT type is a main element in the governance of DLT. A DLT application can be open for enterprises or restricted for some partners like access to some parts of data. For instance, the European GDPR requires that users should be able to view and request their data, even to remove data or have the right to change 'right to be forgotten'. This shows that DLTs complies with laws and regulations (Ølnes, Ubacht, and Janssen 2017).

4.3.1. Stakeholders Involved for DLT adoption in collaborative enterprises

A DLT system comprises actors or stakeholders that carry out various roles. In this context of this study, a stakeholder is any individual or entity (Anthony Jnr 2021a), that is, either directly or indirectly interacting with the DLT platform (Rauchs et al. 2018). Stakeholder can be grouped together into four distinct categories depending on the role they play within the DLT system as shown in Figure 8. However, in the DLT system, one entity can take the roles of various stakeholders simultaneously and a specific role can be performed by multiple stakeholders at the same time and stakeholders in a DLT system can take multiple roles. Therefore, DLT platforms has a diverse composition of stakeholders, roles and entities (Rauchs et al. 2018).

Adapted from Rauchs et al. (2018), Figure 8 depicts the stakeholders involved for DLT adoption in collaborative enterprises. The system developers are responsible to write and review source code that comprises of the digital technological building blocks of a DLT system and its related system(s). System developers may be volunteer or professionally employed. They comprise protocol, client, application and external systems. The protocol mainly implements and maintains the core protocol of the DLT platform, whereas the

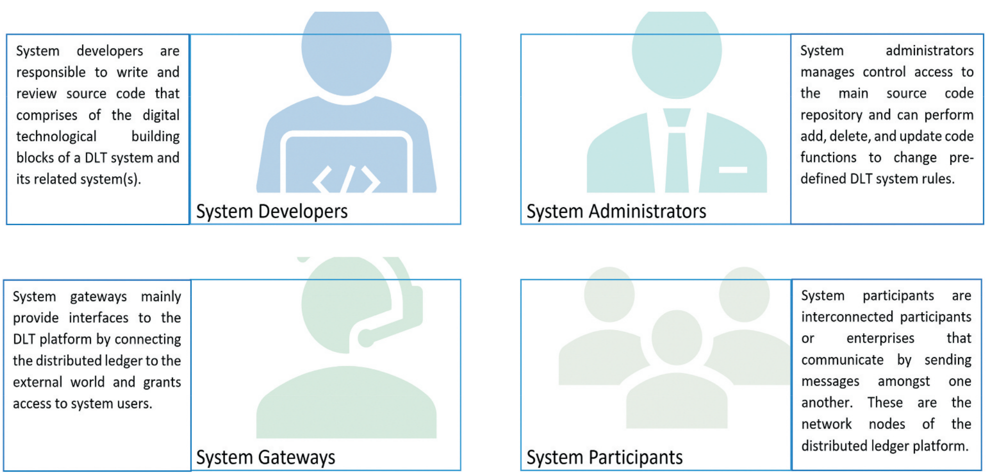

Figure 8. Stakeholders for DLT adoption in collaborative enterprises (Rauchs et al. 2018).

client contributes to developing the DLT client that provides a graphical user interface for the DLT system. Also, application involves implementing applications that are deployed in the DLT platform. Finally, the external systems entail developing protocols to aid the functioning or interaction of subsystems within the DLT network (Rauchs et al. 2018).

System administrators manages control access to the main source code repository and can perform add, delete and update code functions to change pre-defined DLT system rules. System administrators are mostly control and are involved in the DLT governance operation. The roles and responsibilities of a system administrator varies from one DLT platform to another. For example, permissioned DLT platforms may have a dedicated entity managing the role of system administrator, whereas permissionless DLT platforms are often have a loosely associated set of systems administrators who are mostly volunteer core developers rather than an official administrator. Also, in the permissionless DLT platforms, developers do not essentially control the source code, but they suggest changes which are vetted by other independent users who decide to integrate the recommended changes within the deployed DLT platform (Rauchs et al. 2018).

System gateways mainly provide interfaces to the DLT platform by connecting the distributed ledger to the external world. System gateways comprises of gatekeeper(s) (who grants access to system users), oracles (aids transmission of external data in and out of the system), custodians (ensures safety of DLT assets), exchanges (enables sale/purchase of digital assets), and issuers (supplying or saving of tokens which represents the assets saved in the ledger) (Rauchs et al. 2018). System participants are interconnected participants or enterprises that communicate by sending messages amongst one another. Participants comprises of auditors, record producers, lightweight clients and end-users. The auditors usually check and confirms received transactions and records, reports invalid data to the network and relays verified transactions and records. The auditors can also execute an independent audit check for the DLT platform. Next is the record producers or miners/validators who mostly generates and submits sets of individual records for possible inclusion into the distributed ledger. Also, there are the lightweight clients who executes queries for data in relation to specific transactions. Finally, there are the end-users who are indirect users of the DLT platforms who utilise a gateway to access the DLT platform based on their digital wallet (Rauchs et al. 2018).

4.4. DLT Security Attacks and Mitigation Strategies in Collaborative Enterprise

DLT has the capability to become a source of disruptive innovations in collaborative enterprise through optimising, improving and automating industrial processes. As such, many business models are now based on DLT which maintains the workflow routing of business process by automating and streamlining intra-organisational processes and minimising cost (Casino, Dasaklis, and Patsakis 2019). Although the adoption of distributed ledger and decentralised technology is constantly growing, not all enterprises are embracing DLTs due to challenges such as security and privacy (Casino, Dasaklis, and Patsakis 2019). This is because the distributed ledger record can be altered by modifying or deleting the original record if it's not completely secure. For instance, the integrity of data within a block may be vulnerable while being assessed by participating nodes or when a new consensus protocol for assessing blocks are deployed. This is termed as a 'consensus fork' which refers to a technology event analogous to a software update (Ribitzky et al. 2018).

In the past, enterprises have been faced with security hack and related attacks resulting to security breach in their networks and data, hence it is imperative that the security of DLTs should be evaluated (Rauchs et al. 2018; Ribitzky et al. 2018; Lee et al. 2020). Although DLT encrypt each transaction stored on the distributed ledger making it more secured as compared to conventional database which employs a generic encryption security feature to safeguard the entirety of the database. Consequently, if the encryption is breached the whole data becomes instantly accessible (Ribitzky et al. 2018). Evidently, DLT ensures the assurance that data will not be tampered with and promotes provenance of data. This is achieved by employing cryptographic techniques such as private and public key pairs together with the distributed nature of DLT where all shared data has an auditable traceable trail ensuring a reliable digital fingerprint (Ribitzky et al. 2018).

