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Secure Implementation of SIP Trunks for Voice: A Qualitative Study

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Walden University

College of Management and Human Potential

This is to certify that the doctoral study by

Mary C. Kiser

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

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Walden University
2024

Abstract

Secure Implementation of SIP Trunks for Voice: A Qualitative Study

by

Mary C. Kiser

MS, University of Maryland University College, 2013

MS, Touro University, 2006

BSBA, Shippensburg University, 1999

Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Information Technology

Walden University

August 2024

Abstract

Organizations managing their own multi-line phone system are concerned about their telecommunication engineer's ability to secure the SIP trunks properly. Billions of dollars are lost globally each year through exploited security vulnerabilities in Session Initiation Protocol (SIP) trunks. Grounded in the knowledge-based view of the firm as the theoretical framework, the purpose of this qualitative multiple case study was to explore strategies used by telecommunications engineers to implement SIP trunks for voice communications securely. Six voice professionals in the United States volunteered as participants, having completed their own successful, secure SIP implementations for their organizations. Data were collected using semistructured interviews and a review of documentation. Data was analyzed using thematic analysis, and three themes emerged: (a) education and experience, (b) resources and support, and (c) secure configurations. A key recommendation for organizations to consider is cross-training voice teams with networking teams. The implication for a positive social change includes the potential for telecommunications engineers to secure SIP implementations for their organizations, potentially reducing financial losses through SIP vulnerabilities.

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Section 1: Foundation of the Study

Background of the Problem

As technology changes and develops, opportunities for cost savings occur. Companies find these cost savings desirable but can overlook critical steps when implementing new technologies. In the technology niche of telephony, particular purpose circuits known as primary rate interface (PRI) circuits were used to transport voice traffic to the public switched telephone network (PSTN), where calls can be connected to other telephones worldwide. In recent years, session initiation protocol (SIP) trunks have been used to connect voice systems rather than these PRI circuits. This technology has greater call throughput as well as a lower cost (An et al., 2024). However, the technology changed from time division multiplexing (TDM) to internet protocol (IP), similar to internet trunks. These new connection types require different skill sets to establish, configure, and secure these connections that telephony engineers typically have. Due to this skill gap, SIP trunks are commonly vulnerable to security breaches, with over 502 reported SIP vulnerabilities to potentially be exploited (Biondi et al., 2020). To properly secure SIP trunks, I explored the particular skill sets and strategies used by telecommunications engineers.

Problem Statement

Implementing SIP trunks for voice over internet protocol (VoIP) communications opens unique security vulnerabilities not encountered with traditionally used TDM circuits (Koilada, 2019). Successful hacking attempts on VoIP systems have increased by 60%, with losses valued at over $7 billion (McInnes, Zaluska, et al., 2019). The general

information technology (IT) problem is that organizations transitioning to SIP trunks for voice need more critical skill sets and processes to secure network infrastructure related to the SIP connection type properly. The specific IT problem is that some telecommunications engineers lack the strategies to implement successful security practices for SIP trunk security properly.

Purpose Statement

The purpose of this qualitative multiple case study was explore the strategies telecommunications engineers utilized to implement successful security practices for SIP trunk security. The targeted population consisted of telecommunications engineers in the United States, as they are the technical experts charged with implementing and securing the SIP trunks. As more telecommunications engineers employ better security for VoIP systems, the potential social change may include better communications and data protection for individuals' personal and sensitive information.

Nature of the Study

Researchers use the qualitative method when the intent is to focus on human behavior and motivations (Bleiker et al., 2019). I explored migration strategies of telecommunications engineers who have migrated their organizations to SIP for voice trunking with successful security postures. As such, I chose the qualitative method for this research.

When numerical and statistical data are necessary to test a hypothesis, the quantitative method is the appropriate method type to use in a research study (Given, 2008). As such, a quantitative study was not a suitable choice for this research. The

mixed-method approach is best used when both qualitative and quantitative analysis are required (DeCuir-Gunby & Schutz, 2016). As this study did not include any quantitative analysis, the mixed-method approach was not applicable to this study.

I used a multiple case study design for this research. Researchers that use a multiple case design investigate a circumstance in detail within a specific scope to address a specific research question (Bleiker et al., 2019). For this study, I interviewed telecommunications engineers that have securely implemented SIP trunks. As the researcher, I was the primary data collection tool, using devised interview questions to explore successful SIP trunk implementation strategies in the United States.

Ethnographic design is similar to how anthropologists study culture by immersing them within for their observations (Hamel et al., 1993). As I did not immerse myself in a culture, ethnographic design was inappropriate for this study. Narrative design is useful for studies with extended periods, collecting and forming a story of the obstacles encountered and decisions made to understand behavior (Hamel et al., 1993). As this research focused on the skillsets and knowledge of telecommunications engineers to understand requirements to implement effective security practices, narrative design was not applicable.

Research Question

What are the strategies that telecommunications engineers utilize to properly implement successful security practices for SIP trunk security?

Interview/Survey Questions

1. How long have you been a telecommunications engineer?

2. Tell me a bit about your career history with regard to telecommunications.
3. What specific voice training and courses have you taken with your history as a telecommunications engineer?
4. Please describe your depth of networking and IP fundamentals.
5. What part do you play with regard to voice circuit implementation at your organization?
6. What role do you have in securing voice communications circuits and trunks?
7. What is your reaction to the following statement: “TDM circuits are more secure than SIP trunks for voice communications”?
8. How would you describe the challenges of securely implementing SIP trunks?
9. What resources did you use to ensure your SIP implementation was as secure as possible?
10. When you implemented SIP trunks, what steps did you take to secure your implementation?
11. How do you monitor and verify the SIP trunk security as an ongoing operational concern?
12. How would networking and IP fundamentals assist you in your job implementing SIP trunks?
13. Now that your implementation is complete, what lessons learned do you have?
14. Imagine you are mentoring a telecommunications engineer about to implement SIP trunks for his or her organization. What advice would you impart with regard to securing the trunks?

Theoretical or Conceptual Framework

The theoretical framework that I used to ground this study was the knowledge-based view of the firm (KBV). The resource-based view (RBV) framework is used to look at all resources a business possesses, knowledge being one of many; however KBV focuses specifically on knowledge as the most valuable resource with characteristics that distinguish it from other business resources (Grant, 1996). RBV serves as the root theory, but the works of Jay Barney, Robert Grant, Bruce Kogut, Udo Zander, and Ikujiro Nonaka are credited to the expansion justifying its own framework, Knowledge-based Theory of the Firm (Curado & Bontis, 2006). RBV combines strategy and resources to posit the competitive advantage of the firm. These resources are both tangible and intangible. However, KBV singles out knowledge as one of these key resources that leads to a competitive business advantage. The purpose of this study was to explore strategies and knowledge that telecommunications engineers employ for successful, secure SIP trunk implementation for voice, so a theoretical framework that focuses on knowledge and its value in relation to business success was appropriate.

Definition of Terms

Common, foundational terms are defined here to assist readers unfamiliar with operational terminology in telephone services.

Integrated Services Digital Network (ISDN). The communications standard using digital transmissions for telephony was introduced in 1986 as an alternative to analog phone lines (Claxson, 2018).

Session Border Controller (SBC). A hardware or software device used with SIP trunks to provide security for SIP infrastructures (German, 2017).

Session Initiation Protocol (SIP). Signaling and control protocol that has become the industry-recommended protocol for VoIP (Hsieh & Leu, 2018).

Public Switched Telephone Network (PSTN). A circuit-based network providing global connections for phone calling worldwide (Sadiwala, 2018).

Voice over Internet Protocol (VoIP). A technology enabling voice calling using internet connections rather than phone lines (Mcinnes & Wills, 2021).

Assumptions, Limitations, and Delimitations

Assumptions

When conducting a research study, as a starting point, the researcher must make some assumptions that are believed to be true (Hong & Cross Francis, 2020). Identifying these assumptions is a vital part of framing the study. As a qualitative study using interviews as the data collection method, I assumed that the interviewees would be truthful in their responses. The interview questions were not personal in nature, which may have improved the honesty of their responses.

Limitations

The credibility and validity of the research study are essential. Limitations are any potential negative impacts on the study that are out of the researcher's control (Munthe-Kaas et al., 2019). As a qualitative study, research occurred in the interviewees' natural, unique business settings, which means this study will be challenging to replicate. This

study was also a case study in which I focused on specific companies, meaning it may not reflect all companies.

Delimitations

Delimitations outline the boundaries and scope of the study (Theofanidis & Fountouki, 2018). In this study, I focused on the specific vulnerabilities implicit in the SIP circuit connection type to the PSTN; this does not indicate that these are the only security concerns. I also explored strategies for securing SIP trunks but did not intend to compile a complete list.

Significance of the Study

Contribution to Information Technology Practice

As telecommunication providers are reducing their TDM circuit offerings, businesses are transitioning to SIP trunks for their VoIP/PBX system connectivity to the PSTN (McInnes, Wills, et al., 2019). While telecommunications engineers have experience and understanding of the TDM circuits, SIP trunks are distinctly different, bringing a host of security concerns and vulnerabilities not encountered with TDM. Telecommunications engineers without the proper skillsets and knowledge to implement best security practices will leave their systems open for data breaches, toll fraud, and even infiltration into the business network beyond the VoIP system. By studying the knowledge and skill sets of telecommunications engineers who have successfully implemented security practices, recommendations were created for telecommunications engineers and their organizations to consider when implementing SIP trunks for VoIP.

Implications for Social Change

The implications for positive social change may include the growth and creation of more secure voice networks. As telecommunications engineers secure the networks they are responsible for and share knowledge with peers, the spread of hardened voice data and the business networks using SIP trunks may occur. With more secure networks, private and personal data about citizens will be protected, making it more difficult for bad actors to attain personally identifiable information (PII), potentially reducing identity theft.

A Review of the Professional and Academic Literature

In this qualitative case study, I focused on exploring the strategies that traditionally trained telecommunications engineers may use to securely implement SIP trunks for voice. I used a case study design to analyze secure implementations successfully completed by telecommunications engineers in the United States. Peer-reviewed sources and scholarly journal articles for the literature review were found using Emerald Management Journals, Google Scholar, Pro Quest, and Walden University Library. Conference papers, books, magazine articles, and websites comprise the non-peer-reviewed sources. Keywords used to guide the research were *session initiation protocol, voice over internet protocol, voice security, telecommunications security, session border controller, toll fraud, and security vulnerabilities, resource-based theory of the firm, RBV, knowledge-based theory of the firm,* and *KVB.* One hundred and thirty-three peer-reviewed references were cited, 85% of which were published within the last 5 years.

Table 1

Details of Literature Review Sources by Year of Publication

	Older than 5 Years	2018	2019	2020	2021	2022	2023	Total
Peer-reviewed articles	15	12	27	32	19	25	3	133
Non-peer-reviewed articles	3	3	3	3	3	0	0	15
Books	4	2	0	0	0	0	0	6
Web Pages	0	0	0	0	1	0	1	2
Total	22	17	30	35	23	25	4	157

First, I chose a conceptual framework to guide the study with known structures used to understand the target phenomenon and used as a roadmap for the study. In this case, I posited that there exists a knowledge gap in telecommunications engineers' training and knowledge that leads to insecure SIP trunk implementations. Knowledge being a key potential gap area, a theoretical framework focused on knowledge was the most appropriate. Research was done into the framework, its origins, its growth changes and refinements, and its future implications.

Second, I completed library and internet searches to establish an impact scope for the research area. Analysis was compiled on various SIP vulnerabilities that, when exploited, contribute to the global losses of an estimated $7 billion annually (McInnes, Zaluska, et al., 2019). With the aim of evaluating the strategies that can be employed to

implement SIP trunks securely, these vulnerabilities could be mitigated to establish voice services security and overall reduction of losses.

Knowledge-Based View of the Firm

Researchers, based on their subject and study design, will choose a theoretical or conceptual framework as the lens through which they analyze the phenomenon that is their research topic. Theoretical frameworks are more typically seen in quantitative studies, where the researcher creates test conditions to test their theory (Kivunja, 2018). Conceptual frameworks, used for the most part in qualitative studies, are used when there are gaps in understanding phenomena, and these frameworks develop and evolve as knowledge is gained in their focus areas (Mphahlele & Mbati, 2023; Varpio et al., 2020). In this qualitative study, I focused on gaps in strategies and knowledge in telecommunications engineers; a conceptual framework focused on knowledge would be best suited. More specifically, because I focused on the strategies telecommunications engineers employ to securely implement SIP trunks for voice, the KBV framework is appropriate as knowledge, and the use of specialized knowledge is the basis for the strategies used. KBV is an extension of RBV, so this literature review includes an analysis of both frameworks to provide a full understanding.

