

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnana Sangama, Belagavi-590018, Karnataka



A TECHNICAL SEMINAR REPORT (21CS81) ON

“The SSL to TLS migration and its vulnerabilities”

Submitted in Partial fulfillment of the Requirements for the Degree of

Bachelor of Engineering in Computer Science & Engineering

By

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

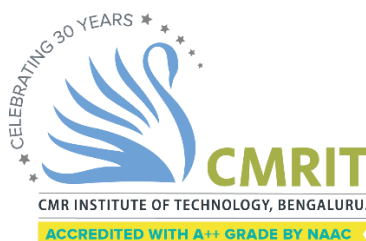
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CERTIFICATE

This is to certify that the Seminar entitled “**The SSL to TLS migration and its vulnerabilities**” carried out by **Mr. ANIKET RITAM**, USN **1CR21CS219**, , bonafide student of CMR Institute of Technology, Bengaluru, in partial fulfillment for the award of degree of Bachelor of Engineering in Computer Science and Engineering of the Visvesvaraya Technological University, Belagavi during the academic year 2023-24. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library.

The seminar report has been approved as it satisfies the academic requirements in respect of Technical Seminar prescribed for the said Degree.

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DECLARATION

I, **Mr. ANIKET RITAM**, USN **1CR21CS219**, bonafide student of CMR Institute of Technology, Bengaluru, affiliated to Visvesvaraya Technological University, Belagavi., hereby declare that the entire seminar work entitled “**The SSL to TLS migration and its vulnerabilities**” has been carried out by me during VI semester of degree of Bachelor of Engineering in Computer Science and Engineering at CMR Institute of Technology, Bengaluru during the academic year 2023-24 under the esteemed guidance of Dr. V.N. Manju, Associate Professor, Dept. of CSE, CMRIT, Bengaluru . The report is original, and it has not been submitted in part or full for any other degree in any University.

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Date:04/06/2024

ABSTRACT

This report takes you on a journey through the evolution and workings of SSL/TLS certification and its profound impact on internet security. We begin by introducing SSL certification, tracing its evolution into TLS certification, and exploring the factors that have driven its growing importance in protecting online communications. The discussion highlights the shift from unsecured HTTP to secure, encrypted connections, emphasizing how early challenges in data integrity and confidentiality paved the way for these advanced protocols.

Delving deeper, the report examines the underlying technologies that support secure web interactions. It explains how domain verification is achieved through mechanisms such as CNAME and CValue records, which ensure that the correct server is reached and authenticated before any data is exchanged. Central to this process is the secure handshake protocol that underpins SSL/TLS. The report details the dual-phase encryption methodology—starting with asymmetric encryption during the handshake, where public and private keys are used to establish a secure communication channel, followed by the use of symmetric encryption for efficient data transfer once a shared secret (session key) is established.

The abstract also discusses the broader impact of SSL/TLS certification on the environment, society, and the domain of internet security. By enhancing the trustworthiness of online interactions, these protocols have not only improved security but have also played a key role in fostering a more resilient digital ecosystem. The report concludes with reflections on how SSL/TLS certification has transformed internet security, underscoring its continued relevance in an era where data protection is more critical than ever.

ACKNOWLEDGEMENT

I take this opportunity to express my sincere gratitude and respect to **CMR Institute of Technology, Bengaluru** for providing me a platform to pursue my studies and carry out the Technical Seminar.

It gives me an immense pleasure to express my deep sense of gratitude to **Dr. Sanjay Jain**, Principal, CMRIT, Bengaluru, for his constant encouragement.

I would like to extend my sincere gratitude to **Dr. Kesavamoorthy R**, HOD, Department of Computer Science and Engineering, CMRIT, Bengaluru, who has been a constant support and encouragement throughout the course of this project.

I would like to thank my guide **Dr. V.N. Manju, Associate Professor**, Department of Computer Science and Engineering, for the valuable guidance throughout the tenure of the project work.

I would also like to thank all the faculty members of Department of Computer Science and Engineering who directly or indirectly encouraged me.

Finally, I thank my parents and friends for all the moral support they have given me during the completion of this work.