Additionally, Figure 9 depicts a basic architecture for the DLT which shows possible security attacks in the DLT network. The architecture comprises of seven layers (network layer, transaction layer, distributed ledger layer, trust layer, application layer, enterprise layer and DLT security attack layer) and is modelled in ArchiMate modelling tool. As seen in Figure 9, the network layer comprises the storage and peer-to-peer network employed within the DLT platform. Next, the transaction layer is responsible for validating transactions initiated by the smart contracts invoked by collaborating enterprises. It also involves mining process (Dewan and Singh 2020). Then, the distributed ledger layer comprises of the DLT governance category employed to administer the usage and access of the DLT as either private or public. Then, the trust layer consists of incentive mechanism and consensus mechanism that can be used for validating transaction in the network. The application layer comprises of decentralised applications deployed by DLTs such as smart contracts, etc. to support enterprise business operations towards smart digital transition (Jnr et al. 2021a, 2021b). In this study, the enterprise layer is included as this layer captures all stakeholders involved in the adoption of DLT as seen in Figure 8. Finallytly, the security layer captures possible security attacks that can be employed to exploit the DLT platform as seen in Figures 9 and 10.

The possible security attacks in the DLT network are shown in Figure 10.

Figure 10 depicts possible DLT security attack in collaborative enterprises. Each of which are discussed below;

4.4.1. Patch file forgery attack

A patch file forgery attack is a technique of attacking a precise device within the network via the patch file itself or through a connected router (Lee et al. 2020). In DLT platforms, if a patch is deployed to a network device through an altered patch file, it can result to data deletion, permission change, device malfunction and eavesdropping (Fachrunnisa and Hussain 2020). Thus, there is need for existing DLT platforms to ensure that the integrity of centrally distributed patches for batch updates of connected devices are enforced to upload the security and management of the DLT network (Lee et al. 2020).

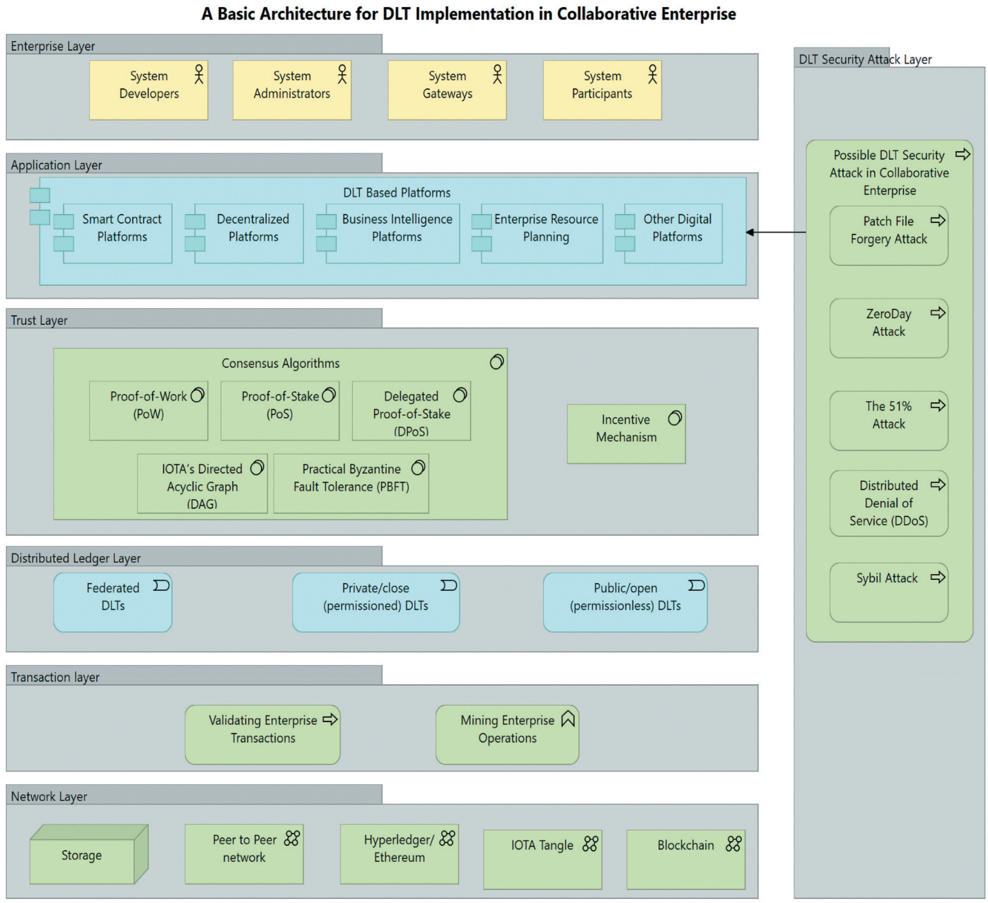

Figure 9. A basic architecture showing possible security attacks in the DLT network.

4.4.2. ZeroDay attack

This is a method that attacks the DLT infrastructure due to the unavailability of required patch needed to address known software vulnerability. Due to lack of possible countermeasures against such software vulnerabilities, such security attacks cannot be prevented, and any network device within the nodes can be compromised. Therefore, there is need to provide periodic security updates, blocks, blacklists and whitelists attacks via real-time monitoring of all changes (Lee et al. 2020).

4.4.3. Sybil Attacks

A Sybil attack is a type of attack in which a malicious user or attacker disguises malfeasance or gains access by generating numerous false identities to increase control over the DLT network. This can be an intentional or wilful action with the intent to harm the DLT infrastructure (Rauchs et al. 2018). Hence, since identity is an exogenous property, the DLT platform by itself cannot avert such malicious attacks. It will depend on the involvement of an outside agent such as a Sybil-resistance mechanism or a credentialing authority or such as POW or PoS to mitigate these attacks. Another notable technique for

