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Designing a Blockchain-Based Marketplace for 5G Network Slices

Industrial Economy

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The thesis is equivalent to 20 weeks of full time studies. The authors declare that they are the sole authors of this thesis and that they have not used any sources other than those listed in the bibliography and identified as references. They further declare that they have not submitted this thesis at any other institution to obtain a degree.

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ABSTRACT

Recent advances in 5G have introduced the concept of network slicing, enabling telecom operators to create virtualized network instances tailored to diverse service demands. However, existing blockchain-based marketplace proposals for slice provisioning often lack integration with telecom infrastructure, alignment with industry standards, automation for SLA data handling, and architectural consistency. This thesis addresses these gaps by designing a blockchain-based marketplace platform that enables short-term provisioning of 5G network slices through standardized, interoperable, and automation-ready interfaces.

Using a Design Science Research methodology, the thesis develops and evaluates an architecture that integrates distributed ledger technology with TM Forum Open APIs and aligns with 3GPP standards. Smart contracts are employed to enforce service level agreements (SLAs) in a transparent and tamper-evident manner, enabling automation of SLA verification and secure forwarding of SLA-related data toward operator systems. Rather than attempting to replace billing infrastructure, the proposed architecture supports provisioning-level automation and integration with existing workflows.

The main contributions include the specification of a unified architecture that connects blockchain with existing telecom interfaces, the suggested architecture, and a qualitative validation of its technical feasibility and interoperability through expert feedback. The solution demonstrates how automation, traceability, and interoperability could be achieved within SLA service delivery, offering a reference model for similar infrastructure-focused domains. While monetization was not the primary focus, the results indicate potential to expose advanced 5G capabilities to small and medium-sized enterprises (SMEs), thereby supporting broader adoption in underserved segments.

Keywords: 5G Network Slicing; Blockchain, Smart Contracts, Service Level Agreements; TM Forum Open APIs

SAMMANFATTNING

De senaste framstegen inom 5G har introducerat konceptet nätverksskivning (network slicing), vilket gör det möjligt för teleoperatörer att skapa virtualiserade nätverksinstanser anpassade efter olika tjänstebehov. Befintliga blockchain-baserade förslag för marknadsplatser inom slice-provisionering saknar dock ofta integration med telekominfrastruktur, anpassning till industristandarder, automatisering av SLA-hantering samt arkitektonisk konsistens. Denna uppsats adresserar dessa brister genom att utforma en blockchain-baserad marknadsplatsplattform som möjliggör korttidsprovisionering av 5G-nätverksskivor via standardiserade, interoperabla och automationsklara gränssnitt.

Med en Design Science Research-metodik utvecklas och utvärderas en arkitektur som integrerar distribuerad blockkedjateknologi med TM Forums öppna API:er och följer 3GPP-standarder. Smarta kontrakt används för att upprätthålla tjänstenivåavtal (SLA:er) på ett transparent och manipulationssäkert sätt, vilket möjliggör automatiserad SLA-verifiering och säker vidarebefordran av SLA-relaterade data till operatörernas system. I stället för att ersätta befintlig faktureringsinfrastruktur stödjer den föreslagna arkitekturen automatisering på provisioneringsnivå och integration med existerande arbetsflöden.

Uppsatsens huvudsakliga bidrag omfattar specifikationen av en enhetlig arkitektur som kopplar samman blockchain med befintliga telekomgränssnitt, samt en kvalitativ validering av dess tekniska genomförbarhet och interoperabilitet baserat på expertutlåtanden. Lösningen visar hur automatisering, spårbarhet och interoperabilitet kan uppnås vid leverans av SLA-baserade tjänster, och fungerar som en referensmodell för liknande infrastrukturfokuserade områden. Även om monetarisering inte stod i fokus tyder resultaten på att arkitekturen kan bidra till att exponera avancerade 5G-funktioner för små och medelstora företag (SME), och därmed stödja ökad adoption i underförsörjda segment.

Nyckelord: 5G-nätverksskivning; Blockkedja, Smarta kontrakt, Telekomstandarder, TM Forum Open APIs

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Table of Content

1 INTRODUCTION

Fifth generation (5G) mobile networks represent a significant technological leap, promising ultra-low latency, high bandwidth, and the ability to support a vast number of connected devices. However, as the technical rollout of 5G progresses, the telecom industry is grappling with how to effectively monetize these capabilities, particularly in the enterprise domain. This has sparked growing interest in advanced service delivery models such as network slicing, and in enabling technologies like blockchain that could support automation, trust, and integration.

This thesis explores how blockchain technology, when combined with industry standards and operational frameworks, can enable a flexible and interoperable system for managing 5G network slices. The following sections provide background on the monetization challenges in 5G, the role of enabling technologies, and the research objectives driving the proposed system architecture.

1.1 Background and Motivation

In the enterprise (B2B) domain, the telecom industry faces a broader monetization challenge as 5G networks mature. Traditional mobile data services have become commoditized, and offering faster connectivity has not translated into proportionate gains in productivity or digital transformation for businesses (Infovista, 2024). According to industry analyses, unlocking the full value of 5G will require operators to move beyond basic connectivity and develop new enterprise-focused services and business models (PwC, 2023). Several factors have inhibited monetization so far. Unlike the 4G era, which catalysed the growth of high-demand applications such as mobile video streaming and ridesharing, the 5G era has yet to produce a similarly transformative "killer application" to drive widespread adoption (McCauley, 2025). Another aspect is the cost and complexity of deploying 5G infrastructure (e.g., densifying networks, upgrading core systems) have exceeded expectations, putting financial strain on mobile network operators without an immediate payoff (Accenture & Umlaut, 2024). Finally, many operators adopted a "build it and they consumers will come" approach, which rapidly rolling out 5G networks without a clear use-case strategy, leading to a mismatch between advanced network capabilities and actual enterprise demand. The operators have struggled to align 5G offerings with the needs of specific industries and to convince businesses of 5G's value proposition (GSMA Intelligence, 2024a).

Given these challenges, telecom operators are now exploring new strategies to realize 5G's potential, particularly in the enterprise domain. One promising approach is deeper collaboration with enterprise customers, including co-developing tailored solutions rather than selling generic connectivity services (Infovista, 2024; PwC, 2023). The logic is that by working closely with businesses (e.g., in manufacturing, healthcare, entertainment), operators can create specialized 5G-enabled services that directly address those customers' needs. Industry analysts note that successful monetization of 5G in the enterprise sector will require a paradigm shift in service delivery models and a closer alignment with vertical industry requirements (McCauley, 2025). Leading consultants have pointed to enterprise-oriented platforms such as smart factories, immersive media, and IoT solutions — with the key goal of unlocking new revenue streams, rather than relying solely on consumer mobile broadband (Accenture, 2023).

Operators have begun to pilot offerings like private 5G networks and edge computing solutions for industry partners (Ericsson, 2023). But the massive investments in 5G have not yet yielded commensurate improvements in broader economic productivity or digital transformation, especially in mature markets (GSMA Intelligence, 2024b). This indicates that simply deploying advanced network technology is insufficient; innovative business models and supporting systems are needed to bridge the gap between 5G's technical capabilities and real-world value creation. The solutions that integrate with operators' existing OSS/BSS infrastructure—i.e., the internal systems used to manage service operations, performance monitoring, and billing—and support standardized service delivery are likely to play a key role (Ericsson, 2025).

One such promising solution is 5G network slicing, a foundational concept that allows telecom operators to divide a physical network into multiple virtual networks, each optimized for specific applications and use cases. Each slice behaves as an independent network, with tailored resource allocations to meet performance requirements for different types of services. This allows telecom operators to deliver highly flexible and customized network services across different industries and sectors (Debbabi et al., 2022; Kaloxylos, 2018). For example, a slice can be configured for mission-critical communications with low latency, while another might be designed to support high-throughput services for streaming applications. Network slicing, therefore, facilitates the on-demand provisioning of network resources, enabling telecom operators to offer a variety of services to enterprise customers who need specific service levels for a defined period (Afraz et al., 2023).

However, the ability to provision and manage network slices dynamically and in alignment with enterprise-specific requirements remains a significant challenge in the 5G era. Existing telecom Business Support Systems (BSS) and Operational Support Systems (OSS) are not well-suited to support the rapid and flexible provisioning of network slices for enterprise-grade applications. These systems were designed for long-term, subscription-based services and struggle to handle the agility, integration, and scalability required for slice-based service delivery (Ericsson, 2023; Afolabi et al., 2022).

Blockchain technology offers a potential solution to this challenge. By using blockchain, telecom operators can create a decentralized and transparent system to automate the provisioning of network slices. Blockchain's key characteristics—immutability, transparency, and decentralization—enable the automation of service delivery, ensuring that slice provisioning, Service Level Agreement (SLA) enforcement, and billing processes are tracked and verified in a trustless manner. This could eliminate the need for intermediaries, streamline operations, and provide all stakeholders with a shared, auditable record of sliced orders, performance metrics, and billing data (Afraz et al., 2023).

Blockchain can be used to establish smart contracts that automatically execute transactions once predefined conditions are met, such as provisioning a slice when a customer request is made or enforcing penalties if the agreed-upon SLA is violated (Androulaki et al., 2018). This introduces a high level of automation and efficiency, reducing manual intervention and enabling telecom operators to manage network slices in a way that is both operationally scalable and aligned with customer-specific requirements, all while maintaining trust and transparency throughout the process (Afolabi et al., 2022).

The integration of blockchain with BSS/OSS systems presents a viable approach to overcoming the challenges operators face in monetizing 5G and moving beyond traditional connectivity models. Blockchain can help telecom operators manage dynamic provisioning of network slices while maintaining interoperability with existing systems—an essential requirement for large-scale deployment (Karagwal et al., 2023).

Service Level Agreements (SLAs) define the expected performance levels such as latency, throughput, and availability—that operators commit to delivering. They serve as the contractual foundation for both service assurance and billing. In the context of network slicing, SLAs become especially critical, as different slices are designed to meet different performance requirements across industries (Karagwal et al., 2023). Ensuring these SLAs are verifiable and enforceable is central to building trust and accountability in slice-based service delivery.

This thesis investigates the design of a blockchain-based marketplace for 5G slice provisioning, focusing on how blockchain can support automated, standards-based service delivery while integrating with telecom operators' existing BSS/OSS infrastructure.

1.2 Enabling Technologies: Blockchain, NFV, SDN, and SLA Frameworks

Several enabling technologies underpin the proposed solution. Blockchain is increasingly viewed as a foundational layer in telecom infrastructure, providing distributed consensus and secure automation via smart contracts (Androulaki et al., 2018). Blockchain's strengths in trust, decentralization, and programmability make it a strong fit for managing and validating dynamic operations in 5G slicing scenarios (Afraz et al., 2023).

Network Function Virtualization (NFV) and Software Defined Networking (SDN) are also essential enablers. NFV decouples network functions from dedicated hardware, allowing them to run on virtualized environments such as containers or VMs (Juniper Networks, 2025). SDN provides centralized programmability, allowing dynamic resource allocation across slices. Together, they offer the flexibility needed for on-demand service provisioning (Bruschi et al., 2021; Foukas et al., 2017).

Finally, Service Level Agreements (SLAs) are critical for defining and monitoring performance expectations between operators and customers. Automating SLA tracking and enforcement through blockchain ensures verifiability, minimizes disputes, and streamlines billing in dynamic and performance-sensitive network environments (TM Forum, 2025b; Wang et al., 2019).

1.3 Industry Standards

To achieve operational feasibility, any blockchain-based marketplace must adhere to telecom standards ensure compatibility with legacy systems. The TM Forum has developed a comprehensive suite of REST-based Open APIs that provides a standardized integration layer between external platforms and internal BSS/OSS environments (TM Forum, 2023).

Open Digital Architecture (ODA) is an industry-standard framework developed by TM Forum that aims to modernize and modularize telecom IT systems. It replaces traditional, monolithic OSS/BSS architectures with a cloud-native, component-based model where standardized APIs and a common data model enable interoperability, agility, and vendor-neutral integration. ODA promotes the use of loosely coupled microservices, allowing telecom operators to rapidly innovate, deploy, and manage services across diverse platforms and suppliers while reducing reliance on proprietary middleware (TM Forum, 2019; TM Forum, 2025b).

