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Blockchain-Powered Value Creation in the 5G and Smart Grid Use Cases

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ABSTRACT Before the implementation of a solution, it is cost-efficient and practical to be able to evaluate and analyze the expected value of use cases. Especially, this is emphasized in blockchain (BC) use cases, which typically have a wide business ecosystem and possibly disruptive business models. This paper presents two BC use case value evaluations and results. The IoT use cases were selected from two different industry segments: telecommunications-oriented 5G network slice brokering and the energy industry-related internal electricity allocation in a housing society. The use case value was assessed by applying a resource configuration framework and 4C – commerce, context, content, and connection – business model typology against BC and smart contracts characteristics and capabilities. The results derived from the data collected from the expert workshops proved the expected value of the use cases, and in general, the feasibility of BC technology for facilitating various value-creating resource configuration processes was shown. Furthermore, the resource configuration framework proved to be a valuable theoretical approach for analyzing and developing also the BC-enabled novel use cases and business models. According to the findings, further development of the framework is proposed with an introduced novel decentralized resource configuration prototype that can replace predominant platform-based business models.

INDEX TERMS Blockchain, business models, decentralization, resource configuration, smart grid, 4C typology, 5G.

I. INTRODUCTION

Novel digital era business models have been transforming and disrupting traditional industries at an unprecedented speed [1]. The telecommunications and energy industries are no exception, and are undergoing a paradigm shift [2], [3]. New 5th generation wireless network technologies (5G) are foreseen to transform industries through wireless services provided at gigabit speeds, millisecond latency, support for wide range of novel applications connecting Internet-of-Things (IoT) devices and objects, and versatility by virtualization enabling innovative business models across multiple vertical sectors [2], [4]. The present connectivity market is characterized by incumbent network operators whose business is structured around service mass provisioning with high advance investments in infrastructure and exclusive long-term licenses granted by regulators [5]. At the same time, in the energy industry, the responsibility for delivering power is being transformed from a centralized production and distribution energy system into a dynamic mode of decentralized operation due to the deployment of IoT-enabled smart meters, the diffusion of renewables and distributed generations and the development of smart energy applications [3].

As a decentralized technology, blockchain (BC) enables completely new technological systems and business models. A vast amount of use case ideas exist that are inspired by the decentralized nature and possibilities of BC. Yet, there are quite few frameworks that are purely targeted for evaluating BC use cases, and take into account the BC system's specific characteristics.

A Crypto 2.0 Lenses evaluation framework [6] is proposed and developed particularly for financial applications. Another often referenced evaluation framework is created by Greenspan [7] introducing an eightfold checklist on what should be considered before BC implementations assessing the feasibility of the use case against the

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key characteristics of BC. Greenspan's technology-focused framework is more general than Crypto 2.0 and can thus be used more widely across industries. The third evaluation framework [8], designed by the Ministry of Economy, Trade and Industry (METI) in Japan, is a detailed assessment which also takes into account the comparability between conventional and BC systems. As they point out, ISO/IEC has created evaluation models to be used within the introduction of a new centralized information technology (IT) system but these cannot be applied to decentralized BC systems, which have several unique tradeoff characteristics. However, despite being a comprehensive comparison between centralized and decentralized systems, METI's framework concentrates on the evaluation of system replacement options and leaves BC-enabled brand new services and drastic business process changes out of the study. In addition to these frameworks, [9] provides valuable insight into consensus mechanism evaluation in the form of a questionnaire.

To better comprehend the value creation potential of BC-based use cases, there is a need for novel, supplementary approaches. We have previously concluded, that for evaluating, analyzing and creating value out of the use case, systemic and business opportunity-centric perspectives can be suitable [10]. Therefore, in this study, two value-creation-oriented, state-of-the-art business model frameworks are used for assessing the value creation potential of the industrial blockchain use cases. The assessments also comprise the surrounding ecosystems, 5G and Smart Grids in this case. These extensions are motivated by the conception that blockchain is primarily an ecosystemic innovation and for finding the whole spectrum of potential sources of value creation the ecosystemic perspective must not be neglected.

The frameworks selected for the study are the resource configuration framework and the 4C typology. The *resource configuration framework* provides a "*system-based, value-creation-centric perspective for designing and organizing a firm's resource configuration*" [11]. The framework facilitates the envisioning and designing of unique combinations of digital, multi-sourced resources and linking them with various needs originating from the ecosystem of multiple stakeholders. The framework is designed with particular emphasis on the value co-creation perspective, i.e., identifying all value co-creators and their diverse needs and resources is accentuated. In turn, the *coherent 4C typology* – commerce, context, content and connection – is developed to structure different types of the Internet-era business models, and analyze how, and to what extent, they create and capture value, and how they should be adapted [12].

To the best of authors' knowledge, both the resource configuration framework and the 4C typology are applied for the first time to two selected blockchain-powered industrial use cases: a telecommunications-oriented 5G network slice brokering use case and an internal electricity allocation in a housing society use case in the energy industry. The first use case enables autonomous 5G network resource brokering, leasing, billing and payout in the BC [13]. Another is a renewable energy-oriented smart grids use case, in which entities within a housing society can balance electricity production and consumption among themselves without the control of an external intermediator [14].

This research extends earlier research [10], which focused on one telecom use case. At this time, the goal is to benefit and create value for the industry more widely by exploring BC-enabled value creation from several aspects. Despite the goal of generality, the aim is to preserve the level of detail via specific use case assessments. The paper specifically seeks to address *how the blockchain technology can facilitate value creation in the context of future telecommunication and energy ecosystems*. Furthermore, the applicability of the business model frameworks, inherently targeted to more conventional centralized settings, in evaluating decentralized BC use cases is discussed, and further development of the resource configuration framework with a novel decentralized prototype is proposed.

The use cases analyzed in the paper were created in workshops coordinated by the Blockchains Boosting Finnish Industry (BOND) [15] research project in 2017. In these future-oriented cross-disciplinary workshops, both the industry and the academic communities were utilized from technology and business perspectives.

This paper is organized as follows. At first, related work is overviewed: research methods, blockchain & smart contracts and utilized theory frameworks. In chapter III, the use cases are presented, and the use cases are evaluated in chapter IV. Feasibility and applicability are analyzed, and a novel decentralized prototype is proposed in chapter V. Finally, conclusions are drawn.

II. RELATED WORK

In this chapter, research methods are presented, blockchain and smart contracts are overviewed, and utilized theoretical frameworks, resource configuration framework [11] and 4C typology [12], introduced.

A. RESEARCH METHODS

The aim of this study was to assess recent blockchain and smart contracts use cases outside the financial technology (FinTech) domain from both business and technology perspectives. In the use case evaluations, special attention was paid to the value creation potential of the use cases and accordingly the business model frameworks that center on value creation processes were chosen as the units of assessment. These frameworks are the resource configuration framework [11], [16] and the 4C typology [12] which are described below in detail. The reason for this kind of dual approach is the ecosystemic nature of blockchain systems which sets new requirements also for the methods used. Thus, to comprehensively determine the various value creation potentials both use case-specific and also wider ecosystem-level evaluations were conducted. The evaluations made during the study along with their motivations are summarized in the following:

1) "Resource configuration prototypes in 5G and energy" (IV A) presents different business models and resource configuration prototypes in 5G and Smart Grid ecosystems and identifies the prototypes for our two BC use cases. This phase can be seen as necessary pre-work for understanding the underlying mechanisms of value creation in the selected domains.
2) "Resource configuration microprocesses" (IV B) reflects how and to what extent the value-creating microprocesses can be found in the BC use cases and also enlightens the limitations of the centralized approach to meet the requirements of the use cases
3) "4C Business Model Typology of Ecosystemic Value Creation" (IV C) deepens the ecosystemic view on 5G and Smart Grid business models and also begins the discussion on how BC can facilitate value creation

The BC use cases analyzed in this study were developed using the qualitative anticipatory action learning (AAL) method [17]–[19]. AAL is a future-oriented, cross-disciplinary, practical deployment-oriented method, utilized in particular to address the management of disruptions in the business environment [20], organizational collaborative learning [21], and in developing future scenarios [22], [23]. The use cases assessed in this research paper were created in scenario workshops coordinated by the BOND project [15] in 2017. In these cross-disciplinary future-workshops, both the technology and business perspective were covered utilizing participants from industry and academia. The adopted AAL workflow consisted of:

1) Preparing a BC use case template based on the Industrial Internet consortium's [24] use case template;
2) Preparing interview and workshop question set for gathering information for the use cases;
3) Use case workshops and interviews in companies;
4) Defining use cases according to workshop results utilizing a BC use case template;
5) Iterative workshop for focusing on the selected use cases, and
6) Analysis of the use cases.

The reliability and validity of the foresight-oriented research, in general, is difficult to manage [19]. The process of developing use cases utilizing cross-disciplinary, cooperative and dialogical approaches, like the AAL method, has been found to be essential in securing the quality of the research [25]. In qualitative research, the reliability and validity can be further addressed via enhanced transparency of the research workflow, and its thorough documentation from raw data to outputs in the form of use cases [26]–[28]. Furthermore, external validity of the research was improved and subjectivity reduced by analyzing two use cases from different industry domains, and by systematically assessing the outcomes based on their suitability and desirability [27].

B. BLOCKCHAIN AND SMART CONTRACTS

BC is a decentralized technology for data management and it was first developed to support Bitcoin cryptocurrency [29]. In Bitcoin, a BC works as a distributed database gathering all transaction data confirmed by participating nodes. Generally, a BC is a public ledger whose content is updated in a decentralized manner thus omitting the need for a centralized third party and increasing the level of data transparency [30]. Because a BC network is a peer-to-peer (P2P) network and no central server or intermediary is in place, some kind of *consensus* mechanism is needed for ensuring the coherency of data between the nodes in a BC. Currently, there are several ways to form consensus and these mechanisms are comprehensively discussed, e.g., in [9], [31], and [32].

Furthermore, in BCs, utilization of *cryptography* enables authoritativeness behind all interactions [33]. For example, digital signatures can be used to verify that the person trying to spend the money actually controls the private key. Overall permissions for different actions: read, write and validation, strongly vary depending on the type of BC. In *permissionless* BCs anyone can participate in all aforementioned actions, but in *permissioned*BCs, or alternatively in *DLTs (distributed ledger technologies)*, the permissions are limited to a set of known and accepted nodes. Permissioned BCs are preferred in use cases where nodes need to be known, e.g., to comply with regulation [34].

