Creating Value Through Blockchain Powered Resource Configurations: Analysis of 5G Network Slice Brokering Case

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Abstract—**The exponential growth of wireless services with diversity of devices and applications has inspired the research community to come up with novel concepts to improve the efficiency of resource use. It is cost efficient and practical to be able to evaluate and analyze expected value of use cases before actual implementation of the solution. This paper presents blockchain network slice brokering use case value analysis and results in the industrial automation application scenario. The use case value was assessed applying resource configuration framework against blockchain and smart contracts characteristics and capabilities. According to the findings, expected value of blockchain network slice brokering use case was proven and in general feasibility of blockchain technology for novel resource configurations use cases for various network functions was stated. The use case enables industrial automation processes and related manufacturing equipment to autonomously and dynamically acquire the slice needed for most efficient operations. The resource configuration framework provides a dynamic framework for analyzing and developing the blockchain enabled novel use cases and business models.**

Keywords: Blockchain, edge computing, industrial automation, network function virtualization, network slicing, resource configuration, system model, 5G.

I. Introduction

Blockchain (BC) is a decentralized transaction and data management technology developed first for the Bitcoin cryptocurrency. Since, the technology has been developed towards smart contract (SC) concept that enables automation of complex multi-step processes. Integrating SC to BC enables distributed and heavily automated workflows. It is cost efficient and practical to be able to evaluate and analyze expected value and feasibility of blockchain use cases before actual implementation of the solution. As a decentralized technology, BC enables completely new technological systems and business models. Yet, there are quite few frameworks that are purely targeted for evaluating BC use cases, and take into account BC systems' specific characteristics. Jaffrey and Batlin have proposed Crypto 2.0 Lenses evaluation framework developed particularly for the financial applications [1]. Another often referenced evaluation framework is created by Greenspan [2] introducing an eightfold checklist on what should be considered before BC implementations assessing the feasibility of the use case against key characteristics of blockchain. Greenspan's framework is more general than Batlin's and can thus be used more widely across industries.

If we want to evaluate, analyze and create value out of the use case, systemic and business opportunity centric perspective can be more suitable. Resource configuration framework is system-based, value-creation-centric perspective for designing and organizing firm's resource configuration [3]. The framework considers needs and resources of value co-creators when conceiving of resource configuration, and provides the foundation for conceiving of and designing novel ways to link heterogeneous resources with heterogeneous needs in a digitally enabled world [3]. In this study, we apply the resource configuration framework towards more general industrial use cases. In that process, we use the telco oriented 5G network slice broker [4] as an example but at the same time we strive to get our work to benefit and create value to the industry also more widely. Despite the goal of generality, we aim to preserve the level of detail in our research via specific use case assessment. The paper specifically seeks to address *how the blockchain technology can facilitate the resource configuration value creation microprocesses and the 5G network slice broker use case in industrial automation use.* The rest of this paper is organized as follows. At first, materials, methods and system model are introduced. In Chapter III, use case is analyzed applying resource configuration framework and BC characteristics. Finally, conclusions and further work are discussed.

II. Materials and Methods

In this chapter, capabilities of blockchain and smart contracts are introduced, and the 5G network slice broker use case described and its resource configuration concept analyzed.

A. *Capabilities of Blockchain and Smart Contracts*

Blockchain is a decentralized transaction and data management technology, and a distributed database solution maintaining a growing list of data records that are confirmed by the nodes participating in it. The data is recorded in a public ledger, including information of every transaction completed. This kind of solution does not require third-party organization in the middle. The information about every transaction completed is shared and available to all nodes. This makes the system more transparent than centralized solutions [5]. BC based systems have a wide range of characteristics which together make them unique. We propose and use in our study the following main categories of BC characteristics and capabilities: traceability and immutability, security and privacy, disintermediation, near real-time, consensus, trust and smart contracts [6], [7], [8] and [9]. Clack et al. [10] define a SC as *an automatable and enforceable agreement by computer, although some parts may require human input and control. Enforceable either by legal enforcement of rights and obligations or via tamper-proof execution of computer code.* This definition covers both "smart legal contracts" and "smart contract code". SCs are scripts stored on the BC enabling general-purpose computations to occur on the chain. SCs operate as autonomous actors, and the behavior of those is predictable. Since the SCs reside on the chain and have a unique address, the code can be inspected by every network participant, and all the network participants get a cryptographically verifiable trace of the contract's operations. A SC can be triggered by addressing a transaction to it, and executes automatically in every node of the network, according to the data provided when triggering the transaction [11].