Resource-based View of the Firm Background

Theories and frameworks, such as RBV, were conceived to understand an organization's behavior and predict success. RBV's roots stem from Edith Penrose's 1995 book titled *The Theory of the Growth of the Firm* (Lazonick, 2022; Nair & Trendowski, 2008). This seminal work shifted focus from the value of a firm being

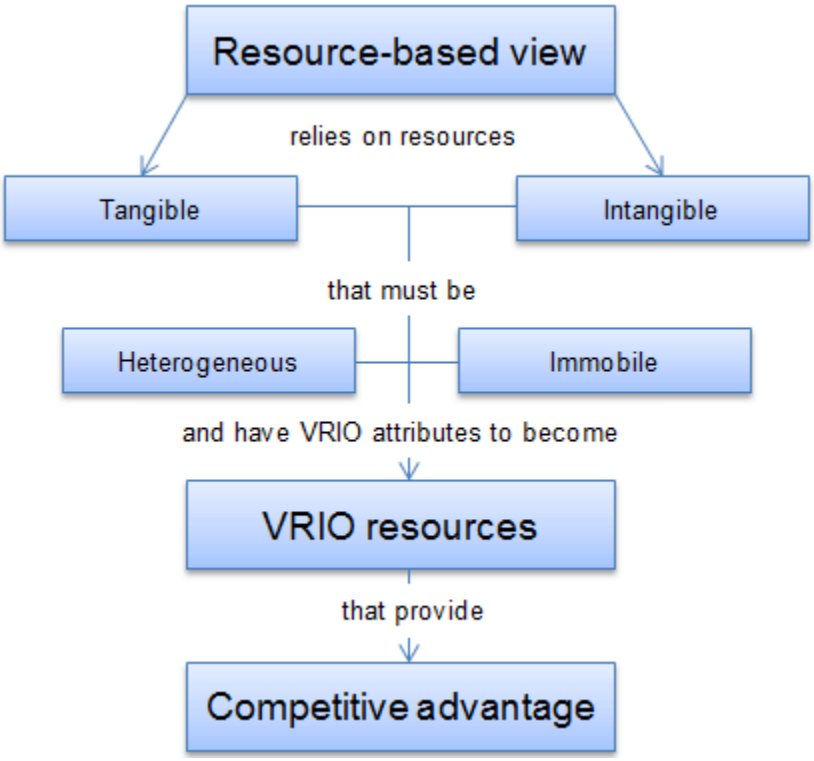
supply, demand, and price to actually defining the components of an organization and their strategic value to market success (Grant, 1996). Dissecting the components of a business/firm/organization expanded the agreed-upon formula for success from the view of examining profit margin growth to a formula that looks at the organization's resources for growth rate. Penrose's research question differentiated her work from others in the field by not asking if a particular firm can grow but instead focusing on what governs their growth (Davis & DeWitt, 2021; Nair & Trendowski, 2008). While Penrose's work was the first seminal work, other scholars added to the theory.

Penrose began by defining two categories of factors that contribute to a firm's growth; resources, defined as things purchased or paid for that make up the firm, and services provided by those resources to make revenue (Chatterjee et al., 2021; Penrose, 1995). Staff, due to being paid for, were included as a resource, as well as buildings, equipment, and materials (Narayanan & Nadarajah, 2022). Jay Barney is credited with furthering Penrose's work on the growth of the firm into what is widely recognized today as the resource-based theory of the firm in his 1991 work (Ployhart, 2021). Barney linked Penrose's firm definition categories deeper into a sustainable competitive advantage for firms by clarifying the types of resources and the qualities of them that provide the competitive advantage. These are (a) tangible resources, (b) intangible resources, and (c) the heterogeneous nature of the resources (Barney, 1991; Jancenelle, 2021). Tangible resources are physical things such as buildings, leases, machinery, materials, land, and capital (Alvarez-Melgarejo & Torres-Barreto, 2022; Hamilton & Philbin, 2020). Intangible resources include intellectual property, brand recognition, trademarks, and the

knowledge of employees (Novianti, 2019; Oprean-Stan et al., 2020). These resources also need to be heterogeneous in nature, meaning different firms have different combinations of these tangible and intangible resources (Barney, 1991). However, these resources alone do not bring a sustainable competitive advantage to a firm. What sets these resources apart to gain that advantage are the criteria of valuable, rare, and costly to imitate (Barney, 1991; Hamilton & Philbin, 2020; Novianti, 2019). The strategic advantage of a firm is derived from the utilization of its resources in a unique way, as depicted by the diagram below in Figure 1.

Figure 1

Resource-Based View of the Firm Diagram



Note. The basic tenants of the resource-based view of the firm are diagrammed. From *A systematic review of resource-based view and dynamic capabilities of firms and Future Research Avenues* by Kero, C. A., & Bogale, A. T. (2023). *International Journal of Sustainable Development and Planning*, *18*(10), 3137–3154.

Knowledge-based View of the Firm - A Separate Theory

RBV focuses on difficult-to-copy attributes of an organization (both tangible and intangible assets) as foundations for strategic success with no distinguishing between the value of attributes, while KBV singles out knowledge as the single most important attribute (Curado, 2006; Novianti, 2019). In its initial stages, KBV was considered a

subfocus area of RBV; it was not recognized as a true theory of the firm; however, knowledge management and information technologies surrounding knowledge as a significant resource solidified KBV as a concrete theory (Curado & Bontis, 2006). KBV, as a management concept, centers on an organization's ability to create, capture, and apply knowledge toward a strategic market advantage. This breakout of KBV from RBV came at an economic shift from production companies to service companies and the distinction between them as related to their profit centers being in intellectual capital (Hesniati et al., 2019; Kengatharan, 2019).

Types of knowledge within an organization can be collected into categories at different levels, from individual staff abilities, to group wisdom, to organizational-level culture (Abdi et al., 2018). Seeking to hire staff members with problem-solving skills, the ability to recognize the importance of and assimilating information, and a talent for appropriate knowledge application both create new knowledge and apply knowledge to contribute to success (Cooper et al., 2023). After the team building stage of a team or workgroup, group wisdom builds as another type of knowledge as a resource for an organization. The true synergy of a well-bonded but diverse team is the grown knowledge these teams create.

Knowledge must also meet criteria to make it relevant for a strategic advantage. First, it must be transferrable, especially within the organization (Duarte Alonso et al., 2022). Vu et al. (2023) defined transferability as the crucial difference between employees knowing about the knowledge and knowing how to apply the knowledge. Documenting knowledge in a way that makes it transferrable across the organization

makes it useful in a long-term perspective related to sustainable advantage (Arsawan et al., 2020). Second, the knowledge must have the capacity to be aggregated or built upon (Arsawan et al., 2020; Duarte Alonso et al., 2022). Innovations that arise from knowledge aggregation directly relate to competitive advantage (Vu et al., 2023).

Appropriability refers to the ability to take ownership and generate the same value the resource generated before ownership; in other words, once a firm gains knowledge, the ability to the knowledge work for them to the same level of returns (Bressan et al., 2022; Duarte Alonso et al., 2022). In the context of KBV, as organization-specific knowledge is grown and created, its ability to be appropriated by other firms decreases its value. As firms grow and knowledge related to their business is created and cemented for value, the generality or ability to be adopted by other firms for the same returns makes the knowledge less valuable. This is an expansion of the RBV tenants of heterogeneity and immobility. The more specialized the knowledge and the less transferrable it is, the more strategic value that knowledge provides for that organization (Park et al., 2020; Stadler et al., 2022).

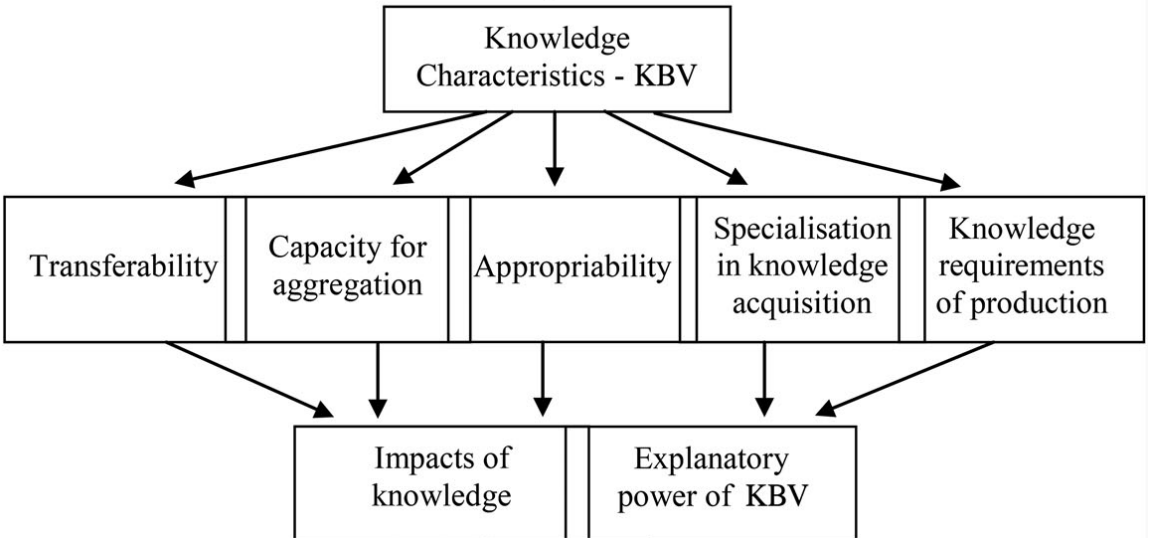
Specific to KBV, knowledge must also meet the specialization in knowledge acquisition criteria. This criterion holds that the knowledge must be specialized in the business value areas, not just general informational knowledge (Duarte Alonso et al., 2022). This is also related to the idea of innovation. Acquiring all the specific knowledge in an area brings value, but applying that knowledge in innovative and new ways to bring further value stems from these criteria (Malik et al., 2022).

Finally, the knowledge requirements of production refer to the input of specific knowledge to the creation of the product or service at the profit centers of the organization (Duarte Alonso et al., 2022). This knowledge is valuable and essential to an organization's strategic advantage in its market space (Grant, 1996). Taking the knowledge and applying it to the production process to generate profitable and valuable goods or services is the essence of this criterion; the actual ability to acquire value from the knowledge.

While knowledge is a recognized resource of a firm, these qualities of knowledge separate out the theory from RBV to its own, KBV, positing that knowledge is as useful or more useful than other tangible and intangible resources a company has in its unique configuration as an organization with strategic market advantage and growth potential (Curado, 2006). These qualities are depicted in Figure 2.

Figure 2

Knowledge-Based View of the Firm Diagram



Note. The characteristics of knowledge that make it a significant strategic resource; the fundamental premise of the KBV theory diagramed. From *Managing knowledge in the context of gastronomy and culinary tourism: A knowledge-based view* by Duarte Alonso et al. (2022). *Tourism Recreation Research*, *47*(2), 145–159. Supplemental Index.

Knowledge-Based View of the Firm – Recent Expansions

In more recent years, parallels have been drawn from KBV to current IT systems recognized as essential enterprise business systems (Chen, J. et al., 2020; Irwin et al., 2018). Knowledge management and talent management are now related to KBV as they focus on keeping and gaining more knowledge through documenting current staff knowledge. Critical strategic knowledge cannot stay within the minds of the staff members or groups alone to continue to be a resource of an organization, making

management of knowledge pertinent to the utilization of knowledge within a firm to create value.

Organizations can use social ties and networking to retain current knowledge and foster the growth of new knowledge (Curado, 2006; Hamilton & Philbin, 2020). Ge & Liu (2022) provide some data suggesting that the cost of gaining external knowledge is much lower than investing in ground-up learning, also indicating that social ties and networking are of value when it relates to knowledge as a resource. This highlights the importance of talent management in addition to knowledge management. An organization's ability to retain and bring in new skillsets and knowledge to maintain or gain its marketplace advantage becomes critical (Irwin et al., 2018).

Supporting and Opposing Theories

Theories of the firm are born out of abstractions of businesses to understand and predict phenomena and behaviors, and all are aimed at a business's sustained market advantage (Grant, 1996). These theories grow and change as organizations morph due to economic climate and goods or services offered evolve, observing new phenomena. Depending on market segments and business focus, sustained market advantage can come about in different ways as well. Natural-resource-based theory is a complementary framework credited to Stewart Hart, distinguished by the firm's relationship and advantage born of relation to the natural environment around it (Hart, 1995). As different nations and political agendas are focused on pollution and sustainment, this theory observed the phenomenon of success and advantage with those factors impacting a business or market segment (Caputo et al., 2019).

