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DN Secure AI: Cyber Threat Discovery Using DNS Traffic Intelligence

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ABSTRACT

Addressing DNS systems is now something that many people do every day. Concerns about DNS cybersecurity have gained traction due to the widespread use of DNS systems. This article presents a viable paradigm for DNS threat awareness. As a technique, the primary DNS risks are first categorized, then defined theoretically, and last shown via examples of how a hacker exploits a particular DNS danger to generate vulnerabilities. To further emphasize the lack of study in this area, we secondly examine relevant publications that have dealt with DNS attacks during the last five years. The third consideration is the industry repute of the DNS threat prevention technologies. In order to demonstrate the usefulness and drawbacks of the chosen DNS threat prevention strategies, experiments are carried out. Based on these benefits and negatives, a technical awareness framework is produced as use guideline, which is seen as the key contribution of this article. The suggested architecture also includes suggestions for enhancing DNS resolution efficiency, security, and privacy from the client's point of view. To measure how well the suggested system works, we use the security triad: availability, integrity, and confidentiality. The main points of this paper are as follows: first, it offers a thorough analysis of DNS threats, making sure each one is understood clearly; second, it provides a dynamic framework for using that framework to defeat DNS threats; and third, it uses Neo4j to connect databases that are rich with information about DNS threats, including CVE, CWE, CAPEC, and CPE, which are provided by MITRE and NIST. The goal of this knowledge graph was to provide a representation of information that could efficiently integrate data from many sources related to DNS risks awareness, a specific area of cybersecurity. So far as we are aware, this is the first paper to offer a framework that enables DNS-over-Encryption protocols. We also created a benchmark that compares different DNS threat prevention methods using the basic security triad: confidentiality, integrity, and availability. Lastly, we made recommendations to enhance the privacy, security, and performance of DNS resolution from the client's point of view.

Cybersecurity, domain name system (DNS) encryption, security policies, knowledge of DNS risks, online security

1. INTRODUCTION

Every facet of modern life is now reliant on the internet. In the world of entertainment, online television platforms have mostly supplanted traditional television stations, digital media files have largely supplanted compact discs, and online electronic games have largely supplanted traditional games, including those that operate offline. Online courses have effectively handled the fast growth in

numerous scientific domains, and electronic learning platforms have become vital to the communication process between instructors and students in the field of education. The internet has become an essential tool for commercial activities in discovering new markets and resources and forming new relationships. Therefore, depending on the internet to execute any kind of business is now practically essential. As a result, Domain Name System (DNS) is the backbone of the internet, enabling users to access the websites they seek. Websites are the backbone of the internet; the Domain Name System (DNS) is the mechanism by which each website is identified. In order to identify machines that may be accessed over the internet, a mechanism called the Domain Name mechanism (DNS) is used [1]. Any malicious actor may easily create packets that match the specifications of the transport protocol as DNS is often sent via UDP/IP. The Domain Name System (DNS) includes resource records that link various types of data to domain names. The need of DNS traffic identification in botnet communication assaults was shown by Al-Mashhadi [2]. The security of DNS is important because firewalls and cyber security defense software often trust DNS packets [3]. ypically, two DNS threads are present: DNS security breaches and hijacks [4, 5]. The goal of a DNS hijack is to trick the user into thinking they are connected to a trusted domain, even when the cybersecurity defense software is letting their traffic through unimpeded. Attacks and abuses of DNS traffic are prevalent, nevertheless. An important part of the network that connects to a malicious domain is, hence, the DNS's security. An exposed DNS query may reveal sensitive information including the IP address, location, and online searches of both the sender and the receiver in the event of a DNS leak.