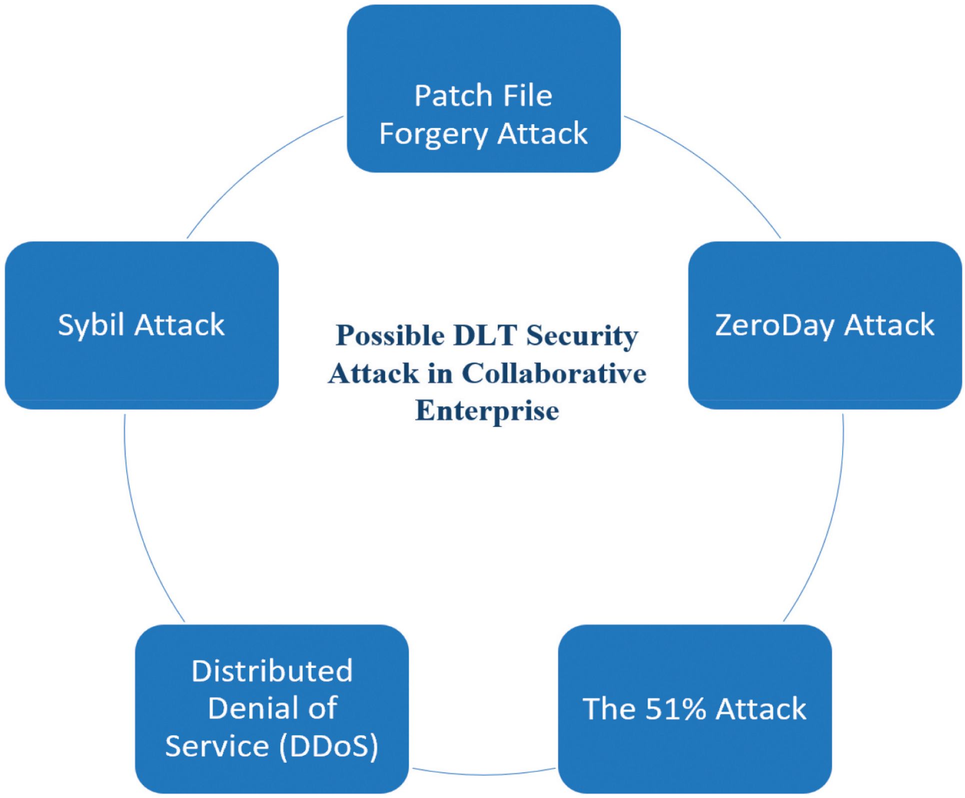

Figure 10. Possible DLT security attack in CE.

preventing Sybil attacks is to incorporate the consensus algorithm for public or permissionless DLT platforms (Ølnes, Ubacht, and Janssen 2017). PoW and PoS makeit computationally challenging resulting to time-consuming and costly to generate new records (Rauchs et al. 2018). Although permissioned or public DLT platforms do not require this prevention as these systems carefully vet all entities before granting them permission to join the node network and generate records.

4.4.4. The 51% Attack

This is an attack in which an attacker or malicious user group with a majority of computing power or votes in a DLT platform generates records faster within the network other than the rest of the nodes. Ultimately, these records are included to the network, resulting to the records of honest or legit nodes to be substituted based on the conflict resolution rule (Lee et al. 2020). The 51% attack is a typical attack against DLT platforms and PoW-based platforms are mostly vulnerable to these attacks (Rauchs et al. 2018). In the 51% attack, an attacker manipulates and store forged transaction data after gaining control of more than 50% of the hash nodes of the entire network nodes (Lee et al. 2020), forcing other blocks to use a distributed ledger that contains forged data (Ølnes, Ubacht, and Janssen 2017).

4.4.5. Distributed Denial of Service (DDoS)

DDoS is an attack that results in the disruption of services provided by a server by flooding the server with traffic from compromised network devices. If such attack occurs within the DLT platform the integrity and authentication services are interrupted (Lee et al. 2020). DDoS attacks can be prevented by not using loops within the DLT source code such as If/While/for in basic data request. Another method to prevent DDoS traffic is by employing the resource consumption limit of DLT, so that a malicious user cannot sent request within the network indefinitely. Although, DDoS attacks on the entire DLT network are impossible on all nodes at once (Lee et al. 2020).

4.5. Model and proposition development

Recently, DLTs has received substantial attention in enterprises. This is because, DLTs possesses the potential to support enterprise initiative (Lee, Azamfar, and Singh 2019). While DLTs such as cryptocurrencies are already adopted by individual users and several enterprises and the full impact of DLTs has yet to achieved due to several factors that inhibit its wide adoption. This subsection presents the factors that inhibit DLT adoption in collaborative enterprise which are categorised into organisational, economic, technological, informational and strategic as suggested by (Ølnes, Ubacht, and Janssen 2017). The identified factors and developed propositions are presented below;

4.5.1. Organisational factors

4.5.1.1. Organisational Mindset. This factor relates to how individuals and organisations are willing to change their norms to recognise the opportunities of the disruptive technologies such as DLTs and ultimately change from prior enterprise paradigms. Findings from the literature (Zamani and Giaglis 2018) highlight those enterprises are often slow to change from prior business process for anxiety of losing their competitive edge. Hence, the more radical the technological innovation, the most difficult it is for businesses to adopt due to the possibility of requiring new skills, new knowledge and competencies. Therefore, in adopting DLT, collaborative enterprises need to be more flexible (Zamani and Giaglis 2018).

4.5.1.2. Infrastructural Limitations. The infrastructural setbacks relate to lack effective standards, regulation, distributors, processes and markets needed to make the disruptive innovation into a fully marketed product (Zamani and Giaglis 2018). In a collaborative enterprise, the adoption of DLT is almost by definition not a single organisation's decision (Venkatesh et al. 2020). Hence, it requires all enterprises in the businesses network to decide to collaborate on which DLT infrastructure is to be deployed. Moreover, inadequate interoperable infrastructure to support the seamless adoption of DLT across cross-organisational setting is a barrier to adoption of DLT (Zamani and Giaglis 2018).

4.5.1.3. Lack of Trust. One of the characteristics of DLTs is their 'Trustless' which is due to their decentralised consensus method as they do not need a third-party trusted central authority to verify transactions (Lacity 2018; Scuri et al. 2019). Decentralisation is one of the foundations of DLT, which aids fast transactions at reduced costs. Nonetheless, several researchers stated that this may also raise serious trust issues among partners. Thus, most enterprises are apprehensive to adopt DLTs due to lack of trust among partners (Scuri et al. 2019).

Based on the proceeding discussion, the following proposition is made:

P1. The organisational factors will positive inhibit DLT adoption in collaborative enterprise.

4.5.2. Economic factors

4.5.2.1. Incurred cost. The adoption of DLT will require enterprise to investment in this disruptive technology (Serrano-Calle and Delarue 2018), and DLT platforms are seen by many industries as being relatively immature. This results to doubts for enterprise as regards to cost benefit trade-offs and the adoption of DLT for business process (Rauchs et al. 2018).

4.5.2.2. Incurred Risk. Digitalisation has introduced uncertainty the adoption of DLT platforms requires the use of new applications formerly unknown. Such ambiguity creates risks for collaborative enterprise as businesses need to provide financial and human resources to support the adoption of DLTs to promote their business goals. In this respect, DLT presents quite a challenge for enterprises to support seamless integration of legacy system with digital platforms within the enterprises pre-existing structures (Zamani and Giaglis 2018).

4.5.2.3. Inadequate foresight. Lack of creativity is a significant inhibitor that mitigates against the capitalising and use of disruptive innovations. This relates to collaborative enterprises less prepared to or being unable to support novel ideas which radically prevent the creation of innovative services and products. Thus, the foresight is the ability of enterprises to predict what innovations may create new market opportunities (Zamani and Giaglis 2018).

Based on the above, the following proposition is stated:

P2. The economic factors will positive inhibit DLT adoption in collaborative enterprise.