Behavioral theory of the firm (BTF) would be an example of a competing theory of the firm. BTF's foundation is in organizational behaviors that a firm exhibits when entering a new market space to gain a strategic advantage. This theory posits that advantage is not gained through the unique formula of various resources a firm has, as RBV and KBV suggest, but the behaviors of the individuals, teams, and the whole of the business that make successful and sustainable market advantages (Greve & Zhang, 2022). An interesting expansion on BTF is the Theory on Firm Risk Taking, which specifically targets the phenomenon of an organization's approach to risk management and the statistical criteria that factor into risk-taking behavior (Yung & Chen, 2018).

There are many ways to analyze a firm and to describe the many phenomena that exist concerning business success, failure, growth, strategic advantage, and ability to evolve amid internal or external pressures or driving forces. A newly emerged theory of the firm that looks at future survival is tied to the ability to innovate. Innovation Theory of the Firm, presented first at a conference in 2011, focuses on the changes information technology has on businesses and the impact they have on the market advantage and strategic value of a firm (G. Costello et al., 2011; G. J. Costello, 2018).

Knowledge as Strategy

RBV generally cites three categories of resources for firm advantage: physical capital resources, human capital resources, and organizational capital resources (Pereira & Bamel, 2021). Considering these categories, the resources must also meet the criteria of adding value, being rare, being difficult to imitate, and the resource's ability to be organized (Chen, J. et al., 2020). The knowledge staff members have and contribute to an

organization can be included within the human capital resources category; however, RBV doesn't truly acknowledge the phenomenon of the role of knowledge itself as a strategic resource. KBV adds knowledge-based resources to the listing of resource categories for firm advantage, along with the qualifications that the knowledge should have transferability, capacity for aggregation, and appropriability (Duarte Alonso et al., 2022; Park et al., 2020; Pereira & Bamel, 2021). While there are many ways to look at companies from a value perspective as theoretical frameworks for academic research, KBV is the most appropriate for this particular study. Considering the billions of dollars lost each year through vulnerabilities present when organizations implement the newer voice technologies, the knowledge of the human capital resources, the knowledge-based resources of an organization, is a critical component. The question that both RBV and KBV try to answer is why some firms outperform others, and part of business performance and success is minimizing losses (Cuthbertson & Furseth, 2022). When considering minimizing losses and the knowledge required to maintain that advantage, KBV was again confirmed as an appropriate theoretical framework for this study.

Knowledge and Organizational Learning

A relationship between knowledge and learning plays a part in an organization's ability to create, maintain, and grow organizational knowledge. This study, in particular, posited that there is a gap in knowledge and strategy employed by telecommunications engineers when transitioning their organizations from TDM circuits to the newer SIP technology that directly correlates to the exploitation of SIP vulnerabilities equating to billions in global losses per year (Koilada, 2019; McInnes, Zaluska, et al., 2019). To

deeper understand how this circumstance is created, in addition to the RBV and KBV theories, we can also use the Organizational Learning Theory (OLT), as learning and knowledge are primary components of this study's exploration focus. Organizational Learning Theory focuses on the process of individual knowledge as it becomes organizational knowledge (Abdi et al., 2018). This is relevant to firms as a competitive advantage, technological alliances, and the telecommunications industry as a whole. With only one or two telecommunications engineers per organization, there may exist institutional knowledge to draw from for legacy systems, but when facing innovative and technology evolutions, individuals need to turn to educational materials, peer professionals, and industry resources (Fernandes et al., 2022; Novianti, 2019). Through these external sources, information is gained that, in turn, relates to a competitive advantage. While it seems at odds with the basic tenants of both RBV and KBV, OLT and Innovation Theory are opening the view to assert that sharing information, especially through technological alliances, does not negatively affect a firm's strategic advantages (Abdi et al., 2018).

Knowledge and Innovation

With regard to the implementation of the newer SIP trunk technology, the strategies used by the telecommunications engineers typically charged with this operational change are mainly based on the knowledge they have or gain to complete secure implementations successfully (Fernandes et al., 2022). These secure implementations are necessary due to the numerous security vulnerabilities intrinsic to the SIP protocol and SIP trunks as

transport for voice communications. These vulnerabilities will be further detailed to fully explore the risks faced by companies that have insecure SIP trunks implementations.

Not related to the Innovation Theory of the Firm framework that studies the relationship between adopting new technology and its impact on market advantage, there is a different but valuable relationship between innovative technologies and the knowledge of a firm (Fernandes et al., 2022). The KBV tenant of appropriability, which focuses on the ability to incorporate knowledge into processes to take full advantage of the market advantage, applies to the realm of innovation (Park et al., 2020). Appropriability can also be defined as the ability of the resource owner to benefit from the resource (Pereira & Bamel, 2021). When companies adopt new technologies and incorporate innovation into their operations, it is imperative that they also gain and adopt the encompassing knowledge into their processes. The full and total knowledge of the newly adopted technology, including proper information security practices, needs to be assimilated into the firm's institutional knowledge.

SIP Literature and Vulnerabilities

As SIP trunks traverse the internet, there are many security vulnerabilities related to SIP. To adequately secure these SIP trunks, engineers need to understand the differences between the TDM and SIP connection types. TDM circuits, being sole-purpose voice connections, were not connected to packet-switched networks, meaning the security risk exposure was low (Sadiwala, 2018). SIP being an IP-based protocol, these previously isolated communication channels have moved to the internet, becoming vulnerable to attack vectors that plague internet trunks (Claxson, 2018; Sadiwala, 2018).

Annual loss figures expressed in dollars are presented to quantify losses through breaches that use SIP as an entry point (Claxson, 2018). Claxson (2018) does not present any technical solutions but does suggest that businesses that are more aware of the cyber risks and train staff to be aware as well stand a better chance of protecting their data. Likewise, Suthar and Rughani (2020) delve into the IP packet structure and specifically dissect VoIP packets. Suthar and Rughani (2020) explore different VoIP protocols in their study: H.323, SIP, Media Gateway Control Protocol (MGCP), and Real-time Protocol (RTP). Background data about the advantages and disadvantages of VoIP are relevant, as well as a security vulnerability assessment, with the intent of understanding the business drivers for this TDM to SIP move (Kumar & Roy, 2021). Khan et al. (2021) went so far as to identify installation and implementation errors that contribute to these SIP vulnerability exploits, pointing to insufficient knowledge by the implementers. Additionally, since the COVID-19 global pandemic, many companies opened their network perimeters to allow for remote access for employees to work, expanding the attack surface for hackers has grown allowing for even more SIP security gaps to be exploited (de Neira et al., 2023). The types of vulnerabilities related to SIP trunks for telecommunications are toll fraud, denial of service attacks (including distributed denial of service attacks), caller ID spoofing, and system administration failures. Each of these will be discussed in more detail in the following professional literature review.

Toll Fraud

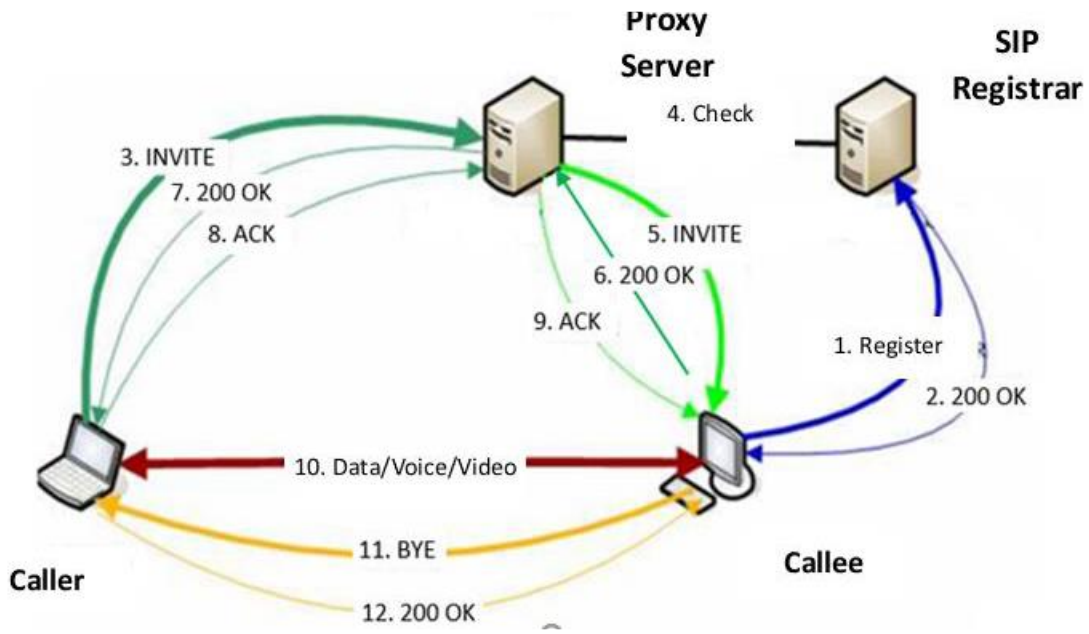
Toll fraud, also known as toll evasion, is a vulnerability that causes financial losses to organizations not protected against the risk. With Toll Fraud, PBX systems are

hacked, and long-distance calls are made through the hacked system. The owner of the system receives a larger than expected telephone bill due to the calls made by the hacker (McInnes, Zaluska, et al., 2019; Mcinnes & Wills, 2021). While this vulnerability does not cause harm to the system or the data, nor does it disrupt phone services, it comes with high financial costs, which contribute to global annual fraud losses. Sahin et al. (2017) presents data from 2015 showing $38.1 billion in losses from telecom service providers due to fraud. McInnes, Zaluska, et al. (2019) cited published figures from the Communications Fraud Control Association (CFCA), validating the breadth of the losses realized annually from toll fraud and PBX hacking through SIP trunks. McInnes (2019) used a honeypot to quantify breach frequency due to improperly secured SIP trunks for voice and discussed their findings in this work. The transition from legacy voice (TDM) circuits is a factor in non-secure SIP implementations (Koilada, 2019; Mcinnes & Wills, 2021). Connections to VoIP and the new SIP trunk transport method further enabling this type of fraud have been made (Carrillo-Mondéjar et al., 2022). Further, toll fraud is one of the two most common types of fraud on VoIP systems (Carrillo-Mondéjar et al., 2022). Commonly this type of vulnerability is exploited when poor security leads to compromised extensions on the PBX and manipulates the SIP packet through tools openly available on the internet (Volodina et al., 2018). The fraudster first sends the register command (number 1 in the figure below) with the correct password for the compromised extension. Once the system returns the OK command (number 2 in the figure below), the connection is made, and the fraudster can send Invite commands to any

recipient caller of their choosing. The charges for the calls then belong to the compromised extension for payment by the true number owner rather than the fraudster.

Figure 3

VoIP Flow Diagram



Note: The signal flow of VoIP calls. From *Penetration testing for VoIP* by Sanlioz et al., 2021, *Computers and Informatics*.

This again links the exploitation of this vulnerability to poor security implementation.

Caller ID Spoofing

Callers using Caller ID spoofing appear to be calling from a phone number they do not own (Chaudhry et al., 2017; Kumar & Roy, 2021). Caller ID spoofing's purpose is to "pretend" to be a legitimate business-related call with the intent of scamming the answerer. This is not a difficult task for determined individuals; tutorials on the internet are easily available with walkthroughs and links to download the necessary software

(Sahin et al., 2017). However, this activity, when done with fraudulent intent, is illegal under the Truth in Caller ID Act, which became law in 2010 (Senator Nelson, 2010).

While Caller ID spoofing as a security risk is not solely SIP trunk related, the ability to exploit this vulnerability exponentially increases with SIP trunks. To protect against Caller ID spoofing, the caller number needs to be authenticated in some way to validate that the caller ID matches the actual caller (Chaudhry et al., 2017). Researchers and practitioners, through literature, present their own schemes designed to make SIP for VoIP more secure through authentication to address this security issue (Suthar & Rughani, 2020).

Authentication mechanisms to validate the calling number are proposed with technologies from blockchain to custom-coded security packages (Dhillon & Kalra, 2019; Hsieh & Leu, 2018). Hsieh and Leu (2018) also discuss the use of SIP for VoIP, the trend in voice to move from TDM circuits to SIP trunks, and the vulnerabilities this technology brings. Hsieh and Leu (2018) take their experiment further; by using a certificate authority and database server through a proxy and RTP relay server, the SIP protocol can be further secured. Dhillon and Kalra (2019) propose a security scheme with biometrics to tighten security for calling. Dhillon and Kalra's (2019) study details their biometric SIP authentication proposal and tests its effectiveness. The data presented shows that this authentication scheme only adds 295 ms to the call initiation.