2. RELATED WORKS

One solution to the typo squatting issue was suggested by Moubayed [7] and it relies on machine learning. They have developed a method that can accurately identify malicious domains. Analyzing the same characteristics in an unlabeled dataset using the K-means clustering technique further validates the observed tendencies. A shorter domain name with fewer unique letters is indicative of a valid domain, according to the data. In addition, the F-score, accuracy, and precision are all improved by the created ensemble learning classifier. Having said that, there are a lot of domains that have been flagged as possibly malicious. So, we use the ensemble learning classifier, and the results reveal that we can keep the same feature statistical trends while reducing the number of domains labeled as possibly suspicious by almost a factor of five. In order to identify denial of service attacks, Hananto [8] presented a system that uses DNS traffic to authenticate DNS DDOS assaults early on and NetFlow activity, which signals DDOS attacks. The model can categorize denial-of-service assaults based on their volume, using metrics like statistical entropy of NetFlow traffic and statistical values of the DNS NXDOMAIN response. Spaulding [9] laid forth a method for proactive detection algorithms to identify botnets' use of harmful domain names. Using the idea of the difference function over the number of NXDomain replies for a given domain with a sliding time frame, the authors constructed a detection technique. As early as 48 hours before registration, their detection method achieved 99% accuracy using DNS traffic from certain TLDs for the precalculated list of domains created by the malware versions known as Conficker. Chau [10] put out CGuard, an adaptive defensive architecture that protects the cache entries that are under assault by only updating them via available high secure channels. It actively detects cache poisoning and seeks to defend them. Using the programmability and flexibility of software-defined networks (SDNs), Mittal [11] introduced a new method for preventing distributed denial of service attacks. The basic idea behind the technique is to send DNS answer packets along the same way that the related DNS request packet used. The evil host that launched the distributed denial of service assault will destroy itself in this manner. Their suggested paper has one drawback: getting DNS replies will take 8 to 9 seconds longer than it does with the existing DNS setup. A solution that can identify and classify DNS tunneling was proposed by Almusawi and Amintoosi [12]. Deccio [14] performed tests to verify DNS security by sending recursive DNS requests to a broad set of servers using different faked addresses. The findings show that the suggested SVM classification approach is effective with a measure of 0.80. Half of the 62,000 networks that the authors examined got the request and responded with a dependable repeat query (4.6%). Out of all the networks that were exposed to scam sources, only 6.2% actually acknowledged the queries. About four thousand DNS server instances were found to be vulnerable to cache poisoning attacks by the authors.

3. MATERIALS AND METHODS

Following the layout in Figure 1, this section lays out the specific actions needed to put the proposed framework into action. Here is a list of the steps: • Researching existing literature to identify potential DNS attacks and the most prevalent dangers to DNS infrastructure; providing examples and explanations

for each threat. Furthermore, the DNS records that are linked to it are also specified.

Table 1. Summary of related works in DNS security.

Work	Problem	Solution
[7] (2018)	Typo squatting vulnerability	Machine learning model to discover DNS typosquatting
[8] (2018)	DNS DDoS attack	Detect DDoS attack by measuring statistical entropy of NetFlow traffic
[9] (2018)	DGA domains	Devised a detection algorithm
[10] (2018)	Cache poisoning	Detect cache poisoning attempts and protect the cache entries
[11] (2018)	DDoS attack	Prevention mechanism
[12] (2018)	DNS tunneling	Detecting DNS tunneling
[14] (2020)	Cache pointing attack	Identifying and testing DNS security
[15] (2020)	DNS over HTTPS	Prevention DNS threats by DoH
[16] (2021)	ARP Poisoning	Preventing ARP spoofing by Static IP table
[17] (2022)	DoH abuse	No solution is provided
[18] (2022)	Information disclosure	Prevention DNS threats by DoH
[19] (2022)	DDoS attack	DoH
[20] (2022)	DDoS attack	No solution is provided

A thorough examination of each strategy is offered, and the procedures for preventing DNS attacks are given. • The characteristics that were retrieved in the previous stage are taken into account while developing

Table 2. The logic components of the proposed method.

Input	Methodology	Output
Related works	Investigate and analysis of the related works	Defining the main DNS threats
DNS prevention methods	Analyze DNS prevention methods	Features of each DNS prevention methods
Features of DNS prevention methods	Evaluation of DNS prevention methods	Prove applicability of the DNS prevention methods
Experiment [21] results	Develop framework to enhance DNS security	Framework
Framework	Evaluations of the developed framework	Evaluations Results

a DNS awareness framework. Table 2 displays the methodology's logical components.

Common Threats of DNS Infrastructure

Investigating the literature to identify the key dangers that may be produced by assaulting the DNS is the first stage in our suggested technique, which is presented in this section. As shown in the section that follows, eleven threats were extracted at this stage.

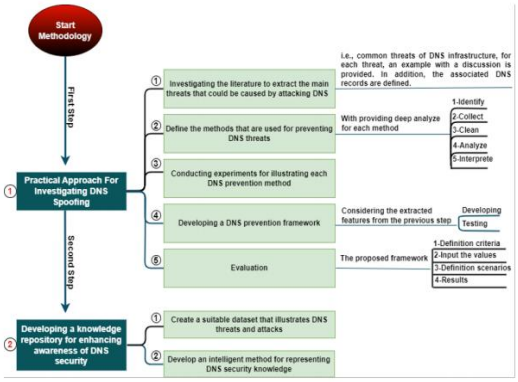

Fig. 1. The steps of the proposed methodology.

