Universiteit Leiden
Faculty of Science
Leiden Institute of Advanced Computer Science
ICT in Business Masters Program

APPLICABILITY OF BLOCKCHAIN TECHNOLOGY IN TELECOMMUNICATIONS SERVICE MANAGEMENT

Name: **Mohamed Atef Ibrahim**
Date: **May 22nd, 2017**

1st Supervisor: **Dr. Hans Lefever**
2nd Supervisor: **Tino De Rijk**

MASTERS THESIS
Leiden Institute of Advanced Computer Science (LIACS)
Leiden University
Niels Bohrweg 1
2333 CA Leiden
The Netherlands

ACKNOWLEDGEMENTS

Firstly, I would like to dedicate this work to my parents and family, especially my wife who has always been there and spared no effort to support me.

My special appreciation goes to my mentor, Dr. Hans Le Fever, for his wonderful mentorship, insightful guidance, and patience since the very beginning until the end.

My supervisor Tino De Rijk had a valuable contribution to this research with his thorough review, extraordinary detail orientation and insights that enriched the arguments.

I also extend my sincerest gratitude for Mrs. Judith Havelaar for all her help, support, understanding and consideration.

I would also like to thank Prof. Dr. Aske Plaat, Dr. Arno Knobbe and Drs. A.C. Berendse for their encouragement and support.

I also thank Mrs. Iman Van der Kraan for her kind efforts and encouraging words.

Finally, my gratitude is for my friends who believed in my ability to accomplish this goal and continuously encouraged me and all of those who helped me in collecting the data and also people who agreed to take part in the research interviews.

ABSTRACT

Blockchain technology is based on storing data in cryptographically secured chains of blocks. At its core it is a distributed database that maintains a continuously growing list of transactions using a peer-to-peer network. By design a blockchain is immune to tampering or the modification of previous transactions using cryptographic techniques.

The basic inherent characteristics of the blockchain technology qualified it to prove its applicability in the financial services sector. Its first and most widely used application is crypto-currencies and smart contracts. The first large scale application of blockchain was for the application of a crypto-currency. It was conceptualized in 2008 by Satotshi Nakamoto introducing a purely peer-to-peer version of electronic cash that would allow online payments to be sent directly from one party to another without going through a financial institution.

Blockchain - as the underlying technology for bitcoin and other crypto-currencies - is a shared digital ledger, or a continually updated list of all transactions. This decentralized ledger keeps a record of each transaction that occurs across a fully distributed or peer-to-peer network, either public or private. A blockchain’s integrity hinges on strong cryptography that validates and chains together blocks of transactions, making it nearly impossible to tamper with any individual transaction record without being detected[1].

The potential benefits of the blockchain are more than just economic—they extend into political, humanitarian, social, and scientific domains—and the technological capacity of the blockchain is already being harnessed by specific groups to address real-world problems[2].

This thesis intends to explore the applicability of a blockchain solution in the service management domain of the telecommunications industry.

Cascading the above definition on the delivery of telecommunications services gives many possibilities. For instance where the service managers need to manage an end-to-end service management process extending from the receipt of a customer complaint, through creating a trouble ticket for first, second or third lines of support, or issuing a work order to field maintenance teams to visit one of the network’s sites to resolve a physical problem.

---

1 (http://www.pwc.com/us/en/technology-forecast/blockchain/definition.html)
2 Swan Melanie (2015) "Blockchain blueprint for a new economy ".

Such an end-to-end service management process faces many challenges in terms of managing the transactions of customer complaints, trouble tickets and work orders between different entities, correlating work orders to trouble tickets and trouble tickets to specific customer complaints and the traceability of the transactions and accountability over the needed actions to be performed. Also, the governance of such a process where different databases exist for customer complaints, trouble tickets and work orders is time consuming and doesn't realize the full governance capabilities needed for continuous improvement.

The thesis addresses these particular challenges by employing the design science research methodology to develop a blockchain based solution to implement the ITIL specified event management process, and then incrementally and iteratively enhance that design through interviews with qualified professionals in the telecommunications service management field. The study took place over a 50 days period and six design generation and evaluation iterations.

The results indicate that blockchain technology resolves traceability issues, data integrity issues, contract management issues and governance issues in the service management domain of the telecommunications industry. Interestingly, its smart contracts features provide an opportunity to significantly contribute to the efficiency and effectiveness of automating and managing a service management process and realizing new governance capabilities and eventually enhance the process performance. The results also indicate that adopting blockchain technology can influence organizational culture especially in a competitive environment.

Furthermore, these results encourage future research to explore creating a new enterprise data architecture model, shaped around the integrity of immutable, auditable data and process controls. The results of this research can be helpful to various business domains planning to implement private blockchain solutions as it specifies design considerations, a layered architecture and technical specifications for a private blockchain solution.

Keywords:
Blockchain technology, Design science, telecommunications, service management, Event management.

TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

BSS – Business Support System

CRM - Customer Relationship Management

EMS – Element Management System

ERP – Enterprise Resource Planning

ICT – Information and Communication Technology

ITIL – Information Technology Infrastructure Library

ITU – International Telecommunications Union

NMS – Network Management System

OSS – Operations Support System

RAN – Radio Access Network

SNMP – Simple Network management Protocol

SOAP – Simple Object Access Protocol

TMN – Telecommunications Management Network

List of Appendices

CHAPTER 1 – RESEARCH OBJECTIVE

INTRODUCTION

The delivery of telecommunications services has been evolving while the existing systems are facing many challenges. Technological innovations can provide solutions to face and overcome a few of those challenges. Technology is advancing and it can change the delivery of the telecommunications services as it is impacting all other aspects of life. Accordingly, since telecommunications are crucial and directly impact human life, the speed and quality of a delivered telecommunication service becomes of paramount importance to service providers and regulators to enrich the users' customer experience. Key performance indicators of such a system have to be defined and continuously monitored with the overall performance of the system brought into perspective.

Telecommunications services providers and mobile network operators are continuously striving to make their service management processes more efficient and effective in achieving its required goals. One of the main goals of such processes is the timely resolution of customer complaints and network faults. This study targets developing a telecommunications service management blockchain solution and validating the solution based on its potential impact on the service management process to resolve customer complaints and network faults, and ultimately enhance customer experience.

Mass adoption of blockchain technologies, across a broad range of use cases, is becoming inevitable. This study is targeting seizing the opportunity of using an emerging technology with diverse applications to develop a solution for existing challenges in the service management of the telecommunications sector. The "Event management" process shall be the use case to validate the solution.

The evolution of telecommunication technologies and services is imposing many new challenges on mobile network operators like with IoT (Internet of Things) where the access to telecommunications services will be extended to cars, home appliances and medical devices. Accordingly, customers can now also be machines who cannot initiate customer complaints due to service quality issues. The number of connected devices is rapidly growing as in 2012 it reached 8.7 billion[3] with anticipation for the number to reach 50.1 billion in 2020. With the industries transforming, technological innovations as blockchain technology provides new ways to cope with such transformation.

Blockchain organizing can change the meaning of work profoundly, improve productivity, protect our privacy, and improve decentralization and democratization. The best idea is to start improving your own processes with blockchain technology by making them ready to transfer them to decentralized shared transaction networks[4].

Service management processes and systems can utilize the above capabilities by blockchain to improve the service delivery, quality, customer experience of telecommunication services. It can also improve the early detection and resolution of network events as equipment faults and failures and face the existing challenges in telecommunications service delivery.

The proposed design will give special focus to develop a solution using blockchain technology as the underlying technology to implement a telecommunication service management process of a mobile network operator. The blockchain solution is targeting tackling the main process challenges to meet ITIL standard requirements. The event management process which is a part of the End-to-End service management process will be used as a use case for the solution validation as per the ITIL service operation guide.

Problem Statement

An ITIL service management process is a complex process that involves many entities with different capabilities and responsibilities. It is also worth mentioning that the different process stakeholders are geographically distributed and that there are numerous transactions that occur between the different entities to achieve process objectives including but not limited to: Customer complaints, trouble tickets, work orders, and customer support requests. There are direct and indirect relationships between the different transactions listed.

The main challenges facing this process are:

- Data integrity.
- Stakeholder accountability.

[3] https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/

[4] Paul Bessems - Blockchain organizing: the new trust industry - January 31, 2017 https://itsm.tools/2017/01/31/blockchain-organizing/

- Correlating the transactions and
- Traceability of the transactions.

Blockchain technology has proven to overcome the mentioned challenges in other applications as crypto-currencies, where all transactions are:

1- Secured using cryptographic techniques.
2- Clear accountability as each user has only control over his account through an e-wallet.
3- Interrelated and time stamped.
4- Traceable and transactions history cannot be manipulated by an unauthorized entity.

The research problem addresses studying the applicability of blockchain technology in the service management of telecommunications services and testing the validity of the blockchain solution through a use case on the event management process as specified by the ITIL framework.

In conclusion; the research project pursued is responding to the below research questions:

1. Can the basic characteristics of blockchain technology as immutability and disintermediation can resolve service management challenges as trust, accountability and conflicts in the telecommunications sector and if so, then how?
2. Can a service management blockchain technological solution be a complementary solution to existing ERP systems used in telecommunications service management?
3. Can a blockchain technological solution meet ITIL framework requirements?
4. What are the needed ICT requirements to deploy a blockchain service management solution in a mobile network operator infrastructure?

PURPOSE OF THE RESEARCH

The purpose of this project is to develop a private blockchain solution to implement the processes within an end-to-end service management process of a mobile network operator to handle network faults and customer complaints. The application of such a solution enables the organization to enhance the effectiveness and efficiency of the process and develop governance capabilities capitalizing on the basic inherent features of blockchain technology allowing:

- Secured transactions using cryptographic techniques.
- Clear accountability as each user has only control over his account.

- Creating interrelations among transactions and time stamping of each process transaction.
- Traceability of transactions and transactions history cannot be manipulated by an unauthorized entity.

This provides the organization with enhanced governance over the existing domain capabilities, offers a competitive position against competitors, enables greater efficiency in the utilization of resources in delivering telecommunications services capabilities and presents an opportunity for improved success in the service management.

DEFINITIONS

The service management Process: This process describes the interactions between lower level processes and activities needed to resolve a technical customer complaint e.g. coverage problem, call drop problem…etc. excluding billing problems.

The event management process: This process monitors all events that occur through the IT infrastructure to allow for normal operation and also to detect and escalate exception conditions[5].

Level 1 support: The entity responsible for performing network surveillance, alarms detection, alarm analysis and preliminary troubleshooting to direct the action to the right entity for handling either by escalating to Level 2 support or to field maintenance team in case physical action is needed.

Level 2 support: The entity responsible for performing configuration of network elements and advanced troubleshooting, and providing technical support to field maintenance teams this entity may direct the action for handling either by escalating to Level 3 support or to field maintenance team in case physical action is needed.

Level 3 support: The entity responsible for the resolution of complex technical problems that could not be resolved by the Level 2 support teams escalated to them in the form of CSRs (Customer Support Request).

Field maintenance: The entity responsible for interacting physically with the network elements located in the network sites. This entity owns the corrective maintenance and preventive maintenance processes and also responsible for implementing physical optimization actions.

[5] ITIL V3 Service Operation p.35.

Customer experience: This entity is responsible for acting as a single point of contact between the customer care teams and the technical teams, performing technical customer complaints analysis and follow up with other technical teams until resolution of the customer complaints.

Network Operation Center (NOC): A network operations center (NOC) is a central location from which network administrators manage, control and monitor one or more networks. The overall function is to maintain optimal network operations across a variety of platforms, mediums and communications channels[6].

Network Management System (NMS): A network management system (NMS) is an application or set of applications that lets network administrators manage a network's independent components inside a bigger network management framework. NMS may be used to monitor both software and hardware components in a network. It usually records data from a network's remote points to carry out central reporting to a system administrator[7].

Operations Support System (OSS): Generally refers to the system (or systems) that perform management, inventory, engineering, planning, and repair functions for communications service providers and their networks[8].

A transaction: Is a collection of changes to a database that is accepted or rejected as a whole. Every time a transaction modifies the database, the software ensures that the database's rules are followed. If any part of a transaction violates one of these rules, the entire transaction will be rejected with a corresponding error9.

Unique Node List (UNL): Each server, s, maintains a unique node list, which is a set of other servers that s queries when determining consensus. Only the votes of the other members of the UNL of s are considered when determining consensus (as opposed to every node on the network). Thus the UNL represents a subset of the network which when taken collectively, is "trusted" by s to not collude in an attempt to defraud the network. Note that this definition of "trust" does not require that each individual member of the UNL be trusted.

Smart Contract: is software that emulates the logic of contractual clauses. It holds the rules for processing any transactions made between participating parties. Blockchain based contracts can be partially or fully executed or enforced without human interaction.

Academic and Professional Relevance

[6] https://www.techopedia.com/definition/5377/network-operations-center-noc
[7] https://www.techopedia.com/definition/11988/network-management-system-nms
[8] http://www.etsi.org/technologies-clusters/technologies/past-work/oss
[9] http://www.multichain.com/blog/2015/10/private-blockchains-shared-databases/

From an Academic perspective, Blockchain technology is an emerging technology that was conceptualized in 2008. At its core it is a distributed database that maintains a continuously growing list of transactions using a peer-to-peer network. By design a blockchain is immune to tampering or the modification of previous transactions using cryptographic techniques. The basic inherent characteristics of the blockchain technology qualified it to prove its applicability in the financial services sector. Its first and most widely used application is crypto-currencies and smart contracts. This research intends to explore the applicability of a blockchain solution in the service management domain of the telecommunications industry.

From a professional perspective, technological innovations have helped humanity overcome many challenges. One of the challenges telecommunications service providers and mobile network operators are facing is the delivery of telecommunications services. Fast resolution of customer complaints and early detection of network faults can enrich customer experience. The use of multiple databases for service management adds complexity, and sets strict constraints on the governance capabilities of the organization in managing its service delivery. Managing ICT investments in this domain also needs to be optimized due to the limited resources, ensuring the highest return for minimal investment. This study intends to develop an innovative blockchain based solution to implement a service management process providing the organization with enhanced governance capabilities.