Spam and fraud on VoIP calling cause billions of dollars in losses per year (Koilada, 2019). With this real threat of spam and fraud related to VoIP calling, the Federal Communications Commission (FCC) is requiring communications providers to

implement Secure Telephone Identity Revisited (STIR) and Signature-based Handling of Asserted Information Using Tokens (SHAKEN). STIR/SHAKEN authentication will decrease spoofed robocalls (Sherman et al., 2021). Koilada (2019) explored recent security technology trends for IP PBX systems for VoIP, adding depth to the toll fraud problem and examined frameworks to address it.

The breadth and depth of attacks on SIP trunks through toll fraud, DoS attacks, and other SIP vulnerability exploits fully define the security risks of using SIP for voice (Suthar & Rughani, 2020). Volodina et al. (2018) dissected historical attacks, utilizing traffic visualization to gain insights into indicators of an attack. The data presented outlines the use of the SIP INVITE packet as a common theme in multiple attacks (Volodina et al., 2018). Volodina, Suthar and Rughani, and others contribute to the field by deepening the understanding of how adversaries manipulate SIP.

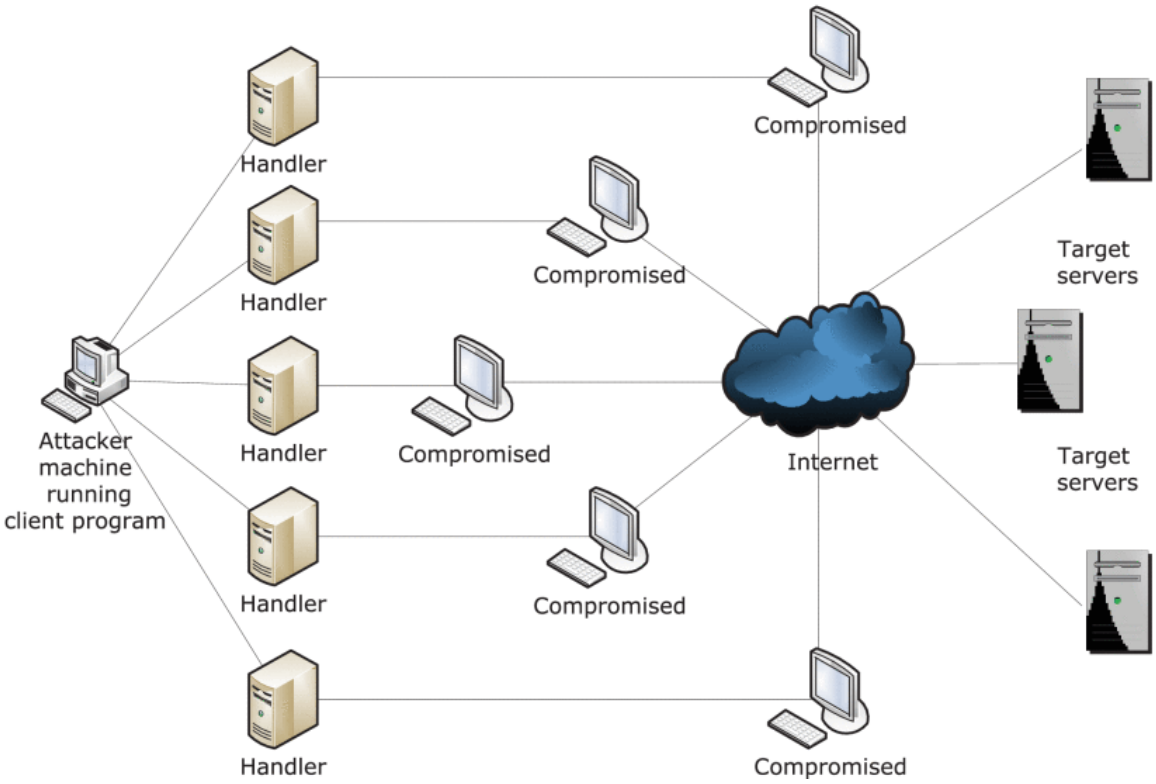
Denial of Service

SIP trunks are open to similar attacks that plague any company open to the internet as an internet connection type. A common attack type on internet trunks is Denial of Service (DoS) attacks. The internet-facing servers are flooded with so many requests that they cannot process any legitimate requests, effectively stopping all operations (Tripathi & Hubballi, 2021; Yu, 2016). Attacks perpetrating from a single source are termed DoS attacks; however, they can come from multiple sources in a coordinated attack, termed Distributed Denial of Service (DDoS) attacks. These DoS and DDoS attacks can happen with voice communications as well, flooding PBX systems and

crippling a company's ability to make and receive phone calls, and can be especially detrimental in the event of an emergency (Safoine et al., 2018; Tas et al., 2020).

Figure 4

Simple Diagram of a DDoS Attack



Note: A DDoS attack diagram showing one attacker using distributed computers to attack from several vectors rather than just one. From *A Survey of Denial-of-Service Attacks and Solutions in the Smart Grid* by Huseinović et al., 2020, *IEEE Access*.

Currently, there are no effective methods that can be implemented to prevent these types of attacks, however identifying the patterns that lead to identifying these attacks, determining the source, and blocking the traffic to allow legitimate traffic again is the best protection (Avila Pesantez et al., 2018). As DoS attacks were not a risk to PRI

circuits, telecommunications engineers may not be prepared to mitigate these risks when transitioning to SIP trunks for telecommunications systems (Biondi et al., 2020).

In-depth investigations into DoS attacks on PBX systems aim to identify what to look for to detect a DoS attack (Yu, 2016). The Invite and Register message flooding are of particular focus of this study. Yu (2016) proposed security protections, although the proposed methods do not seem novel. Potential further research in this area would be beneficial to the industry. Nazih, W. et al. (2020) also studied DoS/DDoS attacks on VoIP networks. Nazih et al. (2020) categorized the currently accepted approaches for protecting VoIP against such attacks, evaluated these approaches and their published tested scenarios, and presented findings on effectiveness. Not all the proposed defense mechanisms work in all cases, but organizations can apply the best system for their risk profiles by understanding the attack vectors and protections available (Avila Pesantez et al., 2018).

Novel approaches have been researched and presented using detection algorithms designed to monitor network traffic changes indicative of a DoS or DDoS attack (Semerci et al., 2018). Semerci et al. (2018) expand their research into architecture decisions that affect SIP trunks' security and add strategies to implement SIP trunks securely. The University of Zilina had a case study written as the university chose its VoIP solution, one section devoted explicitly to VoIP security (Moravcik & Kontsek, 2019). Shortly after implementing the SIP trunks, there were approximately 500 SIP attacks (Moravcik & Kontsek, 2019). The scope of the security defined for this case was

protection against DoS/DDoS attacks. The telecommunications engineers at the University of Zilina utilized IP tables to combat these attacks.

Server-based performance models for detecting SIP-based DoS attacks have been researched for use in the industry (Abualhaj et al., 2019; Febro et al., 2022). An experiment presented by Tas et al. (2020) used legitimate traffic and eluded normal DoS protections like rate-limiting and black-listing. However, the server-based performance model uses CPU load on the SIP servers as the basis for the detection methods, which were triggered by the traffic load, detecting the DoS attack. Significant work is presented on SIP vulnerabilities and existing protections, but Tas et al. (2020) contribute to the field by introducing their own protection method.

System Administration Failures

A study published by Carrillo-Mondéjar et al. (2022) focused on malicious calling on VoIP systems, cited vulnerabilities listed on the Common Vulnerabilities and Exposures (CVE) public database going back ten years as evidence of consistent attack vectors for telephony systems in which system administrators play an integral role. This public database, sponsored by the U.S. Department of Homeland Security (DHS) Cybersecurity and Infrastructure Security Agency (CISA), and maintained by the MITER corporation CVE project team, is the authoritative source of vulnerabilities for IT systems and software (Bahaa et al., 2022). It is typical practice for system administrators to consult this resource in order to keep their systems at the highest security posture possible. Vulnerabilities discovered, along with a category classification denoting the impact of the vulnerability in affected systems, are posted to this resource website. In

2020, 107 different vulnerabilities were listed for VoIP alone in the CVR database (Biondi et al., 2020). Until telephony moved from time-division multiplexed circuits to IP-based trunks, telecommunications engineers worried little about the security of systems connected to the internet.

Configurations for Security

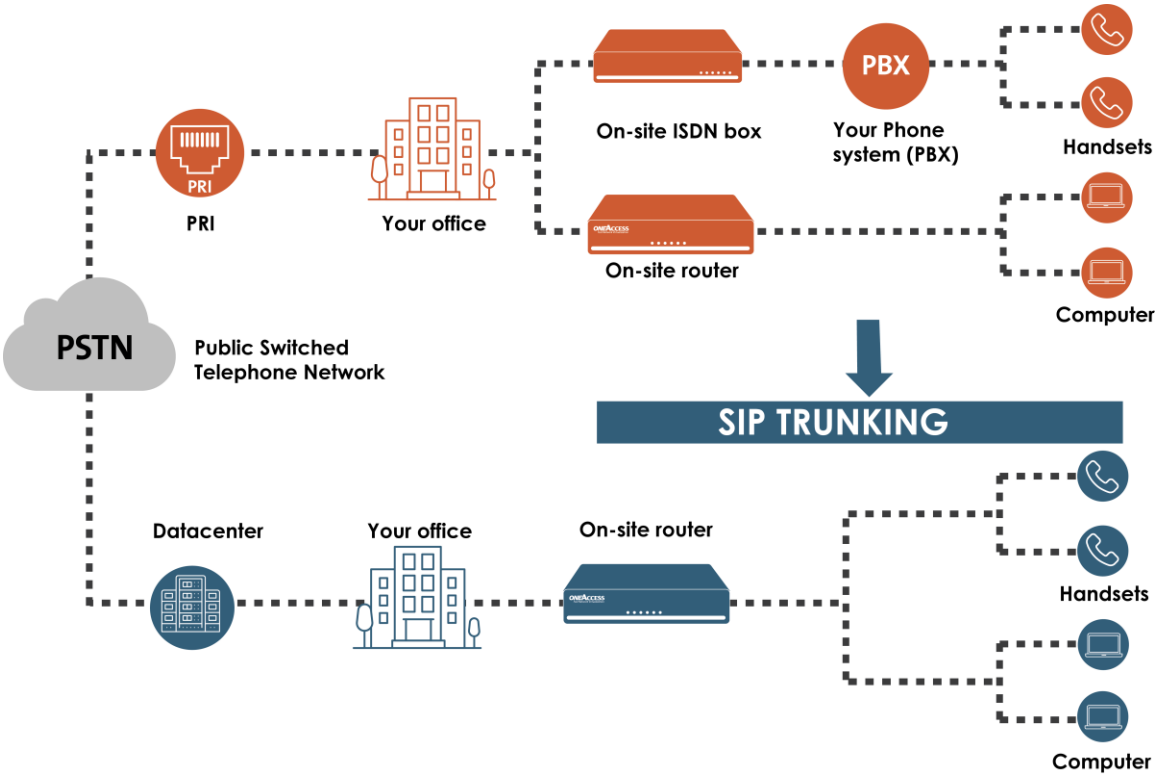
Not only does the literature discuss the types and prevalence of attack vectors for SIP trunking for voice services, but other research studies also focus on the ways security should be implemented (Saidat, 2019). Konshin et al. (2020) utilized an Asterisk IP PBX system, a competitor of larger, more costly systems such as the Cisco Unified Call Manager system, for their study on security. The low cost of the Asterisk IP PBS system makes it an attractive option for organizations looking to lower telephony costs (Konshin et al., 2020). Konshin et al. (2020) experimented with a test system made of an IP PBX, a SIP server, and Cisco networking equipment, completing analyses on network performance to find optimal settings. The relevance of this study is the SIP server configurations tested. Security should not be risked for performance; a balance should be achieved.

The device that SIP trunks connect to inside the implementing organization's network is called a Session Border Controller (SBC) (Praveen, 2022). These SBCs are central to securing the SIP trunks to protect against incoming attacks (Kaul & Jain, 2019). German (2017) posits that companies put too much reliance on this device alone to secure the SIP trunks and omit other standard protection methods, such as anti-virus and

intrusion detection. Companies need to think of SBCs as one of many protection methods rather than the sole point of protection.

Figure 5

SIP trunks and PRI Circuits in Telephony



Note: Denoted in orange is the PRI circuit path to the PSTN from a PBX, while blue denotes the SIP trunk path. The data center is where the SBC is located, connecting the corporate network to the PSTN. From *SIP Trunking* by Ekinops, 2023, (https://www.ekinops.com/solutions/voice-data-access/sip-trunking).

Another gap in the literature that Saidat (2019) addressed is a model created that organizations can quickly implement. The model proposed is called the enhanced redundant session initiation protocol model. Saidat (2019) implemented this model at an

actual SIP provider, and testing showed the model decreased session initiation protocol attempts. Performance data of SBCs was even presented, although cost data would have been beneficial if this model was intended to be adopted widely (Grant, 1996; Saidat, 2019).

