Ethereum Name Service: the Good, the Bad, and the Ugly

PENGCHENG XIA, Beijing University of Posts and Telecommunications, China
HAOYU WANG*, Beijing University of Posts and Telecommunications, China
ZHOU YU, Beijing University of Posts and Telecommunications, China
XINYU LIU, Beijing University of Posts and Telecommunications, China
XIAPU LUO, The Hong Kong Polytechnic University, China
GUOAI XU, Beijing University of Posts and Telecommunications, China

DNS has always been criticized for its inherent design flaws, making the system vulnerable to kinds of attacks. Besides, DNS domain names are not fully controlled by the users, which can be easily taken down by the authorities and registrars. Since blockchain has its unique properties like immutability and decentralization, it seems to be promising to build a decentralized name service on blockchain. Ethereum Name Service (ENS), as a novel name service built atop Etheruem, has received great attention from the community. Yet, no existing work has systematically studied this emerging system, especially the security issues and misbehaviors in ENS. To fill the void, we present the first large-scale study of ENS by collecting and analyzing millions of event logs related to ENS. We characterize the ENS system from a number of perspectives. Our findings suggest that ENS is showing gradually popularity during its four years' evolution, mainly due to its distributed and open nature that ENS domain names can be set to any kinds of records, even censored and malicious contents. We have identified several security issues and misbehaviors including traditional DNS security issues and new issues introduced by ENS smart contracts. Attackers are abusing the system with thousands of squatting ENS names, a number of scam blockchain addresses and malicious websites, etc. Our exploration suggests that our community should invest more effort into the detection and mitigation of issues in Blockchain-based Name Services towards building an open and trustworthy name service.

1 INTRODUCTION

The domain name system (DNS) has already become an indispensable component of the functionality of the Internet since 1980s. It operates like a phone book, i.e., translating human-readable domain names to the numerical IP addresses for accessing other computers or devices under these addresses. DNS is built in a hierarchical and distributed way, which makes the system resilient and scalable. However, DNS has always been criticized for its inherent design flaws, making the system vulnerable to kinds of attacks [51]. A recent report suggested that a group of hackers have launched DNS hijacking attack at least 30 organizations, including government ministries, embassies and security services as well as companies and other groups in Europe and the Middle East [27].

Thus, many efforts were made from both the research community and the industry, aiming to make the DNS system more secure and reliable [12, 13, 15]. For example, the Domain Name System Security Extensions (DNSSEC) is one of the attempts [15]. DNSSEC is a set of extensions to DNS to support cryptographic authentication of DNS data, authenticated denial of existence, and data integrity. However, DNSSEC does not provide confidentiality of data, which means that DNSSEC responses are authenticated but not encrypted. Besides, the signing and checking process of the digital signature will increase the DNS query latency and affect the user experience. Moreover, the

---

*Corresponding Author: Haoyu Wang (haoyuwang@bupt.edu.cn).

Authors' addresses: Pengcheng Xia, Beijing University of Posts and Telecommunications, Beijing, China; Haoyu Wang, Beijing University of Posts and Telecommunications, Beijing, China, haoyuwang@bupt.edu.cn; Zhou Yu, Beijing University of Posts and Telecommunications, Beijing, China; Xinyu Liu, Beijing University of Posts and Telecommunications, Beijing, China; Xiapu Luo, The Hong Kong Polytechnic University, HongKong, China; Guoai Xu, Beijing University of Posts and Telecommunications, Beijing, China.

complexity of implementing and maintaining DNSSEC impedes its adoption, making it hard to be widely deployed in the wild [11].