The 3rd Generation Partnership Project (3GPP) complements this with detailed architectures for network slicing and service orchestration, including Network Slice Subnet Instances (NSSIs) and service exposure frameworks. These standards allow for vendor-agnostic interoperability and are increasingly adopted by major telecom operators (Debbabi et al., 2022; Kukliński et al., 2018).

Ericsson, as an industrial leader, emphasizes the need for standard-aligned automation and interoperability in enabling 5G services. Their recent work underscores how blockchain and TM Forum APIs can be layered into OSS/BSS workflows to support modular, SLA-bound service delivery, without overhauling existing infrastructure (Ericsson, 2023).

1.4 Research Problem

As 5G networks evolve toward service-based architectures, telecom operators face a key challenge: the lack of a standardized and automated mechanism for offering and managing network slices in a scalable and operationally feasible manner. Existing Business Support Systems (BSS) and Operational Support Systems (OSS) were designed for static, long-term services, and are ill-equipped to support the dynamic provisioning and SLA-based management that network slicing requires (Ericsson, 2023).

Currently, there is no integrated platform or marketplace that enables operators to provision, manage, and monetize network slices in a way that is both automated and aligned with telecom industry standards. Manual processes dominate slice lifecycle operations—from instantiation to SLA monitoring and billing, which reduces scalability, increases operational cost, and limits the ability to adapt services to enterprise-specific needs.

Blockchain technology offers a promising solution by introducing automated, verifiable SLA enforcement between operators and their customers. Through smart contracts, SLA parameters can be encoded and automatically validated against real-time performance data, creating a transparent and auditable basis for service assurance and billing (Afraz et al., 2023). However, to achieve this in practice, such solutions must be integrated with existing OSS/BSS platforms using standardized APIs and modular architectures.

In summary, the core research problem is how to design a system that enables telecom operators to provision and manage 5G network slices through a blockchain-enabled architecture that supports automated SLA handling, aligns with telecom standards, and integrates seamlessly with current operational systems.

1.5 Research Aim and Objectives

The aim of this research is to design a blockchain-based framework for a 5G network slice marketplace that enables telecom operators to provision and manage dynamic network slices more efficiently in a secure, automated, and scalable manner. The thesis explores how blockchain technology can support the technical requirements of such a marketplace, specifically in terms of automating slice provisioning, managing service level agreements (SLAs), and ensuring the transparency and trust of the entire process (Hyperledger Foundation, 2025).

The focus is on creating an integrated architecture that can seamlessly operate within existing telecom environments, leveraging standardized telecom interfaces such as RESTful APIs defined by the TM Forum Open APIs and incorporating relevant specifications from the 3rd Generation Partnership Project (3GPP) (TM Forum, 2023). These standards ensure that the blockchain-enabled marketplace can integrate with existing Business Support Systems (BSS) and Operational Support Systems (OSS) without disrupting current operations. This approach is necessary, as telecom services cannot be developed in isolation but must work alongside established systems used by large telecom firms for their existing customers.

To address this design requirement, the research combines conceptual design with qualitative evaluation of current systems, adapted to new circumstances created by blockchain technology. A Design Science Research (DSR) methodology is used to formulate the architecture of the proposed blockchain-based marketplace. During the design process, expert interviews with senior telecom architects and product managers will provide valuable insights and validate design assumptions. This feedback will guide the development of architecture, helping to identify key integration points with existing telecom systems, such as slice managers, ordering systems, and billing platforms.

The outcome of this research is practical reference architecture for the blockchain-based marketplace. The goal is not only to propose a theoretical model but to develop it via a standards-aligned architecture that telecom vendors and operators can realistically adopt to implement the solution. The research objectives are aimed at demonstrating how blockchain can be leveraged to address the operational challenges of automating slice provisioning and ensuring interoperability, ultimately unlocking new monetization opportunities for 5G networks.

1.6 Research Question

In line with the aim above, our primary research question is:

How can a blockchain-based network slice marketplace be designed to support provisioning using industry standards?

1.7 Scope and Delimitations

This thesis investigates how telecom operators can design and implement a blockchain-based marketplace to support the provisioning of 5G network slices. The primary contribution of this research is a high-level system architecture and data model that demonstrates how blockchain mechanisms can be applied on a platform to automate the processes of slice provisioning, SLA monitoring, and billing integration. The model also provides a transparent, tamper-evident ledger of slice requests and performance, ensuring trust between stakeholders (Hyperledger Foundation, 2025).

The scope of the thesis includes the following key components and activities:

- **Architecture and Data Model Design**: The research focuses on designing the architecture and data model that will underpin the blockchain-enabled marketplace. The design is based on current best practices in telecom system architecture, ensuring interoperability with existing telecom systems and scalability for future demands (ETSI, 2014). The data model captures key SLA attributes (e.g., bandwidth, duration, and latency). The architecture also specifies how these attributes interact between the marketplace, the operator's OSS/BSS systems, and external interfaces. Particular attention is given to ensuring that reference identifiers and SLA metadata are consistently spread across the system, enabling accurate billing and service assurance.
- **Use Case Definition**: A representative use case will be developed to demonstrate the functionality of the marketplace. This scenario will focus on a customer requesting a network slice for enterprises. The use case will outline the roles of actors, the sequence of interactions, and the expected benefits of using the blockchain-based marketplace in this context.
- **Process Flow Modeling**: The research will develop a detailed process flow model of the service lifecycle, from the moment a customer requests a network slice, through offer negotiation, slice instantiation, SLA monitoring, and billing. The architecture will demonstrate how blockchain technology interacts with traditional telecom systems, such as slice management and network orchestration, while also handling SLA verification and dispute resolution (e.g., detecting SLA breaches and enforcing penalties based on predefined logic). The goal is to visualize how the blockchain solution complements and enhances existing operational processes.
- **Qualitative Feasibility Evaluation**: A qualitative evaluation will be conducted based on expert feedback to assess the feasibility of the proposed solution. The experts are architects and Strategic Product Manager from Ericsson. This evaluation will critically review the assumptions made during the design process, such as the readiness of APIs or the scalability of blockchain transactions. It will also address potential technical or organizational barriers, such as whether current OSS platforms can expose the necessary APIs for integration. The evaluation aims to identify key challenges and opportunities for implementing the marketplace within a real operator environment.

Certain related aspects are considered out of scope for this thesis. These aspects, while relevant to the broader context of 5G slice marketplaces, are excluded due to time constraints and the specific focus on standardized slice provisioning for enterprise customers:

- Full implementation or production deployment of the blockchain system: This thesis is focused on design and prototype-level demonstration only. It does not involve developing a fully operational blockchain network for live, carrier-grade deployments.
- Real-time network performance: The research does not address low-level radio access network (RAN) slicing algorithms or real-time radio resource management. It assumes that the network can fulfil slice requests as negotiated, focusing on orchestration and business-layer control rather than RF optimizations.
- Formal legal frameworks and liability arrangements: While the blockchain system can enforce SLAs technically, the thesis does not cover the legal or regulatory frameworks needed for a commercial slice marketplace, such as legal contracts, dispute arbitration, or regulatory compliance.
- Quantitative performance benchmarking: The thesis does not include quantitative performance evaluations such as measuring blockchain transaction latency or the throughput of slice instantiation. Performance considerations are discussed qualitatively; empirical testing will refer to previous research on the subject.
- Multi-operator or cross-domain marketplace scenarios: The scope is limited to a single operator offering slices to its own customers. Scenarios involving cross-operator slice trading or the federation of marketplaces across multiple operators are acknowledged as interesting extensions but are not covered in this work.

2 LITERATURE REVIEW

As 5G networks mature, telecom operators are increasingly exploring new service delivery and monetization models beyond traditional connectivity. One such model is network slicing, which enables operators to allocate virtualized network resources tailored to specific application requirements. At the same time, blockchain technology has emerged as a potential enabler for automating and securing operational workflows—such as provisioning, Service Level Agreement (SLA) verification, and cross-party accountability—within the telecom service lifecycle.

To explore how blockchain might support this evolution, this chapter reviews existing academic and industry research on decentralized architectures for 5G slice provisioning. The review focuses specifically on how prior models have addressed—or failed to address—the technical, operational, and standardization challenges identified in Chapter 1.

The chapter serves three key purposes:

- To summarize prominent research initiatives on decentralized slice brokerage.

- To analyse how blockchain and smart contracts are used in existing models, particularly in relation to provisioning and SLA-related processes.

- To identify common limitations, particularly related to interoperability, standardization, and alignment with telecom-grade BSS/OSS infrastructure.

By clarifying what prior work has accomplished and where it falls short, this chapter motivates the need for a new framework, one that combines blockchain automation with standards-based integration into telecom systems.

2.1 Blockchain-Based Marketplaces for 5G Slicing

As telecom networks evolve toward service-based architectures, the concept of network slicing has gained significant attention for its potential to enable flexible, on-demand, and application-specific network services. A parallel research trend has emerged around the use of blockchain to support automation, trust, and decentralization in the provisioning and lifecycle management of these slices. Several studies have proposed blockchain-based slice marketplaces or brokerage systems, often incorporating smart contracts to facilitate configuration, provisioning, and SLA verification. However, the extent to which these solutions integrate with telecom standards and operational environments remains limited.

Afraz and Ruffini (2020) introduced a decentralized brokerage model for network slices using Hyperledger Fabric. Their architecture replaces a centralized broker with smart contracts implementing sealed-bid double auctions, enabling buyers and sellers to trade slices transparently and securely. The system supports automated bidding and settlement while maintaining transparency over SLA compliance. Their results demonstrate that permissioned blockchain platforms are capable of near-real-time transaction throughput, with transaction latencies below one second and throughput around 100 transactions per second (TPS). But the study abstracts away integration with Business Support Systems (BSS) and Operational Support Systems (OSS).

He et al., (2021) proposed NetChain, a blockchain-based framework for ensuring Quality of Service (QoS) aware slicing. In this model, slice metadata and SLA parameters are recorded on-chain for immutability and auditability. While NetChain enables SLA validation and provides a basis for trust among stakeholders, it does not automate billing processes or address how the blockchain interacts with telecom operators' existing infrastructure.

Zanzi et al. (2020) developed NSBchain, which also leverages Hyperledger Fabric to create a secure network slice brokerage environment. Their focus is on decentralized SLA enforcement, enabling operators to validate compliance based on performance metrics. However, like other proposals, NSBchain does not explain how SLA enforcement would integrate with billing systems or operator-grade support systems workflows.

The 5GZORRO project, funded under the EU H2020 initiative, explored blockchain for cross-domain trading of 5G assets, including slices and virtualized resources. The architecture utilizes Trusted Execution Environments (TEEs) and smart contracts to enhance security and SLA trustworthiness. Despite addressing important marketplace concerns like multi-domain federation and secure orchestration, the project relies on off-chain mechanisms for SLA input and only partially considers standardized OSS/BSS integration (5GZORRO, 2023).

Finally, Fernandez-Fernandez et al. (2023) proposed 5GaaS, a decentralized marketplace built on Ethereum. The platform enables slice requests, crowdfunding, and billing through smart contracts and state channels. While comprehensive in scope, 5GaaS operates largely independently from telecom operational systems and does not align with industry-standard interfaces.

Across these models, common limitations emerge:

1. Integration with existing OSS/BSS systems is often abstracted or omitted,
2. Standardized APIs such as those defined by TM Forum are rarely implemented, and
3. Billing automation remains underdeveloped despite being a critical part of commercial viability.

To better understand the operational feasibility of these proposals, Table 2 compares their support for blockchain platforms, trust mechanisms, billing automation, and alignment with telecom standards.

Table 1: *Summary comparison of Blockchain-Based Slice Marketplace Architectures*

Feature	5GaaS	NetChain	5GZORRO	NSBchain
Blockchain Platform	Ethereum (Public/Permissioned)	Hyperledger Fabric	Platform Agnostic (Uses TEEs)	Hyperledger Fabric
Primary Focus	Decentralized Marketplace, Crowdfunding, Billing	Quality of Service, Assurance, Immutable Logs	Secure Multi-Domain Resource Trading	Secure Brokerage, SLA Enforcement
BSS/OSS Integration	Partial (Billing aspects)	Assumed / Abstracted	Acknowledged, Partial	Abstracted
Use of Standards	Not Explicitly Mentioned	Not Explicitly Mentioned	Not Explicitly Mentioned	Not Explicitly Mentioned
Billing Automation	Smart Contract Based	Limited / External	Partial / External	Limited / External
Trust Mechanism	Smart Contracts, State Channels	Blockchain Immutability	TEEs, Blockchain	Blockchain Immutability

These observations serve as the foundation for identifying key research gaps, which are discussed in the following section.