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CHAPTER 1

INTRODUCTION

In the early days of the internet, transmitting data was as simple as sending a postcard—plain, open, and vulnerable to anyone who might intercept it. As online services began to handle increasingly sensitive information, the need for a secure method to protect data in transit became urgent. Secure Sockets Layer (SSL) emerged as the pioneering cryptographic protocol designed to encrypt communication between a web server and a client (typically a browser). By ensuring confidentiality, integrity, and authentication, SSL laid the groundwork for trusted online interactions, transforming the internet from a public forum into a secure channel for commerce, communication, and information exchange.

Despite its groundbreaking role, early iterations of SSL were not without significant shortcomings. The protocol's initial versions suffered from weak encryption algorithms and were susceptible to a range of sophisticated cyber-attacks, including notorious exploits like POODLE, BEAST, and Heartbleed. These vulnerabilities were compounded by inadequate authentication mechanisms, leaving users' sensitive data exposed to interception and manipulation by malicious actors. The limitations of SSL highlighted the critical need for an evolution in security protocols—one that could address these inherent flaws while keeping pace with the rapidly evolving landscape of cyber threats.

In response to these challenges, the industry transitioned to Transport Layer Security (TLS), an enhanced protocol built on the foundations laid by SSL. TLS introduced stronger encryption methods, more rigorous authentication processes, and a comprehensive set of security enhancements designed to withstand modern cyber-attacks. Over time, TLS has undergone multiple revisions, each iteration refining its capabilities and bolstering its defenses. Today, TLS is the de facto standard for securing online communications, playing an indispensable role in HTTPS connections and safeguarding everything from online banking transactions to personal communications.

This report delves into the evolution and workings of SSL/TLS certification, exploring the journey from the inception of SSL to the modern implementations of TLS. We examine the key technologies that underpin these protocols, analyze the vulnerabilities that have been identified over time, and highlight best practices that have emerged to ensure robust, secure

communications in today's digital world. Through a comprehensive evaluation of SSL/TLS certification protocols, this study aims to provide a clear understanding of how these technologies have transformed internet security and continue to adapt in the face of new challenges.

1.1 Problem Statement

This study aims to evaluate and analyze the vulnerabilities inherent in SSL/TLS certification protocols that secure network communications. Despite the critical role of SSL in establishing trusted online interactions, early implementations suffered from significant security flaws, including weak encryption algorithms and susceptibility to attacks such as POODLE, BEAST, and Heartbleed. The subsequent evolution to TLS sought to address these vulnerabilities through enhanced encryption and authentication mechanisms. However, challenges remain, particularly with legacy systems and specific configuration practices that may still expose sensitive data or incur performance penalties. This research focuses on identifying these critical weaknesses, exploring the current methodologies employed in TLS certification, and determining best practices to ensure robust and secure communications in modern web infrastructures.

CHAPTER 2

SURVEY OF TECHNOLOGY

This chapter outlines overview highlights the diverse surveys and innovations driving the evolution of SSI/TLS Certification.

S.No	Title	Author and Journal details	Findings	Research gaps/ Limitations
[1]	Performance Impact of SSL/TLS in E-commerce Websites	Smith, J. & Doe, A. (2019) <i>International Journal of Web Security</i>	- Demonstrated how SSL/TLS encryption (significantly improved security for online transactions.	The study primarily used asymmetric encryption during the entire session, causing noticeable latency and increased CPU usage. - Limited scope in exploring symmetric encryption optimizations/
[2]		Patel, R. & Wilson, T. (2020) <i>Journal of Network Cryptography</i>	- Analyzed SSL 3.0, TLS 1.2, and TLS 1.3 to show improvements in key exchange mechanisms and reduced handshake steps.	- Mostly focused on protocol-level improvements without thoroughly testing real-world performance across varied server configurations.
[3]	Vulnerability Assessment	Nguyen, P. & Romero, L. (2021) <i>Cybersecurity</i>	Identified common implementation flaws	- Focused on a narrow set of server environments (Linux-based); did not test