Domain name squatting

"Dominant name squatting" refers to when someone registers or uses someone else's trademark in the hopes of profiting from it. Cybersquatters register variants of well-known trademark names using a number of squatting strategies, shown below: One method that is often used to make money online is typosquatting, which targets people who type in web addresses incorrectly (e.g., www.examlpe.com instead of www.example.com) [39]. To collect unintended traffic caused by bit-flip faults in computer memory, some people register domain names with one different bit from popular domain names; this practice is known as "bitsquatting" [40]. For example, you may use youtube-login.com instead of youtube.com, which is an example of combosquatting. The domain name consists of a popular brand name plus one or more words. Its scope was examined by Kintis [41]. Using homophones and the user's bewilderment, one may create squatted domains using the soundsquatting technique. Some examples include idyll, weather, idle, and idol [42]. Domain name squatting leaves users open to several dangers, such as viruses, frauds, monetization, and trademark infringement. The website (gmail[.]com) is the target of many forms of domain name squatting, as seen in Table 3.

Table 3. Example of several types of domain name squatting for the gmail[.]com.

gmail[.]com	Original Domain
gmaill[.]com	Typosquatting
jmail[.]com	Soundsquatting
gmailg[.]com	Bitsquatting
gmail-login[.]com	Combosquatting

AWARENESS FRAMEWORK

Here we provide the suggested framework by outlining the benefits and drawbacks of each DNS threat protection solution that was chosen. With this technical foundation in mind, cybersecurity experts

may implement their strategies to raise awareness about the need of a safe DNS system. The effectiveness of DNS-over-Encryption (DoE) in preventing DNS attacks was investigated in the experiment that was undertaken to evaluate the proposed architecture. In order to do this, we ran a battery of tests to measure how well DoE prevented different kinds of DNS assaults. Based on our findings, DoE successfully blocks man-in-the-middle attacks, cache poisoning, DNS spoofing, and others. By identifying and blocking harmful traffic while allowing normal traffic to continue through, DoE successfully completed all of the simulated assaults. Beyond its attack-prevention capabilities, we discovered that DoE had little effect on DNS system performance as a whole. Using DoE hardly increased the time it took to resolve a domain name, and it had no discernible impact on the total amount of successful inquiries.

Based on the findings, it seems that DoE can effectively mitigate DNS attacks. Testing revealed that it had minimal impacts, and in many cases DoH is faster; the time required to resolve a domain name was only slightly longer when using DoE, and the overall number of successful queries was not significantly affected. Not only does it effectively block malicious traffic, but it also has minimal impact on the overall performance of the DNS system.

Our findings strongly support the idea that DoE is useful in protecting DNS against attacks. Therefore, we advise that people and businesses think about using DoE to secure their DNS infrastructure. The framework is shown in the part that follows:

KNOWLEDGE GRAPH AS AWARENESS TOOL

The steps for creating a knowledge graph are given in this part. For the purpose of raising awareness, MITRE and NIST DNS threat datasets have been made available. The free and open-source program GraphKer loads a comprehensive and up-to-date cybersecurity graph database into Neo4j with a public record of every CVE, CWE, CAPEC, and CPE that is supplied by MITRE and NIST [53].The Neo4j code for data extraction from datasets is shown in Figure 1.

Algorithm 1: NEO4J Code for Extracting Data from Datasets

```
Connect to datasets
If connection
    Collect CVE, CWE, CAPEC, and CPE files
    Collect DNS threats
    Generate f
Else
    Send error
Open Neo4j
If connection
    Insert f to join database
    Update user privileges
Else
    Send error
```

Exploration tools like Neo4j Bloom or Cypher may be used to query the database once all datasets have been loaded. Our database queries for the visual graph examples are written in Cypher Query Language (CQL) and executed using the Neo4j browser. Lastly, we restrict the knowledge network to our study domain's scope (DNS threats) and extract information from related graphs. We created the necessary datasets and they had the following attributes: Publication Year, Reference ID, Author, Title, URL, Publisher, Version, Schema, Date, Name, Status, Resources Required, Description, Likelihood of Attack, Typical Severity, Submission Name, Extended Name, Skills Required, Abstraction, Submission Organization, Modifications, Prerequisites, Submission Date, Mitigations, Examples, Indicators, Notes, Alternate Terms, Scope. The DNS knowledge graph in Neo4j is displayed in Figure 2. One connection in DNS-KG is shown in Fig. 3. Figure 4 displays the Bitsquaitting DNS hijacking attack. Extensive explanations of Figures 2-4 are offered below. Figure 2 shows the Neo4j-connected public records collection for CVE, CWE, CAPEC, and CPE from MITRE and NIST. We loaded data from the MITRE and NIST databases into Neo4j using the Python application GraphKer. Furthermore, we insert the data into Neo4j from a backup file that is routinely published as a Neo4j database. This allows us to efficiently query the data using cypher or explore it using Neo4j Bloom. The connection between our network graph and the described data is shown in Fig. 3. It shows how we automatically update the data in the vulnerability database by connecting the software operating on our devices to the corresponding entries. Because of this, we are able to quickly detect new vulnerabilities and proactively implement appropriate solutions. The capacity to thoroughly investigate relationships is seen in Fig. 4. For example, if we begin with a bitsquatting threat, we can find all the alarms that have been recorded in CAPEC. Then, we can look at all the related metrics to figure out how big the assault may be.