Research Implications

The implications of performing this research are:

1. Developing an understanding regarding the applications of blockchain technology in domains other than financial services and crypto-currencies.
2. Identify a new application of blockchain technology in the service management sector generally and the telecommunications industry in specific.
3. Grasping the opportunities offered by blockchain technology and understanding the challenges it might face when introduced to the telecommunication industry.

Contribution to the existing body of Knowledge

The research intends to enrich the existing body of knowledge addressing the possible application of blockchain technology outside the financial services sector and cover the existing body of knowledge gap related to the applicability of blockchain technology in the service management domain of the telecommunications industry.

Contribution to our understanding of the world

Such a research adds to our understanding of the world as it provides the fundamental understanding of the potential application of blockchain technology in the service management domain of the telecommunications industry and presents a validated solution utilizing an emerging technology that may provide a wide range of possibilities and applications to service management as much as it has disturbed the financial industry with crypto-currencies as its application.

It is well known in organizational theory that coordination difficulties increase with size. Large centralized units will have a higher tendency to rely on formal coordination measures via standardization of input and procedures, while smaller decentralized units are more flexible in terms of ad hoc coordination *(Mintzberg 1979)*. Organization theory thus points to a number of possible benefits of decentralized decision-making. First, it may facilitate the use of knowledge and experience accumulated by local staff. Second, it may improve flexibility and adaptability in the organization. Third, it may motivate employees and stimulates entrepreneurship. Fourth, it may strengthen feelings of responsibility among employees *(Jacobsen and Thorsvik 2002)*.

Extending these arguments to service management telecommunications organizations, it can be argued that the basic inherent characteristics of the blockchain technology provide a database with the following characteristics:

1- Public.
2- Distributed.
3- Synchronized.
4- Secure.

Those characteristics provide a very wide range of applications in managing transactions within the service management domain.

STRUCTURE OF THE REPORT

Chapter 2 covers the conceptual foundation of blockchain technology and the concepts of design science for information systems, introducing the definitions, review of the literature and theories.

Chapter 3 describes the methodology of this research, design development process, participants' selection criteria, and Data collection procedures and also describes the interview protocol.

Chapter 4 discusses the preliminary design developed by the researcher and its foundation.

Chapter 5 analyses and presents all the iterations of the solution design. It also discusses findings from the structured interviews.

The final chapter contains the summary, conclusions and recommendations for further study or practice.

Chapter 2 – Conceptual Foundation

Concepts of Blockchain Technology

A blockchain is a database that maintains a continuously growing list of transactions using a peer-to-peer network and a time stamping server. It gets its name from storing the transactions in blocks and links those blocks using cryptography creating a chain of blocks. By design a blockchain is immune to tampering or the modification of previous transactions using cryptographic techniques. It has four main basic inherent characteristics:

1- Public: where any node in the blockchain network can download the complete blockchain.
2- Distributed: by the storage of data across the blockchain network the risks of a centralized database has been avoided like hacking or being a single point of failure.
3- Synchronized: The synchronization in a blockchain network is achieved through a process that does not rely upon much examination of blocks but rather trusts the blocks that the node has because the proof chain backs them. It's extremely easy to verify the proof chain and once that is complete the node only needs to make sure the blocks it gets match the proof chain. As the account tree is being built the only thing that matters is that it ends up having the master hash of the latest block. Once that is complete and the node is synchronized it can begin to update the account tree normally by accepting valid blocks[10].
4- Secure: by applying verification, hashing, cryptography, interrelating transactions, the use of public keys and private keys

One of the key definitions that need to be introduced here is hashing, where a hashing function is defined as below:

Hashing function: A hash function is an efficient function mapping binary strings of arbitrary length to binary strings of fixed length (e.g. 128 bits), called the hash-value or digest[11].

Another key definition is that of the mining process, this process is responsible for adding transaction records to the ledger. The ledger of the previous transactions is called “blockchain” as it is the chain of blocks containing previous validated transactions. This process is implemented by the mining nodes that interact to reach a secure, tamper-resistant consensus.

---

[10] J.D. Bruce, Purely P2P Crypto-Currency With Finite Mini-Blockchain, May 2013. Rev 1. https://pdfs.semanticscholar.org/3f64/123ce97a0079f8bea66d3f760dbb3e6b40d5.pdf Accessed 9 Apr, 2017.
[11] Cryptography and number theory, CA642. http://www.computing.dcu.ie/~hamilton/teaching/CA642/notes/Hash.pdf

The most important technical specification of the miner nodes is specified to be the hash rate. The hash rate measures how powerful a blockchain miner's machine is. Specifically, it measures the number of times a hash function can be computed per second, where a hash function takes an input of any given length and produces an output of a specified length. In this iteration, the design must consider in more detail the issue of choosing a hash function to perform the address calculations for the given application and the hash rate of the mining nodes resembling the mining pool in this private blockchain.

(Berke, 2017) in comparing consensus protocols and access permissions in public Vs. Private blockchain applications mentions that the process used to get consensus (verifying transactions through problem solving) is purposely designed to take time, currently around 10 minutes. Transactions are not considered fully verified for about one to two hours, after which point they are sufficiently "deep" enough in the ledger that introducing a competing version of the ledger, known as a fork, would be computationally too expensive. This delay is both a vulnerability of the system, in that a transaction that initially seems to be verified may later lose that status, and a significant obstacle to the use of bitcoin-based systems for fast-paced transactions, such as financial trading.

In a private blockchain, by contrast, operators can choose to permit only certain nodes to perform the verification process, and these trusted parties would be responsible for communicating newly verified transactions to the rest of the network. The responsibility for securing access to these nodes, and for determining when and for whom to expand the set of trusted parties, would be a security decision made by the blockchain system operator[12].

THE TELECOMMUNICATIONS MANAGEMENT NETWORK (TMN) ARCHITECTURE

This section shall cover the architecture of a telecommunications management network to develop the needed understanding to position the solution within the existing standardized telecommunication architectures and where the proprietary vendor interfaces exist.

The TMN architecture has been layered horizontally as element Management, Network Management and Service Management layers. The Layered architecture is given in Figure 1 - TMN layered Architecture. The Network elements interface with the element Management system over the Qx interface (Proprietary of the vendor that manufactured the network elements) and the other interfaces of the EMS with other layers of management functions is over the Q3 interface.

[12] Harvard Business Review "How safe are blockchains? It depends", Allison Berke, March 07, 2017.

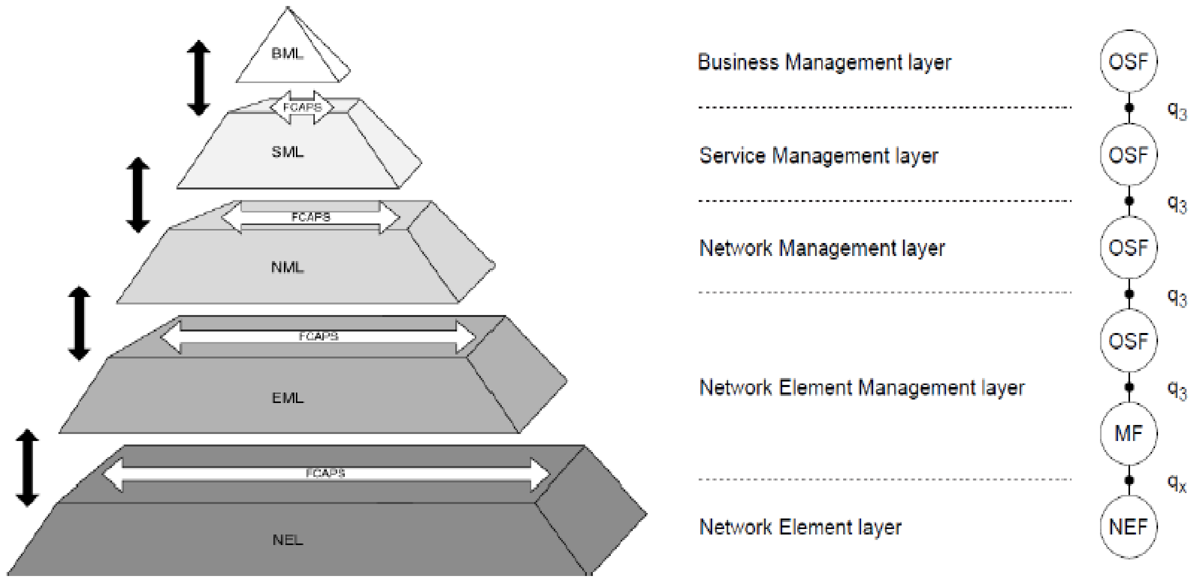


FIGURE 1 - TMN LAYERED ARCHITECTURE

The functions of the various Network Management layers are given below:

- Network Element Layer: This layer includes the Switches, Routers, and Transmission Systems etc.
- Element Management Layer: This layer manages the elements comprising of networks and systems including the network configurations.
- Network Management Layer: This layer manages the network and systems that deliver those services e.g. capacity, diversity, congestion etc. This layer manages from a multi-vendor perspective. It provides the Network View, Correlation of Network events, Single sign on to network elements and managers, Traffic Management, Monitoring network utilization & performance.
- Service Management Layer: This layer manages the service offered to the customers e.g. meeting the customer service levels, service quality, cost and time-to-market objectives etc. Order Management, Orchestration, Middleware, Provisioning Management, User account management, QoS management, Inventory management, monitoring of service performance.
- Business Management Layer: This layer manages the overall business i.e. achieving the return on investments, market share, employee satisfaction, community and government goals etc. Customer Management, Fault Reporting, Customer Billing, Business Reporting Tools falls in this layer.

Review of Literature

This section situates the research project in the context of the already existing body of knowledge about the topic. It also provides the theoretical basis for the research. It gives an overview what has already been done in the field by other researchers and therewith sets the scene for the research.

The researcher used the Google scholar database, Researchgate database and the Mendeley database as a main source of scientific literature related to the topic of the research. The researcher also had access to many web pages, blogs and forums related to blockchain technology and its various applications. The keywords used to search the databases were: Blockchain, Blockchain technology, Blockchain applications, process automation, blockchain versus relational database, research design, blockchain design, blockchain mining, blockchain hashing, hashing algorithms, blockchain security, blockchain confidentiality and blockchain network.

This research shall adopt the design science methodology through following design science guidelines and using design evaluation methods *(Hevner et. al, 2004)*.

Blockchain technology is founded on storing data in cryptographically secured chains of blocks as with the growing use of text, audio and video documents in digital form and the ease with which such documents can be modified a new problem arises: how can one certify when a document was created or last modified? *(Haber and Stornetta, 1991)* proposed two solutions to this problem both involving the use of one-way hash functions, whose outputs are processes in lieu of the actual documents, and of digital signatures.

(Nakamoto, 2008) conceptualized the first large scale application of blockchain. It was for the application of a crypto-currency. In that paper Satoshi Nakamoto Introduced a purely peer-to-peer version of electronic cash that would allow online payments to be sent directly from one party to another without going through a financial institution.

(Crosby et. al, 2016) Conducted further research exploring the applications of blockchain technology beyond crypto-currencies as in “BlockChain Technology: Beyond Bitcoin”. Since Blockchain is a new emerging technology most of the scientific literature about it is of explanatory and exploratory nature. The focus of most of the scientific literature existing is on the most popular and widely used applications of blockchain technology. On the global scale, the most popular blockchain technology applications are crypto-currencies such as bitcoin and smart contracts such as ethereum. Though the development of other applications in other domains is still immature, a rapid increase of new applications for blockchain technology is anticipated; - “Non-Financial applications opportunities are also endless. We can envision putting proof of existence for all legal documents, health records, and loyalty payments in the

music industry, notary, private securities and marriage licenses in the blockchain. By storing the fingerprint of the digital asset instead of storing the digital asset itself, the anonymity or privacy objective can also be achieved."

(Pilkington, 2016) published "Blockchain Technology: Principles and Applications" [13]. In a first part, he presented the core concepts. Secondly, he discussed a definition by Vitalik Buterin, the distinction between public and private blockchains, and the features of public ledgers. Thirdly, he stated the foundational and disruptive nature of blockchain, and presented the risks and drawbacks of public distributed ledgers, and showed why the latter explain the shift toward hybrid solutions. Finally, he sketched out a list of important applications, bearing in mind the most recent developments.

(Mazonka, 2016) in his paper "Blockchain: Simple Explanation" presents a step by step introduction to what blockchain is and how it works. He presents the concepts of Hashing, Hash functions, hash chains and public key cryptography. The subject of choosing the best hashing Strategies and hash functions was covered in a master thesis in software engineering from Thapar University by *(Singh, 2009)* where he concluded that choosing a best hashing strategies and hash functions is purely concerned to the given problem. Choosing an effective hash function for a specific application is more an art than a science depending on the requirements and the constraints. *(Askitis, 2009)* was concerned with the performance of the hash tables where a hash table is a fundamental data structure in computer science that can offer rapid storage and retrieval of data, he described how to efficiently implement a cache-conscious array hash table for integer keys, then experimentally compared its performance against two variants of chained hash table and against two open-address hash tables—linear probing and bucketized cuckoo hashing—for the specific task of maintaining a dictionary of integer keys (with payload data) in-memory. He concluded with that the array hash was also among the fastest hash tables to delete random keys, but it can become slower than both a chained hash table and bucketized cuckoo hashing in a specific case involving key deletion.

(Swan, 2015) in her book "Blockchain, Blueprint for a new economy" introduces the main applications of blockchain as currencies and smart contracts, then proceeds to presenting applications beyond currency, economics and markets. The book demonstrated that blockchain technology's many concepts and features might be broadly extensible to a wide variety of situations. These features apply not just to the immediate context of currency and payments (Blockchain 1.0), or to contracts, property, and all financial markets transactions (Blockchain 2.0), but beyond to segments as diverse as government, health, science, literacy, publishing,

[13] Marc Pilkington is Associate Professor of economics at the University of Burgundy, France.

economic development, art, and culture (Blockchain 3.0), and possibly even more broadly to enable orders-of-magnitude larger-scale human progress.