2.2 Integration with Telecom Infrastructure

Telecom operators depend on Business Support Systems (BSS) and Operational Support Systems (OSS) to handle the core activities of service provisioning, performance monitoring, customer management, and billing. These systems form the operational backbone of the telecom environment and are typically designed for stable, long-term services with predictable lifecycles (Foukas et al., 2017; TM Forum, 2023).

However, 5G network slicing introduces new requirements for flexibility, speed, and granularity that legacy BSS/OSS platforms were not built to support. Many blockchain-based slice marketplace models in the literature treat integration with these operational systems as an abstract future step or assume that such integration will occur without providing technical details (Afraz & Ruffini, 2020; He et al., 2022; Zanzi et al., 2020).

Another critical shortcoming is the limited use of standardized APIs for system interoperability. Although frameworks such as the TM Forum Open API initiative offer a modular and vendor-agnostic way to connect external platforms to BSS/OSS environments, few studies explicitly include these in their designs. This omission reduces the operational feasibility of blockchain-based telecom solutions and hampers industry adoption (TM Forum, 2023).

This thesis responds to this research gap by developing a marketplace architecture that explicitly supports standardized integration with telecom-grade operational systems. The specific interface models and integration points are detailed in the results chapter.

This gap in integration and standardization highlights a broader issue in current research: while many blockchain-based architectures for network slicing demonstrate technical promise, they often fall short in addressing real-world telecom constraints. To understand how existing models attempt to operationalize blockchain-based marketplaces, the next section reviews several prominent proposals and evaluates their strengths and limitations in relation to interoperability, automation, and commercial feasibility.

2.3 Identified Gaps in Current Research

Despite increasing interest in blockchain-based architectures for 5G network slicing, current research exhibits several limitations that hinder practical implementation in real-world telecom environments. This section identifies three key areas where existing solutions fall short: integration, standardization, and billing automation. Each of these gaps directly informs the design goals of this thesis.

2.3.1 Integration Gap

A recurring issue in the literature is the limited integration between blockchain-based slice marketplaces and existing telecom infrastructure, particularly Business Support Systems (BSS) and Operational Support Systems (OSS). Most studies either abstract away these systems or assume they can be easily adapted, without addressing the technical and organizational complexities involved. In practice, these systems are deeply embedded and often vendor-specific, with limited flexibility. Without a clear integration path, such as the use of standardized APIs or modular interfacing strategies, proposed solutions risk remaining in proof-of-concept stages.

2.3.2 Standardization Gap

Closely related to the integration challenge is the lack of adherence to telecom industry standards. Few blockchain-enabled architectures actively incorporate standardized APIs—such as those promoted by TM Forum for provisioning, monitoring, or service assurance. This omission limits interoperability across different vendor ecosystems and undermines scalability. For operators that rely on multi-vendor environments, the absence of standardized integration mechanisms becomes a critical barrier to adoption. Future architectures must align with telecom standards to ensure modular, vendor-neutral deployment and integration.

2.3.3 Billing and Automation Gap

Although smart contracts are widely proposed as tools for automation and trust in 5G service delivery, most implementations stop short of defining how these mechanisms connect with existing telecom billing systems. In particular, the automation of SLA verification and the structured transfer of verified performance data to operator billing platforms is rarely described in detail. While some architectures mention billing, they typically rely on external systems or manual reconciliation. This lack of clarity poses a problem for short-duration or usage-based services, where manual workflows may be inefficient.

In the context of this thesis, smart contracts are used to automate slice provisioning and verify SLA compliance. Rather than implementing full billing logic, the proposed architecture supports the secure exchange of SLA-related data toward existing systems—providing a technical foundation for interoperable and trustworthy slice provisioning workflows without attempting to replace operator-grade billing platforms.

2.3.4 Lack of Unified Architecture

Across the literature, there is considerable variation in blockchain platforms, orchestration mechanisms, and trust models. While diversity of experimentation is valuable, the lack of a unified reference architecture, particularly one aligned with telecom standards, makes it difficult for operators to evaluate and adopt these solutions. There is a clear need for architecture that goes beyond technical feasibility and offers standardized, interoperable, and operationally realistic models for blockchain-enabled slice provisioning.

2.4 Theoretical Framework

While the methodological foundation of this study is Design Science Research (DSR), as detailed in Chapter 3, the development and evaluation of the proposed blockchain-based architecture are also informed by several theoretical perspectives. These frameworks help contextualize the technical design within broader organizational, behavioural, and ecosystem-oriented dimensions.

Socio-technical systems theory (Bostrom & Heinen, 1977; Trist & Bamforth, 1951) provides a foundational lens for understanding the challenges of implementing technical innovations in established operational environments. This theory highlights that the success of new technologies depends not only on their technical feasibility but also on alignment with organizational structures and cultural norms. In this context, the blockchain marketplace is not just a technical layer but a socio-technical construct that must fit into legacy OSS/BSS processes and organizational control frameworks.

Innovation diffusion theory (Rogers, 2008) is particularly relevant to the study's findings on adoption barriers. Rogers identifies key factors influencing adoption, such as perceived complexity, compatibility with existing systems, and trialability. These concepts align with interview findings about operator resistance to automation, the immaturity of certain APIs, and the need for phased rollout models. By applying this framework, the study interprets technical and organizational obstacles not as isolated issues but as predictable adoption dynamics in large-scale infrastructure environments.

Generalization the study acknowledges principles of design generalizability from the design science literature (Gregor & Hevner, 2017). Although the artifact was designed within a telecom-specific context, its use of standards, modular structure, and blockchain-based verification logic may serve as a reusable design template for similar domains. This generalizability is particularly relevant for regulated infrastructure industries such as energy, logistics, and IoT services, where secure, interoperable provisioning is also critical.

2.5 Chapter Summary

This chapter has reviewed the current state of research related to blockchain-based architectures for network slice provisioning in 5G environments. It began by surveying existing marketplace proposals such as 5GaaS, NSBchain, NetChain, and 5GZORRO, identifying their common ambition to support SLA-aware and decentralized service delivery. While these initiatives demonstrate the potential of blockchain and smart contracts in telecom, they remain largely disconnected from operational realities in production-grade networks.

A comparative analysis revealed that most models lack practical integration with telecom operators' existing BSS/OSS systems. Standardized interfaces—particularly those aligned with industry frameworks like TM Forum's Open APIs—are often omitted, reducing the feasibility of deployment in real-world, multi-vendor environments. Moreover, billing capabilities are typically underdeveloped, with few implementations describing how verified SLA data would flow into existing charging or billing platforms.
Three primary research gaps were identified:

1. **Integration Gap**: Most studies assume, rather than demonstrate, how blockchain-based systems interface with operator infrastructure.

2. **Standardization Gap**: The use of industry standards is largely absent, limiting interoperability and reusability.

3. **Billing and Automation Gap**: While smart contracts are frequently proposed, they are seldom connected to real-world billing logic. There is a lack of models that use smart contracts to verify SLA compliance and forward trusted usage data to external billing systems in a structured and standardized way.

A fourth, secondary observation highlights the absence of unified reference architectures, leaving operators without actionable blueprints for implementation.
Several theoretical frameworks that support interpretation of the findings. Socio-technical systems theory highlights the need to align technical solutions with organizational structures and legacy systems, framing the blockchain marketplace as both a technical and organizational innovation. Rogers' innovation diffusion theory helps explain observed adoption barriers, such as system complexity and resistance to automation. Finally, the study applies principles of design generalizability to show how the proposed architecture—though telecom-specific—can inform reusable solutions in other regulated infrastructure domains like energy, logistics, and IoT

In summary, while the conceptual value of blockchain-based marketplaces is supported by prior research, their lack of integration with telecom standards and legacy systems limits their practical impact. This thesis aims to address these gaps by designing a blockchain-enabled slice marketplace architecture that is explicitly built for integration, leverages standardized APIs, and focuses on automated provisioning and SLA verification. In doing so, it seeks to move beyond proof-of-concept toward an operationally realistic and standards-compliant solution for short-term 5G service delivery.

3 METHOD

This study adopts the Design Science Research (DSR) methodology as outlined by Hevner et al. (2004), which emphasizes the creation and iterative refinement of artifacts that address real-world problems. It is particularly suitable for this study as it supports both the development of practical architecture and its validation through expert feedback and prototyping. In the following sections, each DSR step is described in relation to how it was applied in this research.

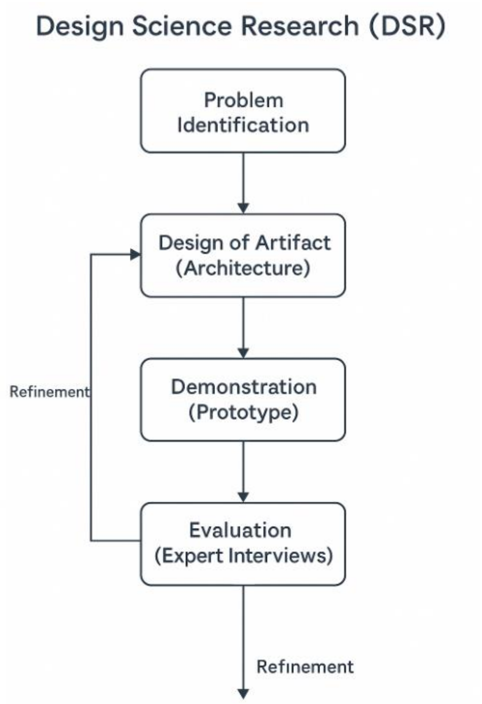

Figure 1: *Design Science Research model uses for architecture* (Hevner et al., 2004)

The core research objective is to develop standards-compliant reference architecture for a blockchain-based network slice marketplace that supports automated slice provisioning. Key requirements include aligning with industry standards such as TM Forum Open APIs 3GPP's network slicing framework. The DSR process consists of several core steps: problem identification, design of the artifact, demonstration, evaluation, and communication. While grounded in the DSR framework proposed by Hevner et al. (2004), This study adopts an artifact-oriented development approach (*see figure 1*), which aligns well with the goals of Design Science Research (DSR). The research follows an iterative process of designing a marketplace architecture and refining it through feedback loops, consistent with DSR principles that emphasize deep analysis and stakeholder involvement.

An iterative design of the marketplace architecture and refining it through feedback loops, aligning with DSR principles of in-depth analysis and stakeholder involvement (Hevner et al., 2004). The approach is also exploratory and qualitative, reflecting the emerging and innovative landscape of 5G slice monetization, the combination of building an artifact and gathering expert insights ensured the research addressed both the creation of a solution and the investigation of its real-world value (Hevner et al., 2004; Iivari, 2007).

3.1 Problem Identification

This study identifies the core design problem as the absence of a standardized, interoperable architecture for blockchain-enabled 5G slice marketplaces that supports automated provisioning and SLA enforcement. While prior sections have detailed the technical and operational challenges facing telecom operators, the key issue here is how to structure a solution that aligns with telecom-grade standards and can be realistically integrated into existing BSS/OSS environments. Within the DSR framework, this challenge is framed not just as a technical gap, but as a need for an actionable and standards-aligned design artifact. The goal is therefore to develop an architecture that is both generalizable and practically grounded, one that enables secure, automated, and transparent service provisioning using modular, standards-based interfaces. The problem identification phase of DSR thus served to define the artifact's requirements based on gaps found in the literature and constraints observed in real-world telecom environments (Lortie et al., 2025; Stevenson et al., 2024).