B. Blockchain 5G Network Slice Broker Use Case in an Industrial Automation Scenario

Business literature provides us with plentiful examples of business model and value chain frameworks and their elements. The traditional frameworks have limitations in dealing with systemic complexities, dynamics of activities, and the element of locations. In this paper, value network configuration (VNC) framework proposed by T. Casey et al. [12] is employed. A value network consists of interlinked business actors and functional technical resources that work together to create value through products and services. A VNC results as actors take on roles and establish business interfaces among each other through revenue models and contracts.

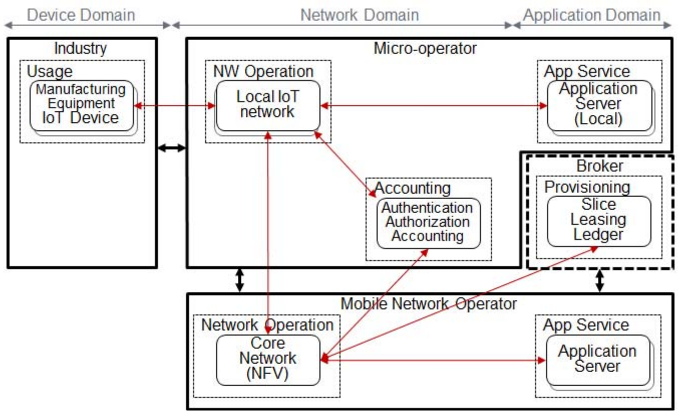

Fig. 1. 5G network slice broker industrial automation scenario value network configuration framework elements and interfaces.

In general, the functional value network architecture for the industrial automation use case consist of Internet-of-things (IoT) devices with machine-to-machine (m2m) modules, radio access network (RAN) access nodes, virtualized core network (CN), and central and local edge server nodes for applications, micro services and data [13] as shown in Fig. 1. Technical interfaces are described as narrow arrows and business interfaces as bold black ones. In the typical industrial application, the extremely low latency and high reliability requirements are critical, and it is preferable to keep the deployment of infrastructure local. In addition to RAN and CN resources, the network slice could include cloud server locally at the site owned and managed locally by the facility, micro-operator (μO) [14] or separate cloud service provider. Control plane functions like accounting operations can be managed by the local μO and or a MNO. Management responsibilities will be shared among operators and service providers including the broker. Local deployment is operated and managed by the μO, which leverages network slicing to provide industry/factory customers with local customized service. Furthermore, as a real option a μO can virtualize its small cell infrastructure into slices and act as a neutral host towards MNOs to extend their services into the local area. The network slice management process can involve the customers, μOs, and broker. This enables the customers, e.g., both the factory owner and factory-within-factory (FWF) partners, to manage application critical network functions and capabilities themselves, while MNO controlled network functions will be deployed at a central location in the operator network. The FWF concept involves setting up a factory within the premises of the principal manufacturer requiring that several use case specific dedicated slices can be provided in parallel. In the local area access for IoT multi-tenancy context, the end-to-end (e2e) service level agreement (SLA) can be defined qualitatively for each customer based on the reserved resources, reliability, latency and availability. [15] defines multi-tenancy as the capability to offer connectivity services to multiple tenants and to combine resources from different operators. Network exposure mechanism enables μOs and MNOs to securely expose the service capabilities from the network infrastructure, such as network functions and network interfaces, to verticals, and application providers [16]. This allows the tenants to gain access to the network information, retrieve network information and provide statistical data back to the network for resource optimization [17]. The level of exposure and related SLA with tenants can facilitate external exposure while user agreements and policies can be enforced to maintain security, privacy and trust of information exchanged which also will be of interest to regulator, related e.g., to competition and net neutrality.

Introduced novel network slice broker role, depicted in Fig. 1 and 2, enables μOs to request and lease resources from infrastructure providers (InPs), like MNOs, dynamically according to their business and use case needs. According to current standardization state of art [18] and [19] the broker can be deployed on the master operator-network manager (MO-NM) management and orchestrator (MANO) layer where the information needed for its operation is available through type 5 interface to sharing operator network manager (SO-NM) and through type 2 interface to shared RAN. As a future 5G vision, a μO, third party or a joint venture formed by service providers or participating operators can act as a slice broker and correspondingly the broker ledger would work more and more as a resource marketplace beyond the transaction facilitator. A broker serves customers to procure and provision the type and number of the required virtual network elements and slices from one or multiple InPs based on the customer's requirements defined in the negotiated SLA. A broker can aggregate the dedicated slice resources, network functions and applications from one or multiple InP stores that dynamically design, install, program, and configure all the network-specific elements that correspond to specific business use-cases. The workflow of a network slice service offering in general consists of customer specification (scheduling, quality of service (QoS), required resources, network functions, etc.), slice design according to those specifications, marketing, pricing, composition, operation, and management and finally termination.