(Bessems, 2017) Introduces blockchain as a new and disruptive concept to organize trust in the supply and demand chain. He studies the impact of blockchain technology in his paper "Blockchain organizing: the new trust industry" on third trusted parties existing in the traditional coordination mechanism, like 'the firm', 'the bank' or 'the government'. He concludes his paper with that blockchain organizing will affect the IT industry. New systems will be designed and built. They will not be based on company borders and own databases. They will be based on an ontology and taxonomy, with the two smallest building stones (humans and their tools), and transaction at the core. Organizational models will be based on organization principles like: 'programmable institutions', 'structured flexibility,' and 'apart together'. IT systems will be built with these new organizational principles as the starting point.

(Melika, 2017) Introduces one of the interesting patents currently pending regarding the application of blockchain technology in telecommunications. He describes cryptographically managed telecommunications settlement occurring in real time with generation and termination of a telecommunications channel. Upon the generation of a communications channel, a contract fund is established between two or more telecommunications services and recorded on a cryptographic ledger. Over the course of regular intervals of channel service, crypto-currency is released from the contract fund. Upon termination of the communications channel, the released amount of the contract fund is transferred to the receiving provider telecommunications, the remainder back to the requesting telecommunications service. Transactions between crypto-currency wallets are all published to the cryptographic ledger[14].

(Kumar, 2009) conducted an in-depth discussion of the functions of the Element Management Systems and Network Management Systems in Telecom Networks. This paper also gives a brief about the evolution of telecom Network Management, different network systems deployed in the network and the network management issues faced by Telecom Service Providers. This document also discussed in detail the different standards of the ITU-T and Telecom Management Forum [TMF] for Telecom Network Management, their synergy and functional areas for Telecom network management. It discussed also in detail the EMS functions and NMS functions bringing clarity into the boundaries between them. It also specifies the interface requirements for the EMS/NMS systems to inter-operate with the EMS, NMS, OSSBSS and ERP systems.

[14] Generic Cryptographically managing telecommunications settlement.Melika, G. A Thobhani, A. https://www.google.com/patents/US20170078493 2017 Google Patents

On the other hand there is the ITIL (Information technology infrastructure library) which is a framework of best practices for managing IT services providing the practical foundation of assessment for the applicability of blockchain technology to satisfy best practice guidelines.

Accordingly, this research intends filling the research gap in the existing body of knowledge related to the application of blockchain technology in the service management domain of the telecommunications sector, the above sets the theme for comparing the results of this research to the results of other researchers and situate the results in the body of existing knowledge.

DESIGN CONSIDERATIONS FOR THE BLOCKCHAIN SOLUTION

This section addresses responding to a few preliminary questions before developing the design as an artifact. Responding to these questions will provide the foundation of the design:

1. Question 1: Why do the key inherent characteristics of Blockchain technology qualify it to compete with other existing technologies?

Blockchain technology's inherent characteristics enable it to support critical business processes, but the decision of using blockchain instead of relational database depends on the nature of the intended application and the business process that it shall support where blockchain will definitely be the better choice in case the application can make use of a distributed database to store information that will support some critical business process, and updates to that database must be cryptographically protected against tampering, and the history of the transactions is of business value. One of the key inherent features of blockchain technology is that it is designed to be used by a group of non-trusting parties, and requires no central administration.

With the assumption that all the parties interacting in a process are trusted parties within the same company, this eliminates the need for a private blockchain to create a trustless ecosystem. It would be preferable in those specific scenarios to benefit of the superior performance offered by conventional database solutions whether relational or distributed.

So far, till date the performance of a relational database exceeds that of a blockchain one. Accordingly, if high performance is a key requirement of the application, then a relational database or even a NoSQL distributed database shall be a better fit. On the other hand there are a few advantages of blockchain technology over relational databases in terms of fault tolerance. For example, as there are a number of nodes in the blockchain network maintaining the full chain, it is practically difficult to reach the same level of robustness using a relational database. Also, the distributed nature of the blockchain network minimizes the possibility of hacking multiple nodes, where while using relational databases hacking a single node is a prominent threat.

In conclusion, blockchain, relational databases and NoSQL distributed databases can all support critical business processes but each has its own domain of excellence, while relational databases excel in performance, and NoSQL distributed databases excel in robustness and performance. Blockchain excels in providing robustness and fault tolerance that can hardly be achieved by relational databases, and is a better fit for applications that depend on shared trusted immutable state with a small amount of data. Accordingly, detailed requirements analysis shall guide the decision of either to use blockchain, NoSQL distributed database or a relational database.

2. Question 2: Are all the features of the blockchain technology implemented in public blockchains needed in a private blockchain solution?

The system design shall adopt a solution based on the use of blockchain as a database and its features. The blockchain-database itself is required in the solution to maintain the records of all Customer complaints, Trouble tickets, work orders and Customer support requests and maintain the relationships between them in a single blockchain instead of the existing different centralized databases each holding the records of a specific type of transactions.

The feature that exists in other public blockchain based applications (crypto-currencies) that is not needed in a private blockchain is the incentives scheme used to reward the nodes for transactions processing and block validation, in the design of a private blockchain there are no external parties that need to be rewarded for providing transactions processing and block validation which eliminates the need for incentives or for an incentives scheme.

3. Question 3: Is this solution for service engineers that do not follow rules or try to hide their own shortcomings, in short is it addressing a human issue?

The answer to this question is yes, but this is just one aspect of different aspects addressed by the solution. In a broad context, the solution addresses how blockchain technology is used to create a trustless ecosystem where transactions are allowed between different entities such as competitive vendors and contractors without the need for a third trusted party or intermediary or a sole owner of the data records of the transactions, maintaining the rights of different entities, minimizing conflicts and immune to be tampered by a single entity. In such an ecosystem, the data representing the facts related to a transaction is immune from being tampered or misused.

4. Question 4: Is the solution intending to solve an internal problem in a company or does the problem extend to external companies (extending to the service chain)?

The solution also addresses some issues that arise along the service chain of a mobile network operator especially the ones heavy reliant on a managed services operation model or outsourcing, where the responsibility of implementing the operational processes is transferred to the performing organization which maybe a vendor or subcontractor. If the operator is adopting a managed services operation model in the processes presented in this study, the contractual rights of all the entities in the service chain are maintained through the application of contractual terms on predefined key performance indicators.

It is also worth mentioning that one of the applications of blockchain technology that may have great potential use in the telecommunications industry is the smart contracts. In a managed services setup the smart contract can be used to govern the service delivery by vendors or subcontractors to network operators based on the predefined terms of service delivery and key performance indicators which are mostly related to network KPIs and percentages of compliance with the resolution time of network faults.

Chapter 3 – Research Methods

Research Design

This research used qualitative research methodology and the approach used was case study as it focuses on a single unit for analysis *(Saldana, 2011)*. The single unit of analysis in this research is the "ITIL Event Management process". The case study qualitative research enabled the researcher to study and to focus on a single process *(Creswell, 2014; Saldana, 2011)*. The qualitative methodology was chosen for this research as there's no need for result generalization *(sun, 2009)*. The objective of the research is to go behind the statistical and numerical analysis and to achieve a deeper understanding of the applicability of blockchain technology in implementing a key process in telecommunications service management. The nature of the data in this research was not numeric, the interviews with subject matter experts (as a data collection method) enabled the participants to describe their experiences, and points of view towards certain subjects. The qualitative research expected an interaction between the researcher and the subject (phenomena) *(Sun, 2009)* and the investigator and the investigated phenomena were independent *(Slevitch, 2011)*. All these factors support the selection of the case study as an approach for this qualitative research.

The induction approach has been chosen since the application of the blockchain technology in the service management domain of the telecommunications industry is a new topic with much debate and little existing literature. The proposed research will be of exploratory nature where it will mainly depend on literature search, expert interviews and focus group interviews. *(Bücker, C. 2015)*

The qualitative approach has been chosen as the evaluation of the design by the qualified interviewees shall be of Non-numerical data, interpretive and descriptive, based on Observation of a natural setting and In-depth description of a situation or observations of "natural setting". *(Bücker, C. 2015)*

The case study research strategy is proposed through the application of the design using blockchain technology on the "ITIL Event management process" where several methodologies can be used to collect and analyze data including:

Interviews with stakeholders/experts either management, staff or partners of exploratory nature to identify the key success factors that the technology need to provide, the structured interviews and questionnaire will cover but will not be limited to the following questions:

a. What are the requirements from a technological perspective to implement the service management processes?
b. Based on those requirements what will be the evaluation criteria for a blockchain solution to validate the solution?
c. Does blockchain technology provide the needed requirements to implement the service management processes?
d. After reviewing the solution, how does it meet the specified evaluation criteria?
e. What are the drawbacks of using blockchain technology instead of the existing ones?
f. What are the perceived benefits of using blockchain technology instead of the existing ones?

Most of the qualitative research studies depend on the interview as a main instrument to collect the data *(Saldana, 2011)*. The interview enables the participants to share their stories, experience, and to have in-depth answers that focus on the participant's experience and opinion related to the research topic *(Murtezaj, 2011)*. Interview formats can range from highly structured interviews to unstructured interviews *(Saldana, 2011)*. Several factors affect the degree of structure in the qualitative research such as the purpose of the study and the availability of the participants *(Devers & Frankel, 2000)*. Another data collection method used in qualitative research studies is document analysis, which provides the opportunity to review the documents related to the topic under study *(Creswell, 2014)*. These various methods are triangulated against one another to ensure the rigorousness of the study, as using more than one data collection method helps to decrease the weaknesses of any single approach *(Aziz, 2013)*.

In this case study qualitative research the researcher used semi-structured interviews with participants; the participants were experts in their domain and the telecommunications industry, but they had little in-depth knowledge of blockchain technology. The semi-structured interview enabled the researcher to have more flexibility to start the interview with a brief introduction about the idea, objective of the research and to illustrate the concepts of blockchain technology. Document analysis method enabled the researcher to review the documents related to the research topic; document analysis was a secondary data collection method in this case study qualitative research. The documents used in this research included:

1- The ITIL service operation Guide;
2- Books related to Blockchain technology;
3- The Event management process;
4- The Service management process;

5- Research papers related to blockchain technology;
6- Research papers related to blockchain technology applications;

Participants Selection Criteria

There are two sampling techniques: probability sampling and non-probability sampling *(Malhotra, 2007)*. Probabilistic sampling is not suitable for qualitative research studies as there is no need for generalization *(Creswell, 2014)*. Non-probabilistic sampling techniques rely more on the personal judgment of the researcher than the chance of selecting ample element *(Malhotra, 2007)*. The purposeful sampling, as a non probabilistic sampling technique, was selected to be used in this qualitative research. It was based on the assumption that the researcher needed to understand, discover, and gain insights, thus the researcher must select the participants who would be able to provide the required data and information from which the most can be learned. Participants were selected according to the objective of the research and their ability to contribute to the research *(Aziz, 2013)*.

Samples for qualitative researches are generally much smaller than those used in quantitative research *(Mason, 2010)*. There is a point of diminishing return to qualitative samples, as the study progresses more data does not necessarily lead to have new information *(Mason, 2010)*. The sample size in general depends on the research design *(Creswell, 2014)*.

The concept of data saturation is where no new information or themes are observed in the data from the completion of additional interviews or cases, is a useful one in tems of discussing sample size in qualitative research *(Boddy, 2016)*. Saturation, in qualitative data collection, is when the researcher stops collecting data because fresh data no longer sparks new insights or reveals new properties *(Creswell, 2014)*. Although the concept of data saturation is helpful at the conceptual level, however in practical terms it provides little guidance for estimating the actual sample size *(Boddy, 2016)*.

Hennink, Kaiser and Marconi (2016) showed that code saturation indicate that the researcher has heard all the necessary information, while meaning saturation is needed to understand all the data, they also showed that: Nine interviews were needed to reach code saturation and 16-24 interviews were needed to reach meaning saturation. Most of the studies related to sample size in qualitative research provide guidelines without empirical arguments as to why certain numbers should be used when selecting the sample size *(Mason, 2010)*. Marshal, Cardon, Poddar and Fontenot (2013) suggest that qualitative case study researches should generally contain 15 to 30 interviews.

The target participants included telecommunications engineers, telecommunications service managers, operation managers, corporate governance managers and telecommunications support staff. The interviews were on-line meetings through on-line meeting tools such as skype, the reason being the participants were located outside the Netherlands (The residence country of the researcher). The sample size in qualitative research was irrelevant, as the aim was the participants were evaluated based on their ability to provide rich information rather than being a representative of a large group *(Slevitch, 2011)*.

The below criteria has been developed to ensure that any research participant has the adequate qualifications in terms of knowledge and years of experience in telecommunications service management, and blockchain technology awareness to validate the solution design:

TABLE 1 - RESEARCH PARTICIPANTS SELECTION CRITERIA

Criterion	Requirement
Experience in telecommunications service management or governance.	5 years or more of participation in telecommunications service management processes either as a user, manager or in a governance role.
Familiarity with blockchain technology.	Awareness of the basic concepts of blockchain technology.
Familiarity with ITIL standards and terminologies.	Understanding of “Event management” process and the needed transactions to fulfill it as per ITIL standards.
Approval to share the interview transcript.	Consent to conduct the interview and share its contents.

For the purpose of this research, all the participants were selected based on their experience in the telecommunications service management field and their understanding about the knowledge and information presented by the ITIL service operation guide. The researcher relied on his relationship with groups of experts in the telecommunications field to participate in this research. All the participants had at least five years of experience in the telecommunications industry implementing various telecommunications service management processes.

A review of a short biography about each candidate facilitated the selection of the participants for this research. Table 2 illustrates the position and years of experience of the participants in this research.