3.2 Artifact design and development

Following Design Science Research (DSR) principles (Hevner et al., 2004; Peffers et al., 2007), this phase focused on building a blockchain-based marketplace architecture for 5G network slice provisioning. The approach follows Brocke and Maedche's (2019) DSR Grid recommendation, emphasizing real-world relevance, input knowledge grounding, and iterative design-evaluation loops (*see figure* 1). The artifact was developed iteratively with strong alignment to telecom industry standards, primarily TM Forum Open APIs and 3GPP specifications, to ensure interoperability with existing OSS/BSS infrastructure. The following system was identified:

3.2.1 BSS/OSS

In the context of telecommunications, Business Support Systems (BSS) and Operational Support Systems (OSS) form the foundational IT backbone for managing services and customer interactions (TM Forum, 2023; TM Forum, 2025b). BSS encompasses customer-facing functions such as product catalogue management, order handling, charging, and billing. OSS, in contrast, supports network-facing operations like provisioning, configuration, and performance monitoring. Since the aim of this study is to design a blockchain-based slice marketplace that integrates with existing telecom infrastructure, aligning the artifact with standard OSS/BSS functions is critical. The architecture was therefore designed to interact with typical BSS processes (e.g., service ordering and billing) and OSS functions (e.g., slice provisioning and SLA monitoring). This alignment ensures that the prototype is not only technically feasible, but also compatible with real operator environments (Ericsson,2025).

3.2.2 The marketplace portal

For slice requests, smart contracts (encoding SLA terms), TMF Modules, and interfaces to operator systems (Stowell,2023). A detailed process model and data schema were created to map the end-to-end workflow: from a customer's slice request and smart contract negotiation, through automated slice instantiation and performance tracking, to final billing. For example, essential slice parameters (bandwidth, duration, latency, etc.) were included in blockchain transactions and linked to operator OSS/BSS data models. Ensuring consistent identifiers and SLA metadata propagation across the blockchain and off-chain systems was a design priority (Javed et al. 2022)

3.2.3 Smart Contracts

Which encapsulates the business rules and SLA terms on the blockchain. Each contract embodies the agreement for a slice service and is responsible for automating transactions. In our system, smart contracts perform several roles: they record commitments, validate events, and execute logic when conditions are met. Once the orchestrator confirms slice activation, the smart contract may note the activation and begin tracking SLA time. Performance violation events (sent by the Performance Manager) are logged as transactions against the contract. Because these contracts run on the distributed ledger, every state change is cryptographically signed and immutable (TM Forum, 2024a). This ensures a "secure, decentralized audit infrastructure", any stakeholder can trust that the rules.

3.2.4 Blockchain selection

To select a suitable blockchain platform for the prototype, we reviewed several alternatives including Ethereum, Hyperledger Fabric, and Corda. Key evaluation criteria included support for permissioned access, modular architecture, API compatibility, and integration feasibility with telecom OSS/BSS systems. Based on these criteria and drawing on the findings of Afraz & Ruffini (2020), Nour et al. (2019), and Javed et al. (2022), Hyperledger Fabric was selected. This platform offered the required enterprise-grade features, while allowing fine-grained access control and chain code support. The selection was made prior to prototype implementation and shaped all subsequent design decisions.

3.2.5 TMF API

To communicate with each other, the systems need APIs. TM Forum has spearheaded the development of standardized Open APIs, designed as REST-based interfaces that expose key BSS and OSS functionalities in a modular and interoperable manner (TM Forum, 2025b). These APIs allow operators to move away from complex point-to-point integrations towards more agile, plug-and-play architectures based on microservices principles (Stowell,2023). The TMF that was used:

- **TMF628 Performance Management** API provides a standard method for defining, scheduling, collecting, and retrieving performance measurements from network resources and services. It enables external systems to interact with performance monitoring functions in a consistent and scalable manner (TM Forum, 2024a). Within the artifact, the Performance Manager component uses TMF628 to initiate measurement collection jobs associated with active network slices. These jobs define key performance indicators (KPIs) such as latency, throughput, or packet loss, which are later evaluated against SLA thresholds defined in smart contracts (TM Forum, 2021).

- **TMF657 Service Quality Management API** is designed to assess and report on the quality of services delivered over a network, providing visibility into SLA status and violations (TM Forum, 2021). It supports quality measurement queries, threshold breach alerts, and historical quality trend data. In the context of this research, TMF657 is utilized by the Performance Manager to access and report service quality insights to the smart contract layer. This enables on-chain SLA tracking and real-time enforcement of contractual terms.

- **TMF641 Service Order Management API** defines a standardized interface for submitting, tracking, and managing service orders within telecom environments. According to TM Forum (2023), this REST-based API supports the complete lifecycle of service orders, including creation, validation, acknowledgment, and status updates. In the proposed slice marketplace architecture, TMF641 plays a central role in enabling the Marketplace Portal and Service Orchestrator to exchange structured order data. When a customer submits a slice request via the portal, the request is formatted as a TMF641-compliant service order, ensuring compatibility with existing BSS/OSS infrastructure.

The implementation of the marketplace on a blockchain market guided telecom standard. The iterative design process involved multiple feedback loops, at each iteration, the artifact was refined architecture based on stakeholder input and technical feasibility. Throughout development, Ericsson engineers and telecom standards (TM Forum, 3GPP) were consulted to validate design decisions and ensure the artifact would integrate with real-world operator environments. This exploratory and standards-aligned design process reflects the core principles of Design Science Research: building and refining artifacts that address real-world problems while contributing prescriptive design knowledge (Hevner et al., 2004; Peffers et al., 2007).

3.3 Demonstration

Before formal demonstration of the architecture, empirical insights had to be gathered. The study relied on expert interviews as the primary data collection method. Therefore, Semi-structured in-depth interviews were conducted with four senior professionals from the telecommunications industry, selected for their specialized expertise in areas relevant to 5G slicing and enterprise services (network architecture, BSS/OSS processes, and telecom blockchain initiatives)

Table 2*: Showing interviewees role, contribution and length of interview*

Interviewee	Role/Area of contribution	Definition of Role	Area of contribution	Length of Interview
A	Chief Architect (Charging)	Responsible for Charging integration	Billing and smart contract integration	42 minutes
B	Strategic Product Manager (Network Slicing)	Overall, of product strategy for network slicing offers	Marketplace logic and slice productization	72 minutes
C	Head of OSS/BSS Architecture	Oversees architecture for OSS/BSS systems	Integration of Blockchain in BSS/OSS /Security	20 minutes
D	Strategic Product Manager	Business cases	SME targeting and slice offerings	50 minutes

Engaging experts from a variety of senior roles ensured that a comprehensive range of perspectives spanning technical architecture and product strategy. The participants included a Chief Architect responsible for charging systems and smart contract integration, a Strategic Product Manager overseeing network slicing productization and marketplace design, a Head of BSS/OSS Architecture focused on the integration of blockchain with operator systems and security processes, and a Strategic Product Manager specializing in connectivity solutions and market offerings. The experts contributed informed and practice-oriented feedback on the proposed slice marketplace, validating whether the challenges identified in the literature are recognized in operational environments and helping refine the architectural model based on real-world priorities.

3.3.1 Interview format

The semi-structured interview format was chosen to balance consistency with flexibility (Wood & Ford, 1997). The interview guide was prepared with coverage of the marketplace design considerations ensuring each session addressed the core aspects of the proposed architecture and its issues (Bell & Hardiman, 1989).

At the same time, the semi-structured approach allowed experts to freely introduce and elaborate on issues. Interviewees deemed important, enabling the discovery of novel insights beyond the predefined questions (Wood & Ford, 1993). All interviewees (*see appendix A-D*) were asked a common set of foundational questions to make the responses comparable but also tailor some follow-up questions to each expert's domain expertise.

It ensured comprehensive coverage of the topic while leveraging each expert's unique knowledge. Each interview was conducted via remote video conference; with consent, sessions were audio-recorded and later transcribed for analysis *(see Table 2 above).*

3.3.2 Procedure and integration with artifact design:

In each interview, the researcher first presented the current state of the marketplace architecture (*see Table 2*), often walking the expert through system diagrams and the sequence of steps involved in slice trading and management. Then invited the expert's evaluation of its completeness, correctness, and practicality. Experts were encouraged to critique underlying assumptions, identify any missing components or interfaces, and suggest improvements or alternatives (Wood & Ford, 1992).

3.4 Evaluation

The process effectively made the interviews an evaluation phase for the artifact. As the experts reacted to and assessed the proposed design, their feedback was systematically noted and later used to iterate on and refine the architecture. Incorporating expert feedback in this way is consistent with DSR methodology, which emphasizes stakeholder involvement in evaluating design artifacts against real-world requirements (Hevner et al., 2004). In fact, expert interviews are suited for assessing conceptual models and architecture, through their tacit knowledge and experience, industry experts can validate whether the artifact's design assumptions hold true in practice and highlight any oversights from an operational perspective (Gordon & Gill, 1992). Thus, the interviews did not only collect data passively but actively served as a mechanism to improve the design's rigor and relevance. Through these dialogues, we gathered both affirmations of the proposed approach's strengths and candid critiques of its weaknesses, informing subsequent design adjustments.

3.4.1 Data analysis

To systematically analyse the expert feedback collected during the evaluation phase, we employed thematic analysis as outlined by Braun and Clarke (2006). This method is well-suited to exploratory research and aligns with the iterative, feedback-driven nature of Design Science Research (Hevner et al., 2004). Thematic analysis enabled inductive coding and theme generation based on expert responses, thereby supporting the refinement of the artifact in a structured yet flexible manner.

Following Braun and Clarke's six-step process (2006), the analysis began with familiarization, reading through all transcripts in depth to gain an overview of the content. Then conducted open coding, identifying significant statements and observations related to the research questions and the proposed marketplace architecture. The coding was primarily inductive, allowing themes to emerge organically from the data rather than applying a predefined coding frame. This approach ensured that the analysis reflected the actual concerns, insights, and recommendations raised by the domain experts coding progressed, similar codes were clustered into broader candidate themes, capturing common patterns across interviews. Adopted a semantic focus, meaning that the analysis concentrated on the explicit content of the interviews rather than interpreting underlying or latent meanings.

3.5 Validity, Reliability, and Limitations

To ensure methodological rigor and strengthen the trustworthiness of the findings, this study incorporated several qualitative research best practices, aligned with the Design Science Research (DSR) paradigm. These measures addressed both the validity (accuracy of findings) and reliability (consistency and reproducibility) of the research process.

- **Triangulation and Traceability**
  To improve the credibility of insights, triangulation was applied where possible (Denzin, 1978). Key themes and emerging issues from expert interviews were cross validated with secondary sources such as industry standards and documentation. This helped to distinguish anecdotal observations from broadly recognized industry challenges. In addition, all expert input was documented using a traceable chain of evidence: each interview comment was tagged with the participant (anonymized as A–D), the relevant context, and the corresponding design change. This allowed clear tracking of how raw data informed specific architecture decisions, thereby enhancing construct validity (Hevner et al., 2004).

- **Interview Protocol and Reliability**
  To support consistency across expert sessions, a semi-structured interview guide was used, based on the roles of the participants. While allowing flexibility in discussion, the protocol ensured that all interviews covered the core evaluation themes, enabling comparability of responses (Simon, 1969). By aligning questions with the participants' areas of expertise (e.g., billing, orchestration, platform architecture), the study reduced interviewer bias and maintained thematic consistency (Wood & Ford, 1993).

- **Generalization**
  As this study is based on expert interviews within a specific industrial context, the findings are not intended to be statistically generalizable, but rather to provide deep, practice-oriented insight into architectural feasibility.

- **Ethical Considerations**
  All interviewees participated voluntarily and provided informed consent for audio recording and transcription. Personal identifiers were anonymized, and transcripts were stored securely. The study was conducted in accordance with Blekinge Institute of Technology's research ethics guidelines, ensuring that participants could withdraw at any time without consequence.

- **Analytical Rigor and Coding Approach**
  Interview transcripts were analysed using thematic analysis in an iterative manner. Codes were applied systematically, and emerging themes were reviewed at multiple points during the analysis. To further enhance reliability, feedback on the coding scheme was sought from supervisors and peers. This peer debriefing process helped to validate category definitions and mitigate the risk of researcher bias (Mann, 2016). Revisiting the data iteratively reduced the likelihood of overlooking divergent perspectives and ensured a more robust interpretation of findings.