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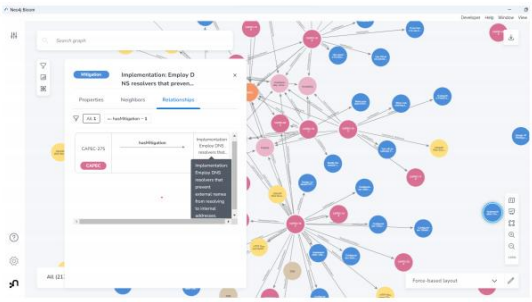


Fig. 2. Knowledge graph of DNS in Neo4j.

Recommended Usages of Cybersecurity Knowledge Graphs

By combining information from several sources, including security logs, vulnerability databases, and threat intelligence feeds, cybersecurity knowledge graphs may help in threat detection and response. Doing so may aid in the early detection of possible dangers and the subsequent mitigation of such hazards. Information regarding events, including the systems impacted, the vulnerabilities exploited, and the actions done to fix the problem, may be centrally stored in cybersecurity knowledge graphs, which can enhance incident response. As a result, events may be responded to more quickly and with less damage. Cybersecurity knowledge graphs provide a holistic perspective of the company's security posture, which may be used for risk assessment and management. By doing so, potential weak spots in the organization's defenses may be identified and addressed.

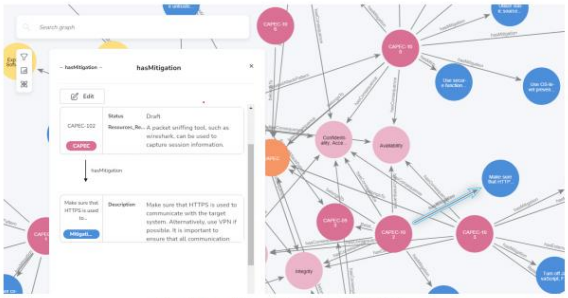


Fig. 3. One of the relationships in DNS-KG.

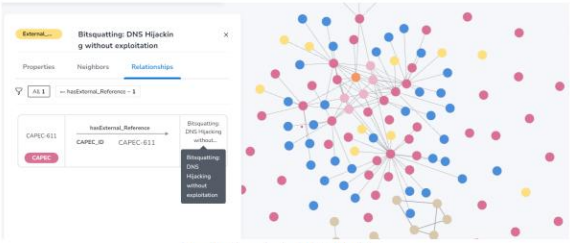
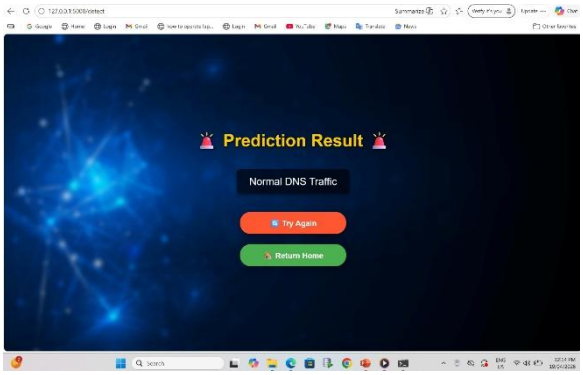
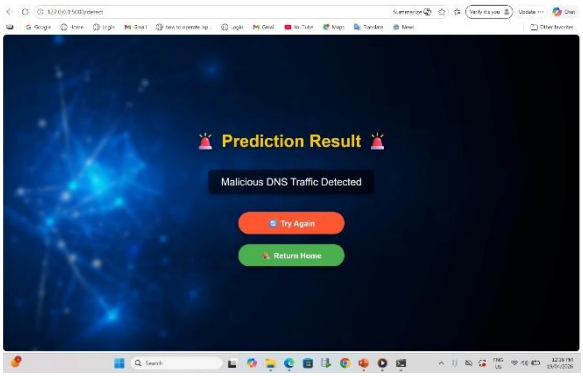


Fig. 4. Bitsquaitting DNS hijacking.