Being a maturing technology, several potential BC deployment considerations have been found in research and early trials, particularly in the financial sector. These include throughput, scalability and latency in large public BCs, legal enforceability, transactional confidentiality particularly in the public BCs, consensus mechanism determination and complexity, and integration with legacy systems and workflows [33].

Smart contracts (SC) are self-executing scripts residing on a BC and enabling general-purpose computations to occur on the chain [33]. The SC concept was introduced in 1994 [35] and defined as "*a computerized transaction protocol that executes the terms of a contract*". Every SC possesses a unique address and transactions containing data can be sent to that address to trigger the execution of the SC code. Thereafter, every node in the network independently processes the code [33]. This makes the SCs autonomous and fully predictable, thus having features of software agents. Additionally, the code and the trace of operations of SCs can be freely inspected by all network participants and verifiability of the trace is cryptographically ensured. SCs enable automation of complex multi-step processes and proper, distributed, heavily automated workflows [33]. They have many applications in different domains, enabling, e.g., decentralized applications, like voting, auctions, lottery, escrow systems, crowd funding and micropayments, etc. [34].

Several companies and public organizations/foundations develop BC platforms that are mostly open sourced. The platforms enable fast prototyping, development and

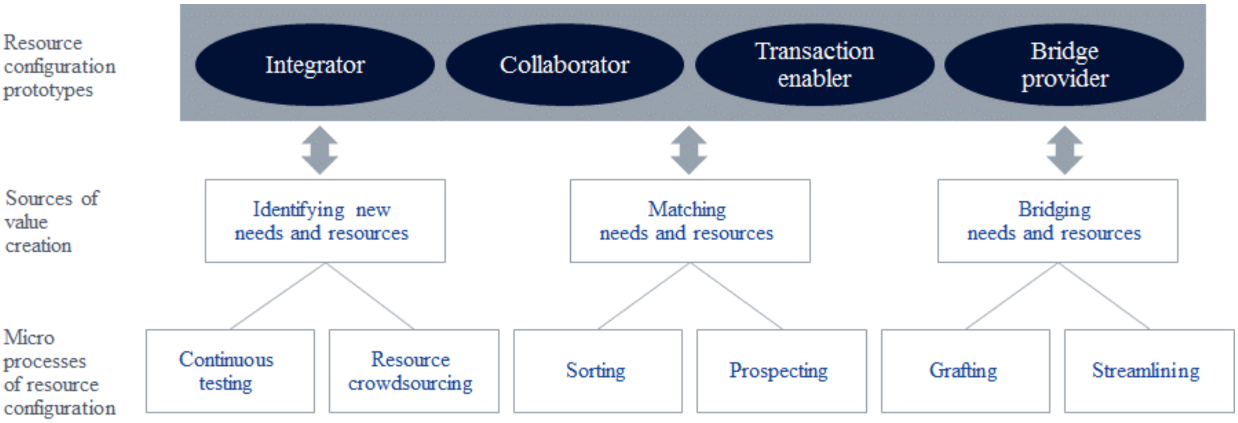

FIGURE 1. Novel resource configurations & value creation adapted from [11].

deployment of new BC applications. The platforms can be categorized to Bitcoin-based, FinTech, consortium/enterprise, sidechain/anchored, and SC platforms. SC platforms enable building and enforcing smart contracts on top of the BC. In these platforms, complex logic beyond simple cryptocurrency transfers are expressed utilizing a programming language [34].

C. RESOURCE CONFIGURATION FRAMEWORK

The resource configuration framework takes a systemic view on how companies' resources can be designed, organized and orchestrated to create value [11]. The framework facilitates envisioning and designing unique combinations of digital, multi-sourced resources and linking them with various needs originating from the ecosystem of multiple stakeholders. The framework is designed with particular emphasis on the value co-creation perspective, i.e. identifying all value co-creators and their diverse needs and resources is accentuated. Amit and Han [11] have explored various sources of value creation in a digital world and found several configuration prototypes where companies may have one or more roles depending on their capabilities. In the value creation process, firms may work as an integrator (prototype A), collaborator (prototype B), transaction enabler (prototype C) or bridge provider (prototype D), and correspondingly take care of resource configuration microprocesses like streamlining, sorting, resource crowdsourcing or continuous testing [11], as shown in Fig. 1.

As an *integrator* (A), a focal orchestrating firm converts resources into a new form and thus creates value for customers. This can be regarded as a traditional type of resource configuration, which is typical for, e.g., manufacturers [36]. When acting as a *collaborator* (B) the orchestrating firm collaborates with partners generating assets to supply and service the need of consumers. The resources to meet the consumption are not solely from the disintegrated retailer but are contributed by its partners. Thus, the prototype B company does not transform resources like the prototype A company does, but it creates value by collaborating and engaging other 'complementor' firms' resources with its own [37].

A *transaction enabler* (C) is associated with a platform business model [38] enabled by digitalization. Broader and easier access to resources allows the orchestrating firm to build two or multi-sided markets to match resources and needs. A *bridge provider* (D) bridges certain groups of market participants that were not connected before based on the proliferation of virtual resources, and benefiting from bridging unconnected needs, such as Google's advertising model [11].

The reference [11] defines also specific notation to illustrate prototypes of resource configurations and roles of the focal firm (F). An example of this notation is presented in Fig. 2, in which the conceptualization of the setting for a typical prototype C transaction enabler is shown. The focal firm is F, and F's resources are accordingly R_F, and needs, N_F. Value co-creators 1 and 2 (C-V) are notated in the same way. The arrow denotes that certain resources are utilized to meet certain needs. As shown in Fig. 2, a prototype C firm contributes resources (R_F) to facilitate or enable transactions between two groups of value co-creators whose needs (notated as N_1 and N_2) can be addressed by the other group's resources (here R_2 and R_1). One example of this kind of prototype C firm is LendingClub [39], an online crowdfunding loan/credit platform. In the LendingClub, single lenders can lend funds to single borrowers. The borrowers pay premiums for their loans so that lenders will get their profits. In the LendingClub case, the focal firm (F, LendingClub) can be seen as the enabler that facilitates lending/borrowing transactions between borrowers (C-V_2) and lenders (C-V_1). Efficiency and effectiveness of loan needs matching with

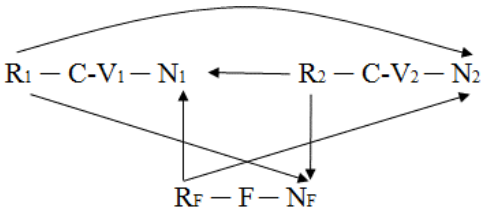

FIGURE 2. Conceptualization of the setting for typical prototype C, Adapted from [11].

available resources is the source of value creation in this case. The matching is a bidirectional process. In this case, the availability of resources (R_1, capital) and profits required (N_1) by the lender (C-V_1) are required to match the needs of the borrower (N_2). The solvency and reputation of the borrower (R_2) also need to match to the risk and profit requirements of the lender (N_1). The LendingClub (F) contributes by providing needed information and algorithms (R_F) for locating borrowers and lenders, i.e. enabling the match efficiently. The LendingClub gets its revenue (N_F) from both borrowers and lenders [11].

D. 4C TYPOLOGY

Traditional business model research has focused on a system of inter-dependent components such as resources and competences, organizations [40], customer value proposition [41], and cost and revenue [42]. Recently, a converging conceptualization has emerged incorporating key processes for business models that connect them to the context, opportunity processes, value processes and advantage processes [43], [44]. In parallel, business model analysis discussion has focused on the design of successful business models. 4C typology [12] assess Internet-age business models from value creation and value capture perspectives, and provides foresight on their adaptability, particularly in business transformations. The 4C typology consists of four layered prototypical business models where antecedent layers act as value levers for higher business model layer prototypes [45]:

- *Commerce* provides transactional matching platforms for buyers and sellers,
- *Context* sorts, prospects and structures information, in order to reduce complexity and asset specificity,
- *Content* sources and identifies various types of content based on user needs, and
- *Connection* enables users to participate and exchange information.

In the business ecosystem, 4C prototypes can exist alone or as a hybrid. Furthermore, synergies in providing services and underlying resource configuration processes between stakeholders has impacts on overall business potential [45].

III. USE CASES

In this study, the resource configuration framework [11] and 4C typology [12] are applied to the selected industrial BC use cases that represent the telecommunication-oriented 5G network slice brokering use case [13] and the internal electricity allocation in a housing society use case [14] in the energy industry. In this chapter, both use cases are described in connection with their broader (telecommunications and energy) ecosystems.

A. TELECOMMUNICATION – 5G NETWORK RESOURCE BROKERING

The next generation 5G mobile networks will revolutionize the way network services will be provided and consumed. A wide variety of users, machines, industries, public services and organizations will each have their special demands, and the 5G network is expected to fulfill these needs. Furthermore, 5G could be the enabler for new innovative business opportunities and use cases, and lower the barrier to collaborate across domains. For example, for industrial control and factory automation 5G can enable fully automated and flexible production and manufacturing systems consisting of sub-processes and subassemblies from several stakeholders. Consequently, this shift to more on-demand and decentralized network services will require changes in the network's architecture, especially at the management and orchestration level [46].

The *5G network slice brokering use case* utilizes a 5G network slice broker [47] in a BC to enable manufacturing equipment to autonomously and dynamically acquire the slice needed for more efficient operations and reduced service creation time. Manufacturing equipment leases independently the network slice required for operations on-demand, approve service-level agreement (SLA) and pay for the service according to actual usage. Network slice trading will be performed in a BC. BC smart contract orders slice orchestration according to agreed SLA from a 5G network slice broker. The SLA between a piece of manufacturing equipment and a network operator will invariably include quality of service (QoS) parameters and, e.g., priority, packet loss and packet delay quality class identifiers (QCIs). Furthermore, key performance indicators (KPIs) will be defined for monitoring the performance per QCI. Time stamping of the utilized network slice and dynamic billing according to actual usage is handled by a BC. The whole process is automated and requires no human intervention [13].