4.5.3. Technological Factors

4.5.3.1. Lack of Interoperability Standards. The number of DLT based platforms which are increasing at a fast pace is creating an enormous number of heterogeneous solutions which has also resulted to interoperability issues, which hinders standardisation (Casino, Dasaklis, and Patsakis 2019). Thus, one of the main setbacks that impacts the adoption of DLTs is the issue of interoperability. Systems deployed for DLT implementation cannot seamlessly communicate to external systems, and it is challenging to send data from a DLT network to an external data source (Atlam and Wills 2019; Hrga, Capuder, and Žarko 2020). Thus, the lack of interoperability standards between collaborative enterprise legacy systems and DLT platforms both at an organisational and technical level (Chatterjee, Parmar, and Pitroda 2019). Findings from a recent study (Hrga, Capuder, and Žarko 2020) advocated for the use of trusted decentralised or centralised services, such as ChainLink or Oraclize which can periodically send data to and across the DLT platform. Another study by Anthony Jnr et al. (2020) suggested the use of APIs to support interoperability of digital systems. But as pointed by Casino, Dasaklis, and Patsakis (2019), the APIs provided by cryptocurrencies are considered not easy to use.

4.5.3.2. Security Issues. In general, confidentiality and cyber-attacks are still an issue for DLTs such as blockchains since data are stored as a public ledger. Several encryption-based or anonymisation mechanisms can be employed to ensure data confidentiality (Casino, Dasaklis, and Patsakis 2019; Zuo 2020). Security attacks as discussed in section 4.4 such as 51% attacks, Sybil attacks, etc. can be employed to exploit DLT system and this impacts CE's adoption of DLTs. Allocating access and administrative rights across several nodes may present a security threat, where if one node is breached the whole network will be in danger (Atlam and Wills 2019).

4.5.3.3. Reduced latency and scalability. Presently DLTs are faced with scalability issues in terms of transaction speed and volume. Existing distributed ledgers have restricted transaction speed and block size for verification. This constrains to address this issue could result to increased expenses for enterprises. Similarly, with increasing number of transactions when enterprise coordinate in providing services the latency is affected as the ledger grows rapidly in size which results to slower transaction time. Also, as new users are added', the participating nodes in the network adds more latency and the latency logarithmically increases. Consequently, DLTs are less competent to scale to process the increased transactions (Atlam and Wills 2019). Thus, may significantly impact CE`s adoption of DLTs.

Based on the aforementioned discussion, the following proposition is stated:

P3. The technological factors will positive inhibit DLT adoption in collaborative enterprise.

4.5.4. Informational factors

4.5.4.1. Data privacy issue. A potential barrier for CEs in adopting DLT is the pseudo-anonymity of nodes which may result to privacy issues (Scuri et al. 2019) as DLT is built based on sharing data about various transactions among all participating nodes within the network. Thus, private or sensitive data such as organisations data will be visible for all participating partners or nodes in the network (Atlam and Wills 2019). Hence, enterprises and individuals are now concerned about the traceability of enterprise transactions and operations implemented across the network. Current actions, such as the utilisation of pseudonyms, are not sufficient to ensure transactional privacy as there are de-anonymisation methods which evaluates transactional graph patterns of cryptocurrencies (Casino, Dasaklis, and Patsakis 2019).

Moreover, the GDPR which give entities certain rights to request for their personal data to be erased can hardly be adhered to in DLTs such as in Ethereum (Serrano-Calle and Delarue 2018; Chatterjee, Parmar, and Pitroda 2019; Kuperberg 2019). This may significantly impact the adoption of DLTs in CE. Therefore, to guarantee the privacy and protect the confidentiality of sensitive data, it is essential for those only authorised partners are granted access to sensitive data stored on distributed ledger (Atlam and Wills 2019). Data minimisation can also be employed to promote data confidentiality and sensitive data can also be encrypted to further limit access to only authorised parties (Ribitzky et al. 2018).

4.5.4.2. Difficulty in data migration. Currently, the migration of data from legacy database to distributed ledger is done via manual process as no automated tools or frameworks exist. Also, if enterprise intends to use both DLT based platforms and legacy systems the simultaneous data search and management to retrieve data from legacy and DLT platform concurrently is quite difficult. Thus, enterprise needs to deploy well defined pre-migration and post-migration plans, tools and mechanisms as such this may dissuade CE from adopting DLTs (Chatterjee, Parmar, and Pitroda 2019).

4.5.4.3. Complexity and inadequate information. The technologically nature of DLTs makes their adoption a bit difficult to understand by non-technologically oriented partners as their operation differ from conventional programming environments (Casino, Dasaklis, and Patsakis 2019). Results from Scuri et al. (2019) revealed that DLT are perceived as very technical and not easy to adopt for non-specialists. Findings from the literature also suggest that lack of knowledge on DLTs such as cryptocurrencies made some enterprise to be sceptic about blockchain (Scuri et al. 2019). Also, lack of understanding and/or information is another aspect which discourages the use of DLTs. As reported by Scuri et al. (2019), inadequate understanding of DLTs could significantly impact enterprise trust DLT platforms.

Based on these arguments, the following proposition is made:

P4. The informational factors will positively inhibit DLT adoption in collaborative enterprise.

4.5.5. Strategic factors

4.5.5.1. Governance structure. Regarding GDPR data accountability and ownership are predominant issues faced when collaborative enterprise adopt DLTs as data are written by various partners. Hence, governance is not easy (Chatterjee, Parmar, and Pitroda 2019). This is evident as DLTs platforms are developed with only limited accountability for public user. As the minority (experts and administrators) who design the DLT platforms dictate the rules in which the system adoption is governed (Ølnes, Ubacht, and Janssen 2017). Therefore, in DLT whether permissioned or permissionless, it is unclear who and how the governance arrangements are institutionalised within the alliance. Although, the existence of administrator in permissioned or private DLT can be subjected to explicit governance that administer the adoption and nature of DLT (Atlam and Wills 2019). Thus, governance factor may influence the adoption of DLTs among CE.

4.5.5.2. Current Maturity State. DLT is still in the initial stage of evolution and there are concerns about the resilience and robustness as regards to widespread adoption of this technology within CE especially for managing huge number of transactions. Besides, there is a lack of understanding regarding the adoption of DLTs in log run in relation to its market potential (Atlam and Wills 2019). Although evidence from the literature as seen in section 4.2.1 suggests that huge organisations like Microsoft Azure, IBM, Amazon, Hewlett Packard, Oracle, etc. have started adopting DLT based products and services which can create the necessary confidence and trust in DLT highlighting its huge adoption in various applications (Atlam and Wills 2019).

Hence, based on the above, the following proposition is stated:

P5. The strategic factors will positive inhibit DLT adoption in collaborative enterprise.

A model is proposed as seen in Figure 11 to present factors that inhibit DLT adoption in collaborative enterprise.

5. Discussions

Digital technologies are presently transforming several industries, and DLTs are one of these technologies which is contributing to drive innovation and improve enterprise ecosystem (Giraldo 2018; Troncia et al. 2019). But the adoption of DLTs requires that enterprises employ new approaches of conducting business and in doing so, they may consider leaving old successful paradigms and implementing new competencies (Zamani and Giaglis 2018). It is required that enterprises develop an understanding of the factors that impacts DLT's adoption for smart digital transformation. Despite several research to address the technical, social, and strategic aspects related to the adoption of DLT.