With the prosperity of blockchain techniques in recent years, researchers are exploring ways to address the issues of traditional DNS by combing blockchain with DNS. Since blockchain has its unique properties like immutability and decentralization, it seems to be promising to build a decentralized name service atop blockchain. Indeed, some blockchain-based DNS (BNS) solutions have already been proposed. For example, Namecoin [42] is claimed to be the first blockchain-based DNS solution, which is a fork of Bitcoin network that offers a new `.bit` top-level domain (TLD) for its names. Similar to Namecoin, UnstoppableDomains [47] and EmerDNS [20] proposed new TLDs like `.zil`, `.crypto` and `.emc`, etc. Handshake [32] takes another way, in which it attempts to replace the DNS root with a more decentralized, secure system. The names on these BNS services can be exclusively owned and managed by their owners, which cannot be taken by the authority (e.g., the government) and can be more affordable to some extent. However, every coin has two sides. The advantages of BNS can be exploited to fulfill malicious purposes. According to a recent study [64], blockchain domain names have been exploited as command and control (C&C) channels by attackers. Furthermore, the domain squatting issues [8] on the BNS services will be more severe than the normal DNS, due to the difficulty of shutting down malicious/phishing blockchain domains.

Ethereum Name Service (ENS) [22] is a decentralized naming service built atop Ethereum [34], one of the most popular blockchains that allows users to create dApps (Decentralized Applications) by developing smart contracts. Different from the aforementioned BNS solutions, ENS aims to propose a complementary solution to DNS by taking advantage of smart contracts on Ethereum to manage the registration and resolution of domain names. It focuses first and foremost on resolving names to web3 resources like blockchain addresses and decentralized websites (dWebs). According to the official announcement [22], it has been integrated by more than 170 popular services including blockchain wallets, dApps and browsers. For example, browsers like Chrome and Firefox have extensions to resolve ENS domain names when users type them into browsers directly. Therefore, ENS has become one of the most popular blockchain name systems in the wild.

Although ENS has been deployed for roughly 4 years, to our best knowledge, it has not been systematically studied in our research community. We are still unaware of the status quo of this emerging name service, especially the security issues and the dark side of the system. There remain a number of unexplored questions, e.g., *how many domain names are registered in ENS? how people are using ENS? whether security issues and gray behaviors are prevalent in ENS?*

This work. In this paper, we take the first step to systematically characterize ENS. To fully understand the registration and resolution process, we first fetch and analyze all the event logs of ENS-related smart contracts and third party resolver contracts (See **Section 4**). At last, we get over 5.6 million event logs. By decoding these logs, we harvest 465, 827 registered names and 107, 617 Ethereum addresses that ever used ENS. Based on this dataset, we perform a detailed analysis of each operating period on ENS (See **Section 5**). We observe that 39.3% of all ENS names are active and 74.4% of users are active (i.e., at least have one name) by the time of our study. We then explore the usage of ENS names by decoding the ENS records and observe that over 67% of record settings are related to blockchain addresses (See **Section 6**). To further examine the security issues of ENS, we have adopted a series of measurement studies (See **Section 7**) to investigate both the traditional security issues (i.e., domain name squatting, malicious domains and scam addresses) and the ENS specific security issue (i.e., name record persistence attack). We obtain the following key findings:

- **ENS is showing gradually popularity during its four years' evolution.** Over 465K ENS names were registered, and 180K of them are active by the time of this study. A number of users are willing to pay high prices for rare ENS names or get as many names as they can.
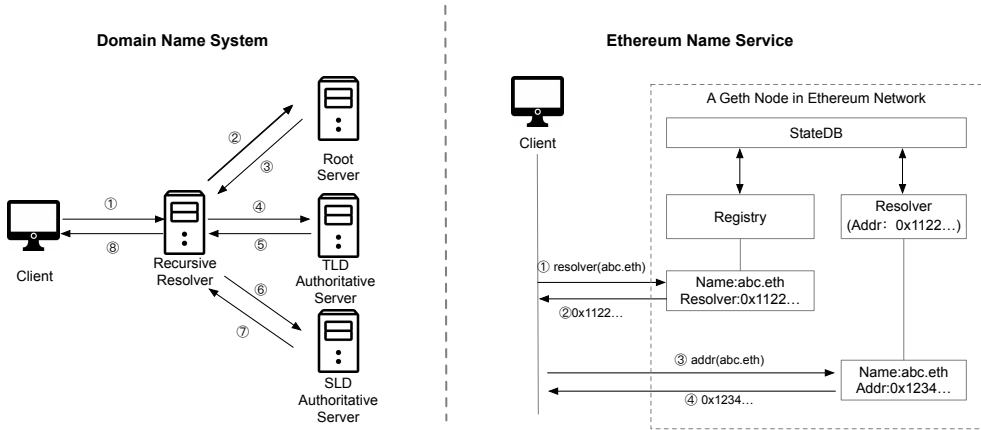
Fig. 1. A comparison of the structures of DNS and ENS.