TABLE 2 - RESEARCH PARTICIPANTS

Coded Name	Years of Experience	Position
A	19	Corporate Operational Excellence Manager
B	11	Technical Support Senior Supervisor
C	12	Network Operations Senior Supervisor
D	20	Transmission Operations Manager
E	13	IP Backbone Network Operations Manager
F	13	IT Presales Manager

Data Collection Procedures

There are two data collection methods in this qualitative research, document analysis and the interviews. The main documents in this study were the ITIL service operation guide, the service management process and the event management process. The researcher used the Google scholar database and the Mendeley database as a main source of scientific literature related to the topic of the research. The researcher also had access to many web pages, blogs and forums related to blockchain technology and its various applications. The researcher used the list of references at the end of each paper as a source for other scientific papers and/or books related to the topic of this research.

Interview Protocol

To conduct the interviews with the participants, the researcher contacted each participant (through a phone call) and obtained his/her approval to participate in the research *(Murtezaj, 2011)*. Individual informed consent was sent to each participant through email, to illustrate the purpose and objective of the study, the rights of the participant, and that the collected data was used only for the purpose of the research. The participant had the right to withdraw from the interview and the participation in this research at any time. The collected data was used only for the purpose of this research and was stored securely in a database designed for the purpose of this research and was not shared with nor used by any other entity *(Sun, 2009)*.

Each participant was contacted through email and phone to set the appropriate date and time for the interview. One day before the scheduled date of the interview the researcher contacted the participant to confirm the interview or to reschedule the date of the interview *(Murtezaj, 2011)*. At the beginning of each interview, the researcher illustrated to the participant the objective of the research, what was the expected result from the interview, and the rights of the participant *(Murtezaj, 2011)*. Each interview was planned to take 90 minutes, the language of the interview was Arabic - as it is the mother tongue of the researcher and the participants -

except for the technical terms that was explicitly expressed in English. The participants had the right to select the date and time to conduct the interview.

Data Analysis

One of the most important features of qualitative data analysis is that in qualitative research the focus is on the text, not on numbers, as in quantitative research *(Schutt, 2011)*. Data analysis in qualitative research is rich in text *(Sun, 2009)*. Qualitative data analysis tends to be inductive *(Schutt, 2011)*. In qualitative research, the data analysis stage is iterative and begins with the data collection stage and write-up of findings *(Creswell, 2014)*. The following steps were used to analyze the collected data through the data collection stage:

1. Step 1: Organizing the data. In this step all the data that was collected during the data collection stage, was organized into four main categories: (a) data related to blockchain technology, such as its basic concepts, features and history, (b) data related to the applications of blockchain technology either financial or non-financial applications, (c) data related to the design of Operations Support Systems (OSS), and (d) the service management processes that are intended to be implemented by the design and the supporting process description documents as the ITIL guide.

2. Step 2: High level review. This step included a quick review for all the material collected during the data collection stage. The aim was to determine which documents were useful for the research purpose. This step also included a creation of a shortlist of the candidate participants in this research, and created the preliminary design of the solution.

3. Step 3: Coding. The results from the interviews and document analysis were grouped together into categories and assigned a label. For example, part of the participants had concerns on the design from different perspectives. The concerns were categorized as technical, architectural or general.

4. Step 4: Description. The aim of this step was to generate detailed rendering information and to develop general themes or categories that formed the major improvements of the design during design iterations and formed the major finding of the research in the final iteration.

5. Step 5: Interpretation. This step involved making interpretations of the findings generated from step 4, which included linking the results to the research questions. This step included suggestions of new questions and possible future research opportunities to cover the points that are not covered in this research. The interpretation includes which factors were the most crucial to the validation of the design *(Creswell, 2014)*.

The interviews were not recorded as participants refused to record the meetings with them. The researcher prepared a printed document containing the design diagram and description. After each interview the researcher updated the document using the ideas and recommendations that appeared during the interview and used the updated document in the next interview. As a part of the data analysis the researcher checked the ideas and recommendation of each participant against the ideas and recommendations of other participants and the data collected from the research papers and books.

CONCEPTS OF DESIGN SCIENCE FOR INFORMATION SYSTEMS

One issue that must be addressed in design science research is differentiating routine design or system building from design research. The difference is in the nature of the problems and solutions. Routine design is the application of existing knowledge to organizational problems, such as constructing a financial or marketing information system using best practice artifacts (constructs, models, methods, and instantiations) existing in the knowledge base. On the other hand, design-science research addresses important unsolved problems in unique or innovative ways or solved problems in more effective or efficient ways. The key differentiator between routine design and design research is the clear identification of a contribution to the archival knowledge base of foundations and methodologies *(Hevner et al. 2004)*.

Building on the above differentiation, this research targets solving existing service management problems using blockchain technology through design-science research methods, the information systems research framework has specified it in the depicted figure 1 below.

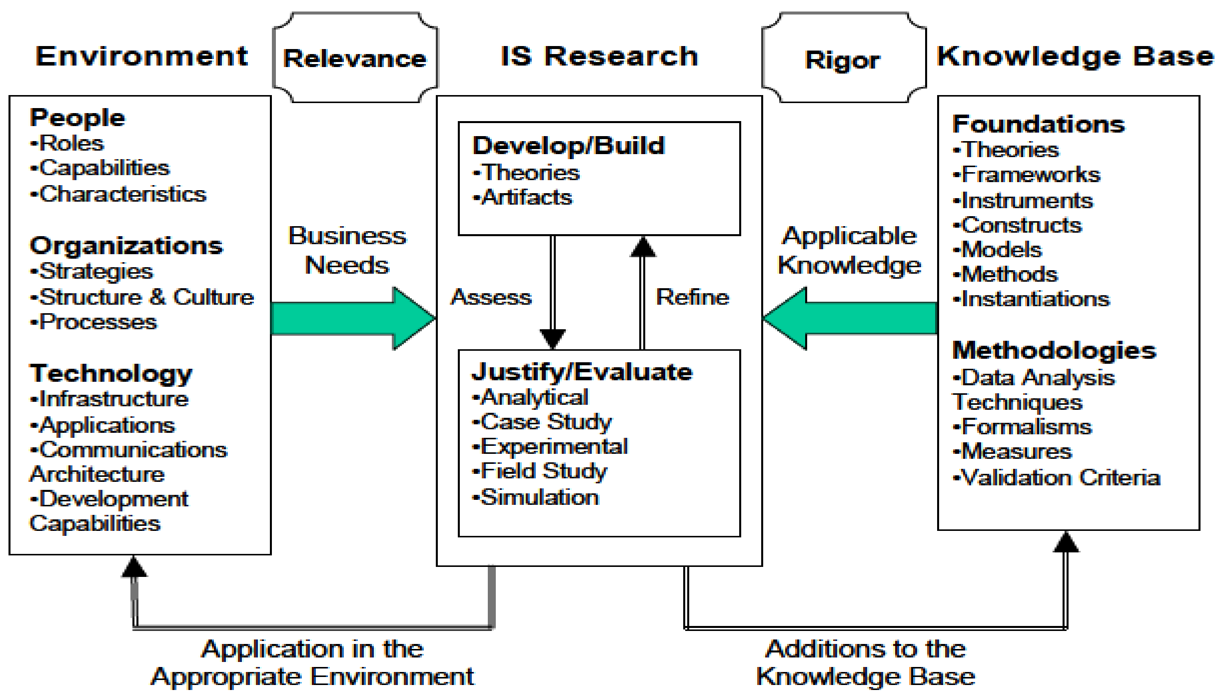


FIGURE 2 – INFORMATION SYSTEMS RESEARCH FRAMEWORK

Design science is inherently a problem solving process. *(Hevner et. al, 2004)* have derived seven guidelines from the fundamental principle that knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact. Table 3 below lists the seven guidelines and their descriptions:

TABLE 3 - DESIGN SCIENCE RESEARCH GUIDELINES

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Where IT artifacts are defined as innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, and use of information systems can be effectively and efficiently accomplished *(Denning 1997; Tsichritzis 1998)*.

Design Evaluation

Evaluation is a crucial component of the research process. The business environment establishes the requirements upon which the evaluation of the artifact is based *(Hevner et. al, 2004)*.

Table 4 below lists the design evaluation methods and their descriptions:

TABLE 4 - DESIGN EVALUATION METHODS AND ITS DESCRIPTIONS

1. Observational	Case Study: Study artifact in depth in business environment
	Field Study: Monitor use of artifact in multiple projects
2. Analytical	Static Analysis: Examine structure of artifact for static qualities (e.g., complexity)
	Architecture Analysis: Study fit of artifact into technical IS architecture
	Optimization: Demonstrate inherent optimal properties of artifact or provide optimality bounds on artifact behavior
	Dynamic Analysis: Study artifact in use for dynamic qualities (e.g., performance)
3. Experimental	Controlled Experiment: Study artifact in controlled environment for qualities (e.g., usability)
	Simulation – Execute artifact with artificial data
4. Testing	Functional (Black Box) Testing: Execute artifact interfaces to discover failures and identify defects
	Structural (White Box) Testing: Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation
5. Descriptive	Informed Argument: Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility
	Scenarios: Construct detailed scenarios around the artifact to demonstrate its utility

The design evaluation method for this research shall be the observational method using case study where service management professionals will participate in the research where the solution shall be studied in depth in their business environment.

Design science is inherently iterative. The search for the best, or optimal, design is often intractable for realistic information systems problems *(Hevner et. al, 2004)*.

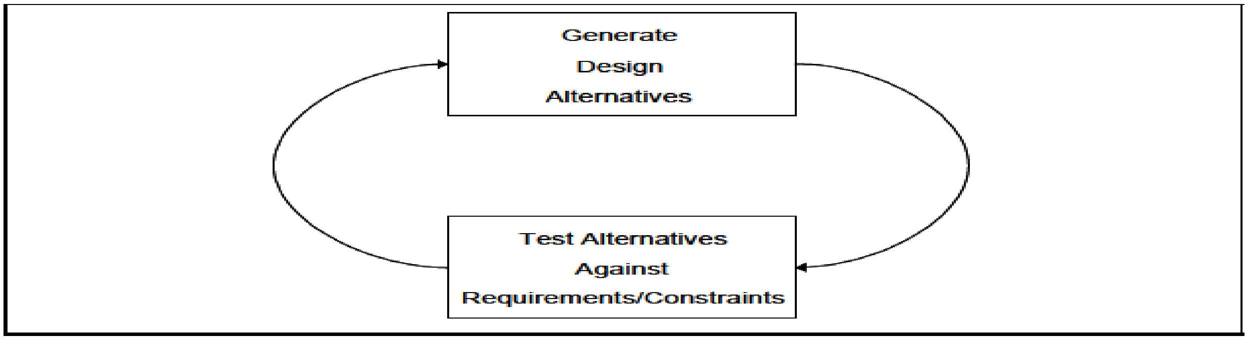


FIGURE 3 - THE GENERATE/TEST CYCLE

Accordingly, the steps for conducting the research shall be as follows:

1- Develop a blockchain solution that can handle the transactions of Customer complaints, Trouble tickets, work orders and customer support requests that satisfies the existing process requirements.
2- Conduct interviews with professional reviewers (Users and managers) to validate and review the design using a case study on the “Event management” process in accordance with the ITIL framework.
3- Analyze the interviews results to refine design.
4- Iterate steps 2, 3 and 4, until final validation by professional reviewers.
5- Analyze the final interviews results to conclude the research.

Chapter 4 – The Design

Design Description

Based on the requirements and design considerations the service management system topology was designed as depicted in figure 2 below, where the four centralized databases for customer complaints, trouble tickets, work orders and customer support requests are replaced by four mining nodes fully interconnected in a full mesh topology and also connected to the organization’s intranet. This allows connectivity with the existing computers in the network operation Center (NOC) and the Network management system (NMS) and accessible through the internet using web or mobile applications.

One of the first decisions to make when establishing a private blockchain is about the network architecture of the system. Blockchains achieve consensus on their ledger, the list of verified transactions, through communication, and communication is required to write and approve new transactions. This communication occurs between nodes, each of which maintains a copy of the ledger and informs the other nodes of new information: newly submitted or newly verified transactions. Private Blockchain operators can control who is allowed to operate a node, as well as how those nodes are connected; a node with more connections will receive information faster. Likewise, nodes may be required to maintain a certain number of connections to be considered active. A node that restricts the transmission of information, or transmits incorrect information, must be identifiable and be circumventable to maintain the integrity of the system. *(Berke, 2017)*

Another security concern in the establishment of network architecture is how to treat uncommunicative or intermittently active nodes. Nodes may go offline for innocuous reasons, but the network must be structured to function (to obtain consensus on previously verified transactions and to correctly verify new transactions) without the offline nodes, and it must be able to quickly bring these nodes back up to speed if they return. *(Berke, 2017)*

THE PRELIMINARY DESIGN

As a starting point for the design, the researcher has referred to the ITU-T document; Principles for a telecommunications management network M3010, the document indicated that the General relationship of a TMN to a telecommunication network is as depicted below.