With the growing trend of cloud-based SaaS, VoIP implementation complexities are added when the implementation includes virtual systems (Abualhaj et al., 2019). Kolhar et al. (2018) explore performance testing for VoIP infrastructures on virtual machines and suggest infrastructure design to build in securities while maintaining performance. Kolhar et al. (2018) expand security concerns of SIP trunks for VoIP to virtualized environments.

Transition and Summary

Section 1 of this study presents a thorough background of the problem, with a clearly stated problem statement and purpose statement defining the qualitative multiple case study nature of this study. The study was presented as a qualitative multiple case study consisting of participants in the United States who have successfully completed SIP trunk implementations for their corporate voice networks. The research question was defined as what are the strategies that telecommunications engineers utilize to properly implement successful security practices for SIP trunk security? Through the literature review, both the foundational theoretical framework used and the technology basis for the research question are discussed at a deep level, formed the platform for this study.

Section 2 follows and defines the qualitative study mechanics and components, such as the role of the researcher, the participants, the research method, the research

design, and the sampling. Important to any study involving human subjects, the ethics of the study will be discussed. Details of data collection for the study are outlined, including the study instrument and data collection methods and techniques. Through the data collection, an analysis must be completed, so the methods of analysis are outlined with an intentional focus on the reliability and validity of the data, analysis, and therefore, the results.

Section 3 presents the study findings, with themes that emerged and how they could be applied to industry to bring about positive change in individual businesses and society.

Section 2: The Project

This section of this doctoral study includes details of the role of the researcher and the participant pool.

Purpose Statement

The purpose of this qualitative multiple case study was to explore the strategies telecommunications engineers utilize to implement successful security practices for SIP trunk security. The targeted population consisted of telecommunications engineers in the United States, who are the technical experts charged with implementing and securing the SIP trunks. As more telecommunications engineers employ better security for VoIP systems, the potential social change may include better communications and data protection for individuals' personal and sensitive information.

Role of the Researcher

In qualitative research, the researchers themselves are the primary data collection instrument (Fusch & Ness, 2015). As such, I was the primary instrument for data collection in this study. The researcher has several tasks related to interview preparation and completion: (a) locate and recruit interview subjects, (b) motivate subjects to fully engage in the interview, (c) address any subjects' concerns or confusion, (d) monitor responses for quality, and (e) manage the interview process to be a positive experience (Trochim et al., 2016).

However, in order to ensure an impartial study, it was important to clarify my own experiences with the research topic. I am a telecommunications engineer by profession and have 14 years of work experience. More specifically, I have managed and

operated TDM circuits and have transitioned to SIP trunks for my current employer. Educated in the traditional technologies for voice communications, there were several aspects of the SIP connection type that were foreign to me as they are based on networking principles that are not included in traditional telecommunications training. My own knowledge gaps through the transition process highlighted areas of need for my industry. Scholarly research further revealed that this research area has been unexplored. My intention was to use peers in my industry as my research participants with the goal of qualifying a typical SIP transition process in order to determine knowledge and strategies that would be useful to employ as others embark on SIP transitions.

One of the critical considerations for research projects that involve human subjects is research ethics. Following the National Research Act of 1974, a national commission was established to create ethical research recommendations, the outcome of which was titled the *Belmont Report* and is still the standard for any biomedical or behavioral research using humans as research participants (Trochim et al., 2016). Three principles were outlined in the study for future researchers to bear in mind: Respect for persons, beneficence, and justice (Brothers et al., 2019). I adhered to these principles in my research. Respect for persons speaks to minimizing my research's impact on the subjects' lives. While I did not use any vulnerable groups such as minors, prisoners, or individuals with mental or physical disabilities, it was still important to do this assessment for any human-focused research. The participants provided their own consent to be participants and not be coerced in any real or perceived way (see Earl, 2020).

Another area of concern for qualitative studies is bias. Researchers must do their utmost to identify their personal biases and mitigate them as much as possible in their data collection and analysis (Yin, 2018). I have seen secure and insecure SIP implementations. I know what knowledge I do and do not have that prepared me for the transition from PRI circuits to SIP trunks in my professional experience. Fusch and Ness (2015) stated that the danger of new researchers is that they are not aware of their personal lens and bias. As the data collection instrument, being aware of my potential bias was an important step to eliminating its effects in my study. Due to my professional experience, I was conscious of not having written the interview questions to shape the answers I get to what I think the answers to my study are. The potential exists to shape the interview atmosphere and questions to draw the conclusions the researcher expects (Yin, 2018). Being conscious of this potential, I was able to avoid it and let the interviews lead me to the true conclusions.

With my professional history with the subject matter, my own biases, and the ethical considerations in mind, I devised an interview protocol to conduct the interviews for data collection in a method to gain the most information pertaining to my research matter. Interview protocols are used by researchers to navigate the interviews with pre-drafted scripts to open and close the interviews, a refined list of open-ended questions, prompts to gain further information when necessary, and a process to refine the interview protocol (Creswell & Poth, 2018). Interview protocols are useful in creating a consistent environment across participant interviews, including the recording and note-taking for later analysis of the interviews (Jacob & Furgerson, 2015).

Participants

For the participant pool, three qualifications must be met. I sought participants who were (a) professionals in the telecommunications field, (b) who had completed a SIP trunk migration or implementation will be sought out, and (c) who worked now or had worked for companies based in the United States. This aligned with the research question by exploring the strategies they employed for a secure SIP implementation. After that broad pool of participants was identified, I eliminated subjects that were not eligible, such as any professional that I could apply pressure or influence on in their life or career. Any perception of influence has the potential to skew responses, and those results should not be used (Brothers et al., 2019; Earl, 2020).

There are several methods to gain participants for research. When the study is focused on a phenomenon that affects a wide variety of people belonging to a certain category, like architects, health conditions, or mothers, for example, the participants can come from all over the world. Social media campaigns are common in these large studies, as well as social networks, to gain access to relevant participant pools for volunteers (Ali et al., 2020). These enable researchers to cast a wider net than the potential pools that are readily available to them through their personal and professional connections (Sauter et al., 2020). However, this study was narrower and more particular, requiring a more targeted approach to find participants. Also, due to the limited amount of time for the study, I needed to focus on access to participant pools more available to me through my personal and professional networks. In order to gain access to potential participants, I leveraged professional relationships and partnerships held by my current employer. Being

an insider to the culture or groups a researcher is studying can be advantageous, bringing benefits such as access, comfortability with participants, and more transparency in interview answers (Creswell & Poth, 2018; Holmes & Gary, 2020). The organization I am employed by belongs to two larger groups of companies for peer networking. One is called University Affiliated Research Centers (UARC), and the other is Federally Funded Research Development Centers (FFRDC). Through these two group affiliations, I could connect to telecommunications engineers in similar positions to mine. Working relationships and rapport had already been created with some of these work peers and could be generated with others to gain enough participants to reach data saturation. Data saturation is when enough participants and data are collected that no new themes emerge for analysis (Farrugia, 2019; Sebele-Mpofu, 2020). I had no influence over their employment status, standing in their companies, or any other position that could be used to influence these participants' responses or participation in my study.

Research Method and Design

The purpose of this study was to examine the strategies used by telecommunications engineers to securely implement SIP trunks for voice services. To accomplish this purpose, I collected data and presented credible and valid findings to address the research question devised for the purpose of the study (see Johnson et al., 2020). To structure the study, an appropriate research method and design were chosen that best aligned with my goal.

Method

Trochim et al. (2016) defined research as a contribution to general understanding by conducting investigations that follow an empirical and systematic structure (p. 5). To adhere to the empirical nature of research, methodologies were created to guide and understand how research is completed based on the intention of the research study. Research methodology refers to the way the researcher intends to examine the subject matter (Vaughn & Jacquez, 2020). This includes how the data sources chosen will be analyzed (Bleiker et al., 2019). The commonly recognized research methods are qualitative, quantitative, and mixed-method (Strijker et al., 2020; Vaughn & Jacquez, 2020). Quantitative studies typically involve a hypothesis, which is a prediction of results, and an experiment or test to validate or invalidate the hypothesis (Given, 2008; Trochim et al., 2016; Vaughn & Jacquez, 2020). Quantitative studies can also be descriptive, where the researcher is predicting relationships between variables, such as causality (Mehrad & Zangeneh, 2019). This study was an exploration of human behaviors and knowledge application rather than data that could be quantified or variable relationships, and therefore, I rejected the quantitative method.

Mixed-method is a combination of qualitative and quantitative are required to fully answer the research question, or when combinations of qualitative and quantitative data collection methods are used (Mikalef et al., 2018). In mixed-method studies, the qualitative and quantitative designs can be applied sequentially or in combination in an attempt to gain a better understanding of the topic than one design alone could provide (Trochim et al., 2016). For instance, surveys as a data collection method requiring

participants to rate items on a numeric scale would require quantitative analysis, and additional interviews to gather additional data to understand the survey responses would be an application of mixed-method design (Mikalef et al., 2018). This study did not include any quantitative design or data collection, so a mixed-method design was also rejected for this study.

Qualitative studies are a way by which a researcher explores a phenomenon to gain an understanding of their research question. The qualitative method is best used when there is no direct causation link between variables or when there is no hypothesis to test but an attempt to understand human situations (Bleiker et al., 2019). Rather than a hypothesis, qualitative studies use research questions, outlining the goal of the research, the target of the data collection, analysis, and the findings to be published (Farrugia, 2019). In this study, I explored implementations of SIP trunks to understand the successful strategies that result in secure implementations. With this research goal in mind, the qualitative method was the most appropriate and chosen research method.

Research Design

Within qualitative research methodologies, there are different designs that can be applied. Because qualitative research is often used for human behavioral studies, a number of the design types are focused on studying human culture, stories, or history, often over time (Creswell & Poth, 2018). Understanding research intentions and population is necessary when choosing the appropriate design.

Phenomenology is used most often when researchers are seeking to explore and understand someone’s experience (Nigar, 2019). Understanding someone else’s

experience requires a suspension of the things the researcher takes for granted from their own life experience. For instance, Gunawan et al. (2021) used the phenomenology design in their research on the experience of nurses through the COVID-19 pandemic. In order to gain the necessary insight into the nurses, the researchers spent 3 months formally interviewing and informally chatting in order to gain an understanding that interviews alone could not provide (Gunawan et al., 2021). With the intention of sharing the themes resulting from this research with government and healthcare entities, the researchers needed the over-time, deep analysis of the nurse's experience that the phenomenology design is typically used for. The point of interest of my study was the implementation of SIP trunks and the strategies employed for security and success in that activity; phenomenology did not align well with the research question and, therefore, I did not use it.

Ethnography is another design where the researcher studies a social or behavioral phenomenon using interviews and observation, often over time (Given, 2008). Researchers using this design need to be able to observe the phenomenon as part of the research to draw their conclusions. Leverton et al. (2021) used ethnographic design in their research on dementia patients' living situations by spending 100 hours of observation across various living settings, combined with 82 interviews. This design was used by the researchers to gain a deep understanding and the breadth of information necessary to reach saturation for their data analysis and conclusion for their research (Leverton et al., 2021; Sebele-Mpofu, 2020). While useful and appropriate for studies

where observation of the phenomenon is important, ethnography was also not chosen for this study.

Case study design was the most appropriate research design for this study. To gather the data required to explore the strategies used for successful and secure SIP trunk implementation, my intention was to interview individuals who have completed implementations, as well as review any documentation on the implementation they created or used. Case study design is used when researchers need to investigate circumstances within the scope of their research question, which is applicable to this study (Bleiker et al., 2019). In order to understand how online learning impacted student motivation, Mese and Sevilen (2021) used a case study design in which they used student writing samples and interviews. Their intention was not to observe motivation over time but a cross-section view of motivation at a time of online learning. Similarly, in this study, observation over time was not necessary, and documents and interviews were the data collected for analysis. As such, I chose a case study design.

One of the critical pieces of qualitative method studies is to collect and analyze enough data to reach what is known as data saturation. Data saturation is the point where no new data is found across the research categories, regardless of additional inputs (Creswell & Poth, 2018, p. 218). Data saturation is especially important for the study's validity. In order to be valid and considered a true and correct source of research, the study should be replicable, which is the link between data saturation and validity (Fusch & Ness, 2015; Sebele-Mpofu, 2020). Should someone else recreate the study, similar results should be achieved, demonstrating that proper method, design, data collection,

and population were used. One issue with data saturation is that it is difficult to define and varies across different studies. When answering the question of how many samples are needed, Marshall is quoted as saying, “An appropriate sample size for a qualitative study is one that adequately answers the research question” (Marshall, 1996, p. 523). For this study, interviews and data collection were continued until the data analysis revealed no new insights.