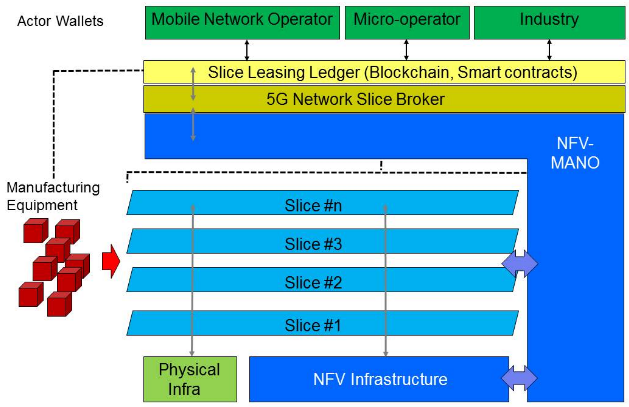

Fig. 2. Concept of network slice leasing by manufacturing equipment in 5G virtualized network function (NFV) infrastructure.

C. 5G Network Slice Broker Resource Configuration

Resource configuration framework is system-based, value-creation-centric perspective for designing, organizing and orchestrating firm's resources. The framework considers needs and resources of value co-creators when conceiving of resource configuration, and provides the foundation for conceiving of and designing novel ways to link heterogeneous resources with heterogeneous needs in a digitally enabled world. Amit et al. [3] 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, collaborator, transaction enabler* or *bridge provider,* and correspondingly take care of resource configuration microprocesses like streamlining, sorting, resource crowdsourcing or continuous testing [3], as illustrated in Fig. 3.

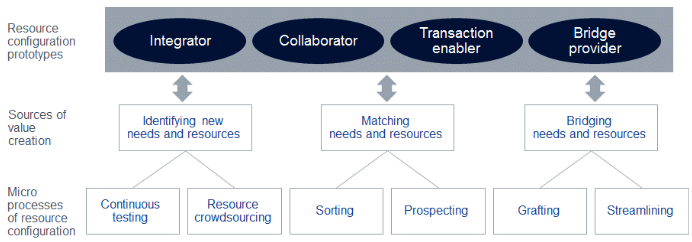

Fig. 3. Novel resource configurations & value creation, adapted from [3]

Amit et al. [3] 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 network slice broker/ledger resource configuration. Fig. 4 presents the conceptualization of the setting for network slice broker/ledger resource configuration. The focal firm F is the network slice broker/ledger. F's resources accordingly R_F and needs N_F. Value co-creators (C-V) are notated in the same way: MNO, µO and Man (manufacturing equipment/owner). The arrow denotes that certain resources are utilized to meet certain needs.

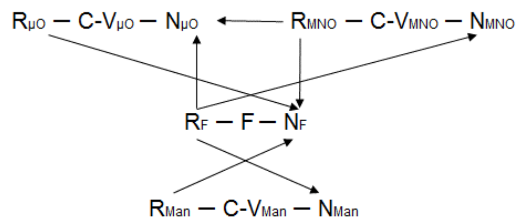

Fig. 4. The conceptualization of the setting for network slice broker/ledger resource configuration.

III. Analysis and Results

In digital based systems, value is principally created in two ways: whether adding new, previously unaddressed needs or reconfiguring existing under-utilized resources in a more effective manner [3]. Further, for more efficient operation of economic processes, the uncertainty between co-operating parties should be lowered as much as possible. BC based systems can provide novel technical capabilities for this kind of trust building. They have been considered capable of providing neutral ground between organizations and thus reducing counter-party and operational risks [20]. Seebacher et al. [6] have surveyed the impact of BC in context of service systems that are a more generic way of describing co-creating service providers and beneficiaries. They found that BC supports the functioning of service systems in many ways by ensuring availability of information, offering mechanisms for coordination, and thus facilitating co-creation of value. In analyzing the frameworks of Amit and Seebacher, we found that in describing the business ecosystem's operation, both agree on the transformation towards more system-based approach in which the traditional firm-based setting of provider and beneficiary is replaced by value-co-creating parties each of which may operate as a resource provider as well as potential locus of value creation. In this kind of environment, the importance of trusted, decentralized business platform will be even more emphasized.