	of TLS Implementations	& <i>Cryptography Review</i>	Provided guidelines for secure configuration, emphasizing the role of certificate pinning and robust cipher suite selection.	Recommendations need validation on larger-scale production networks
[4]	Session Resumption Techniques in TLS	<i>Chen, Y. & Alvarez, M. (2022) Advanced Network Protocols Journal</i>	- Compared session resumption via Session IDs and Session Tickets , finding that both methods reduce handshake overhead and latency by reusing established keys.	- Did not explore potential security implications of long-lived session tickets (risk if a ticket is stolen).
[5]	Analysis of TLS Handshake Optimizations in Cloud Environments	<i>Garcia, M. & Liu, S. (2021). Cloud and Security Journal, 12(2), 89–99.</i>	Explored optimizations in the TLS handshake specifically for cloud-based servers. Demonstrated that enhanced handshake techniques can reduce latency and improve throughput in cloud infrastructures.	Limited to specific cloud configurations; further testing is needed across different cloud providers and deployment models to generalize the findings.

CHAPTER 3

DISCUSSION OF TECHNOLOGY

Establishing a secure connection on the internet is a multi-layered process that begins long before any data is exchanged between your browser and a web server. It starts with the fundamental setup of servers and domains, followed by intricate procedures that ensure every interaction is both authenticated and encrypted. This section delves into each critical phase—from acquiring a server and domain to the meticulous SSL/TLS handshake and beyond—providing a clear, step-by-step breakdown of how modern web communications achieve robust security.

3.1 Server Setup & Domain Acquisition

The journey toward secure communication begins with establishing the physical and digital infrastructure. The website owner first obtains a server—either a physical machine or a virtual instance—to host the website’s files and applications. This server becomes the backbone of the online service. Simultaneously, the owner purchases a domain name from a trusted domain registrar. This domain name serves as the website’s address on the internet, allowing users to locate the server easily. Once the domain is registered, the domain provider configures the necessary Domain Name System (DNS) records, such as A records and CNAME records. These records map the human-readable domain name to the server’s IP address. In cases where a CNAME record is used, it helps to further confirm that users are directed to the correct server, thereby establishing the foundation for subsequent secure interactions.

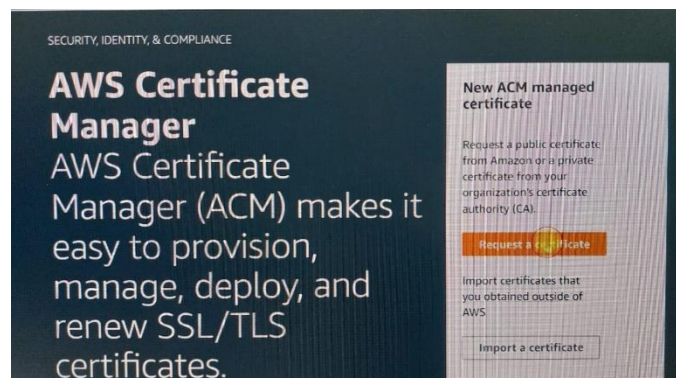
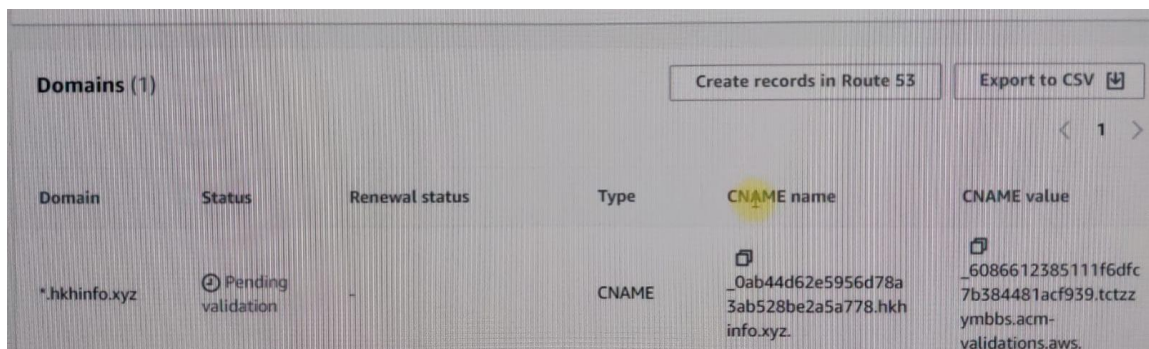