- **ENS is a fully open system where the ENS domain names can be set to any kinds of records, and ENS is on its way to becoming a complementary system of DNS.** The most common use of ENS name is to link to blockchain addresses, accounting for 67.3% of the record settings. Besides, it is also popular to use ENS names for decentralized websites. We also find that people are exploring new ways to interacting with ENS through text records.
- **The open nature of ENS makes it easy to be abused by attackers.** We have identified several security issues and misbehaviors, including traditional DNS security issues and new issues introduced by ENS smart contracts. A few squatters are found holding a lot of famous brand names and their variants, which could be used for malicious purposes. Some malicious decentralized websites and scam addresses are found in records of ENS names. Besides, record persistence issue is found that may cause potential attacks.

To the best of our knowledge, this is the first comprehensive study of Ethereum Name Service, one of the most promising BNS solutions at scale, longitudinally and across various dimensions. Our results motivate the need for more research efforts to illuminate the widely unexplored BNS systems. We believe that our efforts can attract the focus of the research community and promote best operational practices across BNS solutions. We will release our dataset, along with the experiment results to the research community (link removed due to anonymous submission).

2 BACKGROUND

2.1 Domain Name System and Zooko's Triangle

2.1.1 Domain Name System. Domain Name System is a network protocol that associates domain names with various network information. The most common use of DNS is to map domain names to IP addresses, which will help different kinds of computers and other network resources connect to the Internet or private networks. The DNS mapping is distributed throughout the Internet in a hierarchy authority. A typical DNS resolution process is shown in Figure 1. When a client wants to query for the IP of a domain name, it will first query the recursive resolver. If the resolver has the proper information, it will return the information directly. Otherwise, it will query the root servers which has the information of top-level domains (TLDs), and get the information of the relevant TLD server. Then, a query will be made to TLD server for second-level domain (SLD) authoritative server. After receiving the request, the SLD server could respond the corresponding IP address to the resolver. The whole DNS lookup process can take milliseconds.

Table 1. The 8 type of records in the public resolvers.

Record Type	Description
Address	Can be ETH address or other blockchain address
Name	Used for reverse resolution, i.e., mapping wallet addresses to ENS names
Content Hash	IPFS hash, Swarm hash for dWebs and Tor .onion address hash
Text	Key-value text record, and key can be "email", "URL", "vnd.twitter", etc.
DNS Record	DNS record in wire-format
Pubkey	ECDSA SECP256k1 public key
ABI	Application Binary Interface for interacting with contracts
Authorisation	Granting one address full access to one name except authorisations

However, DNS has been criticized for many years, due to various kinds of vulnerabilities and security issues. For example, due to the lack of authentication and integrity checking in DNS, attacks like DNS cache poisoning and DNS tunneling were prevalent in the network [51]. Besides, DNS domain names are not fully controlled by the users and can be easily taken down by the authorities and registrars. Some efforts like DNS over HTTPS (DoH), DNS over TLS (DoT) and DNSSEC are made to solve or alleviate some of these issues [12, 13, 15]. People also use other solutions like Tor or Invisible Internet Project (I2P) for privacy [39, 46]. Nevertheless, DNS and the aforementioned solutions still cannot achieve *human-readability*, *security* and *decentralization* simultaneously, which is known as Zooko's Triangle.