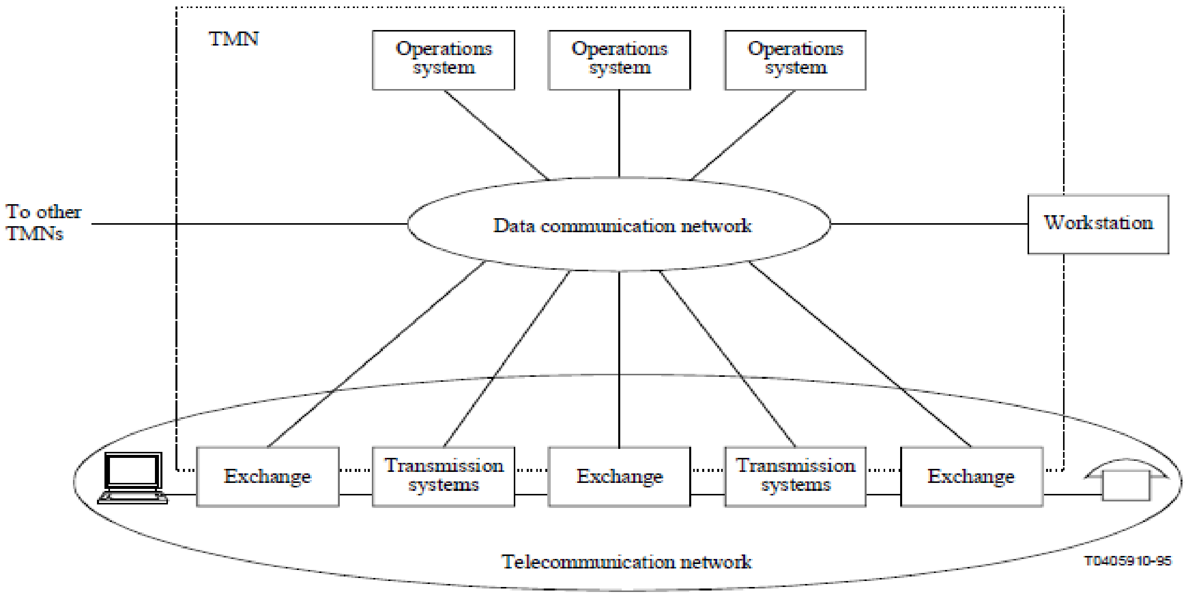


FIGURE 4 - GENERAL RELATIONSHIP OF A TMN TO A TELECOMMUNICATION NETWORK

Based on the above arguments, the full mesh topology has been chosen as a key architectural feature at the core of the solution as depicted in the figure below. Also the APIs must allow the connectivity with two core nodes to ensure that appropriate redundancy is applied to guarantee the best utilization of the robustness feature offered by blockchain technology.

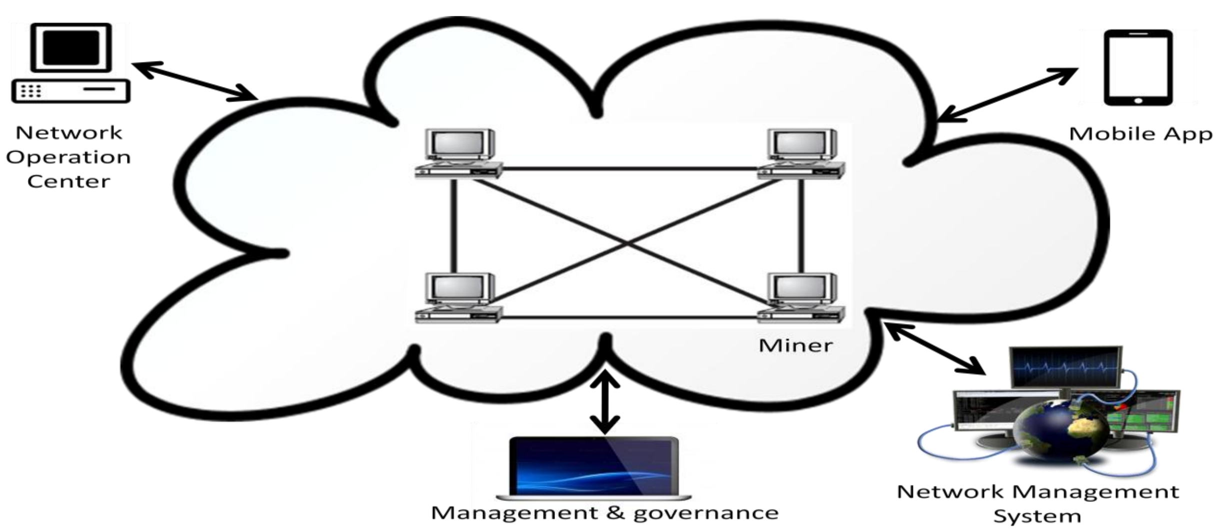


FIGURE 5 - FIRST VERSION OF THE SERVICE MANAGEMENT SOLUTION TOPOLOGY

CHAPTER 5 – DESIGN ITERATIONS RESULTS AND ANALYSIS

DESCRIPTIVE ANALYSIS

In the first iteration of the design evaluation, the Interviewee highlighted the importance of differentiating the OSS data base and the NMS database. The Interviewee also stated after reviewing the design diagram that a blockchain database can replace a relational database existing in the OSS and satisfy the same requirements of the system and accordingly can facilitate the implementation of the “event management” process.

The Interviewee also stated that the most possible drawbacks of using blockchain technology instead of the existing ones are mainly regarding the technical performance of the database as:

1- The throughput of the database which is the number of transactions per second that the database can manage. He requested the solution to be able to handle a throughput of 20 transactions per second for this specific application.
2- The access time of the database and extracting some basic information about each block, as well as measure its access/search time.

The Interviewee also stated what the perceived benefits of using blockchain technology instead of the existing ones are:

1- The complexity of sharing personal credentials for individuals to perform transactions on behalf of each other ensures the full accountability of each person or entity over their account and its transactions, which minimizes conflicts between teams and facilitates conflict resolution.
2- The database will act as the operational history repository of all the operations that have been performed under the processes it facilitates and that history becomes tamper proof.

The Interviewee also mentioned that the possible modifications or technical details to make this solution a better fit for implementing the event management process are:

1- Architectural: Placing the solution in a wider view where the interconnectivity with NMS & EMS is depicted in the solution diagram.
2- Technical: detailing the technical specifications of the miner nodes ensures the technical capability to process the transactions.

It is worth mentioning that the interviewee was concerned about the throughput since large scale blockchains e.g. bitcoin has a very low rate of transactions as low as 7 transactions per second, Private Blockchains on the other hand can be configured in a way where high transactions throughputs are possible, with the only limitation being the weakest node in the network. In a private Ethereum blockchain, one could set the blockchain to a very high number to allow for a larger transaction throughput than the one found on the public Ethereum chain. The Parity client can for example do ~3000 transactions per second on a standard laptop in private chain mode[15].

Accordingly, taking the results of the first interview into consideration the system diagram is updated to be as shown below in Figure 6 - second version of the service management solution topology:

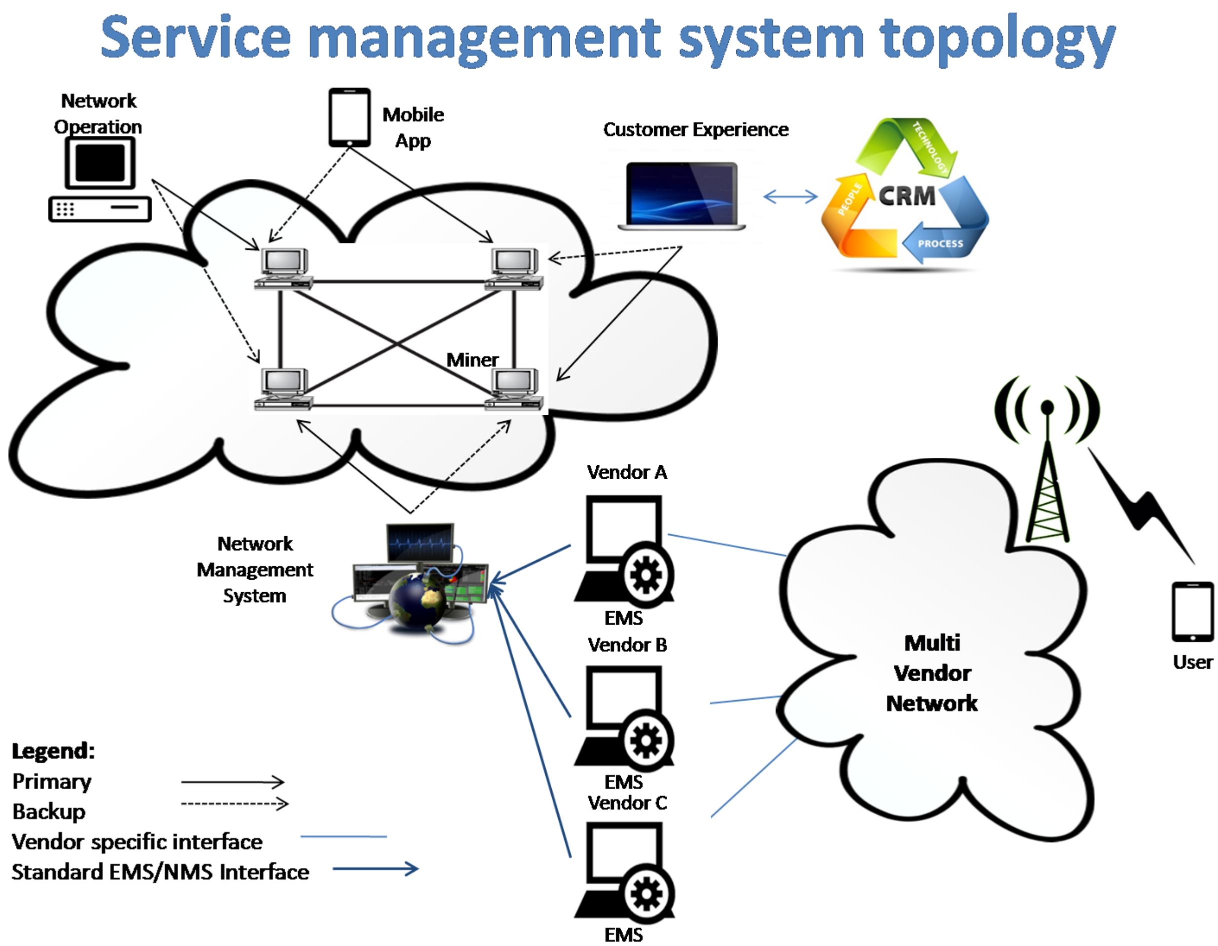


FIGURE 6 - SECOND VERSION OF THE SERVICE MANAGEMENT SOLUTION TOPOLOGY

[15] https://blog.slock.it/public-vs-private-chain-7b7ca45044f

The most common and widely used hashing algorithms in blockchain applications is the SHA 256, and the most common type of miners used is 500 GigaHashes/sec.

TABLE 5 - FIRST ITERATION TECHNICAL SPECIFICATIONS

System Element	Specification
Mining Nodes	20 transactions per second
	500 Giga Hash per second
Hashing Algorithm	SHA 256

In the second iteration of the design evaluation, the Interviewee highlighted the importance of the throughput of the OSS data base. The Interviewee also stated after reviewing the design diagram agreed that a blockchain database can replace a relational database existing in the OSS and satisfy the same requirements of the system and accordingly can facilitate the implementation of the "event management" process.

The Interviewee also stated that the most possible drawbacks of using blockchain technology instead of the existing ones are mainly regarding the technical performance of the database as:

1- The latency of the database which is the time between the transaction initiation and its approval and containment in a block. Each block on the Bitcoin blockchain takes 10 minutes to process. For sufficient security, it is better to wait for about an hour, giving more nodes time to confirm the transaction. By comparison, a transaction on the Visa network is approved in seconds at most. Many financial applications need latency of 30 to 100 ms. Based on his stated requirements he determined that 5 minutes latency is acceptable for this application.
2- The underlying storage of blockchain is with only limited support for data access. Moreover, blockchain data are highly compressed before stored to hard disk, making it harder to have an insight of these valuable data set. This requires an efficient query layer to provide highly efficient query primitives for analyzing blockchain data, which can be integrated with other applications with much flexibility. Moreover, this query layer is also required to provide different levels of abstraction, which are suitable for data analysts, management and application developers.

The Interviewee also stated that the perceived benefits of using blockchain technology instead of the existing ones are:

1- The enhanced robustness of the solution as there is no single point of failure as the case when using a centralized relational database, as the level of fault-tolerance offered by blockchain may be hard to achieve using other methods.
2- The query layer will provide new possibilities for data analysis and report generation.

The Interviewee also mentioned that the possible modifications or technical details to make this solution a better fit for implementing the event management process are:

1- Architectural: Placing a query layer between the miner nodes to manage the authorizations for accessing the database, data analysis and reports customization and generation.
2- Technical: adding the database latency specification of 5 minutes, based on the existing event management process SLA.