- **Limitations of the Evaluation Process**
  Despite these strengths, certain limitations should be acknowledged. First, the evaluation was based solely on expert interviews, without a live deployment or longitudinal observation. As such, real-world behaviours such as operational performance under load, end-user adoption, and long-term SLA enforcement—could not be measured. Second, although experts offered valuable input, their feedback was domain-specific; few had combined experience in both blockchain and telecom architecture, which limited holistic validation. Finally, while peer debriefing was used to refine interpretations, the analysis was ultimately conducted by a single primary researcher, which may introduce some degree of interpretive bias.

In summary, expert interviews and thematic analysis were central to both the evaluation and refinement of the proposed artifact. By embedding traceability, triangulation, and structured feedback into the design cycle, the study ensured that the architecture was not only theoretically sound but also grounded in operational expertise.

4 RESULTS AND ANALYSIS

By applying the Design Science Research (DSR) methodology, this chapter presents the primary results of the study: the development and iterative refinement of a blockchain-based network slice marketplace architecture. The architecture consists of eight core components, which together form a cohesive system design addressing the integration, standardization, automation, and architectural gaps identified in earlier chapters. These components represent the key contribution of the thesis and were validated through expert evaluation.

Each section in this chapter aligns with a specific phase of the DSR process, beginning with system design and continuing through SLA enforcement mechanisms and expert-driven architectural improvements.

4.1 System design

The following step in DSR method is designing the artifact, evaluated from problem identification. The design presents a preliminary system architecture for a blockchain-based 5G network slice marketplace. It is conceived as a model based on literature and TM Forum standards. The system components and their interactions are conceptualized at the architectural level; while a functional prototype was developed, the full automation of all interfaces was not implemented but represented in the system model. The focus is on the core workflow and component responsibilities (ordering, provisioning, and SLA monitoring) rather than low-level technical details.

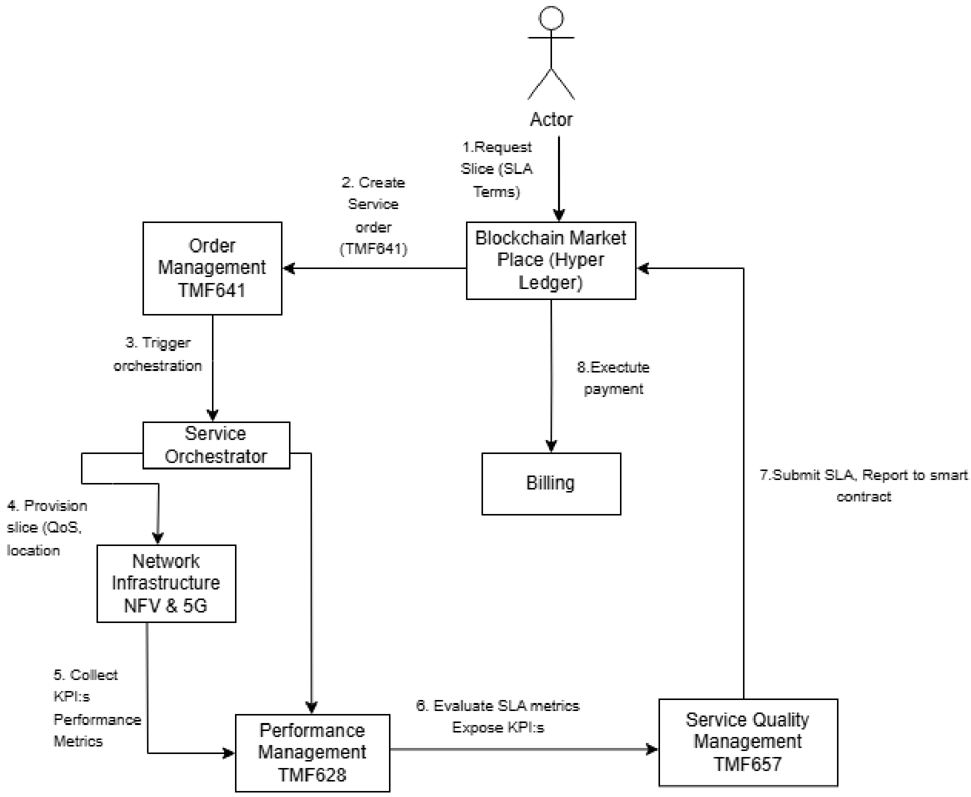

Figure 2: *Conceptual Architecture of Blockchain-based 5G Slice Marketplace (Initial Design)*

Steps involving the Architecture of Blockchain-based 5G Slice Marketplace (*see figure 2*) are as follows:

1. **Slice Order Submission.** An enterprise selects a desired network slice from the marketplace catalogue and places an order via the operator's interface. The system then generates a TM Forum–compliant Service Order (TMF641), including the slice template ID and associated service-level parameters (TM Forum, 2024a). In parallel, a corresponding transaction is recorded on the permissioned blockchain (Hyperledger Fabric), anchoring the order metadata and SLA terms immutably for traceability and auditability

2. **Recording Order On-Chain.** The Blockchain Marketplace built on Hyperledger Fabric submits the order details to its smart contract to record the new order immutably on the blockchain ledger. This transaction includes the slice identifier and SLA terms, throughput, latency guarantees to ensure a verifiable and tamper-proof audit trail of the customer's request (Zanzi et al., 2020).

3. **Invocation of TMF 641.** The operator's system submits the Service Order to the operator's Service Order Management system via the TMF 641 API through a REST call or internal message. This initiates the orchestration process. While the TMF 641 interface manages the provisioning within BSS/OSS systems, the blockchain ledger maintains immutable records, ensuring visibility and trust among authorized participants (TM Forum, 2024b).

4. **Slice Provisioning.** The Service Orchestrator receives the Service Order and initiates the instantiation of the requested 5G slice across network resources (allocating virtual network functions, configuring connectivity, and applying service policies). Once provisioning is complete, the orchestrator acknowledges the successful deployment by updating the Hyperledger Fabric blockchain and, optionally, logging the activation on the blockchain smart contract. The slice is now active and operational (Zeydan et al., 2022).

5. **Monitoring Activation.** Upon activation, the Performance Manager schedules continuous monitoring of the slice using the TMF 628 Performance Management API. This involves creating measurement jobs for relevant KPIs (e.g., latency, throughput, and availability) and instructing network elements or probes to collect data at regular intervals (The Aviator Catalyst Team, 2020).

6. **SLA Evaluation and Enforcement.** As performance metrics are collected, the SLA evaluation module continuously compares the actual values against the predefined service level objectives (SLOs). If any measurement falls below the agreed SLA thresholds, the module identifies a breach and generates a violation event. This event is then reported to the blockchain smart contract through a transaction, ensuring that the violation is immutably recorded on the ledger (Zanzi et al., 2020). Based on the pre-defined logic encoded within the smart contract, automated responses are executed, which may include applying penalties, issuing service credits, or notifying relevant stakeholders. Through this mechanism, the architecture achieves transparent and automated end-to-end SLA enforcement, leveraging blockchain immutability and smart contract automation to uphold agreed service terms.

7. **SLA Reporting.**
   Once the SLA evaluation is complete and any violations are detected. The results are submitted as a transaction to the blockchain smart contract. This step ensures immutability and transparency, as the SLA outcomes, including whether the SLA was fulfilled and any penalties or credits due, some are recorded on-chain. The information will later be consumed by the billing system.

8. **Billing and Payment Execution.**
   Following SLA reporting, the billing system retrieves the results from the blockchain and processes the payment accordingly. Based on the SLA outcome (whether fully compliant or with penalties applied), the billing component applies the correct charges and executes the transaction with the customer. This step is handled entirely within the BSS domain, ensuring regulatory compliance and integration with the operator's financial systems (MEF, 2020).

4.1.1 SLA Monitoring and Evaluation

Another perspective is once the slice is provisioned, continuous monitoring is performed to ensure compliance with the agreed SLA parameters. The design leverages the TMF 628 Performance Management API to support this process through the creation, management, and execution of measurement jobs :(The Aviator Catalyst Team, 2020; TM Forum, 2024a).

The Performance Manager initiates the monitoring process immediately after the slice becomes active. Utilizing TMF 628, it creates one or more measurement jobs that define the specific KPIs to be tracked, such as latency, throughput, and packet loss. These jobs instruct the relevant network elements or probes to collect real-time performance data at pre-defined intervals. (TM Forum, 2024a) The gathered metrics are then reported back to the Performance Manager for analysis. This continuous data collection ensures that the service performance is accurately captured and available for SLA evaluation.

As the performance data is received, the SLA evaluation engine processes the metrics to determine if the service is operating within the agreed thresholds. The engine compares the actual KPI values against the Service Level Objectives (SLOs) defined at the time of the order. If any deviations are identified, for example, if average throughput drops below the guaranteed rate, the system flags an SLA breach (ManageEngine, 2025). This step ensures that any performance issues are detected in a timely and systematic manner.

When an SLA violation is confirmed, the system triggers a predefined response. The violation event is submitted to the blockchain smart contract (chain code) through a transaction, where it is immutably recorded on the ledger for audit and transparency purposes. Based on the smart contract's logic, the appropriate actions are executed automatically (The Aviator Catalyst Team, 2020). These may include issuing service credits, apply penalties, or send notifications to relevant stakeholders. Through this automated response mechanism, the architecture ensures that SLA compliance is enforced objectively and without manual intervention, thereby maintaining trust and accountability within the ecosystem.

4.2 Evaluation of the Proposed Architecture

The proposed blockchain-integrated network slicing architecture was evaluated through a series of expert interviews, following the Design Science Research (DSR) methodology. In this iterative evaluation, industry experts reviewed the initial design and identified specific areas for improvement. Their feedback led to several thematic refinements to the architecture; each aimed at enhancing the model's technical completeness and practical viability. This section presents those refinements organized by key themes rather than by individual interviewee, integrating representative expert quotes to support each improvement. Only architecture-related findings are discussed here; broader business or strategic implications are reserved for the Discussion chapter. Each quote is analysed and linked to a concrete design change, reflecting the evolution from the initial to the final architecture.

4.2.1 Summary of components from interviews

The evaluation interviews served as a key step in the Design Science Research (DSR) methodology by allowing iterative refinement of the proposed architecture

Table 3: *Interviews feedback theme and implementations*

Interviewee	**Feedback Theme**	**Analysed Change**
A	Smart contract linkage to billing	Added Smart Contract ID field to charging flows and billing system interface
A	Smart contracts logic	Moved billing logic out of smart contract; retained only event-triggering
B	Subscriber-level provisioning	Added UDR binding layer and session policy integration (PCF)
B	Contract flexibility	Included module for mid-operation contract expansion
C	Product discovery	Anchored smart contracts to TMF620 Product Catalogue
D	Scope clarity	Defined architecture boundary to optionally include/exclude UDR layer
D	Hyperledger	Clarified the use of the right Blockchain model
D/B	Service Orchestration	Adding ETSI SOL005 and SOL003
All	Standardization	Strengthened reliance on TM Forum Open APIs (TMF641, TMF628, TMF657, TMF620)

Summarizes Table *3* above are the main improvements made to the architecture, categorized by feedback themes and linked to the respective interviewees. Each change reflects actionable input that was integrated into the updated system model. These changes collectively enhanced the artifact's utility, internal consistency, and potential for real-world integration in a 5G slice marketplace context.

4.2.2 Blockchain–Billing Integration and Smart Contract Logic

One theme of feedback concerned the integration between the blockchain smart contracts and the telecom billing/charging systems. Interviewee A pointed out that "*the initial design did not fully specify how usage data and billing events would be linked back to the smart contract*". Analysis of the feedback indicated that an explicit linkage between smart contracts and billing systems should be implemented. Specifically, every service usage record now includes a reference to the corresponding smart contract ID, ensuring that off-chain charging events can be correlated with on-chain agreements. As interviewee C confirmed, "*the charging system must know which smart contract covers each usage session*."

Another closely related improvement was a refinement of smart contract responsibilities in the billing process. Interviewee A cautioned against overloading the smart contract with complex billing calculations. According to the expert, "*embedding complete billing calculations inside a smart contract would make it overly large and complicated*." The smart contract's role could instead be limited to triggering the billing process and recording essential events, while the detailed rating, charging, and invoicing logic are handled by existing BSS/OSS billing systems off-chain. The design choice keeps the on-chain component lightweight and maintainable, relying on proven external billing engines for the heavy computation. The expert's advice to "*primarily use the smart contract to trigger the billing process and not manage all detailed billing logic internally*" (A, B, D) directly informed this change.