2.1.2 Zooko's Triangle. Zooko's Triangle [52] defines three properties that an ideal name system should possess: 1) *human-meaningful*, i.e., the names should be readable and can be memorable by human; 2) *secure*, i.e., the names should be translated correctly even when the system is attacked; 3) *decentralised*, i.e., the names should be translated without central authority in the system. The proposer of this triangle, Zooko Wilcox-O'Hearn, also speculated that any name system could only achieve two of these three properties at most. This triangle has been used to evaluate a name system's performance. For example, DNS names are human-readable but the DNS system is not secure and decentralized. Tor is secure and decentralized but its addresses are not human-readable. I2P addresses are human-readable and secure, but I2P is not decentralized. With the rising of blockchain techniques, some blockchain-based name systems have been proposed, which are claimed to fulfill all three properties in Zooko's Triangle [20, 32, 42, 47].

2.2 Blockchain Name Service and Ethereum Name Service

2.2.1 Blockchain Name Service (BNS). Blockchain techniques have raised great concerns since Bitcoin was invented in 2009, leading to the revolution in many fields. Since blockchain has its unique properties like immutability and decentralization, it seems to be promising to build a decentralized name service on blockchain. Therefore, some blockchain-based name services are proposed in recent years. The most common purpose of BNS is to replace the traditional DNS with blockchain-based alternatives. They usually propose new TLDs that are incompatible with the traditional DNS and the Internet Corporation for Assigned Names and Numbers (ICANN). For example, Namecoin [42] is the first blockchain-based DNS, which claims to be the first solution of Zooko's Triangle. It proposes the `.bit` TLD for users and has the ability to attach identity information or human-meaningful Tor domains. Similarly, UnstoppableDomains [47] and EmerDNS [20] also propose some new TLDs. Besides, Handshake [32] is another kind of BNS, which seeks to replace the DNS root with its decentralized, secure system.

2.2.2 Ethereum Name Service (ENS). Unlike the above BNS attempts, ENS aims to be a complementary solution to DNS by integrating with some traditional TLDs. ENS is built atop Ethereum, the
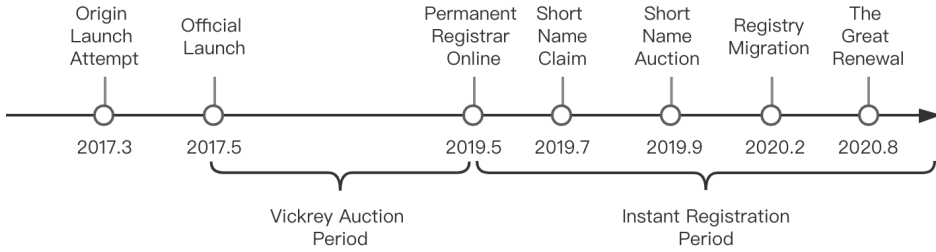
Fig. 2. The timeline of major ENS events.

first blockchain system that supports smart contracts. ENS is controlled by several smart contracts, which can interact with users to register and manage names automatically. Specifically, ENS mainly consists of three kinds of smart contracts: the registry, the registrars and the resolvers [38].

(1) *Registry* stores the mapping of ENS names (of any level) to owners, resolvers and caching time-to-live (TTL) for ENS names' records. In order to avoid trivial enumerations of names during the initial auction (see Section 3.1) and force names with different lengths to be an identifier with fixed length in smart contracts, ENS stores names in the form of hashes of them, which are generated through the process named "namehash". The namehash can be calculated by combining the hash of the highest-level part of ENS domain names (called "labelhash") with namehash of other part and then performing a hash again on it [1]. This algorithm will preserve the hierarchical properties of ENS names. We will describe how we restore ENS names from hash values in Section 4.2.