The use case has been introduced in our previous paper [13]. The workflow of the use case is as follows. A piece of manufacturing equipment requests a specific slice for lease from the slice leasing ledger and accepts corresponding SLA. The slice leasing ledger orders the slice orchestration according to the agreed SLA from the 5G network slice broker. The manufacturing equipment operates in the leased slice and the 5G network slice broker provides information about actual usage to the slice leasing ledger. The slice leasing ledger performs transactions between actors' wallets. The possible actors are a manufacturing equipment owner, a piece of manufacturing equipment, infrastructure providers (InP), mobile network operators (MNO), micro-operators (μO), virtual mobile network operators (MVNO), over-the-top service providers (OTT) and verticals. Fig. 3 presents the use case diagram and workflow for the minimum viable value ecosystem consisting of μO, MNO and manufacturing equipment.

B. ENERGY – SMART GRIDS

The transition towards renewable energy sources is ongoing [4]. In practice, this also leads to the fact that the production of energy will be more weather dependent and price variation is increasing. This kind of energy production is more unpredictable and fragmentary and requires more

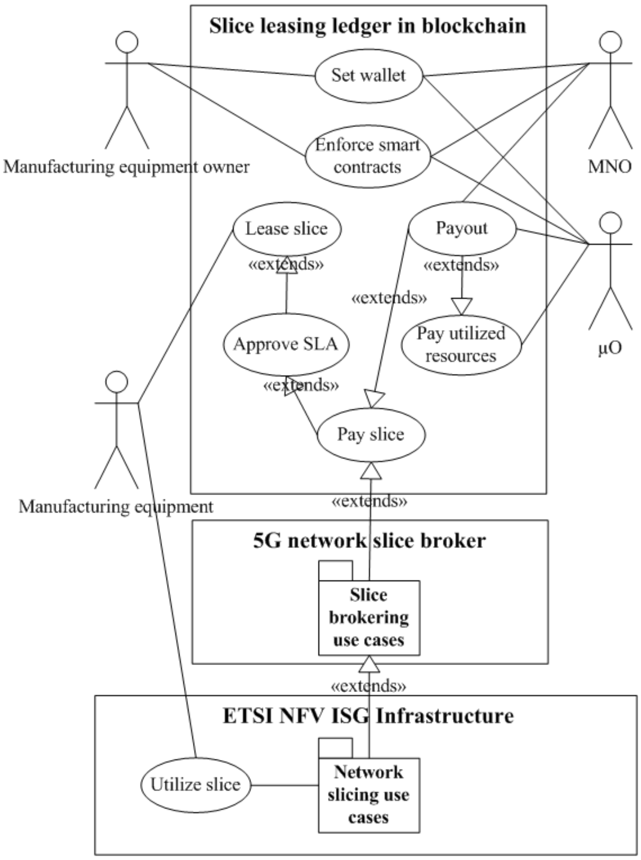

FIGURE 3. 5G network slice brokering use case diagram.

alternatives relating to balancing consumption and supply in both the short- and long term [48]. Due to several local renewable energy sources, energy systems become more decentralized. All these facts require that the energy system should be more flexible in production and consumption. Also new energy storing solutions are needed [49].

In the future, there will be timely variance in the availability of energy. The balance of electricity production and consumption must be ensured somehow and flexibility in all energy resources is essential. One possibility is that electricity could be allocated autonomously by IoT entities among themselves. This could happen without the external intermediator's control [50].

The use case for the energy industry has been presented [14], where "*the internal electricity allocation in a housing society consists of various independent energy transactions between individual smart devices within the housing society*", depicted in Fig. 4. Next, the use case is summarized.

A housing society's smart solar panel array starts to generate electricity. The solar panel array connects to a distributed BC-based P2P marketplace. The marketplace's order book will be searched by the system to find out the highest bid for electricity. The array accepts the best available bid if it fulfills the requirements relating to its costs, investments and other possible parameters. If the bid is not fulfilling these predefined requirements, a new sell order would be issued [14].

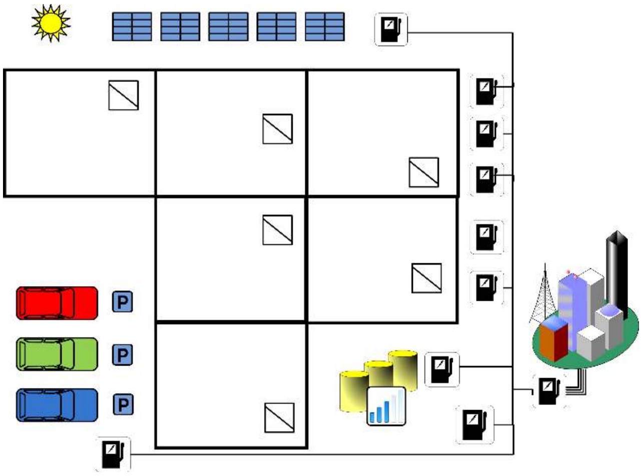

FIGURE 4. Internal electrical allocation in a housing society, adapted from [14].

A battery unit acts as an autonomous buffer for the energy marketplace. The battery unit analyzes the market place's order book and history of market transactions for demand and supply trends, and electricity market price. According to these analyses, the next possible battery-related action will be decided: Recharge (purchase electricity), sell remaining energy or just wait for a better market situation [14].

For example, if some device needs electricity it connects to the distributed marketplace and searches open sell orders from the order book. The device can, e.g., issue a new purchase order with a little higher bidding price than between the solar array and the recharging battery. Then recharging of the battery can be terminated and the solar panel could start to feed the device at a higher price [14].

During energy consumption peak hours, energy buffers might run low. In these situations, the energy can be purchased, for example, from the electric vehicles parked in the housing society's charging stations. The vehicle can decide to sell energy from its batteries for a good price, if it is estimated that the vehicle will not be used that day anymore. The vehicle can then buy the electricity, for example, during non-peak hours like at night and recharge itself for a lower price [14].

In this kind of use case, some capabilities are required from the devices in the network. The devices need to be able to run a smart contract application client to combine the distributed market data with measurements of the traded electricity. In practice, basic computational functionality and networking abilities are required from the devices. The use case would also require a network that consists of full nodes. The smart devices could send and receive data by utilizing the network of full nodes. The network could be maintained, e.g., by housing societies, other buildings, and similar entities [14].

IV. 5G AND SMART GRID USE CASE EVALUATION

In this chapter, the use case evaluations and results are introduced. The two presented use cases with their ecosystems are evaluated by applying the resource configuration and 4C frameworks. The resource configuration prototypes are identified within the overall 5G and energy ecosystems and for the presented use cases separately. Resource configuration microprocesses are reflected solely to the use cases to determine the extent to which these BC-enabled use cases contain different value-creating microprocesses. Furthermore, the 4C business model typology supplements the ecosystemic approach and has also been used for investigating BC-enabled value creation.

A. RESOURCE CONFIGURATION PROTOTYPES IN 5G AND ENERGY

1) INTEGRATOR

In the resource configuration framework, *the integrator prototype (A)* creates value for customers utilizing resources as a traditional vertically integrated firm [36]. In the traditional centralized business model of the energy domain, an integrated energy production facility, e.g., a nuclear power plant, converts fuel into electricity resources to address consumers' electricity consumption needs. This prototype creates very little space for the growth of distributed energy resources (DERs), local demand services, and gives poor support for energy efficiency [51]. In a similar way, the present connectivity market is characterized by centralized incumbent network operators whose business model is structured around mass service offering, capital-intensive long-term investments in exclusive spectrum licenses and communication infrastructure [5].

2) COLLABORATOR

In *the collaborator (B) prototype*, an orchestrating firm collaborates to gain access to complementary value-creating resources. Prototype relates to strategic alliance [52] and ecosystem [37] studies. Reference [51] defined this disintegrated electricity retailer business model, common in liberalized markets, as a firm that does not own generation assets, but instead partners with one or more generators while using its own brand. In the disintegrated telecom virtual operator (MVNO) or network sharing (e.g., MOCN) business model, common in liberalized markets, a firm does not own network assets, but instead partners with one or more MNOs while using its own brand.

3) TRANSACTION ENABLER

The transaction enabler (C) associates with the platform business model [38], in which a focal firm builds two or multi-sided markets to match resources and needs. A platform operator connects groups of users and providers of products and services, mediating their interaction and matching needs. A key characteristic of any platform market is the existence of network effect [53]. In the electricity market, the platform operator facilitates the energy trading between consumers and prosumers as well as among several prosumer groups through contributing resources to enable interactions and matchmaking between two groups of value co-creators (consumer and prosumer) whose needs can be matched by each other's resources [53]. Similarly, 5G enables novel business models to build on network assets and data. Network function virtualization (NFV) and network slicing are emphasized as key enablers for a variety of novel private network and micro-service business models [54]. For example, in multi-tenancy, mobile network tenants could share the same network infrastructure with vertical industry tenants, and each tenant could operate and manage their corresponding network slice by exploiting built-in network slice customization and optimization capabilities. With this approach, the network could be sliced per customer service, when an operator wants to optimize dedicated services for end users (e.g., tactile internet or ultra HD video) or wants to address industry-specific customer needs (e.g., e-health, sensor network, high-speed train), and/or per tenant, when an operator wants to share network costs on an infrastructure or a platform level.

Several new value propositions and/or supporting process-based multi-service, multi-tenant business models, and stakeholder roles and relationships are enabled in this kind of environment including, e.g., provision and brokerage of network assets, connectivity or managed services, data collection or its pre-processing as-a-service for factory tenants [13]. Furthermore, 5G enablers, cloud, virtualization and service integration will lead to an overall shift from hierarchies towards more use of markets to coordinate economic activity related to network assets. This transition is triggered by platform economy antecedents that reduce asset specificity and complexity of product description. The transaction enabler resource configuration prototype associates with the platform business model that creates value via facilitating exchange of information and service interactions between sellers and buyers. At the resource level, a clear transition was seen from controlling all the resources toward sharing of infrastructure and contextual data assets. From the business model perspective, it could be expected that the transparency and openness in business models would gain importance, and the sharing appears to conform more to the ‘‘value from service’’ approach than what traditionally has been the case in the industry. A shift from the purely competitive model of today towards one where more emphasis is placed on converged cooperation and collaboration within ecosystem and across domains was found. *Both of the use cases, the network slice broker and the internal electrical allocation in a housing society, represent the transaction enabler prototype C*, as shown in Fig. 5 and Fig. 6.