Accordingly, taking the results of the second interview into consideration the system diagram is updated to be as shown below in Figure 7 - third version of the service management solution topology:

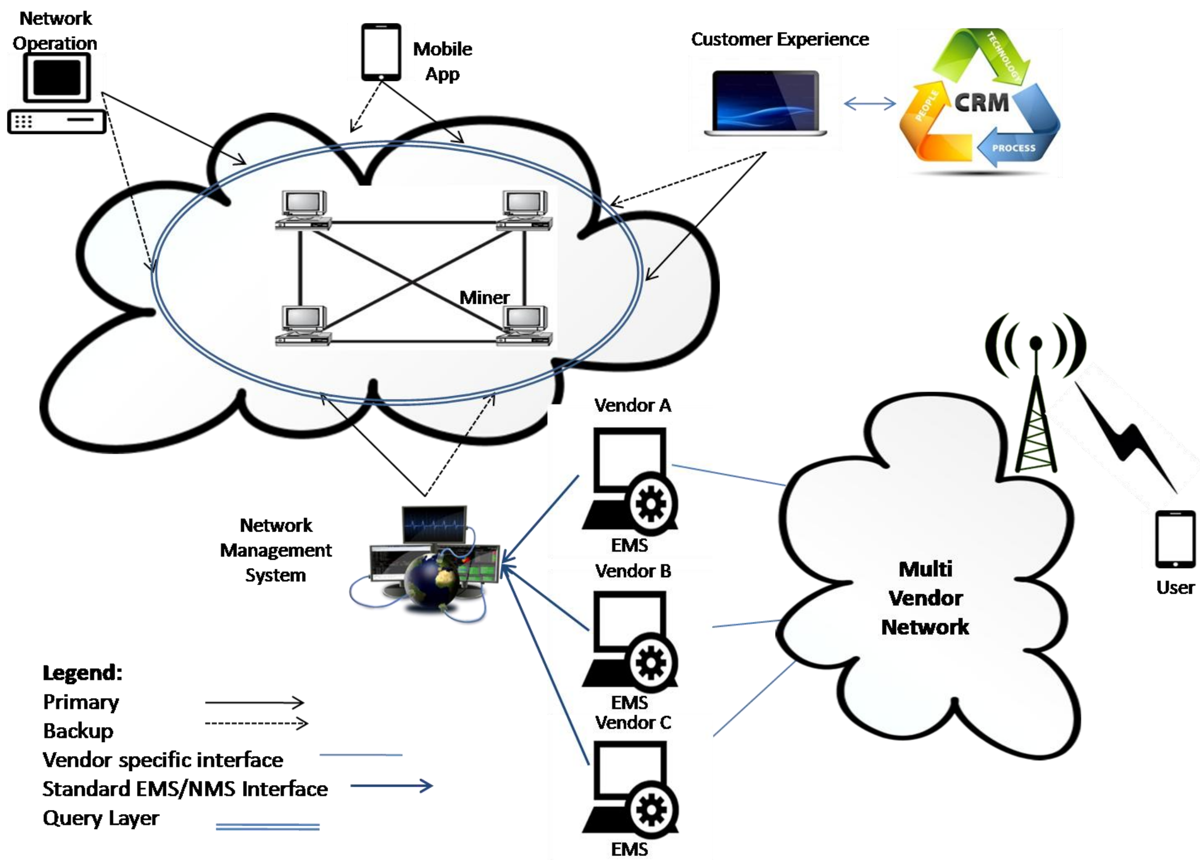


FIGURE 7 - THIRD VERSION OF THE SERVICE MANAGEMENT SOLUTION TOPOLOGY

TABLE 6 - SECOND ITERATION TECHNICAL SPECIFICATIONS

System Element	Specification
Mining Nodes	20 transactions per second
	500 Giga Hash per second
Hashing Algorithm	SHA 256
Database Latency	5 minutes

In the third iteration of the design evaluation, the Interviewee highlighted the importance of the consensus protocol in this private blockchain. The Interviewee also stated after reviewing the design diagram agreed that a blockchain database can replace a relational database existing in the OSS and satisfy the same requirements of the system and accordingly can facilitate the implementation of the “event management” process.

The Interviewee also stated that the most probable drawbacks of using blockchain technology instead of the existing ones are mainly regarding the technical support and administration of the database as:

1- The support and maintenance costs of the administration and maintenance of the blockchain database. Throughout the discussion with the Interviewee that the existing resources for the administration and maintenance may be available in the organization, but they will need to have extensive training on blockchain technology. While on the other hand the other existing database technologies in use are in their maturity phase and the needed human resources with adequate qualifications for administration and maintaining the database are available without new training needs.
2- The delay caused by the processing needed for the consensus of the nodes involved in reaching the consensus.

The Interviewee also stated that the perceived benefits of using blockchain technology instead of the existing ones are:

1- The blockchain database contains an auditable trail of signed transactions that allow all process stakeholders to establish that all actions were authorized and approved by the entities whose data they affected.
2- The immutability of the database against tampering or hacking which are possible when using relational database.

The Interviewee also mentioned that the possible modifications or technical details to make this solution a better fit for implementing the event management process are:

1- Architectural: None

2- Technical: recommended using the ripple consensus protocol for the consensus mechanism in this private blockchain.

Accordingly, taking the results of the third interview into consideration the system diagram shall not be updated to remain the same as depicted in Figure 7 - third version of the service management solution topology.

TABLE 7 - THIRD ITERATION TECHNICAL SPECIFICATIONS

System Element	Specification
Mining Nodes	20 transactions per second
	500 Giga Hash per second
Hashing Algorithm	SHA 256
Database Latency	5 minutes
Consensus protocol	Ripple consensus protocol

In the fourth iteration of the design evaluation, the Interviewee highlighted the importance of the smart contract features of blockchain technology in the automation of such a process. The Interviewee also stated after reviewing the design diagram agreed that a blockchain database can replace a relational database existing in the OSS and satisfy the same requirements of the system and accordingly can facilitate the implementation of the “event management” process.

The Interviewee also stated that there are some considerations that need to be taken into account by the multiple vendors providing the network management services when using blockchain technology instead of the existing ones, the considerations he mentioned are:

1- When multiple vendors are obliged contractually to work together, each tend to use their proprietary systems and databases, it has to be clearly mentioned in the managed services contract that a common blockchain database will be used by the other vendors too without central administration from any specific vendor over the database.
2- The smart contracts features that can be employed to automate the process have to be strictly reviewed and mutually agreed between all the process stakeholders to ensure that they truly reflect the business logic of the process, and implement it with precision, as any discrepancy between the agreed processes and the implementation of the smart contracts features may lead to drastic consequences especially when calculating contractual penalties, due to service level violations or key performance indicators degradation.

The Interviewee also stated that the perceived benefits of using blockchain technology instead of the existing ones are:

1- Having a single database that is immune to tampering by any user, provides an undisputable single version of the truth and can always be referred to with fairness and transparency, this minimizes the probability of conflicts due do having data from different sources.
2- Using a blockchain solution will enhance the trust between the different teams, as sharing data for the benefit of the customer and enhancing the services will encourage a culture of openness and transparency, the blaming culture and finger pointing will decrease and will be replaced by cooperation.

The Interviewee also mentioned that the possible modifications or technical details to make this solution a better fit for implementing the event management process are:

1- Architectural: None
2- Technical: Adding smart contracts features to the technical specifications of the solution to implement the business logic of the process when the certain pre-specified conditions for execution are met.

Accordingly, taking the results of the fourth interview into consideration the system diagram shall not be updated to remain the same as depicted in figure 5, but the technical specifications of the solution shall be updated to include smart contract features of the blockchain technology to implement the business logic of the process.

TABLE 8 - FOURTH ITERATION TECHNICAL SPECIFICATIONS

System Element	Specification
Mining Nodes	20 transactions per second
	500 Giga Hash per second
Hashing Algorithm	SHA 256
Database Latency	5 minutes
Consensus protocol	Ripple consensus protocol
Software	Smart Contract features

In the fifth iteration of the design evaluation, the Interviewee highlighted the importance of specifying the networking requirements interconnecting the elements of the solution. The Interviewee also stated after reviewing the design diagram agreed that a blockchain database can replace a relational database existing in the OSS and satisfy the same requirements of the system and accordingly can facilitate the implementation of the "event management" process.

The Interviewee also stated that there are some considerations that need to be taken into account in the design of the network used for the network management services when using blockchain technology instead of the existing ones, the considerations he mentioned are:

1- Ensuring full redundancy in the links between the different system elements to guarantee interconnectivity in case of a single link failure.
2- The bandwidth of the links used in the interconnections of the solution must fulfill the transactions rate and the traffic between the core nodes of the solution, he suggested 30 Mbps as the minimum bandwidth between the mining nodes.

The Interviewee also stated that the perceived benefits of using blockchain technology instead of the existing ones are:

1- Having a tamper proof database gives very high credibility to the data contained inside it, especially when the data needs to be presented to governmental or regulatory agencies.
2- Using multiple blockchain solutions across the organization will create a new enterprise data architecture model, created around the integrity of immutable, auditable data and process controls. On the contrary, the current systems allow a lot of data to be passed around between different systems as flat files i.e. data dumps, log files, etc. that expose the data often in raw text format, enabling interception, corruption, and manipulation or manual exploits such as data injection, etc.

The Interviewee also mentioned that the possible modifications or technical details to make this solution a better fit for implementing the event management process are:

1- Architectural: No modification except for considering the networking redundancy for the communication between the elements of the solution.
2- Technical: Adding networking specifications ensuring the connectivity between the elements of the solution.

Accordingly, taking the results of the fifth interview into consideration the system diagram shall be not and shall remain as depicted in Figure 7 - third version of the service management solution topology, and the technical specifications of the solution shall be updated to include networking specifications ensuring the connectivity between the elements of the solution.

TABLE 9 - FIFTH ITERATION TECHNICAL SPECIFICATIONS

System Element	Specification
Mining Nodes	20 transactions per second
	500 Giga Hash per second
Hashing Algorithm	SHA 256
Database Latency	5 minutes

Consensus protocol	Ripple consensus protocol
Software	Smart Contract features
Network bandwidth	30 Mbps

In the sixth iteration of the design evaluation, the Interviewee highlighted the importance of specifying the networking protocols on the links interconnecting the elements of the solution. The Interviewee also stated after reviewing the design diagram agreed that a blockchain database can replace a relational database existing in the OSS and satisfy the same requirements of the system and accordingly can facilitate the implementation of the “event management” process.

The Interviewee also stated that there are some considerations that need to be taken into account in the design of the network used for the network management services when using blockchain technology instead of the existing ones. The considerations he mentioned are:

1- Replacing the four fully interconnected mining nodes by a mining pool, exploits one of the main advantages of blockchain technology which is scalability. Using a pool allows scaling of the system to the exact needs of the organization allowing it to be used for other processes within the organization.
2- Specifying the networking protocols used on the links used in the solution, where the SNMP protocol to be used on the links interconnecting the Element management systems with the nodes in the multi-vendor network, and the SOAP protocol on the links interconnecting the Element management systems and the network management system.
3- Renaming the existing “Query Layer” to become “Data Access Layer” as in this layer the authorizations and privileges of the users can be defined and administered and it also presents the data extracted from the database to the application layer where users can see it through the different applications.

The Interviewee also demanded to represent a graphical layered architecture of the system along with the topology and technical specifications. The layered architecture is depicted as in Figure 8 –The layered Architecture below:

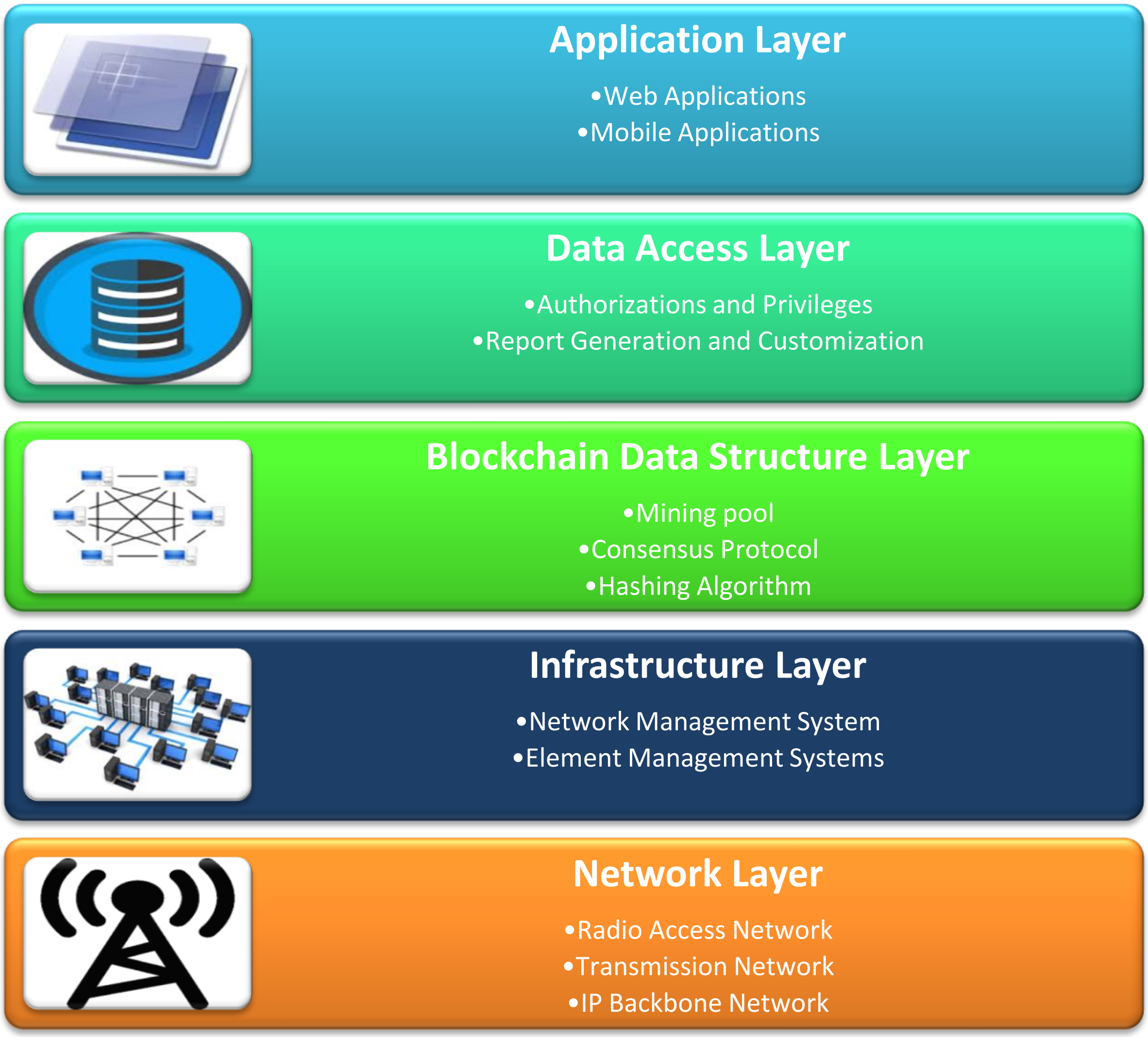


FIGURE 8 –THE LAYERED ARCHITECTURE

In the above layered architecture of the solution, each layer identifies the components of the layer that need to be specified.

The Interviewee also mentioned that the possible modifications or technical details to make this solution a better fit for implementing the event management process are:

1- Architectural: graphically representing the layered architecture of the solution, replacing the mining nodes by a mining pool to exploit the scalability of the solution, and renaming the query layer to become “Data Access Layer”.
2- Technical: Adding the networking protocols on the existing interfaces in the solution.