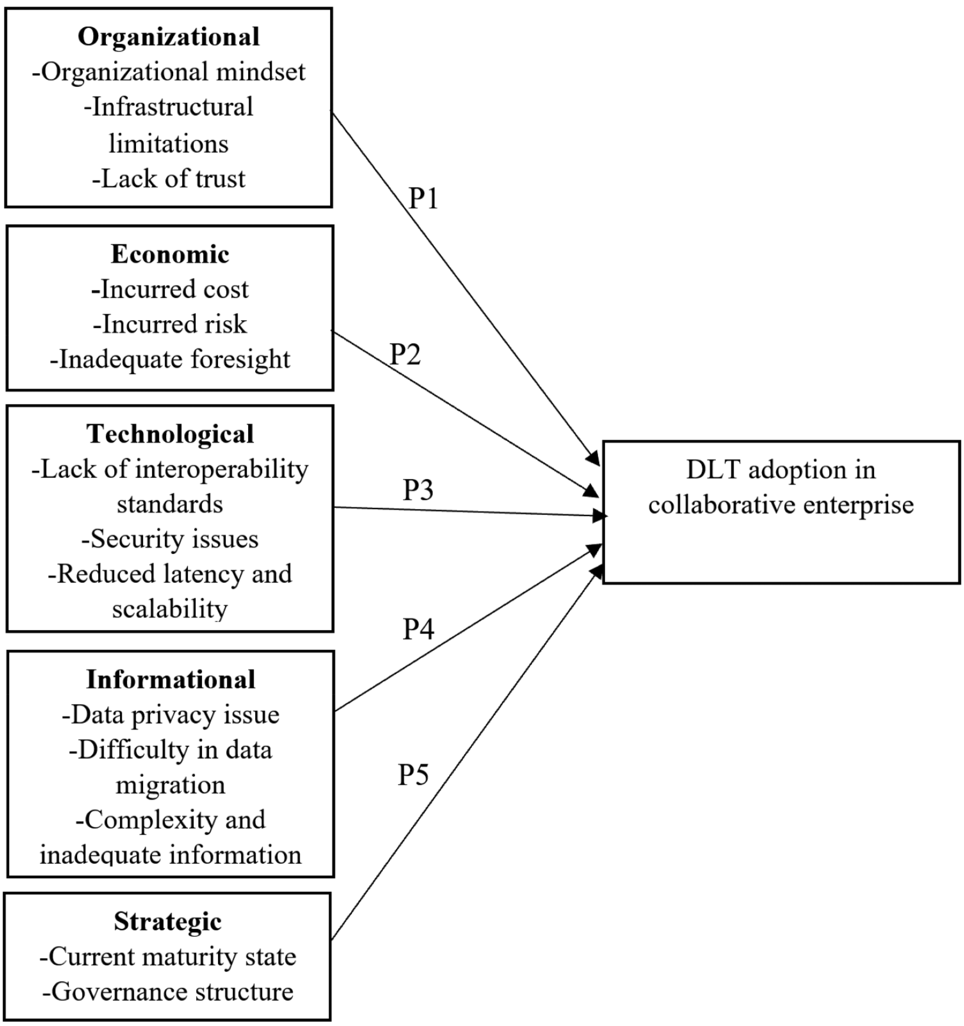

Figure 11. Proposed model.

Research related to DLT adoption in collaborative enterprise is still minimal. Therefore, this study attempts to fill this gap by employing a systematic review to investigate the adoption of distributed ledger and decentralised technology towards smart digital transition in collaborative enterprise. Accordingly, a model is proposed based on identified organisational, economic, technological, informational and strategic factors that inhibit DLT adoption in collaborative enterprise.

This article enriches our understanding of the adoption of DLT explaining how distributed ledger platform are being adopted in collaborative enterprises. In other words, this research provides practical application of DLTs regarding governance and security which are one of the least researched areas in this domain. This paper also highlighted the main challenges that remain in the way of DLT adoption and offers thoughts and insights for the practical implementation for further development similar to prior study (Xu et al. 2019). Similarly, evidence from Ølnes, Ubacht, and Janssen (2017); Scuri et al. (2019) highlighted that due to digitalisation DLTs has emerged as a potentially disruptive, all-purpose technology for collaborative enterprise to support exchange of data and transactions that require trust and authentication. Findings from Scuri et al. (2019) suggested that DLTs confirm accurate records of transactions within enterprises. As pointed by Casino, Dasaklis, and Patsakis (2019), findings from IBM indicated that almost 1000 (about 33%) of C-suite managers affirmed that they are considering or have previously adopted DLTs such as blockchains.

Additionally, findings from Serrano-Calle and Delarue (2018) suggested that distributed ledger platforms can be seen as enablers for the creation of new methods of interaction among stakeholders and the way they produce and consume data. Giraldo (2018) argued that DLTs can provide better availability, integrity and confidentiality of enterprise transactions as compared to traditional database systems by consolidating data located inside the boundaries of collaborative enterprise. Giraldo (2018) mentioned that DLTs can potentially contribute to decreasing inadequacies and promoting economic inclusion in developing economies by being adopted as a payment mechanism, as a consistent communication means and as a means for merging data located within different platforms. This is because DLT platforms are ideally scalable, secure, and decentralised (Hrga, Capuder, and Žarko 2020). Accordingly, DLT is an innovative, multipurpose technology, which offers new means for enterprises to store data. It is a form of distributed computing in which the governance of data or records are democratised by employing consensus mechanisms allows transaction to happen (Ølnes, Ubacht, and Janssen 2017). Presently, there are evidence from cases of DLT adoption in several domains such as smart cities, fintech, healthcare, e-government, education, etc. This study advocates that DLTs also offers potential benefits in collaborative enterprise domain.

6. Implications of study

6.1. Theoretical implications

DLTs are gaining widespread use in enterprise environments (Kuperberg 2019). Explicitly, DLT platforms promise a significant business value, with transacting directly among enterprises, settling transactions cheaply and quickly, removing the need for settlements, providing data provenance, instantly tracing and tracking assets (Lacity 2018). As an evolving disruptive technology, DLTs has incomparable advantages including authenticity, transparency, security and trust. This study provides valuable insights to enterprise information systems practitioners. It identifies various stakeholders that adopts DLTs in collaborative enterprisesthat will be useful for researchers and academics as a foundation upon which other theories can developed.

Theoretically, the proposed model provides a novel business model that can help enterprises to transform how they capture, create and share value generated from data. Hence, findings from this study provides a direction for governing the adoption of DLTs platforms by presenting all possible stakeholders to establish a smart enterprise transition. Therefore, this article opens up a new avenue for enterprise information system research thus, providing decision support for the selection of a suitable DLT application for viable enterprise operation. This study also contributes to research by synthesising existing approaches and presenting an extensive characteristic of DLT. Thus, findings from this review study can serve as a foundation for research on DLTs adoption in collaborative enterprise.