4) BRIDGE PROVIDER

The bridge provider (D) bridges certain groups of market participants that were not previously connected based on the proliferation of virtual resources, and benefiting from bridging un-connected needs [11]. In the unbundled electricity market [55], the balance management service operator can be a local balancing unit [51] or a virtual power plant (VPP) [56] using its resources such as energy efficiency services for the needs of consumers utilizing consumption data collected from the consumers to address the needs of another group,

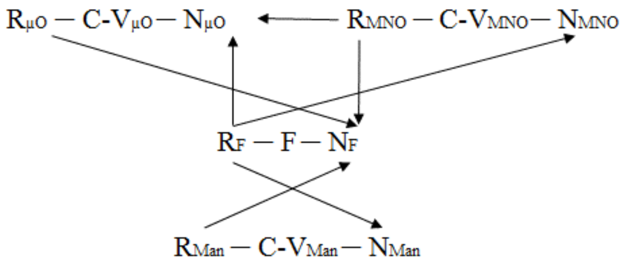

FIGURE 5. The conceptualization of the setting for 5G network slice broker resource configuration [10].

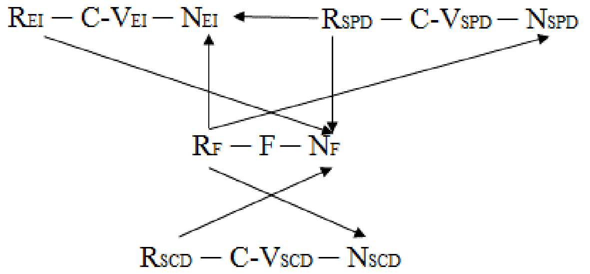

FIGURE 6. The conceptualization of the setting for internal electricity allocation in a housing society resource configuration.

such as the distribution network system operators (DSOs). This enables DSOs to balance the electricity network through utilizing the consumption data and behaviors controlled by the consumers. Similarly in 5G, new roles of aggregators and brokers [57] building on prototypes C and D will emerge.

As mentioned above, article [11] defined specific notation to illustrate prototypes of resource configurations and roles of the focal firm. In this paper, the notation is used for illustrating the selected use cases. Fig. 5 presents the conceptualization of the setting for 5G network slice brokering resource configuration [10]. The focal firm F is the decentralized network slice broker/ledger; F's resources are accordingly R_F, and needs, N_F. Value co-creators (C-V) are notated in the same way: MNO, μO and manufacturing equipment/owner (Man). Fig. 6 presents the conceptualization of the setting for internal electricity allocation in a housing society resource configuration. The focal firm F is the decentralized energy marketplace in BC and F's resources are accordingly R_F, and needs, N_F. Value co-creators (C-V) again are notated likewise: SCD (Smart energy consuming device) the buyer, SPD (Smart energy producing device) the seller and EI (Energy industry), i.e., energy company mainly selling but also buying energy. The arrow denotes that certain resources are utilized to meet certain needs.

B. RESOURCE CONFIGURATION MICROPROCESSES

In addition to the resource configuration prototypes, Amit's value creation framework [11] also comprises various resource configuration *microprocesses*, which are actionable, value-creating processes undergirding the prototypes. The microprocesses of *continuous testing* and *resource crowdsourcing* have means for identifying new needs or under-utilized resources and possibly gathering them together to reach a scale for a new business. *Sorting* and *prospecting*, in turn, by having algorithms for, e.g., categorizing or predicting needs now or in future, aim at matching the needs and resources in a more efficient manner. The most creativity-demanding resource configuration microprocesses, *grafting* and *streamlining*, contain the procedures for making completely novel resource combinations and this way bridge the needs and resources within a digital business ecosystem.

To further investigate the value creation potential of the two BC-enabled use cases, the cases have been reflected against the resource configuration microprocesses, and the applicability of each microprocess to the use cases have been estimated. As a basis for estimations, both the use case descriptions and the research interviews made during the BOND project [15] have been used. Next, the results are discussed and summarized in Table 1.

Continuous testing is quite important in both use cases as it increases the understanding of resource demand and thus helps in fine-tuning the resource offering. Resource crowdsourcing, instead, clearly has high applicability solely to the internal electricity allocation in a housing society use case. In fact, the whole concept of smart grids, as well as demand-response more generally, is all about constant crowdsourcing energy supplies and demands. The faster the crowdsourcing can be carried out, the greater is the value creation potential.

Sorting and prospecting are the key resource configuration microprocesses for the use cases because the capability of categorizing needs and resources makes both network slice brokering and energy brokering more efficient and prospecting enhances this effect even further. In internal electricity allocation in a housing society, for instance, sorting and prospecting are the key functions in the business models of smart grids and peak control.

Grafting and streamlining are the microprocesses that seemed to be slightly less applicable to the use cases. That presumably is because Amit's framework [11] is strongly targeted to digitalization-enabled value creation and the resources configured are mainly inherently digital as opposed to the use cases, in which resources are digitized but inherently physical. Thus, originally, digital resources can be grafted quite easily, but the underlying physical infrastructure sets limits on reconfigurability of digitized assets. Anyhow, resource configuration microprocesses generally showed strong signs of applicability for the use cases studied. It was also identified several strengthening effects that the utilization of BC has on the value creation potential of many resource configuration microprocesses.

The decentralized BC-based approach in the development of both use cases presented were originally strongly inspired by *the limitations of more centralized set-ups* to efficiently meet the requirements. For example, transaction and overall costs were seen to increase remarkably if trusted third parties or other intermediaries were needed between stakeholders. This would quickly have ruined the business models

TABLE 1. Value creation microprocesses' applicability to the 5G network slice brokering and internal electricity allocation in a housing society BC use cases.

Source of value creation	Resource configuration microprocesses	Applicability to the 5G network slice brokering	Applicability to the internal electricity allocation in a housing society
Identifying new needs and resources	Continuous testing Firms test and modify their offerings continuously using a fast feedback loop with their value co-creators.	++ In 5G era, µOs try to differentiate by providing tailored services ++ Near-real-time operation of BCs is sufficient	+++ Real-time energy usage data is available, e.g., demand-response control ++ Reliability of IoT data increases by using crypto mechanisms for verification; metering can even be performed at the device level
	Resource crowdsourcing Firms gather (often a small amount of) under-utilized resources from a large (and preferably widely distributed) group of value co-creators to reach a scale.	- Not so relevant in the Business-to-Business use case, because 5G resources are provided by limited number of InPs/MNOs	+++ The huge increase in the number of small-scale renewable energy sources and people's willingness to receive compensation for their surplus energy => local optimization and productization of local energy solutions +++ Smart contracts may automate aggregator operations and radically cut transaction costs +++ BC-based distributed data management may be more optimal for smart grids which can be regarded as network of systems
Matching needs and resources	Sorting Firms build up methods for categorizing both needs and resources to be able to match them more efficiently and effectively.	+++ In 5G, various needs from vertical industries and applications need to be sorted +++ After sorting, tuned smart contracts automate negotiation which greatly reduces transaction costs +++ Regulatory obligations may be filled with smart contracts and allowing regulators access to BC data	+++ In energy sector, successful sorting is prerequisite for, e.g., peak control and demand response +++ Categorization efficiency is improved with data analysis tools connected to smart contracts +++ Smart contracts can also automate and make incentivizing mechanisms (e.g., energy saving in peak hours) more real-time ++ Sorting mechanisms must preserve privacy and business confidentiality
	Prospecting A firm predicts resource needs and resource controllers' expectations based on data analyses and mediates the most useful pieces of information to value co-creators.	+ Co-opetition of µOs sets strict security and privacy requirements on BCs +++ Various needs from vertical industries and applications can be prospected with help of Artificial Intelligence (AI) and data analysis to support critical QoS services	+++ Prospecting of energy consumption and supply is a strategic energy business process +++ The more accurate and real-time, the more valuable
Bridging needs and resources	Grafting A firm experiments with new combinations of hereto unconnected (or less connected) resources and needs to enhance the value creation of the resource configuration.	-/+++ In telco-specific BC broker grafting's role is limited. In the future, microservices and virtualized resources like storage, computing (edge cloud), data or energy may be grafted to 5G services centrally and locally at the edge - underlying network resources not easily virtualized	++ Companies' co-creation activities and shared ecosystem database create a fertile ground for grafting process ++ Service provisioning will be dominant business model also in energy sector => comprehensive service offering requires innovative service combinations with, e.g., transportation, facility management, healthcare or public sector
	Streamlining A firm reduces the incompatibilities and uncertainties that, e.g., the grafting process creates. This is realized by connecting additional resources, which further streamline the novel process.	+ 5G broker's data can continuously be used as a basis for streamlining the services created in grafting process	+ Innovative service combinations often need post-adjustment and in BC-based smart grids system this kind of streamlining process can be a part of a smart contract feedback loop

which were based on the transacting and crowdsourcing of assets of little value. Further, in both use cases, implementing effective sorting and prospecting microprocesses requires the transparency of ecosystem data which is difficult to achieve if each stakeholder had its own repository with separate access control. Creating adequate trust mechanisms and the means for interoperability in broad business ecosystems was seen to require major investments in a centralized approach.

C. 4C BUSINESS MODEL TYPOLOGY OF ECOSYSTEMIC VALUE CREATION

Value creation has holistic and dynamic nature, which can only be captured by using an institutional and systemic perspective [58], and emphasizing the systemic participation of actors in resource configuration and exchange [59].

To further crystallize the idea of ecosystem-based value creation and especially the role of BC in enabling these ecosystemic value creation mechanisms, the scope of the research is expanded into more general concepts of 5G and smart grids. These two sectors have interesting similarities in their transformation towards servitization and decentralization as well as an extensive ecosystemic business environment with emerging innovative business models. Further, both 5G and the smart grids can be regarded as industrial business ecosystems, which have an enormous potential to create value not only for their ecosystems but also for the society at large. Different categories (economic, environmental, reliability, energy security) of this kind of ecosystemic value in energy systems have been classified [60]. Within these categories, value is created, e.g., by avoiding unnecessary investments in backup systems, facilitating integration of renewable energy sources or encouraging consumers toward more active market participation. As the analysis framework for novel 5G and smart grid business models and applicability of BC to facilitate the related business mechanisms, an ecosystemic 4C business model typology approach is used. The framework has previously been comprehensively researched within energy [60] and within 5G [61], and the results are abstracted in Table 2. In addition to ecosystemic business model examples from both sectors, the propositions of how a BC-enabled business platform could improve the implementation of the ecosystemic business models even further, is gathered. Next, these will be briefly described in each of the 4C layers separately.