Fig 3.1 AWS Certificate Manager -SSL/TLS Manager

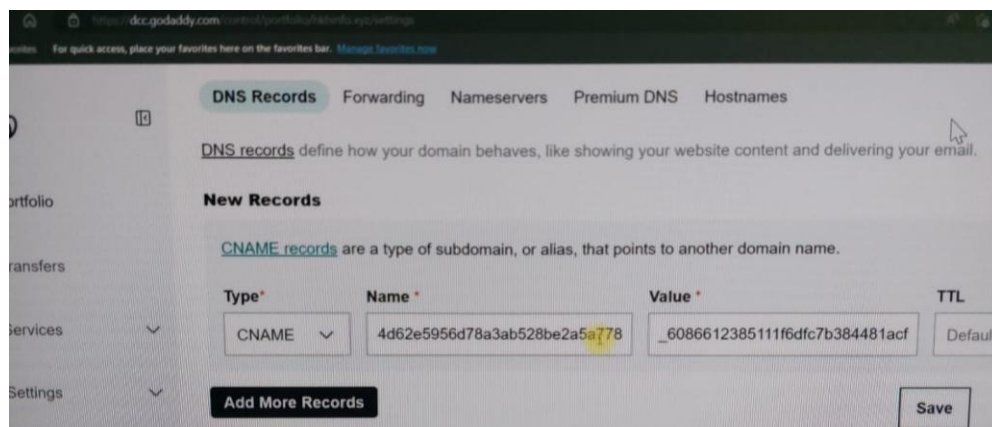
3.2 Domain Resolution and Certificate Check

When a user types a URL (for example, “google.com”) into their browser, the DNS lookup process kicks in. This process leverages the previously configured DNS records to translate the domain name into the server’s IP address. Once the browser connects to the server, the server initiates the security verification by sending its digital certificate. This certificate plays a crucial role by containing the domain information, ensuring that it matches the requested domain. Additionally, the certificate includes the server’s public key—an essential component for the encryption process—and is signed by a Certificate Authority (CA) to verify its authenticity. The browser then performs a series of checks: it verifies the digital signature to confirm that the certificate was issued by a trusted CA, reviews the certificate’s validity period, and ensures that the domain name in the certificate matches the domain being accessed. This rigorous verification process builds the initial trust necessary for secure communication.



Domain	Status	Renewal status	Type	CNAME name	CNAME value
*.hkhinfo.xyz	Pending validation	-	CNAME	_0ab44d62e5956d78a3ab528be2a5a778.hkhinfo.xyz	_6086612385111f6dfc7b384481acf939.tctzymbbs.acm-validations.aws

Fig 3.2 Domain cName and cValue



DNS Records Forwarding Nameservers Premium DNS Hostnames

DNS records define how your domain behaves, like showing your website content and delivering your email.

New Records

CNAME records are a type of subdomain, or alias, that points to another domain name.

Type *	Name *	Value *	TTL
CNAME	4d62e5956d78a3ab528be2a5a778	_6086612385111f6dfc7b384481acf	Default

Add More Records **Save**

Fig 3.3 Domain Provider Record

3.3 SSL/TLS Handshake (Establishing a Secure Connection)

This handshake is pivotal in establishing a secure connection between the client (browser) and the server. The handshake is divided into two distinct phases: the asymmetric (public-key) encryption phase and the symmetric encryption phase.

- **Asymmetric Encryption Phase:**

In this phase, the server's public key, which is part of its digital certificate, is used in conjunction with a private key held securely by the server. The primary purpose of this phase is to securely exchange a piece of data that will eventually lead to the generation of a shared secret.

- **Symmetric Encryption Phase:**

Once a shared secret—commonly referred to as the symmetric session key—is established using the data exchanged during the asymmetric phase, both the client and the server switch to symmetric encryption. This method is computationally more efficient for encrypting large amounts of data and is used to protect all subsequent communication during the session.