4.2.3 Subscriber Provisioning and UDR Integration

The architecture focused on slice activation and monitoring, but Interviewee B identified a significant gap, the need to ensure that end-user devices are provisioned to use the newly created slice. The expert noted that creating a slice on the network is not sufficient on its own, the subscribing user's profile must be updated in that their devices are allowed to attach to that slice. "*It's not enough to just order and provision the slice; you need to ensure the terminals can attach and use it. That means full provisioning*," emphasized Interviewee B. Also, as Interviewee B illustrated the importance of this with a real-world scenario: "*If it's a point-of-sale device running on GPRS, it needs to be provisioned as a 5G subscriber and bound to the new slice*." By analysing the feedback, the design could perform such on-the-fly subscriber reclassification by integrating with standard provisioning interfaces (for instance, using TM Forum's subscriber management API or 3GPP management protocols) to interact with the UDR (Alepo, 2025).

Expert feedback also indicated that updating the UDR alone, e.g., by adding a slice ID, is not sufficient. The network's Policy Control Function (PCF) must also be involved to enforce slice-specific policies such as quality-of-service constraints or bandwidth limits (Alepo, 2025; Siz-Tel, 2025). As Interviewee B noted, the initial version of the architecture was *"missing detail around subscriber provisioning and policy association."* However, Interviewee D offered a more conditional view, stating that the necessity of UDR integration *"depends on how deep you want to go—if you want full control of devices and policies, UDR becomes necessary."* By analysing, the adding to the architecture could incorporate both UDR and PCF integration. UDR integration ensures that user devices are authorized to attach to the appropriate slice, while PCF ensures that slice-specific constraints and priorities are enforced for that subscriber's traffic (3GPP, 2020).

4.2.4 Dynamic Slice Management and Contract Flexibility

The experts also encouraged greater flexibility in how slice services are managed over time, leading to enhancements in the architecture for dynamic slice adaptation and contract update capabilities. Interviewee B suggested that the "*system should support runtime modifications to the service contract*". The initial design treated a slice contract as relatively static (a slice would be ordered with fixed parameters for a set duration). But according to interview D "the *needs can be more fluid, an enterprise may wish to extend a slice's duration, upgrade its bandwidth, or adjust performance levels in response to live conditions or evolving demand*". The analysing of the feedback translated into introducing a Contract Expansion Module (a form of commercial layer within the marketplace logic) that allows controlled updates to an active slice agreement.

As Interviewee B advised, "*You should include a commercial layer for contract expansion, relieving TMF657 from managing all service-quality logic*." The translation to that instead of relying solely on the SLA management API (TMF657) to handle all changes, a higher-level module now handles contract amendments such as extending the rental time of a slice or switching to a higher SLA tier (TM Forum,2018).

When a contract is modified, the system can now trigger a slice reconfiguration via the integrated Network Slice Management Function (NSMF). NSMF reallocates or adjusts slice resources to match the updated service parameters. The expert feedback stated the importance of "*not treating slice provisioning as a one-and-done transaction but as a manageable lifecycle"*. In essence, the model evolved from a static slice provisioning system to a more adaptive slice lifecycle management framework. Interviewees B, C, D indicates that "*this adaptability would significantly increase the marketplace's utility"* The analysing of the feedback translated to the operator can offer this seamlessly via the marketplace's contract expansion feature, and the network can adjust accordingly in real time.

4.2.5 Product Catalogue and Service Standardization

In the initial design, slice offerings were described in technical terms (e.g. specific bandwidth, latency, and duration parameters). Interviewee C and Interviewee D both stressed that exposing slice offerings through a formal catalogue interface would greatly improve clarity and usability. Interviewee C noted that "*the marketplace needs a standardized product catalogue that is exposed to the marketplace*" underlining that enterprise customers must be able to discover and compare slice products easily, just as they would with any other service plan.

The experts highlighted multiple benefits of this approach. First, it enforces homogeneous language for offerings that both providers and customers can understand. Interviewee D praised this aspect, observing that "*A homogeneous language across offerings helps enterprises understand what they are buying without knowing all the underlying network parameters*." By using standardized product templates, the marketplace hides much of the technical complexity from the customer. Non-technical users can select a slice offering based on high-level service guarantees specific use-case templates, rather than manually configuring low-level network attributes. This simplified service ordering was in fact hinted at by Interviewee A as well, who saw an opportunity to adopt templates to "*reduce the need for customers to understand technical parameters.*

" The product catalogue thus acts as the translation layer between business-friendly terms and the underlying technical configurations. The analyzing of the feedback translated to TMF620 Product Catalog Management API (TM Forum, 2018).

4.2.6 SLA Monitoring and Trust Mechanisms

In the initial design, the architecture included real-time performance monitoring of slices through the TMF628 Performance Management API and would flag SLA violations. But experts noted two important considerations: the lack of an automated mechanism to handle SLA breaches, and the need to verify SLA compliance in a trustworthy manner. Interviewee A pointed out that "*automated SLA violation handling is not natively supported*" in the current systems and "*would need additional mechanisms*" to be truly effective. Also, Interviewee A suggested that "*this would provide an immutable trail of the service's performance*". In a discussion with interviewee B, it was noted that "*we should record the SLA metrics on the blockchain so they can be verified later*." By analysing the advice, the design could ensure that neither the operator nor the customer can dispute the performance data after the fact, any attempt to alter or falsify the SLA records would be detectable since it would no longer match the hash committed on-chain.

4.2.7 Service management

As Interviewee B pointed out: *"The service orchestration TM API isn't enough to provision a network slice."* Furthermore, she stressed that *"the orchestration must interact with additional APIs to complete provisioning."* Interviewee D also remarked that *"the design included service ordering and orchestration steps but lacked explicit integration with ETSI-standard APIs."* By analysing this feedback, the architecture could incorporate ETSI SOL005 and SOL003 interfaces to ensure compatibility with the operator's existing NFV infrastructure. By combining these with TMF641 for service ordering, the updated design enables end-to-end slice instantiation through well-established telecom APIs (ETSI, 2024: TM Forum, 2021).

5 DISCUSSION

This chapter reflects on the findings of this study in relation to the research question:
How can a blockchain-based network slice marketplace be designed to support provisioning using industry standards?

The architecture proposed in this thesis offers a standards-aligned response to this question by integrating blockchain smart contracts with telecom-grade OSS/BSS systems via TM Forum Open APIs (e.g., TMF641, TMF628, TMF620). Unlike prior proposals models such as (5GZORRO, 5GaaS, and NSBchain), which lacked standardization or integration paths, meanwhile our model focuses explicitly on real-world deployment. The novelty lies in designing a modular, standards-based reference architecture that supports automated provisioning, SLA verification, and billing integration. This bridge's key gaps identified in the literature, particularly around the integration of blockchain with live operator workflows. Through expert validation and alignment with TM Forum's Open Digital Architecture (ODA), this moves beyond proof-of-concept, offering a practical framework for telecom operators seeking to operationalize blockchain-enabled slice marketplaces.

5.1 Final Architect model

Compared to the initial design (*see Figure 2*), the architecture in *Figure 3* incorporates standard TM Forum and ETSI APIs across the service flow from slice ordering to billing, based on expert feedback emphasizing interoperability and minimal disruption to existing BSS/OSS.

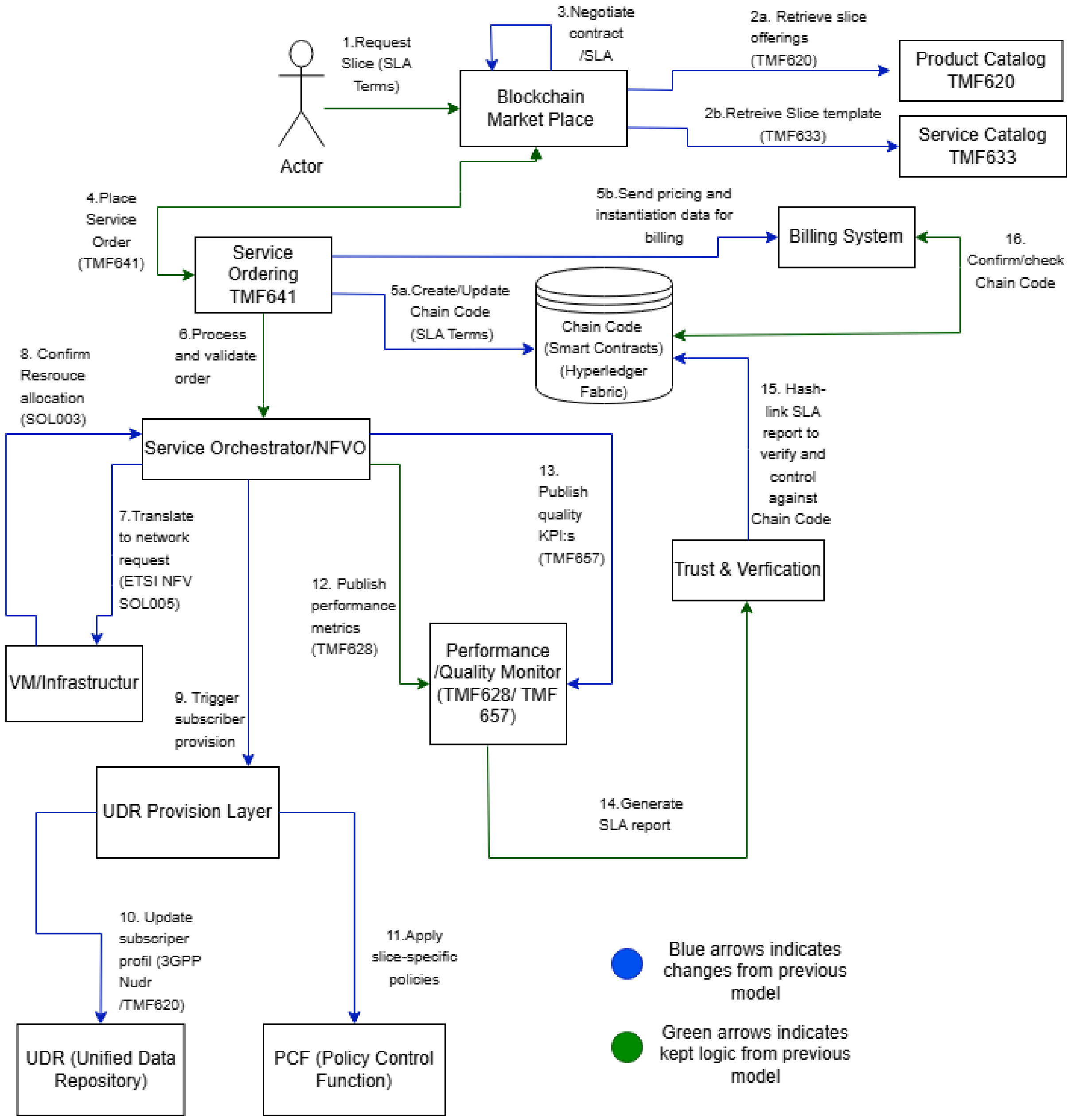

Figure 3*: An architect overview of a blockchain-based 5G slice marketplace*

The final architecture (*Figure 3*) evolves the initial prototype into a modular and standards-aligned solution, based on feedback from telecom experts and insights from prior work. Where the blue arrows indicate changes that have been made from previous model and green arrow indicates logic that was kept from previous. Rather than replacing existing systems, the blockchain marketplace is designed as a lightweight overlay on the operator's BSS/OSS, reflecting practical deployment constraints. Smart contracts capture authoritative slice orders and SLA terms, while provisioning, orchestration, and billing remain within existing subsystems, preserving operational familiarity and minimizing infrastructure disruption. This hybrid model directly addresses limitations in prior research such as 5GZORRO (Breitgand et al., 2021), where multi-party orchestration is emphasized but legacy system compatibility remains underexplored (He et al., 2022).

A key improvement is the use of modular microservices, each aligned with TM Forum Open APIs (e.g., TMF620, TMF641, TMF628), ETSI APIs (ETSI SOL005, ETSI SOL003) enabling scalable and interoperable deployment. This design reflects the Open Digital Architecture (ODA) principles promoted by TM Forum (2022) and resolves the "integration gap" often highlighted in telecom blockchain literature (Fernandez-Fernandez et al., 2024; Zanzi et al., 2020).