1) CONNECTIVITY LAYER

On the *connectivity* layer, using 5G to provide fixed wireless access and extreme mobile broadband to meet the fast-growing traffic demand can be seen as the early use cases with ‘‘as is’’ connectivity business models. Key longer-term themes are the triggering role of the enterprises and verticals, enabling the role of the platforms, and need for openness and collaboration in resource orchestration and services. Basic connectivity layer services are retained in consumer/

TABLE 2. Typical value propositions and facilitating BC features related to 5G and smart grids in 4C framework.

	BC features facilitating ecosystemic value creation	Typical value propositions and business models in 5G	Typical value propositions and business models in smart grids
Commerce	Automated billing processes Multi-sided auctions	Brokering services Network slicing, virtual network functions	Open energy platforms Energy marketplaces
Context	Data availability can be accurately controlled Privacy preserving encryption methods enable data analysis without compromising privacy Smart contracts in automating aggregation functions	Data-as-a-service Data and analytics tools harnessed for deriving useful insights for third parties or for bridging value-co-creators Network resource aggregator Data availability important in the context level!	Flexibility forecasting and network load feedback Energy aggregator services, monitoring, peak control, demand response Data availability important in the context level!
Content	Verifiable tracing of QoS and consumption parameters BC-enabled trust mechanisms enable P2P energy integration and balancing, e.g., using smart contracts to automate balancing functions	Enriched service quality Integration of, e.g., OTT content and edge computing with operator services Balancing supply and demand (e.g., spectrum, slices, computing, storage, microservices)	Power quality Renewable energy integration Consumption feedback Balancing energy supply
Connection	Distributed BC-based systems are very resilient against network failures and attacks Integration of BC-enabled IoT makes control and monitoring functions more reliable Tracking QoS parameters	Chargeable QoS and SLAs for e.g., mission-critical systems and extreme mobile broadband services	Cheap electricity delivery Power reliability

enterprise retail and wholesale. New business opportunities mainly stem from differentiation in quality and performance opportunities, e.g., through chargeable QoS and SLA, missions critical IoT applications for industrial, vehicle connectivity, and health domains, and extreme mobile broadband enhancements for capacity-hungry special events services with augmented reality (AR) and virtual reality (VR). In the smart grids, the business in the connection layer mainly concerns delivering electricity at a competitive price and adequate reliability by building and managing network facilities, e.g., with grid-scale storages or maintenance services [60]. BC as a control and monitoring software platform, inherently organized as a decentralized network, enables better resiliency against network failures and attacks. Furthermore, integration of cryptographically secured BC-enabled Internet-of-Things (IoT) devices can make system operations more reliable. As far as critical infrastructure like energy or information and communication technology (ICT) systems are concerned, system resiliency and security are key attributes.

2) CONTENT LAYER

On the *content*layer, 5G operators can enrich their capabilities and offerings to end customers by partner capabilities like OTT content and applications. Edge computing brings intelligent functionality closer to the network allowing software applications and micro services to access local content and real-time context information, e.g., on the radio channel conditions and IoT data. Edge computing capabilities address specific service demands including bandwidth management, latency, sensitivity, security and privacy, local control and service continuity, analytics and digital automation, and support for constrained environments. Cloud and network providers' edge computing can become natural central points, representing the source and destination of much of the demand combined with context-analytic-enabled optimization capabilities. This can create a new competitive advantage over OTT services through content caching, optimized local content distribution, location services, video analytics, AR and IoT application for existing customer segments as well as for new vertical business segments. Furthermore, security functions will be increasingly applied at the network edge to protect the network by reacting to threats locally. Security and safety service can allow the networks to monitor and adjust network slices and virtualized elements according to detected security threats without human intervention. In energy systems, respectively, quality of delivered power is in focus in the 4C content layer and this target is achieved, e.g., by balancing energy supply and network constrains. Additionally, the integration of renewable energy sources as well as consumption feedback takes place in this layer [60]. How could BC enhance the implementation of these different quality and balancing-related operations? Firstly, BC works as a verifiable transaction log that can automatically trace, e.g., QoS and consumption parameters formulating the reliable foundation for balancing algorithms, automatic balancing negotiations as well as dynamic or SLA-based billing. These functions may be implemented as smart contracts having feedback loops with consumption and other relevant network parameters.

3) CONTEXT LAYER

5G extends current connectivity-driven business models towards *context*- and commerce-based business models built on network assets and data. Networks produce millions of transactional data every second that can be utilized as-a-Service (DaaS) in traffic, logistical and manufacturing systems to increase the accuracy and speed of these processes. In the data brokering model, operators can bridge the right partners with each other at the right point in time exploiting their assets such as customer knowledge, trust, customer relationship and channels. For example, augmented retail applications that can benefit from information about the user's location, device and current movement pattern, all of which the operator can provide anonymously through a DaaS platform. Similarly, smart city systems, logistics and manufacturing need to be fed with data about the accurate location of vehicles and goods but also with data about movement pattern to, e.g., provide better directing of traffic on the roads. In smart grids, in turn, the 4C context layer incorporates a flexibility-related value creation having a prominent business model of an energy aggregator and use cases like flexibility forecast and network load feedback. The energy aggregators, by providing energy management tools (energy monitoring, peak control, demand response) for their customers, try to optimize energy consumption at a customer site [60].

Likewise, in 5G the availability of IoT data is prerequisite for context layer services in smart grids. Key energy balancing functions, being highly coordinated multiparty processes, are completely dependent on transparent system and market data. Therefore, the introduction of BC may be the game changer especially in the context layer. In the BC platform, relevant and verifiable business data is available for stakeholders and privacy preserving encryption methods can be used for enabling more accurate data analyses without compromising privacy. Various trading processes may be automated with SCs that facilitate node-level transactions, billing and dynamic pricing mechanisms in which, e.g., the price of consumed or produced energy dynamically varies depending on the spatial and network status data. Not only trading processes but also the coordination of aggregation process more widely could benefit from an underlying BC platform and SCs as the data for predictive analytics and thus more precise forecasts are available together with almost instant possibilities to automatically react to the changing network load and utilization rate.

4) COMMERCE LAYER

In the uppermost 4C *commerce* layer, different marketplace and brokering services will emerge. However, in firm-controlled electronic marketplaces and platforms, there can be several limitations, which prevent the business ecosystem from operating in the most optimal way. Maximization of profits for shareholders pushes e-commerce platforms to use, e.g., pricing algorithms that may not account for individual platform participants. Reputation systems of centralized marketplaces are vulnerable to spam, tampered ratings and paid reviews and also private customer data may be exposed to personalization algorithms. Further, contracts between the platform and its participants often involve significant transaction costs [62]. These limitations result from a monopolistic business environment, which typically is formed over time as a single centralized company ends up managing the whole marketplace due to the network effects [63].

Decentralized BC platforms may speed up the evolution of efficient marketplaces by providing means for trust-establishing mechanisms such as identification, authentication of origin, transaction history, reputation, and in this way lowering the barriers to market-entry also for small-scale participants. SCs can remarkably automate negotiation processes, e.g., even complex multi-sided auctions between marketplace parties and hence alleviate market coordination tasks. In addition, facilitated negotiation and contracting processes can improve customer experience through easier transactions. Customers are able to set the limits for their market participation, e.g., in which ways they want their electric devices to engage in carrying out demand-response (DR) operations or what their preferences are for their mobile broadband services.

It is noteworthy, that both in 5G and the smart grids, the emerging roles of aggregators (content, context) and brokers (commerce) will move from long-term static contracts to a transaction-driven on-demand platform model. The connectivity and underlying network and IT resources, e.g., spectrum, slices, computing, storage, microservices or, e.g., renewables or storage clusters in smart grids, can better match supply and demand, improve utilization of infrastructure assets and ultimately maximize economic value within the industry. This will enable service and application providers to match their utilization of network assets to customer needs in a flexible and scalable manner.

V. DISCUSSION

In this chapter, use case evaluation results and research constraints are discussed, and the applicability of the resource configuration framework and BC capabilities to implement microprocesses are discussed. Furthermore, the novel theoretical framework is proposed according to the findings in the form of a BC-enabled decentralized prototype.

A. RESOURCE CONFIGURATION PROTOTYPES IN BC SYSTEMS

The research revealed high similarity of resource configuration patterns of both the BC use cases depicted in Fig. 5 and Fig. 6. Despite being ultimately different industries with disparate commodities brokered, the use cases seemed to have many analogies in their business structures: not only resource configurations between stakeholders but also brokering models as well as the changing position of incumbents and general evolution of the ecosystem towards marketplace setup. Additionally, in both use cases, the role of BC is a kind of resource orchestrator, which technically is a shared, chronological, immutable and trusted data storage executing SCs that can automate and self-adjust various business transactions like negotiating, contracting and billing. In particular, the BC and SCs allow any energy market participant, such as participant 1, to match its N_1 with the R_2 of participant 2 (such as the case of energy and flexibility trading), while the R_1 (e.g., financial payment) is directed to N_2 without an orchestrator between the direct value co-creation and value co-capture. This is the opposite of the traditional platform models (prototypes C and D) where a portion of the value flows out of the direct value co-creation and is captured by the platform orchestrator. In decentralized BC brokers, there is theoretically minimal value flowing out of the direct value co-creation and more value is accrued and shared between market participants.

In reflecting the notation of a focal firm [11] to the BC use cases, it was observed that there is no focal firm in place. Rather, the BC platform itself can be seen as a focal firm F. This kind of illustration does not quite describe reality, because a BC system is decentralized, whereas Amit's representations of resource configurations actually describe a centralized system or ecosystem. If the use cases illustrated are truly decentralized, focal firm thinking must be dropped and instead draw the matching of resources and needs between the participants of the ecosystem in a decentralized way. Fig. 7 and Fig. 8 illustrate the decentralized prototypes of the 5G network slice brokering and internal electricity allocation in housing society use cases. As shown, there is high similarity between these two use cases and this pattern is typical in

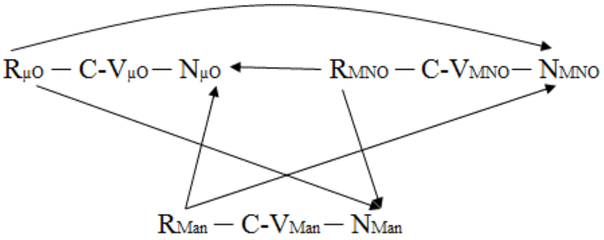

FIGURE 7. 5G network slice brokering; decentralized prototype.