3.4 Detailed Handshake Process

This handshake is pivotal in establishing a secure connection between the client (browser) and the server. The handshake is divided into two distinct phases: the asymmetric handshake process unfolds through a series of clearly defined messages between the client and the server:

- **ClientHello:**

The process begins with the browser sending a “ClientHello” message. This message includes a list of supported SSL/TLS versions (such as TLS 1.2 and TLS

- 1.3), along with a list of cipher suites. A cipher suite is a specific set of algorithms that dictate how encryption and hashing are performed; it includes the key exchange algorithm, the encryption algorithm (e.g., AES), and the hash algorithm (commonly SHA-256). Additionally, the ClientHello message carries a randomly generated number, or nonce, which will later contribute to the creation of the session keys.

- **ServerHello:**

In response, the server sends a “ServerHello” message that confirms the protocol version and cipher suite that will be used for the session. The server also provides its own random number (nonce). This random value, when combined with the client’s nonce, forms an integral part of the key derivation process.

- **Certificate Transmission & Verification:**

The server then transmits its digital certificate to the browser. This certificate includes the server’s public key and is crucial for the authentication process. The browser verifies this certificate by checking the CA’s digital signature, ensuring that the certificate has not expired, and confirming that the certificate’s domain details match the domain requested.

- **Key Exchange to Create the Pre-Master Secret:**

Next, the browser generates a random pre-master secret—a temporary secret value used solely for the purpose of creating the symmetric session key. This pre-master secret is encrypted using the server’s public key (from the certificate) and sent back to the server. Because only the server holds the corresponding private key, it is the only entity capable of decrypting this pre-master secret. Once both the browser and the server have the pre-master secret, they use it, along with the random nonces exchanged in the ClientHello and ServerHello messages, to derive the symmetric session key. This derivation typically involves a secure hash function such as SHA-256 to ensure the resulting key is robust and unpredictable.

- **Session Identification:**

As a final part of the handshake, a unique session identifier (session ID) is created and exchanged. This session ID serves as a reference for the established session,

allowing for the possibility of session resumption without the need to repeat the entire handshake process if the connection is re-established within a certain timeframe.

3.5 Securing the Connection (Symmetric Encryption Phase)

With the symmetric session key now in place, both the browser and the server transition to the symmetric encryption phase. This phase is characterized by the use of fast and efficient symmetric encryption algorithms—such as AES—to secure all subsequent data transmissions. Because symmetric encryption is less computationally intensive compared to asymmetric encryption, it is ideal for continuous, real-time data exchange. In addition to encrypting the data, hash functions like SHA-256 are used to generate message digests that ensure data integrity. This means that any alterations or tampering with the data during transit can be detected immediately, preserving the accuracy and reliability of the communication.

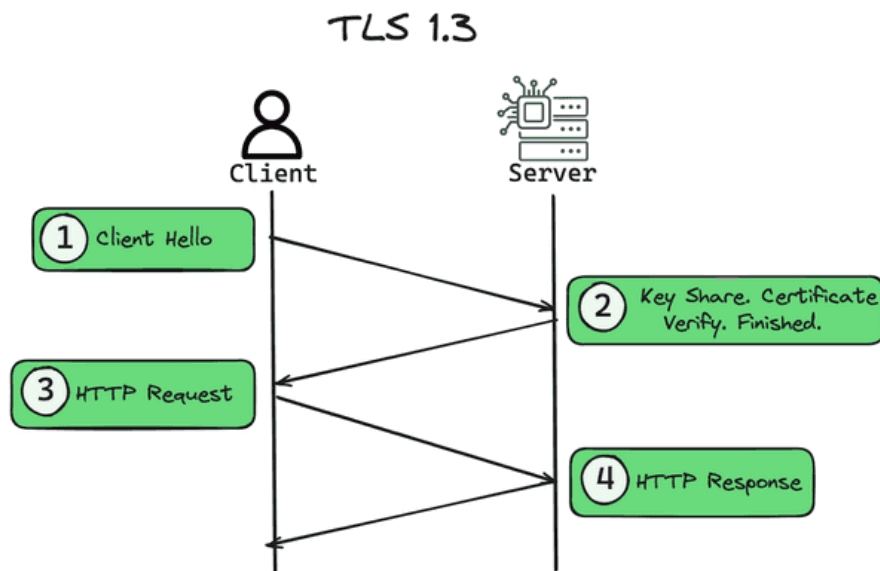


Fig 3.4 TLS Handshake Process

CHAPTER 4

IMPACT ON SOCIETY, ENVIRONMENT AND DOMAIN

Historically, older versions of SSL were susceptible to several critical vulnerabilities that severely undermined the security of digital communications. Notable among these were POODLE, BEAST, and the infamous Heartbleed bug. Each of these vulnerabilities exploited inherent weaknesses in SSL/TLS protocols or their implementations, exposing sensitive data and eroding trust in online interactions.