(2) *Registrar* is a kind of smart contract that owns a name, which can automatically assign subdomain names to users based on some rules (e.g., payment). ENS team has ever used some registrar contracts for `.eth` name registrations, including the Vickrey auction registrar and the permanent registrar. Besides, along with the permanent registrar, the concept of registrar controller was introduced to delegate the name management of name owners. We will detail the registration processes in the Section 3. In particular, users whose DNS names are supported by ENS can claim their DNS names in ENS by proving the ownership through DNSSEC and setting the TXT records containing their Ethereum addresses [3]. TLDs like `.kred` and `.luxe` can be linked with owners' Ethereum accounts directly in their DNS registrars [37].

(3) *Resolver* stores the mapping of names to records. ENS can store arbitrary records while the "public resolvers" implemented by ENS team have predefined eight types of records (see Table 1).

As shown in Figure 1, the ENS name resolution is a two-step process. The user who wants to resolve the name needs to query the registry to find the correct resolver and then get the resolution results from the resolver.

3 THE EVOLUTION OF ETHEREUM NAME SERVICE

As the registration mechanism of ENS is evolving from time to time, in this section, we will detail how ENS works and how ENS names are registered during each stage. According to the official ENS blogs [24], we have summarized the timeline of ENS evolution, as shown in Figure 2. The ENS team initially launched the ENS service in 2017 March while they encountered two severe bugs and the service went offline soon after the launch [25]. After the code revision, they re-launched the service on May 4th 2017, which adopted a Vickrey auction to register names.

---

[1]namehash(example.eth) = keccak256(keccak256(example) + namehash(eth))

3.1 The Initial Auction (Vickrey Auction)

When ENS formally launched on May 4th 2017, the ENS team deployed a smart contract[2] implementing a Vickrey auction for registering names that have a length of more than 6. *Vickrey auction* [48] is a type of sealed-bid auction where bidders submit their bids without knowing how much others have bid and the winner of the auction is the highest bidder while he only needs to pay the second-highest price. Besides, in ENS Vickrey auction, `.eth` names are transferred into hashes (as depicted in Section 2.2.2) to avoid trivial enumeration and names would be gradually released during an 8-week period. These schemes to some extent help people have a greater probability of obtaining the names they want. The Ether paid by a name's bidders will be deposited into a smart contract called "deed" and all the losers of the auction will get a less 0.5% refund[3]. The winner of the name only needs to pay the second-highest price, and she could give up the ownership to withdraw all the Ether she paid after registration for one year. We will perform a detailed analysis on the behavior of this Vickrey auction period (see Section 5.2).

3.2 Permanent Registrar, Short Name Claim and Short Name Auction

3.2.1 Permanent Registrar. After two years of auction, ENS team launched the "permanent registrar" for registering names over 6 in length instead of the auction registrar on May 4th 2019. The permanent registrar aims to run continuously until the registrar contract has to be replaced due to severe deficiency. The charging method of `.eth` names is changed to an annual rent payment model, in which each name needs to be charged 5 US Dollars per year. Along with the permanent registrar, the concept of registrar controller was introduced to delegate the name management of name owners. Thus, a name registered by the registrar controller can set resolver and name records within the registration transaction, which simplifies the registration process.

3.2.2 The Short Name Claim. In July 2019, ENS team opened the reservation of short `.eth` names (names with a length of 3-6), which means that owners of eligible traditional TLD names can request for corresponding `.eth` names and pay rent in advance to obtain the access to their corresponding `.eth` names for one year ($640 in ETH for a 3 character name, $160 for a 4 character name, $5 for a 5-6 character name). An owner of a short second-level traditional name registered on or before May 4th 2019 can claim one of the following names: 1) An exact match of the original name (e.g., `foo.com` to `foo.eth`). 2) Removing the `eth` suffix of original name (e.g., `fooeth.com` to `foo.eth`). 3) Combining the 2LD and TLD of the original name (`foo.com` to `foocom.eth`). Upon application, the ENS team will review the request for validity.