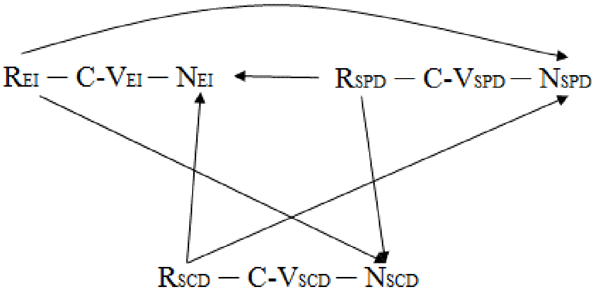

FIGURE 8. Internal electricity allocation in a housing society; decentralized prototype.

BC-enabled end-to-end ecosystem use cases. Together with the identification of BC as the enabler for a fully decentralized system [64], the need for a new decentralized approach to resource configurations in BC use cases is recognized. Therefore, as a generalization of the research results, a novel decentralized resource configuration prototype E is proposed to the resource configuration framework. This prototype describes decentralized BC-based ecosystems without any particular focal firm as an orchestrator. Fig. 9 describes the proposed BC-enabled decentralized prototype E that offers the full autonomy for the market participants.

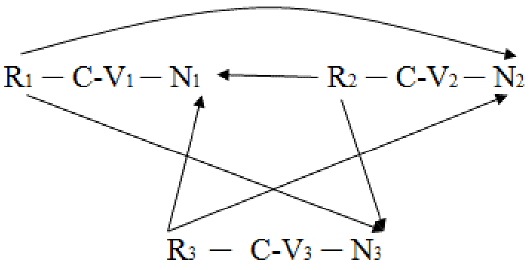

FIGURE 9. **Proposed general BC-enabled decentralized prototype.**

B. RESOURCE CONFIGURATION MICROPROCESSES IN BC SYSTEMS

As shown in Table 1, both of the studied BC use cases were highly applicable with many of the resource configuration microprocesses, which in turn can be regarded as the underlying mechanisms for value creation.

It can also be discovered that the internal electricity allocation in a housing society use case has slightly more resonating factors with resource configuration microprocesses than the 5G network slice brokering use case. One reason for this is that the number of participants in the 5G network slice brokering use case is quite limited and many resource configuration microprocesses require a large number of resource providers as well as customer needs in order to maximize the value creation potential. Another finding in the study was that neither use case is very applicable with grafting and streamlining microprocesses largely because the underlying physical infrastructure has limited configurability. Moreover, to get the greatest benefits from the grafting process, very creative combinations of resources need to be found and obviously, the more extensive and versatile the ecosystem, the better chance to make numerous combinations and lastly find the possibly successful ones. Therefore, in the future, for widening the business ecosystem, various BC-based businesses need to be connected. However, as [65] points out, now there is a diversity of incompatible BC platforms, technologies and software. In order to get over this fragmentation, standards for inter-BC communication need to be developed.

Moreover, it is distinguished that both use cases encompass several BC-enabled operations, which further promote the value creation potential of a particular resource configuration microprocess. We have previously [10] studied the relationship between the characteristics of BCs and the requirements for efficient implementation of the resource configuration microprocesses. These results are summarized in Table 3, and eminently, BCs possess a considerable number of specific features, which not only boost the identified microprocesses but also may generate quite novel ones.

In addition, some considerations have been aggregated in Table 3 to indicate the aspects that may hamper the successful implementation of resource configuration microprocesses if the use cases were implemented using the more traditional *centralized* approach. For example, in platforms with a privileged central operator or authority, transaction and overall costs may increase remarkably, which is destructive to the business models with low-value assets. Further, stakeholders need to trust that a centralized service provider preserves privacy and business confidentiality as well as operates reliably and impartially and retains reasonable service fees. Sometimes it may be difficult to find a neutral single party that would set-up and manage the services.

Reputation systems of centralized marketplaces can be vulnerable to spam, tampered ratings and paid reviews. In addition, transparency, integrity and immutability of ecosystem data is difficult to achieve if each service provider and stakeholder has its own repository with separate access control. Worse still, the business models of existing players may not encourage data sharing and building incentives with mechanisms of controlling, tracking and getting possible compensation of the data/assets is hard to make worthwhile.

In addition, in centralized settings, efficient, reliable and secure machine-to-machine contracting and unique identification of IoT devices is challenging to set-up and manage. Consequently, lack of trust prevents relying on physical IoT assets in large extent. Moreover, reliable provenance of assets, which is central to many contemporary business models, can be laborious and expensive to implement.

C. ECOSYSTEMIC VALUE CREATION IN BC SYSTEMS

When further contemplating the characteristics of BC, it was found that they do not only boost the resource configuration microprocesses. By using the 4C framework, the indications were discovered that the features of BC may also more widely facilitate the implementation of manifold ecosystemic business models and this way have positive impacts on the value creation and value capture in the business ecosystem as a whole. Decentralized BC marketplaces can provide unmodified "access" to information, which enables unchanged search results because different distorting algorithms can be disabled. Also, transactional anonymity and privacy improve security and SCs and microtransactions can lower transaction fees [62]. Likewise, [66] found that BCs facilitate value co-creation by ensuring the transparency and access to information, and providing means for coordination. The reference [67] emphasizes that BCs can provide more neutral ground between organizations and thus reduce counterparty and operational risks. Generally, it can be deduced, that features of BC lower the uncertainty between co-operating

TABLE 3. BC characteristics and capabilities that most facilitate the implementation of a microprocess and aspects that may hamper the effective implementation of a microprocess in a more centralized set-up.

Resource Configuration Microprocess	What is needed for an effective microprocess?	BC characteristics and capabilities that MOST facilitate the implementation of a microprocess	Aspects that may hamper the effective implementation of a microprocess in a more CENTRALIZED set-up
Continuous Testing	Comprehensive test data from multiple digital channels. Means for collecting, analyzing and interpreting the test data	Timestamped, persistent and trusted data storage for, e.g., performance data	Access to data can be intricate in a multi-stakeholder environment with data silos Lack of trust prevents relying on physical IoT assets in large extent
Resource Crowdsourcing	Mechanisms for efficient provision, discovery, access and accumulation of resources	Cryptographic verifiability combined with BC-based smart contracts for automated provision and accumulation of resources => The reduction of transaction costs	Transaction and overall costs increase remarkably if trusted third parties or other intermediaries are needed between stakeholders Efficient, reliable and secure machine-to-machine contracting and unique identification of IoT devices is challenging to set-up and manage
Sorting	Enhanced information transparency and efficient information collection methods. Categorizing algorithms and mechanisms for effective match making and balancing resource supply and demand (unmet needs with their value propositions and under-utilized resources with their characteristics)	Trusted BC-based process data storage provides the data basis for analysis and sorting algorithms. New homomorphic BC encryption methods enable secure privacy-preserving data collection	Transparency, integrity and immutability of ecosystem data is difficult to achieve if each stakeholder has its own repository with separate access control Stakeholders need to trust that a centralized service provider preserves privacy and business confidentiality as well as operates reliably and impartially and retains reasonable service fees
Prospecting	In addition to above, sophisticated data analysis methods and artificial intelligence capabilities may be needed for finding latent needs and the most relevant matching information and assumptions Mechanisms for efficient recommendation and provision	The possibility to combine more enhanced data analysis and artificial intelligence (AI) -based prediction making with BC. The results of analyses can be used as parameters for smart contract-based automated provisions	Complying with reporting obligations may require extra effort from stakeholders Reliable provenance of assets can be laborious and expensive to implement Reputation systems of centralized marketplaces are vulnerable to spam, tampered ratings and paid reviews
Grafting	Easy access to resources at a large scale and inexpensive experimentation costs A way to find the unique complementarity between resources and needs. This often calls for great creativity	The development of interoperating parallel BCs using inter-BC communication protocol paves the road for larger ecosystems with novel resource combinations	Controlling, tracking and getting possible compensation for the data/assets that are used in grafting and streamlining microprocesses can be difficult to implement in a worthwhile manner, especially in cross-domain services The business models of existing players may not encourage data sharing and incentives for it are hard to build
Streamlining	Wide collection of digital resources, e.g., data in various formats, which enable the enrichment of previous bridging process	BC as a decentralized P2P platform facilitates rapid experiments, tuning of business processes as well as automation of processes across traditional business borders	It may be difficult to find a neutral single party that would set-up and manage the services

parties making the operation of many economic processes more efficient.

Correspondingly, the introduction of BC may also have beneficial effects on the implementation of the mechanisms, which are prerequisites for the full deployment of the *servitization* concept. Being one of the key elements in the emerging decentralized ecosystems of 5G and smart grids, the well-functioning service provision and delivery necessitate establishment of various technical system capabilities. For example, virtualization of hardware, granularity of accounting as well as enabling different cost allocation models are all important issues to address and BC may facilitate these significantly. In a BC platform, virtualization of underlying hardware benefits from reliable identification of devices and their permissions enabled via BC-based digital keys and identities. Reducing granularity of accounting is imperative to be able to fully exploit 5G microservices or small-scale renewable energy sources. Many BC platforms inherently entail tokens, which can be used for making microtransactions worthwhile. Further, combined with SCs, tokens enable implementation of flexible pricing mechanisms and cost-effective micropayments. The service ecosystem studies [59] also emphasize the importance of adopting broader and longitudinal views requiring continual and entrepreneurial processes when developing institutional business models. In addition, the long-term success of a firm is seen to be dependent on the ability and agility of facilitating institutional change processes. Incorporating BC with these statements [59] reinforces the view that BC-enabled SCs could improve the formation of a more longitudinal service business perspective along with enabling more reactive service business processes because the operation of SCs cumulates relevant business data in BC as well as provides the possibility to fine-tune processes in an artificial intelligence (AI) -enabled feedback loop.

D. LIMITATIONS OF BC SYSTEMS

Based on the research, BC retains many features that may facilitate value creation in wide business ecosystems, especially in the context of the resource configuration framework. Despite the quite positive general outcome of possibilities of BC in the two selected IoT use cases, it should be noted that BC is far away from being an all-embracing technology that automatically creates value for any use case. On the contrary, the collection of truly potential BC use cases is relatively limited and therefore it is extremely important to evaluate every new BC use case thoroughly before proceeding to implementation phases.