Accordingly, taking the results of the sixth interview into consideration the system diagram shall be updated to include the mining pool instead of the four fully interconnected mining nodes, and the technical specifications of the solution shall be updated to include networking protocols ensuring the connectivity between the elements of the solution.

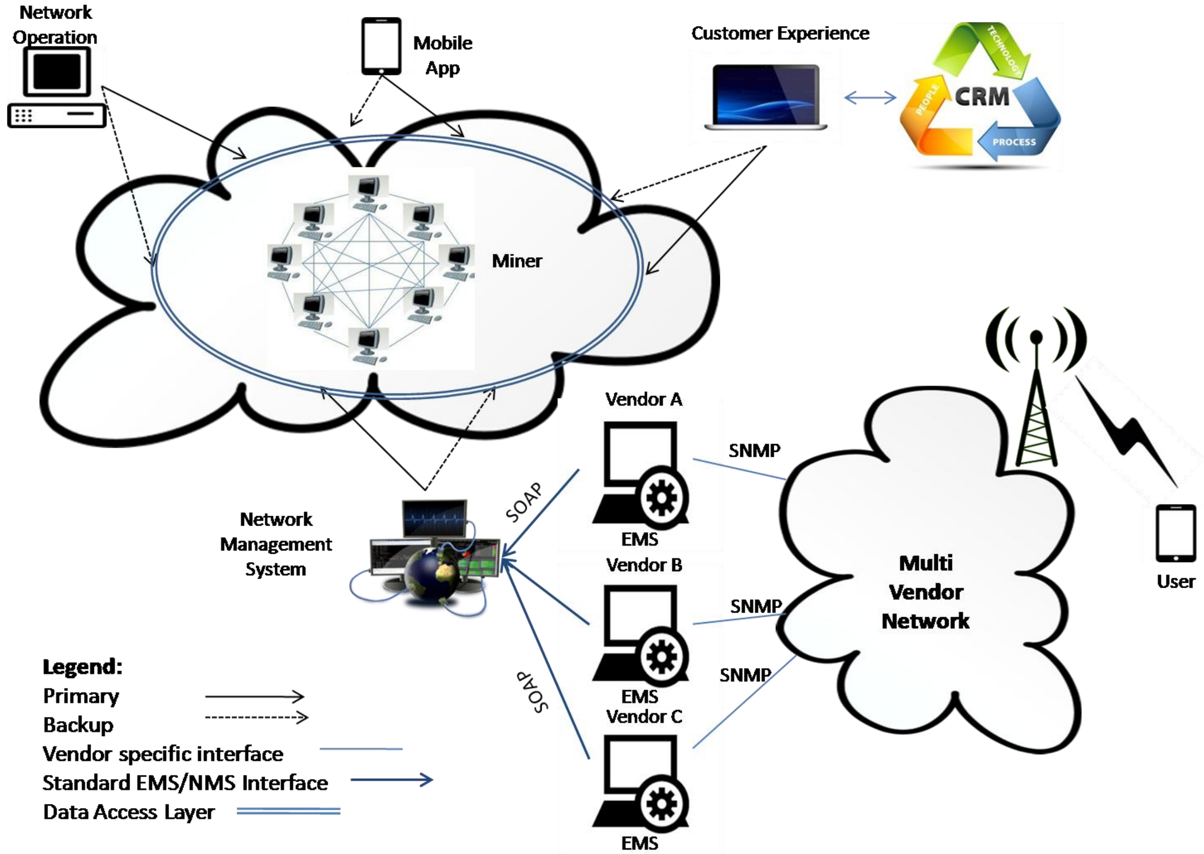


FIGURE 9 – FIFTH VERSION OF THE SERVICE MANAGEMENT SOLUTION TOPOLOGY

TABLE 10 - SIXTH ITERATION TECHNICAL SPECIFICATIONS

System Element	Specification
Mining Nodes	20 transactions per second
	500 Giga Hash per second
Hashing Algorithm	SHA 256
Database Latency	5 minutes
Consensus protocol	Ripple consensus protocol
Software	Smart Contract features
Network bandwidth	30 Mbps
Northbound interface protocol	SOAP
Southbound interface protocol	SNMP

Reliability of results

Research validity has a different meaning in qualitative research as opposed to its meaning in quantitative research. In quantitative research validity is a companion of examining stability or generalizability, whereas in qualitative research, validity means the researcher checks for the accuracy of the finding by employing certain procedure *(Creswell, 2014)*. In quantitative research the primary concern of the study is the validity and the reliability of the instrument, while the qualitative research focuses on the credibility and utility *(Sun, 2009)*.

There are two primary areas of concern regarding the credibility of qualitative research, the rigorous methods of the study and the credibility of the researcher *(Sun, 2009)*. Rigorous methods of study can be achieved through procedures such as triangulation, peer-review, and member checking *(Sun, 2009)*. The credibility of the researcher means to clarify the bias the researcher brings to the study, this may include both personal and professional data and information that affects any aspect of the research *(Creswell, 2014)*.

In this case study qualitative research, the ideas of developing a blockchain based service management solution for the telecommunications industry proposed by the researcher through document analysis and following design science framework and ITU-T standards for information systems was reviewed and enriched by 6 telecommunications services experts. The diverse experiences and backgrounds of the selected experts enabled the evaluation of the solution from different perspectives based on their experiences and current positions. The perspectives covered are: Technical, managerial, governance, organizational and contractual. During the preparation of this research the work of the researcher was reviewed by Dr. Hans Le Fever (The primary supervisor of this research).

Researcher role, experience and bias

The researcher worked as a telecommunications services professional since 2005. Nine years of his experience were in a telecommunications services provider, 5 years in telecommunications operations management role and 4 years in a telecommunications services and processes governance role.

Through those years of experience, the researcher has witnessed many of the challenges that face the teams and management responsible for the delivery of telecommunications services operation and maintenance, also the exposure to telecommunications process development, governance and improvement has revealed many of the hardships facing management and governance teams.

In an environment where an operator outsources the telecommunications services delivery to two or more vendors, The relationship between the vendors takes many forms as usually they have to be cooperating to deliver the services to the mobile network operator under managed services contracts, on the other hand they are competing to take a bigger footprint of the available outsourced scope, and avoid the strict contractual penalties in case of violating the agreed contractual service levels and Key performance indicators.

In such an environment where trust is lacked but the interactions between the different entities are unavoidable, many conflicts arise between the different teams where the scopes are not well defined or if there are contractual grey areas. The conflicts and issues also arise due to the fact that the vendors operating the networks use proprietary network element management systems and different Operations support systems; each system has its own database.

From the management perspective, many cases of duplicated work needed to be present when the case created by one vendor needs to be transferred to another vendor for an action needed from their side. There are also considerable efforts exerted in validation and verification of inter-vendor cases for proper contact management practices to be in place.

From the governance perspective, the tracking a single case that requires the interaction of two or more vendors to resolve a network event among different systems using different databases creates a massive governance challenge. On the other hand, the different databases create “different versions of the truth” as there are always variations between the different data allocated on different databases.

Another challenge that also exists is when the staff receives a trouble ticket, customer complaint or a work order from another vendor, in order for them to execute their processes they need to create another trouble ticket, customer complaint or a work order respectively on their proprietary system. This efficiency challenge can also be overcome by using a single database where one issue is managed in a single track on a single system using a single database that is immune to tampering.

Chapter 6 – Summary And Recommendations for Further Study and Practice

Discussion of the Results

A concise conceptual framework of design-science research in information systems *(Hevner et al, 2004)* was chosen to carry out this research to develop a blockchain based solution for the service management processes of a mobile network operator, where the ITIL service management guidelines are taken into considerations. After the theory's establishment, research design, formulation of the preliminary design, the solution design and its technical specifications were validated incrementally and iteratively through Interviews. The data collected out of each interview was analyzed and used to generate the design for the next iteration. The results show that blockchain technology is applicable to the service management domain of the telecommunications industry. Results also support that adopting several blockchain solutions across the organization will create a new enterprise data architecture model, shaped around the integrity of immutable, auditable data and process controls. The results also show that adopting blockchain technology in a multi-vendor environment has positive impacts on organizational behavior, organizational culture and efficiency. Therefore this concludes that the results indicate complete support for the blockchain technology when employed as an OSS database enabling service management processes.

Benefits of adopting a private blockchain solution

This section presents the professed benefits of adopting a blockchain solution by telecommunications experts. Based on the analysis, it provides higher security and user accountability due to the use of private keys instead of personal credentials, which prohibits individuals from performing transactions on behalf of each other. This in turn ensures the full accountability of each person or entity over their account and its transactions, which minimizes conflicts between teams and facilitates conflict resolution.

The tamper proof characteristics and immutability to hacking nature of the database qualify it to act as the unique operational history repository of all the operations that have been performed under the processes it facilitates and that history becomes the sole source of facts in case of dispute or conflict since it contains an auditable trail of signed transactions. Also, the enhanced robustness offered by the blockchain architecture, as there is no single point of failure, which is the case when using a centralized relational database, providing the organization higher fault – tolerance, and higher business continuity measures.

The results also indicate that the trustless business ecosystem created when using blockchain technology has a positive impact on a few parameters of organizational behavior especially in a multi-vendor managed services environment. Using a blockchain solution will enhance the trust between the different teams, as sharing data for the benefit of the customer and enhancing the services will encourage a culture of openness, transparency and cooperation.

Based on the analysis of the results it is can be concluded that the basic inherent characteristics of blockchain technology as immutability and disintermediation can resolve service management challenges as trust between different vendors, lucid accountability and less conflicts in the telecommunications sector.

One of the perceived benefits is the emergence of new business models and new enterprise data architecture models can emerge. These models will be created around the integrity of immutable, auditable data and process controls, but this benefit can only be achieved upon using multiple blockchain solutions across the organization.

Concerns over adopting a private blockchain solution

This section presents the professed concerns of adopting a blockchain solution by telecommunications experts. Based on the analysis, the major concerns are technical concerns in relation to:

1- The throughput of the database which is the number of transactions per second that the database can manage.
2- The access time of the database and extracting some basic information about each block, as well as measurements of its access/search time.
3- The latency of the database which is the time between the transaction initiation and its approval and containment in a block.
4- The underlying storage of blockchain is with only limited supports for data access. Moreover, blockchain data are highly compressed before stored to hard disk, making it harder to have an insight of these valuable data set.
5- The delay caused by the processing needed for the consensus of the nodes involved in reaching the consensus.
6- Creating full redundancy in the links between the different system elements to guarantee interconnectivity in case of a single link failure.
7- The capacity (bandwidth) of the links used in the interconnections of the solution must fulfill the transactions rate and the traffic between the core nodes of the solution.

From a managerial perspective the following concerns were raised:

1- The support and maintenance costs of the administration and maintenance of the blockchain database.

2- The contractual considerations a telecommunications services provider needs to take indicating to vendors and suppliers that a common blockchain database will be used by the other vendors too without central administration from any specific vendor over the database.
3- The need for thorough reviews for the smart contracts features that can be employed to automate the process and also must be mutually agreed between all the process stakeholders to ensure that they truly reflect the business logic of the process.

CONCLUSIONS

This qualitative research case study generated a design for service management in the telecommunications industry using blockchain technology and suggested a set of ideas for implementing service operation processes described in the ITIL guide. These ideas act as a link between the blockchain as a technology and service management processes in the telecommunications industry.

We can conclude that the most crucial design parameters or the key decisions that need to be taken when designing a private blockchain solution for the service management of a telecommunications service provider are:

1- The processing capability of the blockchain mining nodes.
2- The hashing algorithm.
3- The database Latency.
4- The consensus protocol.
5- The smart contract features of the software.
6- The network bandwidth available between the nodes of the system.

We can also conclude that the ICT requirements to deploy a private blockchain service management solution in a mobile network operator infrastructure:

1- A scalable pool of mining nodes interconnected by the organization's Intranet.
2- A software layer providing user authorizations and privileges, report generation and customization and accessible from remote locations meeting the organization's information security policies requirements.
3- Web applications and mobile applications that shall provide the GUI for the users to efficiently and effectively have access to the database.

The analysis of the results also indicate that a service management private blockchain technological solution can be integrated with existing ERP and CRM systems as a complementary solution in telecommunications service management.

A private blockchain technological solution with smart contract features is fit to implement processes that are based on the ITIL framework requirements as long as the technical performance of the system meets the process requirements.

Recommendations for Further Study and Implications for Research

One of the key recommendations that have great potential for application in the telecommunications industry is the use of smart contracts in the implementation of service management contracts between mobile network operators and vendors, especially where are the operations are following the managed services operational model or where the operation of the network is outsourced to multiple vendors or subcontractors who have to cooperate to achieve the service management process objectives.

Another Key recommendation is studying how new enterprise data architecture models can emerge when an organization adopts blockchain solutions in multiple domains and partially immigrating current core processes and functionalities performed by traditional ERP and CRM systems to blockchain based systems.

The technical performance of blockchain databases field requires in-depth exploration and lateral expansion to provide resources to researchers and practitioners on how to define and measure key blockchain database performance indicators as access time and throughput.

Limitations

The limited number of iterations for design refinement between design and design evaluation are limited to the time frame of this study which may not have produced an optimal solution or low level design.

One of the limitations is the knowledge of the interviewees (who are mainly telecommunications service management experts) about the blockchain technology; it is probable that if they had more knowledge about blockchain technology then their responses during the interviews may have differed.

REFERENCES

Askitis, Nikolas (2009), "Fast and Compact Hash Tables for Integer Keys", Proceedings of the 32nd Australasian Computer Science Conference (ACSC 2009) 91

Aziz, W. (2013). Bridging the leadership gap: A model and an instrument to measure the effectiveness of the leadership development program in Abu Dhabi, UAE (Doctoral dissertation). 1- 137.

Boddy, C. R. (2016) Sample size for qualitative research. Qualitative Market Research: An international Journal, 19(4), 426-432.