By offering a means to monitor and control compliance needs, cybersecurity knowledge graphs may assist firms in meeting security standards. The company can stay out of hot water with regulators and fines if this is done. Cybersecurity knowledge graphs provide a means of sharing information on security risks and best practices, which may enhance security awareness and training. As a result, staff may be better informed about potential security threats and how to protect themselves.

Results





CONCLUSION

Two methods that successfully protect the domain name system (DNS) are DNSSEC and complementary DNS over encryption (DoE). DoE makes sure that DNS requests and responses are encrypted, which prevents third parties from eavesdropping or intercepting them. Hackers can't divert traffic to malicious websites using this method, and users' privacy is protected. Conversely, DNSSEC augments DNS security by authenticating DNS records and answers, making sure they haven't been changed or tampered with while in transit. To prevent spoofing attacks and ensure DNS data integrity, DNSSEC employs digital signatures and the public key infrastructure (PKI). Consequently, DNSSEC and

DoE work together to safeguard the DNS system against threats and make it reliable. Furthermore, our suggested architecture includes suggestions for enhancing client-side DNS resolution security, privacy, and performance: To boost privacy and security, you may use a DNS-over-TLS (DoT) or DNS-over-HTTPS (DoH) service. These services encrypt DNS requests and answers. Two well-known DoH/DoT services are 8.8.8.8 by Google and 1.1.1.1 by Cloudflare. In order to prevent harmful DNS answers and other dangers, it is recommended to utilize a secure DNS resolver. Some examples of such resolvers include OpenDNS and Quad9. To increase efficiency and filter undesired material, users may use a local resolver like Pi-hole or AdGuard. These resolvers cache DNS responses locally, which helps with performance. • A virtual private network (VPN): VPNs encrypt all data sent over the internet and hide the user's DNS queries and IP address, adding another layer of protection and privacy. There is a lot of buzz about the HTTPS protocol right now. A simple inquiry, "Does DNS over HTTPS satisfy the requirements?" was the impetus for the revolution of secure DNS technologies. For the most part, because HTTP isn't a transport layer protocol, the prior question's response was no. Bypassing a suitable transport protocol in favor of HTTP introduces several security holes, such as the following: ETag tracking, extra fingerprinting chances for malicious actors, HTTP cookies, and other HTTP headers (authentication, user-agent, and acceptance language). Hence. A fresh, workable approach to preventing DNS threats is urgently required.
In this article, we provide use guidelines based on a proposed technological architecture for protecting DNS against attacks. This paper's experiments may be found on GitHub [54]. To showcase our suggested awareness approach, we built a knowledge graph using popular threat datasets from MITRE and NIST, including CVE, CWE, CAPEC, and CPE. These datasets are well-known and include all known DNS threats, therefore our suggested methodology may be used in any situation. The following is a synopsis of the work's contributions: DNS security-related studies are discussed critically and analytically. 2. Every DNS threat is thoroughly examined to provide a clear picture of what they are. If academics and professionals use this work as a reference, they will have a better grasp of DNS risks and their effects. The research gap in combating DNS threats has been brought to light via this analytical evaluation of the associated studies. 3. To help security experts handle DNS risks, we have given a technological framework as use guidelines. Fourth, we present suggestions on how the DNS resolution might be enhanced from the client side in terms of privacy, security, and speed. 5. Another thing we've done is come up with a standard that follows the golden rule of security: confidentiality, integrity, and availability. To compare different DNS threat avoidance solutions, Table 4 is used as a benchmark. Table 4 displays the results of the benchmark assessment.

Table 4. Benchmark evaluation.

Prevention method	Confidentiality	Integrity	Availability
DNSSEC	✗	✓	✗
DNS over TLS	✓	✓	✓
DNS over HTTPS	✓	✓	✓
DNS over QUIC/HTTP3	✓	✓	✓

The scope of this study is narrowly focused on end-user DNS security contributions. Although service providers and institutions have not yet put in place the necessary framework to create an all-encompassing protection system, end users will not be able to put the protection methods outlined in our study into practice without their backing. As an example, DNSSEC is one option. Two, you have to explicitly link Neo4j, the knowledge graph tool, with DNS threats like CVE, CWE, CAPEC, and CPE. Hence, a dynamic, automated solution is required, one that links up with the aforementioned databases and refreshes itself whenever fresh data is available in them. Our final caveat is that we only tested DoE in a controlled context; to find out how well it works in the actual world, further research is required. Lastly, it's possible that DoE isn't able to block all threats, even though this research only looked at the most prevalent DNS assaults.

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