4.1 POODLE: Exploiting the Flaws in SSL 3.0

POODLE, which stands for “Padding Oracle On Downgraded Legacy Encryption,” was a significant vulnerability that exploited a flaw in the SSL 3.0 protocol. SSL 3.0 used block cipher encryption, where data was divided into fixed-size blocks, and padding was added to ensure that the final block was complete. POODLE took advantage of the fact that SSL 3.0’s padding mechanism could be manipulated by an attacker. By repeatedly sending specially crafted messages and analyzing the server’s responses, an attacker could gradually reveal parts of the encrypted data.

This vulnerability was particularly insidious because it allowed adversaries to force the use of older, less secure protocols—even when more secure options were available. The threat posed by POODLE was a catalyst for the rapid deprecation of SSL 3.0 and underscored the urgent need for an improved protocol that could withstand such attacks.

4.2 BEAST: Targeting TLS 1.0’s Encryption Method

Following POODLE, the BEAST (Browser Exploit Against SSL/TLS) attack emerged as another critical threat, this time targeting TLS 1.0. Although TLS was introduced to replace SSL and enhance security, early versions of TLS were not immune to vulnerabilities. BEAST exploited weaknesses in the way TLS 1.0 implemented encryption by leveraging a flaw in the cipher-block chaining (CBC) mode. Attackers could intercept and manipulate encrypted data streams, gradually deciphering sensitive information such as session cookies

By exploiting this vulnerability, BEAST demonstrated that even improvements over SSL were not sufficient to guarantee security. The success of the BEAST attack spurred significant changes in the cryptographic community, prompting the development of countermeasures and leading to the adoption of new modes of operation and encryption techniques that would eventually be incorporated into later versions of TLS.

4.3 Heartbleed: The Catastrophic OpenSSL Bug

Perhaps the most infamous of the vulnerabilities, Heartbleed was a bug in the OpenSSL library—a critical component used by millions of websites worldwide to secure communications. The Heartbleed bug allowed attackers to exploit a flaw in the implementation of the TLS heartbeat extension. In a typical heartbeat request, a client sends a small packet to the server to keep the connection alive. Due to a flaw in the code, an attacker could send a maliciously crafted heartbeat message that tricked the server into responding with more data than intended, including portions of its memory.

The implications of Heartbleed were severe: secret keys, usernames, passwords, and other sensitive information could be extracted from a server's memory without detection. The widespread impact of Heartbleed not only led to a massive scramble for security patches but also highlighted the critical importance of regular security audits, rigorous code reviews, and robust development practices in maintaining secure communication protocols.

4.4 The Transition to TLS Certification

The discovery of these vulnerabilities marked a turning point in the evolution of secure communications. In response to the threats posed by POODLE, BEAST, and Heartbleed, the industry moved toward Transport Layer Security (TLS), a protocol designed to address and rectify the deficiencies of SSL. TLS introduced several key enhancements:

- 1. Stronger Encryption Algorithms:**

TLS incorporated more secure encryption algorithms that provided better resistance against brute-force attacks and cryptographic exploits. With improved cipher suites, TLS could offer a higher level of data protection.

- 2. Rigorous Authentication Protocols:**

Enhanced certificate validation processes and more robust methods for establishing trust between clients and servers became a cornerstone of TLS. These measures ensured that the identities of communicating parties were thoroughly verified before any sensitive data was exchanged.

3. Improved Handshake Mechanism:

The TLS handshake protocol was refined to incorporate a combination of asymmetric and symmetric encryption techniques. Initially, asymmetric encryption (using public and private keys) was employed to securely exchange a pre-master secret. This secret was then used, along with nonces from both the client and server, to derive a symmetric session key through a secure hash function (often SHA-256). This session key allowed for efficient and secure symmetric encryption for the duration of the session, reducing the risk of latency and processing overhead that was characteristic of solely relying on asymmetric encryption.