Bücker, C. (2015). Research Participation Scientific Writing. PowerPoint slides for the Research Participation Project course, Master of Science ICT in Business program, Leiden University.

Creswell, J. W. (2014). Research design: Qualitative, quantitative and mixed methods approaches (4th editon). Thousand Oaks, CA: Sage.

Crosby, M et al. (2016) "BlockChain Technology: Beyond Bitcoin", Applied Innovation Review, Issue No. 2, June 2016.

Devers, K. J., & Frankel, R.M. (2000). Study design in qualitative research – 2: Sampling and data collection strategies. Education for health, 13(2), 263-271.

Haber, S and Stornetta, W. (1991), "How to time-stamp a digital document", Journal of cryptology, Vol. 3 No. 2, PP. 99-111, 1991. https://www.anf.es/pdf/Haber_Stornetta.pdf

Hevner et al. (2004). Design science in information systems research, MIS Quarterly Vol. 28 No. 1, pp. 75-105/March 2004.

ITU-T document, Principles for a telecommunications management network M3010

Kumar, R. (2009). EMS-NMS Architecture in Telecom Management Systems, Telecom Engineering Center, Department of Telecommunications, Government of India, http://tec.gov.in/pdf/Studypaper/eMS-NMS%20Study%20paper.pdf

http://www.pwc.com/us/en/technology-forecast/blockchain/definition.html. (n.d.).

Melika, G. A Thobhani, A. (2017) "Generic Cryptographically managing telecommunications settlement." *https://www.google.com/patents/US20170078493* 2017 Google Patents

Glass, R. L. (2001). Frequently forgotten fundamental facts about software engineering. IEEE software, 18(3), 112-111.

Wu, Xindong. (2014) Data mining with big data. IEEE TRANSACTIONS ON KNOWLEDGE AND DATA ENGINEERING, VOL. 26, NO. 1, JANUARY 2014

Greenspan, G (2015) “MultiChain Private Blockchain — White Paper”. http://www.multichain.com/download/MultiChain-White-Paper.pdf Accessed 30 Mar2017.

Mahima, S. (2009). Choosing Best Hashing Strategies and Hash Functions, Master thesis THAPAR UNIVERSITY PATIALA – 147004.

Mason, M. (2010) sample size and saturation in PhD studies using qualitative interviews. Forum Qualitative Sozialforshung / Forum: Qualitative Social Research, 11(3).
Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/1428/3027

Mazonka, O. (2016). Blockchain: Simple Explanation. http://jrxv.net/x/16/blockchain-gentle-introduction.pdf

Murtezaj, V. (2011). Understanding the role of emotional intelligence in negotiating agreement and diplomatic conflict management behavior (Doctoral dissertation) 62-75.

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. https://bitcoin.org/bitcoin.pdf

Piklington, M. (2015) “Blockchain technology: principles and applications”, Research Handbook on Digital Transformations, edited by F. Xavier Olleros and Majlinda Zhegu. Edward Elgar, 2016. *https://papers.ssrn.com/sol3/Papers.cfm?abstract_id=2662660* Accessed 30 Mar 2017.

Saldana, J. (2011). Fundamentals of qualitative research. Oxford, NY: Oxford University Press Inc.

Schutt, R.K. (2011). Qualitative data analysis. In R. Schutt (Ed.), Investigating the social world: The process and practice of research (PP. 320-357). CA:SAGE

Schwartz, D., Youngs, N.,& Britto, A. (2014). The Ripple Protocol Consensus Algorithm. White Paper. Ripple Labs Inc. Retrieved from https://ripple.com/files/ripple_consensus_whitepaper.pdf

Singh, M. (2009) Choosing Best Hashing Strategies and Hash Functions, Master thesis, Thapar University, PATIALA – 147004.

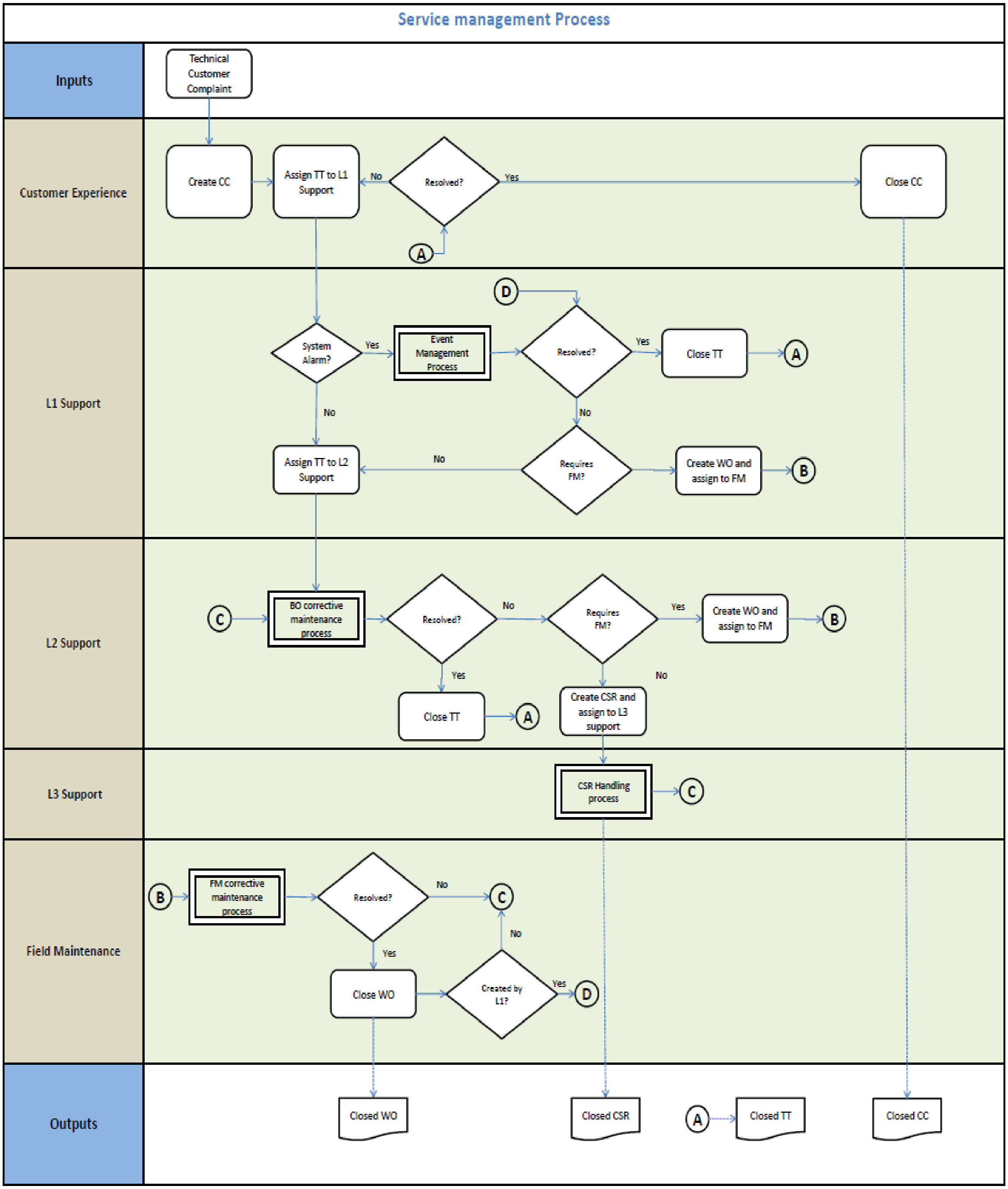
Slevitch, L. (2011). Qualitative and quantitative methodologies compared: Ontological and epistemological perspectives. Journal of Quality Assurance in Hospitality & Tourism, 12(1), 73-81.

Sun, T. (2009). Mixed methods research: Strengths of two combined.

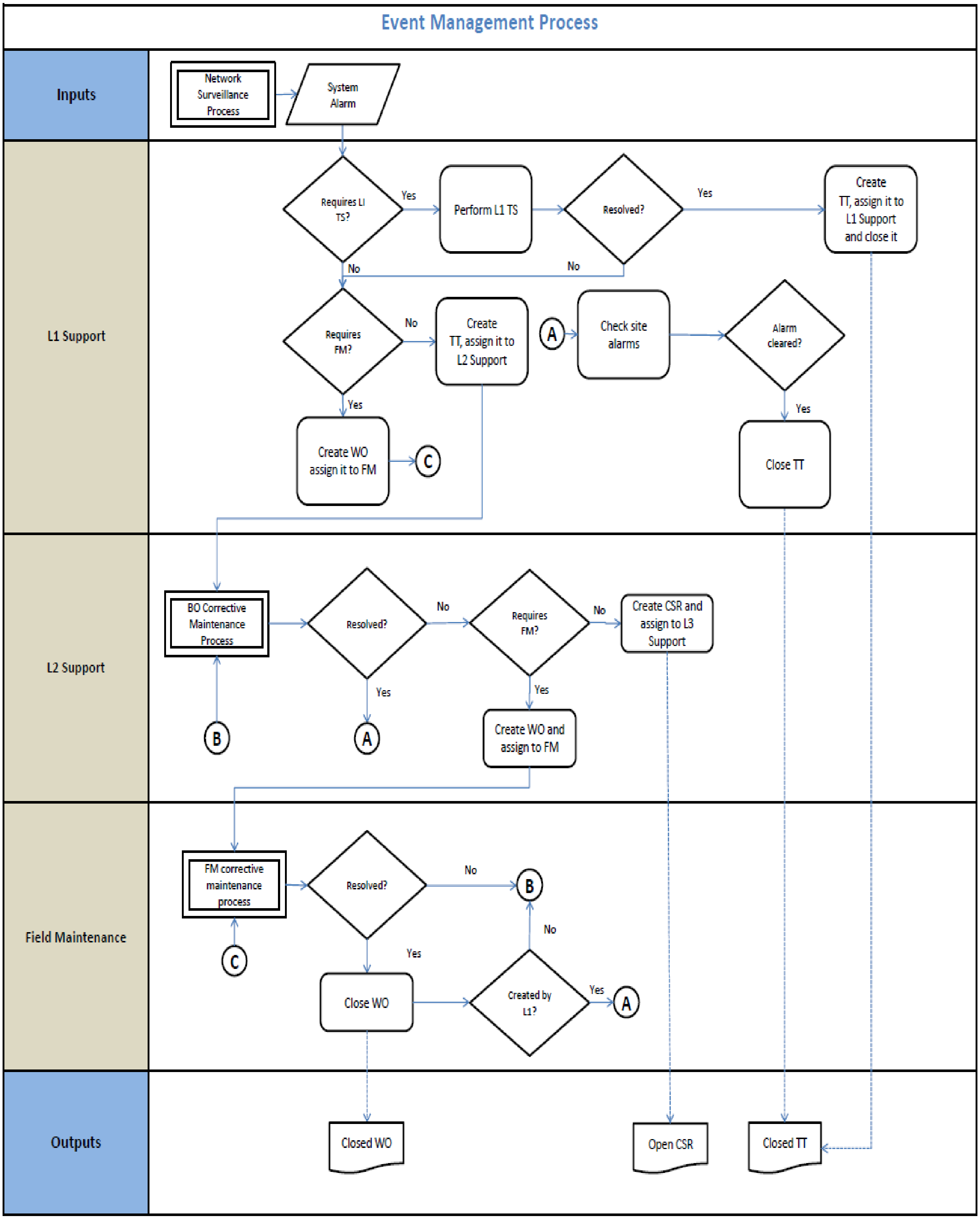
Swan, M. (2015). Blockchain. O’Reilly Media, Inc.

APPENDICES

APPENDIX A – THE SERVICE MANAGEMENT PROCESS



APPENDIX B – THE EVENT MANAGEMENT PROCESS



APPENDIX C – EMAIL REQUESTING PARTICIPATION

Dear Sir/Madam,

My name is Mohamed Atef Ibrahim, I am a master's student at Leiden University. I am conducting a research to develop a telecommunications service management solution using blockchain technology and validating the solution through a case study where the solution is used to implement the event management process described by the ITIL service operation guide.

I need your help and support in discussing and evaluating the design of the solution based on your knowledge and experience. I am writing to invite you to participate in this research by conducting an interview(s) with you at your convenience, the meeting duration, location and schedule will be arranged with you upon your consent.

During the meeting, please feel free to discontinue at any time. You will not be under any type of risk or danger during the meeting. The collected data through the meeting concerning you and your organization (if needed) will be used only to complete the research study and will not be shared with any other entity. Upon completion of my dissertation I will send you a copy.

If you have any questions, please contact me via e-mail: mohamedatef1982@gmail.com

Thank you for your help and cooperation.

Appendix D- Interview Structure

1- What are the database requirements from a technological perspective to implement the service management processes in terms of:
   a. Robustness
   b. Confidentiality
   c. Performance (speed)
   d. Disintermediation
2- Have you reviewed the solution diagram and description?
3- Have you reviewed the flow chart of the event management process?
4- Do you understand it well? If no, which part needs further explanation?
5- Based on your expertise and understanding of the solution, do you believe that a blockchain database can fulfill the Event management process requirements?
6- Are all the features of Blockchain technology required or are just specific elements of it, e.g. hashing/encryption also satisfy the design requirements?
7- Based on your understanding and expertise, what are the possible drawbacks of using blockchain technology instead of the existing ones?
8- Based on your understanding and expertise, what are the perceived benefits of using blockchain technology instead of the existing ones?
9- Based on your understanding and expertise, what are the possible modifications or technical details to make this solution a better fit for implementing the event management process?
10- Is more than one service provider involved in the delivery of the service management processes in your organization?
11- Are there situations where the different service providers have conflicts or issues?
12- What are the most probable root causes behind those conflicts or issues?
13- Is the lack of trust in a multi service provider environment causing duplication of work?
14- What effect may the existence of the distributed ledger have on the mentioned conflicts/issues?
15- Can the smart contracts features be utilized to achieve efficiency gains?