6.2. Practical implications

DLT can be utilised for change in ownership and storage of important data such as business licences, certificates, registries organisational decisions and regulation. DLTs has proven to be an efficient technology, as it offers an eco-system for consensus in a decentralised and complete transparency and immutability of data (Dewan and Singh 2020). Typically, DLT has the potential to improved discoverability of audit trials, enable reduced complexity and costs, and enhances trusted recordkeeping (Ølnes, Ubacht, and Janssen 2017). The deployment of blockchain technology will serve to reduce the overall turnaround time of audits because processes of information gathering will be more streamlined and transparent.

Furthermore, the deployment of DLTs significantly improves intra and inter-departmental collaboration as it aids the integration among several departments, which will significantly decrease conflicts within collaborative enterprises. It offers a high level of security to sensitive data, including corrective action plans and audit feedback. The practical implications of the research relate to the identification of DLTs as an enabling technology for distributed and decentralised enterprise operations by providing more insight on how cross-enterprise alliance can be improved using DLT.

6.3. Managerial and policy implications

Specifically, DLTs such as blockchain, cryptocurrencies, etc. have become buzzwords that are in several cases are used for public relation and marketing purposes (Rauchs et al. 2018). Thus, this article provides an overview and types of DLTs platforms employed in collaborative enterprises. It further presented a model and propositions that provides enterprise managers and decision makers with a clear picture of the governance, security and stakeholders involved in DLT platforms. The model provides a general understanding of the DLTs for enterprises, developers and researchers seeking to develop DLT based in-house systems. The model can be employed as a guide to the different actors interested to develop new DLT systems. For IT managers looking to how they can improve the adoption of DLT in their enterprises, the model can be utilised as a yardstick to understand the organisational, economic, technological, informational and strategic dimensions that influence the adoption of DLTs. Importantly, the identified factors will help decision makers to make informed decisions and tradeoff capable of meeting their enterprise goals.

7. Conclusion, limitation and future works

Digitalisation relating to DLTs in enterprises has received much attention by recent literature. However, there is a lack of academic research that investigated DLT adoption in collaborative enterprise domain. Therefore, this study aims at filling that gap. First, this study provides the characteristics and application of DLT in collaborative enterprise. Furthermore, this study identifies types of DLTs adopted in collaborative enterprise. Next findings from this study examines the governance, stakeholders and DLT security attacks and mitigation strategies in collaborative enterprises. Finally, the factors that inhibit DLT adoption in collaborative enterprise were investigated, and a model and propositions were further proposed thereby extending the body of knowledge concerning DLTs. Distributed ledger technologies are enabling innovative business models and concepts in several enterprise sectors. DLT can facilitating connectivity among enterprise partners and minimise intermediaries within collaborative process serving as a tool to achieve standardised communication channel between collaborative enterprises.

DLT can also be employed to transfer data and allocate resources between different systems, enabling distributed ledger as a service. DLT adoption in enterprise will introduce efficiency, speed, traceability and increase efficiency for data access. There are several directions for future studies. As this current study is based primarily on secondary data from the literature and the proposed model has not been empirical validated. Longitudinal data from case study or survey are recommended to provide practical insights into the adoption dynamics. Moreover, it would be interesting to examine how the adoption of DLT in CEs influences sustainability goals of enterprises and governance implications of its adoption to deepen the research community`s understanding on DLTs adoption. Finally, future research could focus on the more technical features and processes implemented for DLTs adoption within a particular domain. For example, developing an enterprise architecture case scenario of DLT implementation in addressing real world issues in enterprises. Also, the proposed model could be a first step towards more data-driven case developments.

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References

Ahi, A., and A. V. Singh (2019). "Role of Distributed Ledger Technology (DLT) to Enhance Resiliency in Internet of Things (Iot) Ecosystem." *Amity International Conference on Artificial Intelligence (AICAI)*, 782–786, Dubai.

Anthony Jnr, B. 2021a. "Exploring Data Driven Initiatives for Smart City Development: Empirical Evidence from Techno-stakeholders' Perspective." *Urban Research & Practice* 1–32. doi:10.1080/17535069.2020.1869816.

Anthony Jnr, B. 2021b. "Integrating Electric Vehicles to Achieve Sustainable Energy as a Service Business Model in Smart Cities." *Frontiers in Sustainable Cities* 3: 685716. doi:10.3389/frsc.2021.685716.

Anthony Jnr, B., S. Abbas Petersen, D. Ahlers, and J. Krogstie. 2020. "API Deployment for Big Data Management Towards Sustainable Energy Prosumption in Smart Cities-a Layered Architecture Perspective." *International Journal of Sustainable Energy* 39 (3): 263–289. doi:10.1080/14786451.2019.1684287.

Arslan, S. S., R. Jurdak, J. Jelitto, and B. Krishnamachari. 2020. "Advancements in Distributed Ledger Technology for Internet of Things." *Internet of Things* 9 (1): 100114. doi:10.1016/j.iot.2019.100114.

Atlam, H. F., and G. B. Wills. 2019. "Intersections between IoT and Distributed Ledger." In *Advances in Computers*. Vol. 115, 73–113. Elsevier.

Casino, F., T. K. Dasaklis, and C. Patsakis. 2019. "A Systematic Literature Review of Blockchain-based Applications: Current Status, Classification and Open Issues." *Telematics and Informatics* 36: 55–81.

Centobelli, P., R. Cerchione, E. Esposito, and E. Oropallo. 2021. "Surfing Blockchain Wave, or Drowning? Shaping the Future of Distributed Ledgers and Decentralized Technologies." *Technological Forecasting and Social Change* 165: 120463. doi:10.1016/j.techfore.2020.120463.

Chatterjee, A., M. Parmar, and Y. Pitroda (2019). "Production Challenges of Distributed Ledger Technology (DLT) Based Enterprise Applications." *International Symposium on Systems Engineering (ISSE)*, pp. 1–7, Edinburgh, Scotland, UK.

Demirkan, S., I. Demirkan, and A. McKee. 2020. "Blockchain Technology in the Future of Business Cyber Security and Accounting." *Journal of Management Analytics* 7 (2): 189–208. doi:10.1080/23270012.2020.1731721.

Dewan, S., and L. Singh. 2020. "Use of Blockchain in Designing Smart City." *Smart and Sustainable Built Environment* 9 (4): 695–709. doi:10.1108/SASBE-06-2019-0078.

Dobler, M., M. Ballandies, and V. Holzwarth (2019). "On the Extension of Digital Ecosystems for SCM and Customs with Distributed Ledger Technologies: Requirements Analysis, Innovation Assessment, and Prototype Design for the Lake Constance Region." *IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, pp. 1–8, Valbonne Sophia-Antipolis, France.

Erdenebold, T., J. J. Rho, and Y. M. Hwang. 2019. “Blockchain Reference Model and Use Case for Supply Chains within Enterprise Architecture.” *Journal of Information Technology and Architecture* 16 (1): 1–10.