In this study, we extend the value creation process analysis by describing resource configuration microprocesses based on the Amit's model, and especially concentrating on the question how *BC could facilitate the implementation of these processes*. In Table I, the microprocesses of value creation are listed, and the requirements for efficient implementation of these processes described. Additionally, we have proposed the BC capabilities that seem to be most influential in the implementation of the value-creation microprocesses. As a use case study, we assessed the features of the broker/ledger concept against the previously discussed BC capabilities to find the most appropriate value creation microprocesses and roles for the broker/ledger. Similarly, also other industries can either evaluate or brainstorm their own business ideas.

Next, we will analyze value creation microprocesses and their requirements having the focus on the potential contribution of BC.

In **continuous testing** value creation microprocess, firms with their value co-creators continuously test their offerings and adjust them accordingly. To implement this kind of feedback loop, we first need extensive set of data originating from multiple different channels (social platforms, content sites like blogs, location based services etc.). Digital business is also able to produce a significant amount of valuable user information through analysis tools like heatmaps, click tracking, A/B (split) and multi-variate testing. These coupled, create means to generate e.g., highly targeted, custom tenders and further follow their efficacy. In BC based marketplace, blockchain itself operates as a chronological, immutable database giving, with other sources combined, better market insight for next test iterations. Furthermore, BC based SCs can be harnessed to automate offer modifying processes based on the parameters tuned in the feedback loop.

Resource crowdsourcing creates value by bringing together largely distributed, under-utilized resources to reach a scale. Because single pieces of resources are often small in size and value, the transaction cost including costs from searching and offering to negotiating, establishing and enforcing the crowdsourcing agreement must be minimized. While transaction costs fundamentally are interrelated with distrust, the increase of trust generally helps reduce these costs [21]. Trust is one of the key characteristics of BC, and thus can be stated that BC facilitates the resource crowdsourcing process by providing the trusted environment with lower transaction costs. Especially, the costs of verification and networking can be radically reduced as a result of introduction of BC [22]. Moreover, the parts of transaction which concern negotiating, establishing and enforcing transaction may be automated as SCs operate on behalf of resource providers and other value co-creators making and accepting tenders.

The **sorting** process creates value by categorizing resources in a more efficient way that enables more effective matching between needs and resources. Again, the starting point for facilitating this microprocess is comprehensive trusted data set provided by BC. Based on the data, categorizing algorithms can be run and the results can be used for further tuning of business processes. However, gathering extensive data sets may include the risk that the privacy of stakeholders may be compromised. To mitigate this risk, new privacy-preserving encryption methods are being developed. E.g., homomorphic encryption allows data analytics and computations to be run over encrypted data, keeping the raw data hidden [23] and [24].

In **prospecting** process, a firm tries to predict resource needs and resource controllers' expectations and disseminate these forecasts to value co-creators so that they in turn can adjust their business efforts. The prediction making is based on the historical data, which is effortlessly reachable in BC platform, and on enhanced data analysis methods, machine learning and even artificial intelligence (AI). Both matching microprocesses, prospecting and sorting, will also greatly benefit from the functionality of BC based SCs as the test phase of feedback loop begins. After having some results from categorizing or prediction algorithms, the testing of tuned business scenarios may be automated and test results can also be easily verified and used for, e.g., estimating the relevance of previous predictions.

Grafting is the most creativity-demanding microprocess that tries to couple hereto unconnected resources and needs to produce novel complementarity. For facilitating this process, BC as a business platform can have some superior capacities compared to traditional platforms. BC is general-purpose technology with the ability to track transactions, settle trades and enforce contracts across wide range of digital assets which in turn can represent, e.g., currency, IP, data, contracts or physical assets [22]. This means that presumably there will be many industry-specific BCs in the future that can communicate and interact with each other. There are plenty of efforts going on within this space, e.g., [24] and [25], and if realized, plethora of novel, potentially disruptive combinations of digital businesses become possible. Large datasets as well as AI can help in finding unique business combinations, but possibly also crowdsourcing of human intelligence in business process development can produce valuable end results. Crowdsourcing is one of inherent applications in BC platforms, and it is sort of fair incentivizing method that guarantees that those who most contribute in some task, also get the greatest reward if the task turns out to be successful. In some business development visions, BC is integrated to existing enterprise systems as an additional layer which may take care of e.g., business process monitoring and execution [26]. As these tasks are implemented using SCs, BC based implementation eases fast experiments with a great importance in grafting process.