There are already comprehensive BC evaluation frameworks available, although many of them are targeted for financial applications. Secondly, it is noteworthy that the value creation potential of BC use case is highly conditional on the deployment of the BC system and particularly on the chosen BC platform. Currently, there are dozens of different BC platforms available, each having special features, operation principles, performance parameters and restrictions on participant access. General technological challenges often associated with BCs are, e.g., scalability, throughput, transaction verification time, power consumption as well as issues concerning privacy and security [30]. Anyhow, these all are addressed to a certain extent in the different BC platforms, each having distinct emphasis and preferences. Equally important as the selection of a BC platform are also considerations on how the BC platform can be smoothly integrated with legacy enterprise IT systems and IoT platforms. For instance, how will previous transactions be imported into the BC or in the case of a complete system substitution, how can the existing system be progressively replaced retaining the possibility to return to the previous system combination if problems occur [68].

Besides the technical challenges of BCs, there are also other questions to be answered when considering the value creation potential of a BC use case. The role of *regulation* in the use cases is particularly noteworthy and completely pivotal. Because the introduction of BC will restructure business roles and hierarchies as well as responsibilities of stakeholders, e.g., in the electricity sector profound revision of the regulatory framework is needed for enabling efficient renewable energy integration. According to [69], even the basic definitions of actors, such as consumers or suppliers, will not be legally valid in BC-based establishment because of their centralized origins. Instead of trying to define the clear-cut roles for actors, [69] argues that regulating dispersed responsibilities in a decentralized BC environment should solely focus on the quantity and the quality functions of energy supply and especially on finding mechanisms for pooling responsibilities. Currently, in the case of supplier failure, consumers are legally protected, but in the decentralized scenario with variable prosumers, measuring and enforcing accountability may be extremely complicated. The situation is further compounded by the ambiguous *legal* status of SCs. The extent to which traditional contract law doctrines can be applied to SCs is still unclear and in the future factual solutions will probably only be found through practice [70].

The discussion of accountability can also be considered as a part of the wider concept of distributed *governance*. Within the introduction of decentralized BCs, the traditional governance models will also transform towards more decentralized ones, which naturally has far-reaching effects also on business models and value creation opportunities. It has to be noted that the governance has a kind of dual nature, involving the governance of a platform and governance of applications. The governance of a platform is widely discussed in [71] and [72]. Based on these, it can be concluded that especially in public BCs with open-source platform development, the governance of a platform is a quite complex, even anarchistic process, as there is no single platform owner or formal mechanism of multi-party decision-making in place. On the other hand, some BC platforms are developed by individual companies without any open-source code base. Then the ultimate control of the BC platform and hence of the whole BC system is strongly centralized even though the applications on top of the BC platform are executed in a decentralized manner and a platform developer cannot directly modify the state of the system in the BC database. This will lead us to the governance of BC applications, which can also be arranged in multiple ways. At the other extreme, a BC platform may automatically execute smart contracts to which no possibility for later intervention has been left. However, the control of BC applications can also be widely decentralized and democratized, as, e.g., by using different voting mechanisms, even large user crowds can have decision-making power. Usually, in industrial BC use cases, there is a kind of business consortium or ecosystem wanting to govern the BC applications itself and also various platform-related aspects like access of different stakeholders. In this case, the issue significant to business modeling and value creation is, e.g., how this kind of consortium governance can guarantee the integration of the most relevant business partners in the most efficient way, at the same time distributing evenly the benefits but also the costs and responsibilities among the alliance members. While it is necessary to find win-win-situations for all stakeholders, the forming of the ecosystem and the BC governance model may suffer from the incumbents being unwilling to accept new players. Regarding the facilitation of resource configuration microprocesses, the considerations of the governance model are salient, as the model needs to incorporate sufficient flexibility because the form of the business ecosystem constantly changes and incentives for participation as well as resource sharing must be preserved.

In addition to other prerequisites, it is equally important to remember the *networking effects* because as a networking technology, BC complies with Metcalfe's law [73]. Thus, the value of the BC-based system is greatly dependent on the count of connected users. In the use cases, this means that both the amount of resource providers and consumers must first be sufficient to achieve a critical mass. Nevertheless, for proliferation of value creation possibilities, the count of participants should be maximized. This again emphasizes the importance of inter-BC communication in enabling as many resources as possible to be effortlessly integrated into the business ecosystem.

Altogether, the results of the analyses conducted state that BC-powered solutions have many special features to boost the value creation in these two use cases. Compared to traditional centralized solutions, permanent, immutable and transparent records can be created without any trusted party in between. The records can describe transactions or interactions between stakeholders and BC-enabled smart contracts can further automate business functions facilitating cost-effective and low-latency processes across conventional organizational boundaries. Decentralization and cryptographic verifiability of transactions improve overall system security which can be regarded as paramount in many industrial applications. Additionally, sharing business-critical data between companies in multilateral ecosystems can be facilitated with the use of BC which places companies in control of their own data and provides information traceability. However, to release the full value creation potential of these technological promises of BC, supportive standards, laws and regulation need to be developed for, e.g., decentralized identity and governance, increased system independency as well as data sovereignty in extensive global business ecosystems.

VI. CONCLUSIONS

In this paper, the evaluation of two blockchain IoT use cases from two different industries was presented. The resource configuration framework and 4C business model typology were utilized in the evaluation of a telecommunications-oriented 5G network slice brokering use case and internal electricity allocation in a housing society in the energy industry. The practical implications of the study state that blockchain characteristics match well to the value-creating resource configuration microprocesses which can be implemented using modern microservice technologies. Furthermore, both use cases present a transformation from traditional value chains towards ecosystems and decentralized platforms having clear value propositions to the whole end-to-end ecosystem. The theoretical contribution of the study is a new decentralized prototype E to the resource configuration framework. This prototype describes novel blockchain-based ecosystems without any particular focal firm as a transaction enabler. That can have a radical impact on predominant business models in energy and telco domains utilizing IoT technologies. The resource configuration framework proved to be a valuable theoretical approach for analyzing and developing also novel blockchain-enabled use cases and business models. In the future, blockchain-based business model value creation studies need to be expanded to cover novel roles and governance models in decentralized ecosystems. Additionally, practical implementations of blockchain use cases using different blockchain platforms and design parameters will be needed to supplement the overall picture of blockchain value creation potential.

REFERENCES

[1] L. Downes and P. Nunes, *Big-Bang Disruption*, vol. 91. New York, NY, USA: Penguin Group, 2014.
[2] *5G Empowering Vertical Industries: Roadmap Paper*, 5GPPP, 5G Infrastruct. Public Private Partnership, Brussels, Belgium, Feb. 2016.
[3] A. Zahedi, "Smart grid opportunities & challenges for power industry to manage the grid more efficiently," in *Proc. IEEE Power Energy Eng. Conf. (APPEEC)*, Mar. 2011, pp. 1–4.
[4] *Clean Energy for all Europeans*, Eur. Commission, Brussels, Belgium, 2016.
[5] P. Ahokangas, M. Matinmikko, S. Yrjola, H. Okkonen, and T. Casey, "'Simple rules' for mobile network operators' strategic choices in future cognitive spectrum sharing networks," *IEEE Wireless Commun.*, vol. 20, no. 2, pp. 20–26, Apr. 2013.
[6] H. Jaffrey. (Apr. 17, 2015). Crypto 2.0 'Lenses.' Linked in Pulse blog. [Online]. Available: https://www.linkedin.com/pulse/crypto-20-lenses-hyder-jaffrey
[7] G. Greenspan. (2015). *Avoiding the Pointless Blockchain Project*. [Online]. Available: https://www.multichain.com/blog/2015/11/avoiding-pointless-blockchain-project/
[8] METI. (2017). *Evaluation Forms for Blockchain—Based System*. [Online]. Available: http://www.meti.go.jp/english/press/2017/pdf/0329_004a.pdf
[9] S. Seibold and G. Samman. Consensus: Immutable Agreement for the Internet of Value. KPMG. Accessed: Feb. 1, 2019. [Online]. Available: https://assets.kpmg/content/dam/kpmg/pdf/2016/06/kpmg-blockchain-consensus-mechanism.pdf
[10] K. Valtanen, J. Backman, and S. Yrjölä, "Creating value through blockchain powered resource configurations: Analysis of 5G network slice brokering case," in *Proc. IEEE WCNC Wireless Commun. Netw. Conf.*, Barcelona, Spain, Apr. 2018, pp. 185–190.
[11] R. Amit and X. Han, "Value creation through novel resource configurations in a digitally enabled world," *Strategic Entrepreneurship J.*, vol. 11, no. 3, pp. 228–242, 2017.
[12] B. Wirtz, O. Schilke, and S. Ullrich, "Strategic development of business models: Implications of the Web 2.0 for creating value on the Internet," *Long Range Planning*, vol. 43, nos. 2–3, pp. 272–290, 2010.
[13] J. Backman, K. K. Valtanen, S. Yrjölä, and O. Mämmelä, "Blockchain network slice broker in 5G: Slice leasing in factory of the future use case," in *Proc. Joint CTTE and CMI Conf., Internet Things-Business Models, Users, Netw.*, Copenhagen, Denmark, Nov. 2017, pp. 1–8.
[14] J. Mattila *et al.*, "Industrial blockchain platforms: An exercise in use case development in the energy industry," ETLA-Res. Inst. Finnish Economy, Helsinki, Finland, ETLA Working Papers 43, 2016. [Online]. Available: http://pub.etla.fi/ETLA-Working-Papers-43.pdf
[15] BOND. *The Blockchains Boosting Finnish Industry Project Web Pages*. Accessed: Feb. 1, 2019. [Online]. Available: https://www.vtt.fi/sites/BOND
[16] R. Amit and C. C. Zott, "Crafting business architecture: The antecedents of business model design," *Strategic Entrepreneurship J.*, vol. 9, no. 4, pp. 331–350, 2015.

[17] K. Lewin, “Action research and minority problems,” *J. Social Issues*, vol. 2, no. 4, pp. 34–46, 1946.

[18] T. Stevenson, “Anticipatory action learning: Conversations about the future,” *Futures*, vol. 34, no. 5, pp. 417–425, Jun. 2002.

[19] S. Inayatullah, “Anticipatory action learning: Theory and practice,” *Futures*, vol. 38, no. 6, pp. 656–666, 2006.

[20] D. Coghlan and T. Brannick, *Doing Action Research in Your Own Organization*, 3rd ed. London, U.K.: Sage, 2010.