Esposito, C., M. Ficco, and B. B. Gupta. 2021. “Blockchain-based Authentication and Authorization for Smart City Applications.” *Information Processing & Management* 58 (2): 102468. doi:10.1016/j.ipm.2020.102468.

Fachrunnisa, O., and F. K. Hussain. 2020. “Blockchain-based Human Resource Management Practices for Mitigating Skills and Competencies Gap in Workforce.” *International Journal of Engineering Business Management* 12: 1–11. doi:10.1177/1847979020966400.

Ferraro, P., C. King, and R. Shorten. 2018. “Distributed Ledger Technology for Smart Cities, the Sharing Economy, and Social Compliance.” *IEEE Access* 6: 62728–62746. doi:10.1109/ACCESS.2018.2876766.

Giraldo, J. (2018). “X-border Platforms: The Implications of Distributed Ledger Technology.” *Twenty-Sixth European Conference on Information Systems (ECIS2018)*, Portsmouth, UK.

Gräbe, F., N. Kannengießer, S. Lins, and A. Sunyaev (2020). “Do Not Be Fooled: Toward a Holistic Comparison of Distributed Ledger Technology Designs.” In *Proceedings of the 53rd Hawaii International Conference on System Sciences*. pp. 1–10, Maui, Hawaii, USA.

Grover, P., A. K. Kar, M. Janssen, and P. V. Ilavarasan. 2019. “Perceived Usefulness, Ease of Use and User Acceptance of Blockchain Technology for Digital Transactions–insights from User-generated Content on Twitter.” *Enterprise Information Systems* 13 (6): 771–800. doi:10.1080/17517575.2019.1599446.

Gupta, B. B., K. C. Li, V. C. Leung, K. E. Psannis, and S. Yamaguchi. 2021. “Blockchain-Assisted Secure Fine-Grained Searchable Encryption for a Cloud-Based Healthcare Cyber-Physical System.” *IEEE/CAA Journal of Automatica Sinica*. doi:10.1109/JAS.2021.1004003.

Helo, P., and A. H. M. Shamsuzzoha. 2020. “Real-time Supply chain—A Blockchain Architecture for Project Deliveries.” *Robotics and Computer-Integrated Manufacturing* 63: 101909. doi:10.1016/j.rcim.2019.101909.

Howell, B. E., P. H. Potgieter, and B. M. Sadowski (2019). “Governance of Blockchain and Distributed Ledger Technology Projects.” *Available at SSRN 3365519*, 1–24.

Hrga, A., T. Capuder, and I. P. Žarko. 2020. “Demystifying Distributed Ledger Technologies: Limits, Challenges, and Potentials in the Energy Sector.” *IEEE Access* 8: 126149–126163. doi:10.1109/ACCESS.2020.3007935.

Jnr, A. 2021. “Managing Digital Transformation of Smart Cities through Enterprise Architecture–a Review and Research Agenda.” *Enterprise Information Systems* 15 (3): 299–331. doi:10.1080/17517575.2020.1812006.

Jnr, A., and A. Petersen. 2021. “Examining the Digitalisation of Virtual Enterprises Amidst the COVID-19 Pandemic: A Systematic and Meta-analysis.” *Enterprise Information Systems* 15 (5): 617–650. doi:10.1080/17517575.2020.1829075.

Jnr, B. A. 2020a. “Examining the Role of Green IT/IS Innovation in Collaborative Enterprise-implications in an Emerging Economy.” *Technology in Society* 62: 101301. doi:10.1016/j.techsoc.2020.101301.

Jnr, B. A. 2020b. “A Holistic Study on Green IT/IS Practices in ICT Departments of Collaborative Enterprise: A Managerial and Practitioners Perspective.” *International Journal of Social Ecology and Sustainable Development (IJSESD)* 11 (2): 1–26. doi:10.4018/IJSESD.2020040101.

Jnr, B. A., M. A. Majid, and A. Romli. 2020. “A Generic Study on Green IT/IS Practice Development in Collaborative Enterprise: Insights from A Developing Country.” *Journal of Engineering and Technology Management* 55: 101555.

Jnr, B. A., S. A. Petersen, M. Helfert, D. Ahlers, and J. Krogstie. 2021b. “Modeling Pervasive Platforms and Digital Services for Smart Urban Transformation Using an Enterprise Architecture Framework.” *Information Technology & People* 34 (4): 1285–1312. doi:10.1108/ITP-07-2020-0511.

Jnr, B. A., S. A. Petersen, M. Helfert, and H. Guo. 2021a. “Digital Transformation with Enterprise Architecture for Smarter Cities: A Qualitative Research Approach.” *Digital Policy, Regulation and Governance*. doi:10.1108/DPRG-04-2020-0044.