Population and Sampling

This study targeted professionals who successfully implemented SIP trunks for telecommunications. During the interviews, the participants must work in voice services and have migrated their employer from the older PRI circuits to SIP trunks or have worked in this role and completed a SIP implementation. Ideally, the participants have had formal telephony training and education, although on-the-job professional training is also appropriate if no formal education was completed. The location of the educational background was not relevant as a factor in population sampling; however, the company where the SIP migration occurred must have taken place in the United States. This will ensure the participants had similar technology tools and resources as they performed the implementations. Any company that manages their corporate telephony services in-house rather than an outsourced service and any company that is not a telephony service provider were also an applicable source for participants. Participants were selected from this population and interviewed until data saturation was reached. There is no specific number of participants designated as the required number to reach data saturation, but

instead, researchers review the data collected and determine it is appropriate when saturation is reached (Guest et al., 2020; Johnson et al., 2020).

It was impractical to interview every qualified potential participant who meets all of the criteria, so sampling was used to narrow the pool, mitigate bias, and still attain representative data for the population (Ames et al., 2019; Campbell et al., 2020). Researchers can choose between sampling methods such as random sampling and purposeful sampling. Random sampling is an option where the population is broad enough that participants chosen at random can ensure that all sub-populations have an equal chance to be represented (Marshall, 1996). While the potential population that meets the criteria for this study is a large number, the researcher must also have reasonable access to the population (Riese, 2019). Due to the access factor and the niche nature of the research question, purposeful sampling was used for this study rather than random sampling. Purposeful sampling is used by researchers when specialized information is required in their exploration of understanding phenomena (Hong & Cross Francis, 2020). This study sought participants who have worked through implementing SIP trunks with appropriate security measures for their organization; thus, purposeful sampling is appropriate.

Qualitative study canonical books and resources do not specify the appropriate number of participants but instead guide researchers to continue to sample with participants until sufficient evidence to fully understand the phenomenon (Braun & Clarke, 2021; Farrugia, 2019; Marshall, 1996; Peterson, 2019). With that goal in mind, this study used at least four participants. I added participants until the information

collected was repetitive, offering no additional insights into the research question. Although some scholars do not point to repetition solely as the mark of data saturation, they instead refer to three points. In addition to repetition, Fusch and Ness (2015) add that data saturation is reached when the study can be repeated, the same results are attained, and no new codes or themes emerge from the additional data.

The participants were interviewed with semistructured questions to gather the necessary data to analyze my research question. With the population geography of participants spanning the United States, it was impractical to plan for in-person interviews. As such, the interviews were conducted remotely, using the internet-based meeting platform Zoom. The interviews were also recorded, with permission granted by the participant which provided a transcription. This provided a record useful for recalling both verbal and non-verbal details from the interview. The transcriptions, recordings, and notes taken assisted in the data analysis of that theme construction.

Ethical Research

Once participants who met the eligibility criteria defined in the Participants section (2.3) were identified, the informed consent process to invite them to participate as a subject in my study and gain their consent began. To give consent, these participants must fully understand what the researcher is asking, the scope of their participation, and other participant rights (Hariri et al., 2022). At a minimum, the informed consent process requires the information must be presented to the subject in a way that they can comprehend; their consent must be freely given and must be able to be rescinded at any time (Fons-Martinez et al., 2022; O'Sullivan et al., 2021). For documentation purposes of

the informed consent, an informed consent form was used, signed by both the participant and the researcher, and copies are provided to both for their records. As an alternative to paper consent forms, consent could also be given via email.

The informed consent form included the nature of the research topic and the criteria they meet to participate. Further, it included time estimates and the type of activities they would participate in if they volunteered. It is important to clarify exactly what the researcher is asking from the participant in order for their consent to be informed, and as people receive information in different ways, researchers need to be prepared to alter their communication method for the benefit of the participant (Fons-Martinez et al., 2022). To meet this potential need, the informed consent form was the primary and formal method to gain consent; however, phone calls, online, or in-person meetings were also offered.

In order to certify that this study meets ethical standards and that the participants will be treated ethically, this study was submitted for an ethics review through Walden University's Institutional Review Board (IRB) process. The independent board reviews the relative data sources (including participants) to ensure proper documentation and standards are met in relation to ethical research (Lynch et al., 2022; Zimmerman et al., 2022). The IRB approved this study, and the assigned approval number provided was 12-04-23-1009720. This IRB approval number was added to the Informed Consent Form and provided to the participants as validation.

Participants also have the right to data and identification protection (Brothers et al., 2019; Earl, 2020). The informed consent form notes that the participant's identity will

be separated from all data used in the study using a coded key, stored securely, and will be destroyed after the 5-year mandatory retention period. This was accomplished by removing all personal identification data from the data collected and replaced by a participant ID number. The key correlating the participant ID number to the individual participant was stored separately in a password-protected file. Participants also have the right to rescind their consent for any reason at any point during the study by emailing me or calling me at the contact information provided on the informed consent form (see Appendix A). For any participant who rescinds consent, the data collected from their participation will be removed from the data pool, not included in the study and results, and it will be destroyed. No participants rescinded their consent for this study.

Regarding compensation or incentives for participation in research studies, there is mixed research on whether it should be offered and its effectiveness in gaining participants. For COVID-19 research, researchers had an abundance of volunteers at the beginning of the pandemic that required no compensation ("Incentives for Online Surveys Boost Research Participation, but Fraud Remains a Concern," 2022). This is likely due to the global impact of the pandemic and the world's combined goal of understanding and fighting the virus. As the pandemic subsided, researchers witnessed volunteers for studies on COVID-19 research dwindle. Compensations were used and effective to attract general population volunteers ("Incentives for Online Surveys Boost Research Participation, but Fraud Remains a Concern," 2022). Other research suggests that compensation is not as effective as researchers might assume. In a study to test the effectiveness of compensation in a smoking cessation study, the participation population

was divided into three groups and provided $0, $200, and $500 to test the hypothesis (Halpern et al., 2021). The study's results showed very little variance in the consent gained, regardless of the compensation level offered. For this particular study, as it was not a random sampling study from a wide populace where participants may be more inclined to help with a compensation offer, no compensation was offered. This information is included on the Informed Consent Form.

Data Collection

Instruments

Various instruments are used in research to collect the data to be analyzed. Quantitative studies and qualitative studies use very different data collection instruments, although there can be overlaps. For qualitative studies, the researchers are typically the primary data collection instrument (Fusch & Ness, 2015). As such, I was the primary data collection instrument in this study. This role requires me to have a process to follow so that I minimize my effect and influence on the data collected due to the fact that in interviews, the researcher can actually be seen as a co-creator of the data with the participant (McGrath et al., 2019; Roberts, 2020). The researcher must take care and practice when cultivating the environment where the data will be collected, including the technologies used to record the data (Namey et al., 2020). Time must be invested in the rapport and relationship with the participants so comfort and trust can be built, and this should start to happen during the recruitment phase with participants (McGrath et al., 2019).

I am seeking to explore the strategies used by telecommunication engineers for secure SIP implementation. Those strategies are in the minds of those professionals who have successfully done that work. When a researcher needs to understand the individual's experience with regard to the target phenomenon, interviews are the preferred method used (McGrath et al., 2019). I used semistructured interviews as the primary means of collecting data. As opposed to an informal interview, a semistructured interview is pre-written open-ended questions designed to engage the participant on the research topic with room for in-depth answers and expansion by the participant into the phenomenon being studied (Husband, 2020). These semistructured interviews are conducted in the same manner with the same question list with each participant to assist with the consistency of data collection, adding to the validity of the data (Bearman, 2019; Roberts, 2020).

To ensure each semistructured interview was conducted in the same manner, an interview protocol was used. An interview protocol also gives structure to the interview questions with the target of gaining the information that pertains to the research question, as well as how the data is collected, retained, and analyzed (Hunter, 2012; Roberts, 2020). A well-defined interview protocol can also increase the reliability of the study and the data collected (Yin, 2018). Reliability refers to the appropriateness of the methods used for data collection, analysis, and integrity of the study results (Braun & Clarke, 2021; Coleman & Ed, 2022). The interviews were conducted via the online meeting platform Zoom, where the interviews were recorded and transcription was done. The recording of the interviews adds to the validity of the study by retaining the raw data for

verification (Coleman & Ed, 2022). The Informed Consent Form, in the scope of the request of the participant, asked that participants agree to a review of the transcript for accuracy. This additional step, to ensure that what was recorded is what the participant intended to say, adds to the study's validity. While some researchers state that in-person interviews are better than virtual interviews for rapport building, the recording and automatic transcription benefits save time for the researcher and participants (Keen et al., 2022). As the researcher, I tested my interview questions and my recording and meeting platform with a mock participant to pilot test the process. This test, combined with a review of my interview questions and protocols by the doctoral committee, ensured my questions aligned with my research goal, my methodology, and the research method. The interview questions can be found in the Interview Questions section of Part 1 of this study and in the appendix (see Appendix B).

Data Collection Technique

Once the participants had been contacted and provided consent to be included in this study, I reached out to every individual to set meeting times. My primary tool was the online meeting platform Zoom. If participants were uncomfortable or unfamiliar with Zoom, other platforms like Webex, Google Meet, or GoTo Meeting were viable options available to me for the ease of the participant's interview experience, although Zoom was chosen by all participants. Interviews in qualitative research are valuable when they enable the researcher to elicit truthful and rich responses from participants (Keen et al., 2022; Mirick & Wladkowski, 2019). This is accomplished best when the participants are comfortable with and trust the researcher, and that rapport is built from initial contact to

request participation through the interviews and reviews to the conclusion of the study (Brothers et al., 2019; Saarijärvi & Bratt, 2021). This trust is valuable not only to the individual study but to the field of research as a whole for continued human participants (White, 2020). Traditional data collection techniques suggest that interviews should be conducted in person for the best results; however, video, telephone calls, emails, and chat tools can also be used to conduct interviews (Irani, 2019; Keen et al., 2022; Novick, 2008). The skepticism of interview methods other than in-person interviews is directly related to the rapport impact potential, avoiding potential technology barriers, and the additional non-verbal details from observing a participant that can be valuable to the interview (Keen et al., 2022; Mirick & Wladkowski, 2019; Saarijärvi & Bratt, 2021). In this particular study, with the participant pool being from the Information Technology industry, I assumed a basic level of computer savvy that mitigated the concern of technology barriers for the participants. The online meeting platforms, by utilizing video and audio as the basic functionality of the technology, mitigate other typical concerns of lack of non-verbal cues and missing essential nuances of interview responses that may benefit from additional questioning for details (Saarijärvi & Bratt, 2021). The additional benefits of using online meeting platforms include time savings for both the researcher and participants, recording for additional viewing to capture details, and transcription of the interview being more accurate than the interviewer's notes (Irani, 2019).

Once IRB approval of this study was obtained, a pilot test was conducted. Pilot tests are also referred to as small-version tests or feasibility studies (Malmqvist et al., 2019). The value of pilot studies is often overlooked in qualitative research and omitted

as a step in research studies (Shakir & Rahman, 2022). This pilot test was aimed at testing the interview method, interview questions, and data collection techniques more so than actual data gathering for the study. This process allowed refinement of any area of the study methods prior to the full study and also increased my confidence as a novice researcher. During the pilot study, member checking was also trialed. Member checking is the process of validating the data collected by returning it to the participant to check for accuracy (Zairul, 2021). With the combination of the transcription from the online meeting platform, the member checking focus was more on ensuring the participants said what they intended to say than the accuracy of what the researcher recorded. The member checking process also worked to build trust and confidence with the participants by allowing them to modify, explain, or correct what the researcher captured, ensuring they feel accurately represented (Candela, 2019).

Data Organization Techniques

Upon completion of the interviews, the video recording and the audio transcript were the digital artifacts retained, in addition to reflection journal entries, which were digitally captured in Microsoft Word. There are no handwritten or hard copies of the study data. One ethical guideline for studies involving human subjects is to provide confidentiality and maintain anonymity (Farrugia, 2019; O'Sullivan et al., 2021). As outlined in the Informed Consent Form for this study, I protected the information shared with me by the participants by separating any identifiable information from the data used in the study. To accomplish this, I used a coding system to assign numbers to the participants' interviews and transcripts so their names are separated from the data to

maintain their anonymity. An Excel spreadsheet was maintained as the code key in the event I needed to re-contact participants on data already collected. There was no other need to retain which participant provided which data for the study. Also, as outlined in the Informed Consent Form, digital copies will be retained for five years and then will be destroyed.