4. Enhanced Resistance to Known Attacks:

By addressing the specific vulnerabilities exploited by POODLE, BEAST, and Heartbleed, TLS has evolved through multiple versions—each iteration incorporating fixes and improvements to thwart these and other emerging threats.

4.5 Broader Impacts on Security and Society

The transition from vulnerable SSL implementations to robust TLS certification has had far-reaching implications. For businesses and organizations, the enhanced security provided by TLS has translated into greater consumer trust and reduced risk of data breaches. This not only protects sensitive information but also minimizes the environmental impact associated with incident recovery and remediation. Furthermore, the widespread adoption of TLS has played a crucial role in safeguarding the integrity of online transactions and personal communications, thereby contributing to a more secure and reliable digital ecosystem.

In conclusion, while the early vulnerabilities of SSL such as POODLE, BEAST, and Heartbleed exposed critical weaknesses in data protection, the evolution to TLS certification has effectively addressed these issues. By integrating stronger encryption methods, rigorous authentication protocols, and improved handshake processes, TLS has significantly elevated

Addressing these concerns demands ongoing research and development efforts to enhance algorithmic fairness, mitigate biases, and ensure equitable outcomes across all demographic groups. the standard of security in digital communications. This report delves into these transformations, highlighting the technological advancements that have reinforced the security of our online world and underscoring the importance of continuous innovation in the face of evolving cyber threats.

To navigate these complexities, regulatory frameworks play a pivotal role in governing the responsible deployment of TLS. Policies must strike a balance between harnessing the technology's benefits and safeguarding civil liberties, advocating for transparency in data usage, and establishing clear guidelines for lawful implementation. Collaboration between policymakers, technologists, and civil society stakeholders is essential to foster informed discourse and shape ethical standards that uphold individual rights while fostering innovation in facial recognition technology.

Despite promises of enhanced security and operational efficiencies, debates persist over TLS societal impact, especially concerning civil liberties and the potential for discriminatory practices. Addressing these concerns requires robust regulatory frameworks and technological advancements to mitigate biases and ensure responsible deployment

CHAPTER 5

CONCLUSION & FUTURE WORK

The evolution from SSL to TLS certification represents a monumental advancement in the realm of online security. Early SSL protocols, while revolutionary at their inception, were eventually outpaced by the increasing sophistication of cyber threats. Vulnerabilities such as POODLE, BEAST, and Heartbleed exposed critical weaknesses, ultimately undermining trust in digital communications. In response, the industry embraced TLS certification, a protocol built on the foundations of SSL but enhanced through advanced cryptographic techniques, rigorous domain validation, and more resilient handshake processes.

TLS has successfully addressed many of the deficiencies of its predecessor by introducing stronger encryption algorithms, improved authentication mechanisms, and dynamic key exchange procedures. This evolution has not only mitigated the risks associated with earlier vulnerabilities but has also set a new standard for secure data transmission across the internet. Through the secure combination of asymmetric and symmetric encryption, TLS ensures that sensitive data remains confidential and unaltered during transmission, even in the face of emerging cyber threats.

Beyond the technical enhancements, the widespread adoption of TLS has had significant societal and economic implications. Businesses now enjoy a higher degree of consumer trust, knowing that robust security protocols are in place to safeguard online transactions and communications. This increased trust has fostered a more secure digital ecosystem, reducing the frequency and impact of data breaches, and ultimately lowering the environmental and financial costs associated with incident recovery.

Looking to the future, as our reliance on digital communication continues to grow, the role of SSL/TLS certification remains more critical than ever. Ongoing research and continuous updates to these protocols are essential to anticipate and defend against new vulnerabilities. The journey from SSL to TLS is a testament to the cybersecurity community's commitment to innovation and resilience, ensuring that as threats evolve, our defenses adapt in tandem.

Facial Recognition

In summary, the transition to TLS certification has fundamentally transformed online security, providing a robust framework that not only protects sensitive data but also underpins the trustworthiness and reliability of modern digital interactions. As we continue to navigate an increasingly connected world, TLS certification will remain a cornerstone of cybersecurity, paving the way for a safer, more secure digital future for everyone.

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