Streamlining value-creation microprocess further supplements, e.g., grafting process by mitigating the incompatibilities that bridging process generally entails. The microprocess resembles previous processes as far as the facilitation brought with BC is concerned: fine-tuning of SC parameters which control the relationship between value-co-creators as well as combining data analysis tools with BC platform help both in the enrichment of novel complementarity created in the previous bridging process.

To conclude, when reviewing how BC could assist the progression of different value-creation microprocesses, we need to recall that compared to traditional business systems, BC's technological architecture is fundamentally different which may cause additional twist in the operation mechanisms of microprocesses. Traditionally, centralized businesses have overseen resource and service production, aggregation and distributing, searching efficiency gains by integrating both horizontally and vertically. As being distributed, cryptographically secured, consensus based peer to peer (P2P) network which can securely transfer value and build trust, the role of companies and smart contracts deployed by them may change closer to autonomous, decentralized agents [27].

TABLE I. VALUE CREATION MICROPROCESSES, THEIR REQUIREMENTS AND APPLICABILITY TO 5G BLOCKCHAIN BROKER USE CASE

Source of value creation	**Resource configuration microprocesses**	**What is needed for an effective microprocess?**	**BC characteristics and capabilities that MOST facilitate the implementation of microprocess**	**Applicability to the 5G BC broker**
Identifying new needs and resources	Continuous testing *Firms test and modify their offerings continuously using a fast feedback loop with their value co-creators.*	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	++ In 5G era, µOs try to differentiate by providing tailored services. ++ Near-real time operation of BCs is sufficient
	Resource crowdsourcing *Firms gather together (often a small amount of) under-utilized resources from a large (and preferably widely distributed) group of value co-creators to reach a scale.*	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	- not so relevant in our business to business use case, because 5G resources are provided by limited number of InPs/MNOs
Matching needs and resources	Sorting *Firms develop methods and strategies to categorize both needs and resources so that they could be matched in a more efficient and effective manner.*	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.	+++ 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
	Prospecting *Firms predict resource needs and resource controllers' expectations based on historical or current data and disseminates the most relevant information to value co-creators.*	In addition to above, sophisticated data analysis methods and AI capabilities may be needed for finding latent needs and the most relevant matching information and assumptions. Mechanisms for efficient recommending and provision.	The possibility to combine more enhanced data analysis and AI based prediction making with BC. The results of analyses can be used as parameters for smart contract based automated provision.	+ 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 AI and data analysis to support critical QoS services
Bridging needs and resources	Grafting *Firms experiment with new combinations of hereto unconnected (or less connected) resources and needs to enhance the value creation of the resource configuration.*	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.	-/+++ 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
	Streamlining *Firm reduce the incompatibilities and uncertainties that e.g. the grafting process creates. This is realized by connecting additional resources which further streamline the novel process.*	Wide variety of digitally enabled resources, e.g., data in multiple 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.	+ 5G broker's data can continuously be used as a basis for streamlining the services created in grafting process.

IV. Conclusion

This paper presents the value and feasibility analysis of blockchain network slice broker use case applying resource configuration framework. The use case enables industrial automation processes autonomously and dynamically acquire the slice needed for most efficient operations. According to the findings, expected value of blockchain network slice broker/ledger use case was proven, and in general applicability of blockchain technology for the novel resource management and configuration stated. Results show that many of analyzed microprocesses are appropriate tasks for the 5G network slice broker and ledger platform as capabilities of blockchain strongly support implementation of these process mechanisms.

Studied and applied Amit's [3] resource configuration value-creation microprocesses are targeted for an environment consisting of centralized platforms, firms and their resources. Adoption of BC can change the set-up towards new decentralized concepts. Assuming that visions of autonomous agents and organizations operating and interacting in various BC platforms realize, more and more emergent behaviour will also appear in business ecosystems. Furthermore, the role of cryptocurrencies may be significant in creating novel possibilities for digital business and service delivery.

Next phase of the research is to implement the proof of concept realizing the blockchain network slice broker use case. After the validation, the evaluation framework can be assessed and further developed. Furthermore, research is needed to study value-creation processes in this new decentralized environment extending the scope to other virtualized resources and assets particularly at the edge of the network.

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