Kaczmarczyk, A., and M. Sitarska-Buba. 2020. "Enterprise Architecture of the Blockchain Platform." *Journal of Internet and e-Business Studies* 212848: 1–12. doi:10.5171/2020.212848.
Kuperberg, M. 2019. "Blockchain-based Identity Management: A Survey from the Enterprise and Ecosystem Perspective." *IEEE Transactions on Engineering Management* 67 (4): 1008–1027. doi:10.1109/TEM.2019.2926471.
Lacity, M. C. 2018. "Addressing Key Challenges to Making Enterprise Blockchain Applications a Reality." *MIS Quarterly Executive* 17 (3): 201–222.
Lee, J., M. Azamfar, and J. Singh. 2019. "A Blockchain Enabled Cyber-Physical System Architecture for Industry 4.0 Manufacturing Systems." *Manufacturing Letters* 20: 34–39. doi:10.1016/j.mfglet.2019.05.003.
Lee, Y., S. Rathore, J. H. Park, and J. H. Park. 2020. "A Blockchain-based Smart Home Gateway Architecture for Preventing Data Forgery." *Human-centric Computing and Information Sciences* 10 (1): 1–14. doi:10.1186/s13673-020-0214-5.
Li, Z., X. Liu, W. M. Wang, A. Vatankhah Barenji, and G. Q. Huang. 2019. "CKshare: Secured Cloud-based Knowledge-sharing Blockchain for Injection Mold Redesign." *Enterprise Information Systems* 13 (1): 1–33. doi:10.1080/17517575.2018.1539774.
Liu, X., B. Farahani, and F. Firouzi. 2020. "Distributed Ledger Technology." In *Intelligent Internet of Things*, edited by Firouzi F., Chakrabarty K., Nassif S, 393–431. Cham: Springer.
Mattke, J., A. Hund, C. Maier, and T. Weitzel. 2019. "How an Enterprise Blockchain Application in the US Pharmaceuticals Supply Chain Is Saving Lives." *MIS Quarterly Executive* 18 (4): 246–261. doi:10.17705/2msqe.00019.
Mohan, A. P., A. Gladston, and A. Gladston. 2020. "Merkle Tree and Blockchain-Based Cloud Data Auditing." *International Journal of Cloud Applications and Computing (IJCAC)* 10 (3): 54–66. doi:10.4018/IJCAC.2020070103.
Morelli, U., S. Ranise, D. Sartori, G. Sciarretta, and A. Tomasi. 2019. "Audit-based Access Control with a Distributed Ledger: Applications to Healthcare Organizations." In *International Workshop on Security and Trust Management*, edited by Mauw S., Conti M., 19–35. Cham: Springer.
Nguyen, G. N., N. H. Le Viet, M. Elhoseny, K. Shankar, B. B. Gupta, and A. A. Abd El-Latif. 2021. "Secure Blockchain Enabled Cyber–physical Systems in Healthcare Using Deep Belief Network with ResNet Model." *Journal of Parallel and Distributed Computing* 153: 150–160. doi:10.1016/j.jpdc.2021.03.011.
Oktian, Y. E., S. G. Lee, and H. J. Lee. 2020. "Hierarchical Multi-blockchain Architecture for Scalable Internet of Things Environment." *Electronics* 9 (6): 1050. doi:10.3390/electronics9061050.
Ølnes, S., J. Ubacht, and M. Janssen. 2017. "Blockchain in Government: Benefits and Implications of Distributed Ledger Technology for Information Sharing." *Government Information Quarterly* 34 (1): 355–364. doi:10.1016/j.giq.2017.09.007.
Poels, G., F. Kaya, M. Verdonck, and J. Gordijn (2019). "Early Identification of Potential Distributed Ledger Technology Business Cases Using E 3 Value Models." In *International Conference on Conceptual Modeling* (pp. 70–80). Springer, Cham.
Rahmadika, S., and K. H. Rhee. 2018. "Blockchain Technology for Providing an Architecture Model of Decentralized Personal Health Information." *International Journal of Engineering Business Management* 10: 1–10. doi:10.1177/1847979018790589.
Rahman, M. S., I. Khalil, P. C. Mahawaga Arachchige, A. Bouras, and X. Yi (2019). "A Novel Architecture for Tamper Proof Electronic Health Record Management System Using Blockchain Wrapper." *Proceedings of the 2019 ACM International Symposium on Blockchain and Secure Critical Infrastructure*, Auckland New Zealand, 97–105.
Rauchs, M., A. Glidden, B. Gordon, G. C. Pieters, M. Recanatini, F. Rostand, and B. Z. Zhang. 2018. *Distributed Ledger Technology Systems: A Conceptual Framework*, 1–103. Cambridge UK: Cambridge Centre for Alternative Finance.
Red, V. A. 2017. "Practical Comparison of Distributed Ledger Technologies for IoT." *Disruptive Technologies in Sensors and Sensor Systems* 10206: 102060G.
Ribitzky, R., J. S. Clair, D. I. Houlding, C. T. McFarlane, B. Ahier, M. Gould, … K. A. Clauson. 2018. "Pragmatic, Interdisciplinary Perspectives on Blockchain and Distributed Ledger Technology: Paving the Future for Healthcare." *Blockchain Healthc Today* 1: 1–24.

Rückeshäuser, N. (2017). "Typology of Distributed Ledger Based Business Models." *Proceedings of the 25th European Conference on Information Systems (ECIS)*, Guimarães, Portugal, 2202–2217.
Scuri, S., G. Tasheva, L. Barros, and N. J. Nunes (2019). "An HCI Perspective on Distributed Ledger Technologies for Peer-to-Peer Energy Trading." In *IFIP Conference on Human-Computer Interaction* (pp. 91–111). Springer, Cham.
Seebacher, S., and M. Maleshkova (2018). "A Model-driven Approach for the Description of Blockchain Business Networks." In *Proceedings of the 51st Hawaii International Conference on System Sciences*, Waikoloa Village, Hawaii, pp. 3487–3496.
Seok, B., J. Park, and J. H. Park. 2019. "A Lightweight Hash-based Blockchain Architecture for Industrial IoT." *Applied Sciences* 9 (18): 1–17. doi:10.3390/app9183740.
Serrano-Calle, S., and E. Delarue (2018). "Smart Technologies Applied to the Energy Sector. Renewable Energy Expansion Strengthened by Digital Communications and Distributed Ledger Technologies?" *29th European Regional ITS Conference, Trento*, Italy, pp. 1–17.
Tekeoglu, A., and N. Ahmed (2019). "TangoChain: A Lightweight Distributed Ledger for Internet of Things Devices in Smart Cities." *IEEE International Smart Cities Conference (ISC2)*, Casablanca, Morocco, 18–21.
Teslya, N., and I. Ryabchikov (2017). "Blockchain-based Platform Architecture for Industrial IoT." In *2017 21st Conference of Open Innovations Association (FRUCT)*, Helsinki, Finland, pp. 321–329.
Troncia, M., M. Galici, M. Mureddu, E. Ghiani, and F. Pilo. 2019. "Distributed Ledger Technologies for Peer-to-peer Local Markets in Distribution Networks." *Energies* 12 (17): 3249. doi:10.3390/en12173249.
Tsang, Y. P., C. H. Wu, W. H. Ip, and W. L. Shiau. 2021. "Exploring the Intellectual Cores of the blockchain–Internet of Things (Biot)." *Journal of Enterprise Information Management*. doi:10.1108/JEIM-10-2020-0395.
Venkatesh, V. G., K. Kang, B. Wang, R. Y. Zhong, and A. Zhang. 2020. "System Architecture for Blockchain Based Transparency of Supply Chain Social Sustainability." *Robotics and Computer-Integrated Manufacturing* 63: 101896. doi:10.1016/j.rcim.2019.101896.
Viriyasitavat, W., T. Anuphaptrirong, and D. Hoonsopon. 2019. "When Blockchain Meets Internet of Things: Characteristics, Challenges, and Business Opportunities." *Journal of Industrial Information Integration* 15: 21–28. doi:10.1016/j.jii.2019.05.002.
Wu, H., Z. Li, B. King, Z. Ben Miled, J. Wassick, and J. Tazelaar. 2017. "A Distributed Ledger for Supply Chain Physical Distribution Visibility." *Information* 8 (4): 1–18. doi:10.3390/info8040137.
Xu, Y., P. Ahokangas, S. Yrjölä, and T. Koivumäki. 2019. "The Fifth Archetype of Electricity Market: The Blockchain Marketplace." *Wireless Networks* 27: 4247–4263. doi: 10.1007/s11276-019-02065-9
Zamani, E. D., and G. M. Giaglis. 2018. "With a Little Help from the Miners: Distributed Ledger Technology and Market Disintermediation." *Industrial Management & Data Systems* 118 (3): 637–652. doi:10.1108/IMDS-05-2017-0231.
Zuo, Y. (2020). "Making Smart Manufacturing Smarter–a Survey on Blockchain Technology in Industry 4.0." *Enterprise Information Systems*, 1–31. 10.1080/17517575.2020.1856425