Data Analysis Technique

For this qualitative multiple case study, I used thematic analysis. There are six types of data analysis techniques to understand before determining the most appropriate type for each study. Narrative analysis is a method by which researchers use the entire narrative of the story being told by the research participants so their frame of mind and behavior is included in the data collected (Held et al., 2019; Nigar, 2019). This aspect is not within the scope of exploring skills and knowledge used in job functions, so narrative analysis is not appropriate for this study. Another data analysis technique is Interpretive Phenomenological Analysis (IPA). IPA focuses on life experiences and the phenomenon of human experience (Gunawan et al., 2021; Rajasinghe, 2020). There are many types of research studies, most using a Phenomenological design, where IPA will be very appropriate, but for this study, Thematic analysis is the most appropriate. Thematic analysis is the process of codifying data for themes that emerge that relate to research questions (Braun & Clarke, 2021; Soratto et al., 2020; Williams & Moser, 2019).

I used the qualitative data analysis software Atlas.ti for my thematic analysis. All the digital artifacts were imported into the software, which uses artificial intelligence to find patterns and gain insights (Soratto et al., 2020). Reviewing the interview transcripts,

I began by applying deductive coding and finding words, phrases, and categories of data that fit my research question. Deductive coding flows from the research design and framework, a top-down approach (Proudfoot, 2023). With the aid of Atlas.ti, inductive coding also emerged, finding themes and repeated phrases that I may not have expected or looked for. Inductive coding is the bottom-up approach, letting the data lead the themes rather than the framework of the study and research methods (Robinson, 2022). Together, these approaches to the thematic data analysis produced the themes that resulted from the data collection, rendering the study findings.

To validate the data, researchers use one of four triangulation methods. These are method triangulation, investigator triangulation, theory triangulation, and data source triangulation (Bans-Akutey & Tiimub, 2021; Carter et al., 2014; Jentoft & Olsen, 2019; Lemon & Hayes, 2020). Method triangulation is done by researchers using multiple methodologies on the same subject matter to approach the research question or hypothesis from multiple research angles (Dzwigol, 2020; Strijker et al., 2020). Pairing methodologies like qualitative and quantitative can be used for method triangulation or using multiple designs in the same method (Bans-Akutey & Tiimub, 2021). This study is qualitative only and case study only, making method triangulation not a feasible option. Investigator triangulation is accomplished by more than one researcher analyzing the data independently (Stahl & King, 2020). Where both researchers or investigators come to the same conclusion, validity is given to the study results (Hamilton, 2020; Natow, 2020). While I conducted both member checking and pilot testing to add validity and reliability to my study, I did not have an independent researcher to collaborate with in this study, so

investigator triangulation was not a valid option. The third triangulation method is theory triangulation (Carter et al., 2014; Tungka, 2016). With this method, researchers apply more than one theory (research question or hypothesis) to their research to examine the research findings from potential other theories or explanations of the data (Nha, 2021). Theory triangulation was not appropriate for this study, as I used a single research question. Data triangulation uses multiple sources of data to achieve rich and varied information about the phenomenon being studied (Carter et al., 2014; Lemon & Hayes, 2020; Tungka, 2016). Without multiple methods, independent researchers, or multiple theories in this study, the most appropriate type of triangulation for this study was data source triangulation. In the search for valid data that will result in credible study results, multiple participants, which are the data sources, were interviewed until data saturation was reached (Fusch & Ness, 2015; Lemon & Hayes, 2020).

Reliability and Validity

Reliability

A research study is worthless if it is not trustworthy and reliable (McGinley et al., 2021). Researchers must spend time ensuring in every way possible that their research and analysis meet reliability and validity standards (Coleman & Ed, 2022; Peterson, 2019; Rose & Johnson, 2020). These are measured through every stage of the study on four criteria: dependability, credibility, transferability, and confirmability. Dependability specifically refers to the consistency of the instrument used and the study itself, meaning other researchers performing the same study would come to similar conclusions (Hunter, 2012; Janis, 2022). Dependability in this study was verified throughout the study by

means of transcript reviews with the participants. This provided the validation of the data in each interview by the participants themselves, being provided an opportunity for clarification, correction, or addition of relevant details. This prevented the researcher from concluding on misinterpreted data (Keen et al., 2022). Instrument reliability is also important as a marker of the quality of the study results (Ganesha & Aithal, 2022). The interview protocol will be the dependability check on the data collection instrument (Lynch et al., 2022; Roberts, 2020). The final reliability check was the pilot test of the study, completed after IRB approval was gained.

Validity

Credibility, transferability, and confirmability speak to the validity of a study. Credibility means the trustworthiness of the body of work the researcher has presented (McGinley et al., 2021). There are multiple ways a researcher can verify the credibility of their study, but the most prominent is the external audit. A researcher who was not involved in the study or data collection processes would review the entire process through to the conclusions and final paper, checking for agreeance on the research and findings (Rose & Johnson, 2020). I used peers for this review process to check my study's credibility.

Transferability refers to the applicability to other works and the intended audience (Campbell et al., 2020; McGinley et al., 2021). As a professional in the voice communications technology field, my intention is that this study can improve the security surrounding voice communications by finding details from successfully secure implementations that other professionals can learn from. Additionally, by clearly listing

the research population, other researchers can identify if the study results are applicable to other demographics and populations (Campbell et al., 2020).

Confirmability points to the neutrality of the body of work. Ensuring the researcher has not contorted the data gathered through their biased lens (Johnson et al., 2020; McGinley et al., 2021; Peterson, 2019). The first step to reaching confirmability is, in the role of the researcher, to identify any relevant biases that could affect the research (Shufutinsky, 2020). By being aware of one's own biases, a researcher can guard against their effects on the research and add mitigation methods like member checking and triangulation (Natow, 2020).

While not outlined as specific reliability or validity criteria, data saturation is a measure researchers aim for to assist in ensuring the quality of their work (Braun & Clarke, 2021; Fusch & Ness, 2015; Sebele-Mpofu, 2020). Data saturation speaks to the point of data collection where increasing the number of samples collected does not reveal any new results (Braun & Clarke, 2021; Farrugia, 2019; Sebele-Mpofu, 2020). Reaching data saturation in qualitative research shows reliability, as other researchers conducting the study would gather the same data (Fusch & Ness, 2015). For this study, data saturation was reached when coding the interviews reveals no new themes for further research and analysis.

Transition and Summary

Section II of this study reasserted the purpose, defined the role of the researcher, and scoped the participant population and qualifications. Important details were provided on the research method and design to be used. Discussion was provided on how this study

met the ethical considerations required by the IRB and how reliability and validity were achieved. This section also provided the details of how the data was collected, protected, and analyzed, with a thematic approach to present the study findings.

Section 3 was completed upon approval from the IRB to conduct the study outlined in Sections 1 and 2. The findings will be presented in a way that also demonstrates reliability and validity. Section 3 will tie the research completed back to the societal and professional implications that were desired potential outcomes of the study. Recommendations will also be made for future research.

Section 3: Application to Professional Practice and Implications for Change

Overview of Study

The purpose of this qualitative multiple case study was to explore the strategies telecommunications engineers utilize to implement successful security practices for SIP trunk security. By identifying appropriate volunteer participants and interviewing them following my approved interview protocol to collect their experiences, I assessed strategies for future use in the IT field of telephony to increase security and decrease vulnerability exploitation.

The interview questions are categorized into career history, training and education, implementation experience, security considerations, monitoring and verification, challenges and lessons learned, resources and support, and advice for future implementations. I used these questions to collect the experiences of the participants so themes could emerge that directly correlate to strategies that can be used for secure SIP implementations. Three overarching themes emerged: (a) training and education either taken or needed, (b) resources and support, and (c) secure configurations. Together, these themes were important in the successful and secure SIP implementations.

Presentation of the Findings

The research question for this study was: what are the strategies that telecommunications engineers utilize to implement successful security practices for SIP trunk security properly? Semistructured interviews conducted with telecommunication engineers that have successfully implemented SIP trunks securely for voice brought themes of their success to light.

The participants for the study were all current or previous telecommunication engineers, and all that have completed a secure SIP implementation for their companies. These telecommunication engineers have the responsibility of implementing and managing the voice communications within their organization. I reached data saturation after the fifth participant when I received no new information or experiences. One participant had over 30 years of experience, three had 12 to 17 years of experience, and one had 10 years of experience. All the participants have a background in legacy telecommunications, using PRI technology and TDM switches prior to transitioning to SIP. Two of the participants had no formal networking training, while the other three did have networking fundamentals in their background education. While there was no gender bias noted in the findings, all the participants were male.

I used data source triangulation to analyze the interview data collected along with other documents collected. Participants provided organizational network diagrams and configuration guides from vendors as documentation that assisted in their implementations. Other documentation that I used included my reflective journal and interview notes. I conducted member checking shortly after the interviews to ensure the participants agreed the responses captured were the responses they intended to provide. Data source triangulation is one method to add validity to a research study and to ensure data saturation (Bans-Akutey & Tiimub, 2021; Lemon & Hayes, 2020).

Theme 1: Training and Experience

The first theme that emerged from the interviews was the training and work experience the participants had specifically related to IP knowledge. When reviewing the

interviews, I saw that participants belonged to two overarching categories that were relevant to the research question and themes. Some were traditional telecommunication engineers who had little to no IP networking education or experience, and the others were hybrid telecommunication and networking engineers who had formal education and work experience with IP networking. This distinction significantly shaped the strategies used by the individuals in their SIP trunk implementation work. All participants noted that the most critical piece of their successful implementation was understanding the IP and networking aspects of the SIP trunks. The interviewees generally had one of two types of education. Either they had formal education in networking and IP fundamentals that benefitted them in their SIP trunk implementation, or their education was mostly TDM-based and not particularly relevant for SIP trunks, learning their networking skills on the job. The traditional voice engineers had formal education in TDM circuits and the equipment used for their PBX service where they worked prior to the prevalence of VoIP.

Table 2

Frequency of First Major Theme

Source	Legacy Experience	Networking Experience	Formal Training	On the Job Training
Interviews	34	30	22	20
Documents	2	4	0	0

Participant 5 (P5) listed several TDM platform classes that are now rendered irrelevant while also listing informal IP training arrangements that were significantly

beneficial. Conversely, Participant 4 (P4) outlined several IP trainings and formal courses that benefitted the SIP implementation process. Both participants were successful in their implementations, but both highlighted the specific need for IP networking fundamental knowledge. Participant 1 (P1) had no formal training or voice education at all but solely learned on the job.

With or without formal training, the voice engineers interviewed recognized the importance of IP and networking knowledge for their implementations and sought the proper knowledge through different strategies. P1 and P5 both had extensive informal education from trusted peer resources. Informal training is just as valuable as formal training and can even accelerate the education experience as it can be targeted and personalized (De Grip & Andries, 2024). Participant 2 (P2) took online courses to close self-identified knowledge gaps and prepare for the SIP implementation at their organization.

IP and networking fundamentals are pivotal pieces of the strategy for a successful SIP implementation, as shown by this theme. This essential knowledge that an organization has to have ties to the conceptual framework of this study, KBV. This framework puts forth that knowledge stands on its own as an important intangible resource for the success of a company (Chung, 2022). Without the required formal or informal education, all the participants agreed that the security of the SIP implementation would be at risk.

KBV suggests that a firm’s competitive advantage comes from the ability to create, integrate, and apply knowledge (Ge & Liu, 2022; Malik et al., 2022). The

education staff members seek, either formal or informal, is that knowledge creation. The knowledge created by the training, education, and experience of these telecommunications have assisted the firm in maintaining a competitive advantage through secure SIP implementation by minimizing losses and data breaches. This knowledge created will continue to benefit the organization through vulnerability monitoring and mitigating through the life of the SIP trunks.

Additionally, participants spoke of trusted knowledgeable peers that they used to close knowledge gaps. Knowledge assimilation is another aspect of KBV that is relevant to this study (Malik et al., 2022; Wang et al., 2024). Understanding the necessary knowledge had already been assimilated into the organization through other professionals, able to be drawn upon by the individuals that required it was a strength of these organizations and a strategy used by these professionals.

Theme 2: Resources and Support

Another theme that emerged from the interviews as a factor in secure SIP implementations is resources and support. While the telecommunications engineers are critical point people in the implementations, the interviews revealed they were not performed alone in a silo. Other resources identified were peers, vendors, documentation, and third-party implementors. The self-awareness of the skills required, willingness to admit assistance was needed, and access to additional resources was shown to be important in these implementation cases.

Table 3

Frequency of Second Major Theme

Source	Contractors	Documentation	Networking Professionals	Security Professionals
Interviews	37	10	18	11
Documents	0	5	2	1

All participants spoke of the relationship with the SIP circuit vendor as an important factor in their implementation's success. This outside contractor was used as an advisor, a configuration partner, and as a source for best practices. Some vendors also provided supporting documentation to assist in the configuration of the customer-side equipment. P2, P3, and P5 mentioned specifically that the vendor chosen is of particular importance with regard to successful secure implementation.