To preserve performance, only SLA-related hashes are stored on-chain, while heavier telemetry remains an off-chain approach supported by experts who stressed that full on-chain storage was neither necessary nor desirable. As one expert observed, "*the blockchain should signal trust, not carry the full burden of monitoring*." This selective logging balances transparency with system efficiency, ensuring auditability without compromising throughput.

The architecture also enforces SLA commitments through smart contracts, which encode service expectations and serve as immutable checkpoints for billing triggers. This operational loop from ordering to SLA enforcement to billing, is automated yet anchored in existing BSS/OSS logic. As Rasol et al. (2024) and TM Forum (2022) emphasize, real-world automation must build on standards, not bypass them. Our findings support this: the most effective blockchain integrations are those that work *with*, not *against*, existing systems.

The final design delivers automation and verifiability two long-standing objectives in telecom service delivery without requiring wholesale replacement of incumbent platforms. The design also directly operationalizes the research question by showing how blockchain and telecom standards can co-exist through modular interfaces, enabling provisioning that is both automated and industry compliant.

5.2 Comparison with literature

The proposed architecture systematically addresses several persistent gaps identified in prior research on blockchain-enabled 5G marketplaces. While previous models such as 5GaaS (Fernandez-Fernandez et al., 2024) propose innovative orchestration logic, they often depend on custom-built interfaces that risk vendor lock-in. In contrast, our solution adheres strictly to TM Forum Open APIs particularly TMF620 (product catalogue), TMF641 (service ordering), and TMF628 (performance) allowing it to interoperate natively with existing BSS/OSS platforms. This approach echoes recommendations by Tranoris (2020) and TM Forum (2019), who argue that industry-aligned service exposure is foundational for scalable and interoperable automation.

A second issue resolved by our design is the standardization gap, where prior literature either introduces proprietary schemas or lacks alignment with operational telecom architectures. By fully aligning with TM Forum's Gen5 API suite and Open Digital Architecture principles, our platform guarantees that every service interaction—from ordering to performance tracking follows well-defined formats and semantics. This commitment to standards not only eases integration, but also strengthens ecosystem alignment, making the marketplace model applicable across vendor environments. Unlike fragmented designs that "speak their own language," our architecture is intentionally built to fit within telcos' current modernization trajectories (Rasol et al., 2024; TM Forum, 2022). Which reinforces our response to the research question by demonstrating how standardization and real-world interoperability can be achieved in a blockchain-based slice marketplace

A third major improvement lies in addressing the billing and SLA enforcement gap. While several academic frameworks describe the theoretical potential of smart contracts for automated billing (e.g. Javed et al., 2022), few demonstrate how this would tie into live operator billing workflows. Our architecture implements this connection: SLA violations are recorded on-chain, and the smart contract automatically signals billing adjustments either full charges or credits-based on SLA compliance. This makes blockchain a live component of the billing decision-making process, rather than a passive record-keeping tool. In doing so, it goes beyond auditability and delivers operational value.

By covering nearly, the entire slice lifecycle from catalogue exposure to post-deployment SLA verification, the architecture serves as a unified reference implementation. It combines various techniques discussed in literature (e.g. hash-based logs as in Scheid et al., 2019, or the need for on-chain dispute anchoring) but embeds them into a coherent, interoperable workflow. Unlike Ethereum-based public marketplace concepts that assume full decentralization (e.g. 5GaaS), our operator-led, permissioned model offers performance, security, and regulatory alignment, while avoiding the governance and privacy challenges that come with open DLT systems (Fernandez-Fernandez et al., 2024).

5.3 Limitation of the Architecture and Method

Despite addressing several critical challenges identified in the literature, the proposed architecture carries notable limitations that affect its generalizability and operational readiness.

5.3.1 Architectural limitations

The Business Model Implications One of the clearest constraints concerns the system's partial automation of SLA enforcement. While the blockchain component successfully anchors SLA records and performance hashes, our findings reaffirm that billing reconciliation and dispute resolution still require human oversight. As Interviewee A observed: *"Today, if two systems disagree on what should be invoiced, it usually has to be handled manually."* This hybrid model, where trust is established on-chain, but final judgment occurs off-chain contrasts with fully autonomous models proposed in prior research (e.g., Hamdi et al., 2022, Javed et al., 2022).

It reflects a pragmatic compromise but limits the degree of automation that can be achieved in practice. The architecture was developed and evaluated in a single operator setting. Cross-operator orchestration, federation, and shared governance essential for large-scale marketplaces were not fully explored. Prior projects such as 5GZORRO highlight the complexities of multi-party coordination, including distributed SLA evaluation and economic settlement (5GZORRO, 2024). Our study does not address these layers explicitly, which constrains its applicability to broader ecosystems.

The maturity of the TM Forum APIs used in architecture is uneven. While some (e.g., TMF628, TMF620) are widely adopted, others (e.g., for end-to-end inventory and fault correlation) remain under development or lack certification. As Interviewee A noted, *"some TMF APIs are more mature than others which should be taken into consideration."* This mismatch could complicate integration efforts and slow down deployment timelines, especially for operators relying on legacy systems or vendor-specific implementations.

5.3.2 Methodological limitations

The use of the Design Science Research (DSR) methodology in this study proved effective for structuring the development and iterative refinement of the proposed architecture. Its cyclical nature enabled ongoing integration of expert feedback, which substantially improved the design. But a key methodological challenge arose from the proposed architecture, it had no direct precedent, many interviewees had limited prior exposure to comparable systems and struggled to assess its implications fully. In several cases, significant explanation was required before participants could engage meaningfully with the concept. As a result, it was difficult to empirically assess trade-offs between technical feasibility, operational complexity, and performance.

This highlights a broader limitation of using DSR for highly novel technical domains, when the innovation is unfamiliar, domain experts may not yet have the mental frameworks needed to provide comprehensive validation or critique. But while the method encouraged technical improvements, it provided limited structure for evaluating organizational or market readiness, factors that emerged as highly relevant during expert discussions. Thus, while DSR supported technical exploration, its application here would have benefited from integration with a lightweight simulation or proof-of-concept stage to triangulate findings more robustly.

5.4 Strategic Rollout and Gradual Blockchain Integration

Blockchain is a central enabler in the proposed architecture, expert interviews suggested that its introduction could be phased in over time. As Interviewee D remarked, *"Is blockchain necessary here? Or could one start with an operator's internal platform?* Highlighting that deployment could begin as a centralized system and later evolve toward a consortium-based model. This aligns with literature that advocates incremental adoption (MEF, 2020; TM Forum, 2019), especially in environments where regulatory clarity and operational readiness are still developing.

Interviewee B emphasized that early market entry could target well-defined local use cases: *"The initial rollout should focus on limited local markets rather than a global scope, allowing for gradual refinement of products and automation features."* This view supports a modular approach, where catalogue-driven offers can be launched internally before broader inter-operator coordination is introduced. Experts also suggested a tiered service model, offering shared slices with guaranteed QoS for non-critical applications. This allows operators to scale service capacity cost-effectively while retaining SLA assurance, as recommended in Rasol et al. (2024), such a phased model supports strategic flexibility. Blockchain provides the foundation f-or future decentralization, while the operator retains full control during initial rollout stages. This gradual rollout approach demonstrates that the proposed architecture is not only standards-compliant and automation-ready, but also adaptable to varying levels of operational and organizational maturity (Zeydan et al., 2023). Flexibility reinforces the novelty of the contribution that a practical and modular reference architecture that supports blockchain integration without requiring a disruptive overhaul of existing systems which are concrete and actionable answers to the research question.

5.5 Generalizing

While the proposed architecture was developed specifically for 5G network slicing within a single-operator telecom context, several of its core design principles are transferable to other industries facing similar challenges related to automation, interoperability, and trust. Table 4 summarizes these generalizable characteristics and outlines potential cross-industry applications:

Table 4: *Generalizable characteristics of the proposed architecture and potential cross-industry applications*

Characteristics	**Description**	**Potential Cross-Industry Application**
Service Level Agreement Automation	Automated monitoring, verification, and contract enforcement	Energy, logistics
Transparent/Transaction	Trustless verification between actors through immutable logging	Public sector,IoT security
Standardized interfaces	Use of TMF APIs in telecom, with similar concepts applicable in other domains	Healthcare (FHIR-API), finance (ISO 20022)

While the proposed architecture was developed for a telecom context, its design principles demonstrate clear potential for transferability to other industries with similar structural needs (see table 4). The architecture's automation of Service Level Agreements (SLAs) through smart contracts and performance monitoring enables contract enforcement in real-time. This mechanism could be applied to sectors such as energy, where consumption-based billing and compliance to delivery thresholds are critical (Xu et al., 2017), or logistics, where delivery precision is tightly tied to service agreements (Casino et al., 2019).

Secondly, the use of transparent and immutable transaction records via blockchain fosters trust between involved actors without relying on centralized intermediaries. This feature has relevance in domains like the public sector and IoT security, where verifiability and tamper-proof audit trails are increasingly necessary (Beck et al., 2018; Christidis & Devetsikiotis, 2016). Also, the reliance on standardized interfaces, such as TM Forum Open APIs, supports modular and vendor-agnostic integration. This design logic parallels approaches in healthcare, where standards like FHIR are used for data exchange, and finance, where ISO 20022 enables interoperable transaction messaging (Androulaki et al., 2018). The idea of loosely coupled services with standardized interaction patterns strengthens scalability and cross-domain compatibility.

5.6 Adoption Dynamics and Ecosystem Alignment

While this study primarily focused on designing and evaluating a blockchain-based slice marketplace architecture within a single-operator context, the expert interviews also revealed additional insights beyond the immediate scope of technical evaluation. These findings, although not part of the formal validation loop, offer valuable perspectives on organizational prerequisites, adoption barriers, and potential application areas.

Interviewee B also emphasized that "*a technical solution alone is insufficient to ensure broad adoption*." As Expert D noted, "*the biggest obstacle is that operators don't want to give up control – especially not to automated logic*." For even faster adoption this model could focus on Small medium enterprises (SME), "*can't afford private infrastructure" and prefer automated, template-based services.*" This cultural resistance reflects longstanding telecom industry patterns (MEF, 2020; TM Forum), where manual processes and bespoke services dominate. From a theoretical perspective, this aligns with socio-technical systems theory (Bostrom & Heinen, 1977; Trist & Bamforth, 1951), which highlights that successful technology adoption depends not only on technical feasibility but also on organizational alignment and cultural readiness.

Rogers' innovation diffusion theory (2008) helps interpret such resistance as expected friction during the adoption of complex technologies. As the experts also concern, such as API immaturity, system integration complexity, and lack of organizational preparedness"—*closely mirror Rogers' key adoption barriers, including "complexity*" and "*compatibility*." Which is in line with as some interviewees emphasized that small and medium enterprises (SMEs) could become key beneficiaries of such marketplaces, precisely because of their limited access to private 5G infrastructure and need for simplified service delivery. As Interviewee D noted, "*SMEs can't afford private infrastructure" and would instead prefer* "automated, template-based services." This insight aligns with literature on the "use case specificity gap" in 5G slicing, where scalable, low-touch offerings for short-term or event-driven needs remain underdeveloped (e.g., Casino et al., 2019).

Interviewees D also highlighted that "*this API alignment reduces integration costs and fits within current digital transformation roadmap*'. Multiple operators are already exploring blockchain through pilots like MEF's Smart Bilaterals or 5GZORRO, which indicates a growing willingness to experiment with decentralized orchestration (MEF, 2020). These real-world efforts affirm that adoption is not only possible but already in motion—albeit in carefully scoped phases, as also advised by several theoretical models of innovation and system transformation.

These adoption dynamics illustrate that the feasibility of implementing a blockchain-based slice marketplace is not only a technical question, but also an organizational and cultural one. As emphasized in the research question—*how such a marketplace can be designed using industry standards*—our findings show that technical alignment (e.g., with TM Forum Open APIs and 3GPP frameworks) must be accompanied by internal readiness to adopt automation, modularity, and decentralized accountability.