[21] P. Reason, “Choice and quality in action research practice,” *J. Manage. Inquiry*, vol. 15, no. 2, pp. 187–202, 2006.

[22] H. Tsoukas and J. Shepherd, Eds., *Managing the Future: Foresight in the Knowledge Economy*. Hoboken, NJ, USA: Blackwell Publishing Ltd., 2004.

[23] J. M. Ramos, “Dimensions in the confluence of futures studies and action research,” *Futures*, vol. 38, no. 6, pp. 642–655, 2006.

[24] IIC. *Industrial Internet Consortium*. Accessed: Feb. 1, 2019. [Online]. Available: https://www.iiconsortium.org/

[25] J. Floyd, “Action research and integral futures studies: A path to embodied foresight,” *Foresight*, vol. 44, no. 10, pp. 870–882, 2012.

[26] A. Bryman and E. Bell, *Business Research Methods*, 3rd ed. New York, NY, USA: Oxford Univ. Press, 2011.

[27] R. K. Yin, *Case Study Research: Design and Methods*, 4th ed. Newbury Park, CA, USA: Sage, 2009.

[28] J. W. Creswell, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. Thousand Oaks, CA, USA: Sage, 1998.

[29] S. Nakamoto. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*. [Online]. Available: https://bitcoin.org/bitcoin.pdf

[30] J. Yli-Huumo, D. Ko, S. Choi, S. Parka, and K. Smolander, “Where is current research on blockchain technology?—A systematic review,” *PLoS ONE*, vol. 11, no. 10, 2016, Art. no. e0163477.

[31] M. Vukolić, “The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication,” in *Open Problems in Network Security* (Lecture Notes in Computer Science), vol. 9591, J. Camenisch and D. Kesdo an, Eds. Cham, Switzerland: Springer, 2016.

[32] A. Kiayias, I. Konstantinou, A. Russell, B. David, and R. Oliynykov, “A provably secure proof-of-stake blockchain protocol,” IACR Cryptol. ePrint Archive, New Delhi, India, Tech. Rep., 2016, p. 889. [Online]. Available: https://allquantor.at/blockchainbib/pdf/kiayias2016provably.pdf

[33] K. Christidis and M. Devetsikiotis, “Blockchains and smart contracts for the Internet of Things,” *IEEE Access*, vol. 4, pp. 2292–2303, 2016.

[34] A. Baliga. (2016). *The Blockchain Landscape, Persistent Systems*. [Online]. Available: https://www.persistent.com/wp-content/uploads/2016/03/The-Blockchain-Landscape-.pdf

[35] N. Szabo. (1994). *Smart Contracts*. [Online]. Available: http://szabo.best.vwh.net/smart.contracts.html

[36] D. G. Sirmon, M. A. Hitt, R. D. Ireland, and B. A. Gilbert, “Resource orchestration to create competitive advantage: Breadth, depth, and life cycle effects,” *J. Manage.*, vol. 37, no. 5, pp. 1390–1412, 2011.

[37] R. Adner and R. Kapoor, “Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations,” *Strategic. Management. J.*, vol. 31, no. 3, pp. 306–333, Mar. 2010.

[38] Y. Bakos, “The emerging role of electronic marketplaces on the Internet,” *Commun. ACM*, vol. 41, no. 8, pp. 35–42, 1998.

[39] *LendingClub*. Accessed: Feb. 1, 2019. [Online]. Available: https://www.lendingclub.com/

[40] B. Demil and X. Lecocq, “Business model evolution: In search of dynamic consistency,” *Long Range Planning*, vol. 43, nos. 2–3, pp. 227–246, 2010.

[41] M. Johnson, C. M. Christensen, and H. Kagermann, “Reinventing your business model,” *Harvard Bus. Rev.*, vol. 86, no. 12, pp. 50–60, 2008.

[42] A. Osterwalder and Y. Pigneur, *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. Hoboken, NJ, USA: Wiley, 2010.

[43] H. Chesbrough, “Business model innovation: Opportunities and barriers,” *Long Range Planning*, vol. 43, nos. 2–3, pp. 354–363, Apr./Jun. 2010.

[44] C. Zott and R. Amit, “The business model: A theoretically anchored robust construct for strategic analysis,” *Strategic Org.*, vol. 11, no. 4, pp. 403–411, 2013.

[45] D. Messerschmitt and C. Szyperski, *Software Ecosystem: Understanding an Indispensable Technology and Industry*. Cambridge, MA, USA: MIT Press, 2003.

[46] *NGMN 5G White Paper*, NGMN Alliance, Frankfurt, Germany, 2015.

[47] K. Samdanis, X. Costa-Perez, and V. Sciancalepore, “From network sharing to multi-tenancy: The 5G network slice broker,” *IEEE Commun. Mag.*, vol. 54, no. 7, pp. 32–39, Jul. 2016.

[48] J. Wang, A. J. Conejo, C. Wang, and J. Yan, “Smart grids, renewable energy integration, and climate change mitigation—Future electric energy systems,” *Appl. Energy*, vol. 96, pp. 1–484, Aug. 2012.

[49] M. A. Mohamed, A. M. Eltamaly, H. M. Farh, and A. I. Alolah, “Energy management and renewable energy integration in smart grid system,” in *Proc. IEEE Int. Conf. Smart Energy Grid Eng.*, Aug. 2015, pp. 1–6.

[50] S. Nistor, J. Wu, M. Sooriyabandara, and J. Ekanayake, “Capability of smart appliances to provide reserve services,” *Appl. Energy*, vol. 138, pp. 590–597, Jan. 2015.

[51] S. Hall and K. Roelich, “Business model innovation in electricity supply markets: The role of complex value in the United Kingdom,” *Energy Policy*, vol. 92, pp. 286–298, May 2016.

[52] U. Wassmer and P. Dussauge, “Network resource stocks and flows: how do alliance portfolios affect the value of new alliance formations?” *Strategic Manage. J.*, vol. 33, no. 7, pp. 871–883, 2012.

[53] C. M. Weiller and M. G. Pollitt, *Cambridge Working Platform Markets and Energy Services*. Cambridge, U.K.: Cambridge Univ. Press, 2013.

[54] T. Chen, M. Matinmikko, X. Chen, X. Zhou, and P. Ahokangas, “Software defined mobile networks: Concept, survey, and research directions,” *IEEE Commun. Mag.*, vol. 53, no. 11, pp. 126–133, Nov. 2015.

[55] R. A. C. van der Veen and R. A. Hakvoort, “The electricity balancing market: Exploring the design challenge,” *Utilities Policy*, vol. 43, pp. 186–194, Dec. 2016.

[56] N. Bahari, R. Maniak, and V. Fernandez, “Ecosystem business model design,” In *Proc. 24th Conf. Int. Manage. Stratégique*. Paris, France: AIMS, 2015, pp. 1–18.

[57] T. Rasheed *et al.*, “Business models for cooperation,” in *Energy Efficient Smart Phones for 5G Networks: Signals and Communication Technology*. Cham, Switzerland: Springer, 2015.

[58] S. L. Vargo and R. F. Lusch, “Institutions and axioms: An extension and update of service-dominant logic,” *J. Acad. Marketing Sci.*, vol. 44, no. 1, pp. 5–23, 2016.

[59] H. Wieland, N. N. Hartmann, and S. L. Vargo, “Business models as service strategy,” *J. Acad. Marketing Sci.*, vol. 45, no. 6, pp. 925–943, 2017.

[60] Y. Xu, P. Ahokangas, and E. Reuter, “EaaS: Electricity as a service?” In *Proc. 24th Nordic Acad. Manage. Conf.* Bodø, Norway: NFF, 2017, pp. 1–22.

[61] M. Matinmikko, M. Latva-Aho, P. Ahokangas, S. Yrjölä, and T. Koivumäki, “Micro operators to boost local service delivery in 5G,” *Wireless Pers. Commun. J.*, vol. 95, no. 1, pp. 69–82, May 2017.

[62] H. Subramanian, “Decentralized blockchain-based electronic marketplaces,” *Commun. ACM*, vol. 61, no. 1, pp. 78–84, 2017.

[63] E. G. Weyl, “A price theory of multi-sided platforms,” *Amer. Econ. Rev.*, vol. 100, no. 4, pp. 1642–1672, 2010.

[64] J. Löbbers, M. von Hoffen, and J. Becker, “Business development in the sharing economy: A business model generation framework,” in *Proc. IEEE 19th Conf. Bus. Informat. (CBI)*, Thessaloniki, Greece, Jul. 2017, pp. 237–246.

[65] W. Mougayar. *The Blockchain is Still Waiting for Its Web. Here’s a Blueprint*. [Online]. Available: https://www.coindesk.com/blockchain-still-waiting-web-blueprint-getting-us/

[66] S. Seebacher and R. Schüritz, “Blockchain technology as an enabler of service systems: A structured literature review,” in *Proc. Int. Conf. Exploring Services Sci.*, Cham, Switzerland: Springer, May 2017, pp. 12–23.

[67] M. Staples *et al.*, “Risks and opportunities for systems using blockchain and smart contracts,” in *Proc. Data61 (CSIRO)*, Sydney, NSW, Australia, 2017, pp. 1–60.

[68] H. Wang, K. Chen, and D. Xu, “A maturity model for blockchain adoption,” *Financial Innov.*, vol. 2, no. 1, p. 12, Dec. 2016.

[69] L. Diestelmeier, “Regulating for blockchain technology in the electricity sector: Sharing electricity- and opening Pandora’s Box?” in *Proc. 16th Annu. IAS-STS Conf. Crit. Issues Sci. Technol. Stud.*, May 2017, pp. 1–16.

[70] K. Lauslahti, J. Mattila, and T. Seppälä, “Smart contracts—How will blockchain technology affect contractual practices?” ETLA-Res. Inst. Finnish Economy, Helsinki, Finland, ETLA Rep. 57, 2016.

[71] F. Glaser, “Pervasive decentralisation of digital infrastructures: A framework for blockchain enabled system and use case analysis,” in *Proc. 50th Hawaii Int. Conf. Syst. Sci.*, 2017, pp. 1–10.

[72] J. Mattila and T. Seppälä, *Distributed Governance in Multi-Sided Platforms*. Washington, DC, USA: Industry Studies Association Conference, 2017.

[73] K. Alabi, "Digital blockchain networks appear to be following Metcalfe's Law," *Electron. Commerce Res. Appl.*, vol. 24, pp. 23–29, Jul./Aug. 2017.

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