In addition to knowledge and skills discussed in the previous theme, participants used support from other teams within their organizations for their specialties to fill in knowledge gaps. P1, P2, and P5, who are traditionally trained telecommunications engineers, mentioned using their internal networking teams to review planned architecture and firewall access lists to ensure security. All participants listed their organization's cyber or security teams as important resources to utilize when it comes to the security of the SIP trunk connection and monitoring for security breaches.

Documentation was also mentioned several times by participants as a necessary resource. SIP circuit vendors provided some documentation, as well as the manufacturers

of the equipment specific to SIP implementations. Session Border Controllers especially need a secure configuration as they act as both a firewall and a call session connection and monitor. The documentation provided to the participants was detailed, informative, and helpful to the participants. The documentation participants had from their implementations was shared with me as further references for the case studies. These documents included configuration guides from Cisco, Avaya, and Oracle, networking diagrams from their SIP circuit vendors, and best practice guides.

While the knowledge and experience of the telecommunications engineers were crucial for successful implementations, the ability to identify knowledge gaps and seek the information and skillsets needed was also shown to be an important strategy. Knowledge acquisition and gaining new knowledge is another facet of KBV that is relevant with regard to this study (Ge & Liu, 2022; Wang et al., 2024). The ability to acquire new knowledge from external sources contributes to the success of an organization (Barba-Aragón & Jiménez-Jiménez, 2023). This aligns with the theme of resources and support.

External sources, the extent to the knowledge they share, and a firm's ability to internalize that information speaks to KBV's tenant of knowledge creation through integration (Saarenketo et al., 2004). The vendors of the SIP trunks are experts, and internalizing the information they can share is of specific value to telecommunications professionals migrating to SIP trunks. The participants of this study gave examples of the beneficial knowledge these vendors relayed to them that assisted in the secure

implementation. That knowledge can now be shared for further implementations at other organizations or shared with industry peers for extended benefits.

Documentation is another source of knowledge to be acquired and integrated into institutional knowledge. The documents shared during the interviews were reference materials of significance, part of the strategies used for successful secure implementation. These artifacts are the initial steps of personalized documentation for knowledge management. The ability to create and store knowledge as a resource for an organization is an expansion on KBV's view that knowledge is one of the most important resources a firm can have (Chen, J. et al., 2020; Olivera Marjanovic, 2021).

Theme 3: Secure Configurations

The final theme that emerged from the data was the importance of secure configurations in the new equipment for the SIP trunks and the path to the vendor equipment. All of the strategies and knowledge put forth in an effort to secure the SIP trunks culminate in the configuration and monitoring of the equipment that enables those trunks.

Table 4

Frequency of Third Major Theme

Source	Equipment	Configurations	Vulnerabilities
Interviews	25	46	28
Documents	5	5	3

P4 spoke at length of the importance of networking fundamentals to assist with the proper configuration of the internal voice network itself, in addition to the configuration of the SIP trunk specific equipment. Isolating the networks, the voice traffic from the data traffic, is a strategy used to segment IP traffic and minimize any losses should the voice network be breached. P2 also spoke of the importance of a voice subnet in the context of securing voice communications. As networking and subnetting are not typical knowledge traditionally trained telecommunications engineers have, this theme is also supported by Theme 1 and Theme 2. If the engineer does not know these steps are important, or how to do them correctly, the implementation of the SIP trunks will not be secure.

Configuration of the SIP equipment is also important. P1 recounted the critical nature of getting the configuration right on both sides. As the telecommunication engineers are only responsible for their side of the SIP circuit connection and service, this ties in with Theme 2 through the use of external vendors. Additionally, security and stability are brought about by redundant circuits and diverse paths. P2 shared networking diagrams and spoke about the whole service configuration from the PSTN to the vendor through the SIP trunks to his equipment. The vendor's standard practices were applied to provide the specific configurations used.

Once the configuration is completed successfully, it is important to continue to monitor the traffic and equipment to keep them secure. P1 discussed their vulnerability scanning, continually looking for reported vulnerabilities that are present in their voice

system. This practice is common for IP networks; P3 explained and expanded into the types of packet inspection his organization does. P3 also talked about using a tool called Splunk for capturing and sifting through various equipment logs as another monitoring tactic to ensure the security of the SIP implementation. It is important to watch the SIP trunks to ensure they are not being exploited by bad actors.

The strategies employed in the theme of secure configuration are still knowledge-based, linking back to the framework of this study. Knowledge acquisition comes in many forms, as already discussed, and these are additional forms and methods to acquire knowledge and assimilate it into organizational knowledge. As staff and knowledge management systems are the holders of organizational knowledge, they are as important as any other tangible or intangible resource a company can have (Curado & Bontis, 2006; Kraus et al., 2022). Knowledge can be expressed in two major categories: explicit, which is knowledge that can be depicted, explained, and taught, and tacit knowledge, which is held in individuals and difficult to articulate (Gubbins & Dooley, 2021).

Telecommunications engineers, through the process of implementing SIP trunks, have the opportunity to gain explicit knowledge if they are knowledge seekers. Knowledge seeking is the process by which individuals decide to attempt to gain knowledge through interactions with others (Caputo et al., 2019; Gubbins & Dooley, 2021). As the themes have highlighted, being a knowledge seeker was a critical success factor across all the strategies employed. Seeking knowledge from networking professionals and vendors provided the best chance for secure configurations. Without

the knowledge-seeking shown by the participants, important details could be overlooked in the configurations.

The final theme aspect is common practices of networking and cybersecurity teams that telecommunications engineers are not typically familiar with, in the form of monitoring network traffic and equipment logs. This, again, is knowledge-seeking and knowledge-sharing behaviors that improve the knowledge of the organization (Zámborský et al., 2023). Organizations that support and engage in these types of behaviors have more strategic advantages (Barney, 1991; Chen, J. et al., 2020; Grant, 1996; Wang et al., 2024).

Applications to Professional Practice

The general IT problem this study focused on is that organizations transitioning to SIP trunks for voice need more critical skill sets and processes to secure network infrastructure related to the SIP connection type properly. The results of this study show 3 themes of valuable focus areas that organizations can use to improve their telecommunications engineers' skillsets and knowledge. Organizations can ensure that training classes and network fundamentals are available for staff to upskill their abilities. Organizations can also create a culture of information sharing between teams and departments, so telecommunications engineers are inclined to leverage their work peers in teamwork towards secure implementations, like the cyber team and networking team. Resources should also be encouraged within organizations. The ability to admit a gap in knowledge should not be met with fear or discouragement but a sharing of knowledge the

institution has for the good of the project. Organizations can self-assess their corporate culture to ensure the environment supports cross-team collaboration.

The specific IT problem is that some telecommunications engineers lack the strategies to implement successful security practices for SIP trunk security properly. With the present impact of exploitations of SIP trunks for voice communications in both data risk and financial losses, it is important to educate the industry on properly securing these trunks. While this study will not be of particular use to the companies whose implementations were used as the case studies, it would be useful to companies with multi-line telephone systems that have not yet transitioned from PRI circuits to SIP trunks. It would also be useful for the individual telecommunications engineers who will take on the task of implementing SIP trunks for their organization. The results of this study provide key areas that telecommunications engineers can utilize for their implementations.

Implications for Social Change

As a result of this study and the presented results, it is the hope of this researcher that there can be positive social changes as a benefit of the work. An implication for positive social change may include more companies taking advantage of the benefits of SIP trunks for voice communications due to their increased confidence in making the transition. With more companies utilizing the newer technology, vendors can reduce their footprint by removing the legacy services. Less footprint means less power, cooling, and space which has environmental impacts.

Another implication for social change is the increased number of more secure voice networks. With the themes for successful implementations shown in this study, telecommunications engineers will better secure the networks they are responsible for and share their knowledge with peers. This will reduce toll fraud and other vulnerability exploits, resulting in less financial losses for companies. More secure networks will also result in better data protection. This means that private and personal data about citizens will be protected, making it more difficult for bad actors to attain identity and financial data, potentially even reducing identity theft.

Recommendations for Action

The findings in this study show that traditionally trained telecommunication engineers do not receive IP networking fundamentals as a part of their training. The first recommendation is for training and education institutions to change their courses to include IP fundamentals. The historical distinction between network engineers and telecommunication engineers is reduced significantly with the adoption of SIP trunks for voice communications. Education in the voice technology field should be modified to reflect that.

Another recommendation for organizations would be to cross-train their networking teams with their voice teams. This would enable both teams to be familiar with the other's technology to see how they complement each other and to widen the scope of knowledge pools so they can evaluate the implementation plan for the SIP trunks. The networking team can become familiar with the specific IP needs for a voice network, and the voice team can become more exposed to networking and network

security. This recommendation could improve company operations for both networking and voice.

There are several ways these study results could be disseminated. Voice technology courses, at either universities or at technology training providers like INE, could be updated to include networking fundamentals and even could include course segments specifically regarding securing SIP trunks for voice. Conferences for voice communications, like Enterprise Connect by Informa Tech, could include talks on these strategies to share knowledge with other voice professionals. Conferences like Enterprise Connect exist for the express purpose of enriching the education of voice professionals, so this information would fit their mission.

Recommendations for Further Study

For further study, researchers could delve deeper into the specific vulnerabilities for SIP trunks with the intention of identifying ways to mitigate each one. While this study discusses SIP vulnerabilities and general vulnerabilities of IP networking as background research, there could be time spent analyzing each type of vulnerability and how they tie to specific financial and data losses. With over 502 vulnerabilities, several studies could be done.

Additionally, understanding the knowledge and strategies used for successful work would be beneficial to any professional area that a researcher should choose to explore. The framework and model set out in this study could be used as a base for learning key strategies in many industries and professions. Studying the phenomenon of

doing work successfully has many implications that could have positive impacts more broadly than just voice communications.

A limitation of this study is the limited number of companies and professionals able to be interviewed. While data saturation was reached, all participants came from Federally Funded Research & Development Centers (FFRDCs), which obligates them all to conform to government IT policies. Other studies could be done on telecommunications engineers in other industries. Those results will either lend credibility and validity to this study, or expose that different industries have different strategies employed.

Reflections

I knew this would be a difficult journey when I set out to undertake a research project. However, the difficulties I experienced were different than I had predicted, and a number of them were internal challenges. As a telecommunications engineer, I had to challenge my biases and ensure they did not influence this study. The exercise to identify my own biases was a valuable challenge, both for this work and for my own professional growth. I am pleased with my ability to let the study speak for itself, and I will share these results with my peers and industry to improve the security surrounding voice communications.

I want to see how this study can impact my professional field. While I cannot affect how the participants in my study migrate to SIP trunks, as their migrations are already complete, there are other FFRDC companies that did not participate in my study. Sharing the results of my study could further prepare those telecommunications

engineers. It could also shape how the FFRDC companies encourage teamwork in their IT teams to engage in knowledge sharing.

Summary and Study Conclusions

The strategies for secure implementations of SIP trunks that surfaced in this study were education and experience, resources and support, and secure configurations. Professionals preparing to implement SIP trunks for their organization's voice communications can learn lessons here that will result in more secure implementations. Recognizing their own knowledge gaps, telecommunications engineers can endeavor to attend training and lean on other professionals to assist them. Using additional resources in the form of vendors, third-party integrators, and networking professionals can also aid in the education gaps to result in more secure implementations. Focusing on the overall network configuration that expands beyond the SIP trunks, as well as continuing to monitor the whole network, are also strategies that can be learned here. Learning from and sharing this information can result in more secure voice networks all over the world.

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Appendix A: Interview Questions

INTERVIEW QUESTIONS

1. How long have you been a telecommunications engineer?
2. Tell me a bit about your career history with regard to telecommunications.
3. What specific voice training and courses have you taken with your history as a telecommunications engineer?
4. Please describe your depth of networking and IP fundamentals.
5. What part do you play with regard to voice circuit implementation at your organization?
6. What role do you have in securing voice communications circuits and trunks?
7. What is your reaction to the following statement “TDM circuits are more secure than SIP trunks for voice communications”?
8. How would you describe the challenges of securely implementing SIP trunks?
9. What resources did you use to ensure your SIP implementation was as secure as possible?
10. When you implemented SIP trunks, what steps did you take to secure your implementation?
11. How do you monitor and verify the SIP trunk security as an ongoing operational concern?
12. How would networking and IP fundamentals assist you in your job implementing SIP trunks?
13. Now that your implementation is complete, what lessons learned do you have?

14. Imagine you are mentoring a telecommunications engineer about to implement SIP trunks for his or her organization. What advice would you impart with regard to securing the trunks?