On socio-technical systems theory (Bostrom & Heinen, 1977; Trist & Bamforth, 1951), it becomes clear that operators' legacy structures, incentive models, and resistance to change directly affect the adoption of standards-aligned blockchain architectures. Also, innovation diffusion theory (Rogers, 2008) helps explain why perceived complexity and compatibility concerns may delay implementation even if the technical design meets standardization goals. Fully addressing the research question requires considering these human and organizational dimensions, as they ultimately determine the operational feasibility of a standards-aligned blockchain-based provisioning model.

6 CONCLUSION

This chapter summarizes the main findings and conclusions of the study in relation to its aim and research question. Furthermore, the chapter discusses the study's practical implications, limitations, and suggestions for future research.

6.1 Purpose and Research Question

The findings demonstrate that such a marketplace can be designed by combining blockchain-based service agreements with standards-aligned API integration into existing operator systems. In the proposed model, the blockchain layer functions as a shared, trustworthy infrastructure for recording provisioning agreements and monitoring SLA fulfilment. Smart contracts are used to formalize provisioning agreements and allow for the automatic detection and handling of SLA violations during the active lifecycle of a slice.

The solution deliberately focuses only on the provisioning of slices and not the full end-to-end orchestration, fulfilment, or deprovisioning processes. This scope ensures that the marketplace remains lightweight, modular, and realistically deployable within current telecom environments. The model allows customers to request slice services, and operators to process these requests through a standards-based order handling system, while smart contracts ensure transparency and traceability of the provisioning agreement.

Standard telecom APIs, such as those defined by TM Forum, are used as the interface between the marketplace and the operator's internal systems. This ensures that the blockchain-based system does not require replacing or modifying existing BSS/OSS platforms but rather complements them by adding external automation and SLA assurance capabilities. The use of these APIs also guarantees that the design remains compatible with future upgrades and vendor-agnostic systems.

In conclusion, the research confirms that a blockchain-based marketplace for network slice provisioning can be successfully designed by integrating smart contract logic with telecom standards, while ensuring modularity, interoperability, and deployment realism. This represents a meaningful step toward enabling new service models and monetization strategies within the evolving 5G landscape.

6.2 Summary of Contributions

This thesis has explored how blockchain technology can be used to support the provisioning of 5G network slices through a standardized, operator-integrated marketplace design. The primary contribution is the design of a blockchain-based system architecture that enables short-term provisioning of network slices while integrating with telecom operators' existing Business Support Systems (BSS) and Operational Support Systems (OSS). The architecture leverages standardized APIs and modular design principles to ensure compatibility with telecom industry workflows.

A key aspect of the contribution lies in the incorporation of smart contracts to encode and enforce Service Level Agreements (SLAs). These smart contracts formalize the provisioning agreements between customer and operator, and allow SLA performance metrics to be reported, evaluated, and responded to in a transparent and tamper-evident way. Although the solution does not aim to deliver full end-to-end service lifecycle management, it successfully demonstrates how the provisioning phase of a slice order can be automated and trusted through decentralized technologies.

Another important dimension of this thesis is its standards-based approach. Rather than developing bespoke components, the design aligns with widely accepted industry standards, particularly in terms of API definitions for ordering, performance monitoring, and service quality. This adherence to existing frameworks ensures that the marketplace can be integrated into operator environments with minimal disruption and is technically feasible given current telecom infrastructure.

The development of architecture followed an iterative process grounded in Design Science Research. Industry feedback from domain experts played a central role in refining the design. Interviews revealed critical practical considerations, such as the need to offload detailed billing logic from smart contracts and to consider optional integration with subscriber data management functions, depending on deployment depth. While developed in a telecom context, the architecture's design principles of modularity, SLA automation, and trust-based verification are generalized to other domains such as energy, logistics, and IoT.

Although the interview data was not part of the formal validation loop, it offered valuable perspectives on organizational prerequisites, adoption barriers, and potential application areas but the experts also emphasized the commercial relevance of the proposed model, particularly for addressing the underserved needs of small- and medium-sized enterprise (SME) customers. The marketplace model was seen as a viable way to lower the threshold for SMEs to access advanced 5G services.

Through this iterative and practice-oriented design process, the thesis contributes a technically grounded and strategically aligned architecture for telecom operators seeking to innovate in how 5G network capabilities are exposed to enterprise customers. It balances automation, trust, and integration concerns in a way that reflects current operational realities.

6.3 Limitations

While the study demonstrates the promise of a blockchain-integrated slice marketplace, there are several limitations to acknowledge:

- **Scope of Deployment:** The proposed solution was evaluated in a single-operator context. Multi-operator or cross-domain scenarios (where network slices span multiple service providers) were outside the scope of this work. Consequently, issues of interoperability between different operators' systems and the governance of a shared blockchain network remain unresolved in this thesis.

- **Regulatory and Compliance Assumptions:** The design assumes a regulatory environment where using a blockchain ledger for service agreements and performance data is permissible and secure. It does not fully address telecommunications regulatory requirements – for example, lawful intercept, data privacy/sovereignty, or how on-chain records would be treated in legal disputes. These compliance and legal aspects were beyond scope and would need thorough investigation before real-world deployment.

- **Prototype Limitations:** The prototype developed was limited, intended for conceptual validation rather than a full production system. It did not incorporate all aspects of an operational deployment – for example, comprehensive security hardening, a user-friendly GUI for customers, or integration with a live 5G network environment. The results, therefore, demonstrate feasibility under simplified conditions but do not guarantee that all technical challenges (e.g., in a dynamic production network) are resolved. Further development and testing would be required to transition from the conceptual prototype to a deployable service platform.

- **Stakeholder Perspective:** The evaluation of the solution primarily drew insights from a small number of industry experts and focused on technical feasibility. The study did not include direct feedback from potential end-users (SME customers) or from operational personnel who would manage such a system. This limited the assessment of user experience factors and organizational adoption challenges. A broader stakeholder involvement could reveal additional requirements or concerns not captured in this thesis.

6.4 Future Research Directions

Building on this exploratory work, several avenues for future research and development have been identified:

- **Pilot Implementation in Live Networks:** A logical next step is to implement the proposed marketplace in a pilot program with a telecom operator's live (or testbed) network. Such a pilot would involve deploying the blockchain platform, integrating it with real BSS/OSS systems and a network slice orchestrator, and allowing a group of SME customers to order actual network slices on a trial basis. Observing and evaluating a pilot deployment would provide insights into real-world performance, reliability, and user experience, as well as uncover any operational challenges not apparent in the conceptual design.

- **Multi-Operator and Cross-Domain Marketplace:** Future research should explore extending the marketplace model to scenarios involving multiple operators or service domains. This includes investigating how different providers could jointly use or trust a shared blockchain ledger for inter-operator slice transactions, and what governance mechanisms would be needed for a decentralized marketplace. A multi-operator marketplace raises new questions about interoperability standards, data sharing agreements, and competitive trust, all of which merit further study to generalize the solution beyond a single-operator context.
- **Performance and Scalability Evaluation:** To ensure the solution can meet telecom-grade requirements, further work is needed to rigorously test its performance and scalability. For example, experiments could measure the latency added by blockchain transactions in time-sensitive slice provisioning workflows, evaluate how many slice

requests per second the system can handle before performance degrades, and assess the blockchain's consensus overhead under peak loads. Insights from such evaluations would guide optimizations (or the consideration of alternative technologies) to ensure that the marketplace can operate efficiently on a scale. Also, legal and regulatory requirements pose unresolved challenges. Issues such as data sovereignty, GDPR compliance, and lawful interception in a blockchain-based context remain open questions. As one expert warned: *"It's still unclear how compliance issues like GDPR or lawful intercept will be handled in blockchain-based telecom platforms."* These risks become especially relevant in international deployments, suggesting that future designs must incorporate a *legal-by-design approach*, particularly in regulated telecom environments.

- **Advanced Marketplace Mechanisms:** The current design employs a straightforward contract model with pre-set pricing for slices. Future studies could introduce more sophisticated market mechanisms such as dynamic pricing, bidding auctions for sliced resources, or a brokerage system for matching supply and demand in real time. For instance, an auction-based approach might let multiple SMEs bid on available network slice capacity during a major event, with the blockchain transparently executing the highest bids. Exploring these mechanisms could expand the marketplace's utility and economic efficiency, enabling operators to maximize resource utilization and revenue.

- **Regulatory and Legal Considerations:** As the concept of a blockchain-mediated telecom marketplace is novel, it is important to investigate its regulatory and legal implications. Further research should examine how smart contract-based SLAs can be aligned with legal service agreements and what regulatory approvals or oversight might be required. Questions of data governance on the blockchain (e.g., ensuring customer data and performance records comply with privacy laws and can be audited by authorities) are also critical. Collaboration with legal experts and regulators in future work would help ensure that any proposed solution can meet the necessary compliance standards.

- **User-Centric Design and Adoption:** Finally, subsequent research should adopt a more user-centric approach to refine the marketplace concept. Engaging a broader range of stakeholders including SME end-users who buy slices and the operator personnel who would administer the marketplace, which can yield valuable feedback. User trials or workshops could be conducted to evaluate the usability of the marketplace interface, the clarity of slice offerings and SLA terms, and the willingness of SMEs to adopt such on-demand network services. Likewise, involving operations staff in design iterations would highlight practical deployment issues (like integration with business workflows or support processes). Addressing these human and organizational factors in future work will be crucial for transitioning the proposed blockchain-based marketplace from a conceptual design into a widely adopted commercial marketplace.

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8 APPENDIX

Appendix A: Interview Questions – interviewee A

1. Can smart contracts interact with the charging and billing system?
2. Which programming languages can be used for API interaction?
3. Are BSS systems standardized across operators?
4. What problems might arise when orchestrating actions from a smart contract?
5. How do we currently retrieve data from the charging system?
6. Is it possible to reference a smart contract in billing records?
7. Can smart contracts retrieve volume usage data from the BSS system?
8. Is it feasible for a smart contract to trigger a discount or rebate based on SLA violations?
9. What charging models could be relevant besides time, volume, or per event?
10. What aspects of charging or billing would benefit most from automation?
11. How easy is it to integrate new APIs into the current charging systems?
12. What are the obstacles for cross-operator slice usage and billing?
13. What are the benefits and challenges of cloud deployment for charging systems?
14. General feasibility assessment: How realistic is it to integrate smart contracts into charging workflows today?

Appendix B: Interview Questions – interviewee B

1. Regarding the smart contract and the network slice — we want the contract to trigger a process. Do you think this would be possible? What would need to happen from start to finish?
2. Are there any other process flows we should consider to ensure that our end-to-end use case works properly? Is there anything we might have missed regarding provisioning?
3. Do you see any issues with having such contracts and quality exposure on an open market?
4. Is it correct to say that 3GPP has specified all parts within the orchestration domain?
5. Our idea is that quality data would be sent to the Service Quality Management component, which could then initiate compensation or scaling actions via a blockchain smart contract. Do you think this makes sense?
6. Do you think there is a trust issue with this kind of solution, where the customer may not know exactly what they are getting?

Appendix C: Interview Questions – interviewee C

1. How do you typically evaluate the introduction of new technologies in Ericsson's BSS/OSS cloud solutions?

2. We are proposing a blockchain-based marketplace for network slice provisioning and monetization. Does this concept align with Ericsson's current strategy?

3. We have designed an architecture that integrates Hyperledger Fabric with TM Forum Open APIs (TMF620, TMF641, etc.) and 3GPP components like UDR/PCF. Do you see any critical flaws or areas for improvement?

4. Based on your experience, do you think there is a need to zoom in on any specific layer or component in our architecture?

5. Would this approach be realistic to integrate into Ericsson's current BSS/OSS portfolio?

Appendix D: Interview Questions – interviewee D

1. Is there anything important missing in our architecture from a network operator's perspective?
2. What challenges do you think operators would face in implementing this solution?
3. Do you believe that blockchain is necessary for such a marketplace, or could it be built without it?
4. How well do you think automation would work for different enterprise sizes (SME vs large corporates)?
5. Do you see value for operators in targeting SME businesses through a marketplace model?
6. What would be required to make this solution appealing for telecom operators to adopt and commercialize?
7. Are there specific components or APIs (e.g., TMF620) that you think could simplify product understanding and ordering?
8. What business model concerns or risks do you foresee, such as control, transparency, or security?