3.2.3 The Short Name Auction. In September 2019, another auction for remaining short names with a length of 3-6 started. The ENS team chose OpenSea [43], a well-known crypto assets marketplace, as the auction platform, and used *English auction* [21] as the auction method. In an English auction, bids are public and bidders can bid multiple times. The bidder who submits the highest price will win the name and the payment he deposited will be the registration fee of the first year, which is quite different from the Vickrey auction period. After the short name auction, the remaining short names will be open for registration at a price based on their length. According to analysis in Section 5.3, there were few DNS name owners claiming corresponding ENS names while many famous brand names are selling high price in short name auction. This could be related to squatting behaviors and we will further investigate it in Section 7.1.1.

---

[2]Address:0x6090a6e47849629b7245dfa1ca21d94cd15878ef (Etherscan label: "ENS: Old Registrar")
[3]The deed contract would burn 0.5% of the paid Ether in order to create a cost for large amount registration and for registering valuable names

3.3 The Great Renewal

Since ENS introduced the "permanent registrar", expiration and renewal mechanisms like traditional domain names were also introduced into this decentralized naming service. Currently in ENS, all the `.eth` names are charged annually based on their name length and anyone can renew any `.eth` names no matter whether they own the name or not. For old names registered through the Vickrey auction, they were set to expire on May 4th 2020 if not renewed. Besides, all the `.eth` names will have a 90-day grace period after expiration where payment can be made to keep the ownership.

Thus, due to a large number of names were registered in the Vickrey auction period, most of the names will be expired on May 4th 2020 (actually expired on August 2nd considering the 90-days grace period) and the renewal period around August 2020 was called "The Great Renewal" [30]. To avoid massive squatting behaviors and gas competition for registration priority, the ENS team carried out the "decaying price premium" [10], where the price of expired names will start at $2,000 combining with normal annual rent and will decrease linearly to normal annual rent in 28 days.

4 STUDY DESIGN

We present the details of our measurement study on ENS in this section. We first describe the research questions, and then present how we collect the ENS data used for our study.

4.1 Research Questions

Our study aims to understand the status quo of the ENS ecosystem, and investigate the security issues. To this end, our study is driven by the following research questions (RQs).

RQ1 **Popularity of ENS.** Considering ENS has been launched over 4 years and its purpose is to be complementary to DNS, it is thus necessary to investigate its popularity, i.e., *how many domain names are registered, and how many addresses are involved in ENS?* The results could shed light on the adoption level of ENS in the community, which will be studied in Section 5.

RQ2 **Usage of ENS.** Considering the unique features provided by ENS, it is unknown to us *how people are using ENS except for the explicit address translation.* Therefore, it is interesting to analyze the records of all the ENS names. This RQ will be answered in Section 6.

RQ3 **Security Issues of ENS.** Since no existing work has systematically analyzed the security issues in the ENS ecosystem, it is important to understand *whether security issues (both traditional DNS security issues and new emerging ENS specific issues) are prevalent in ENS, and how severe are them.* The observations could offer implications for the design of blockchain-based name services. We will explore the security issues and misbehaviors in Section 7.

4.2 Dataset Collection

It is non-trivial to harvest all kinds of information related to ENS. First, ENS stores ENS domain names (ENS names for short, the same below) in the form of hash values so that we cannot get their human-readable names directly. Second, ENS has multiple resolvers (including third-party resolvers) and they use different types of protocols to encode records in ENS names. Thus, we follow a hybrid workflow to extract comprehensive information on ENS, which is shown in Figure 3. Our dataset collection contains three major steps.

4.2.1 Collecting ENS-related smart contracts. The first step is to collect all ENS official smart contracts that are highly related to core functions of ENS (e.g., name registration and name renewal). Thus, we resort to Etherscan [26], a commonly used Ethereum explorer, to search for related contracts. Etherscan has labeled 28 ENS official smart contracts with human-meaningful names. For
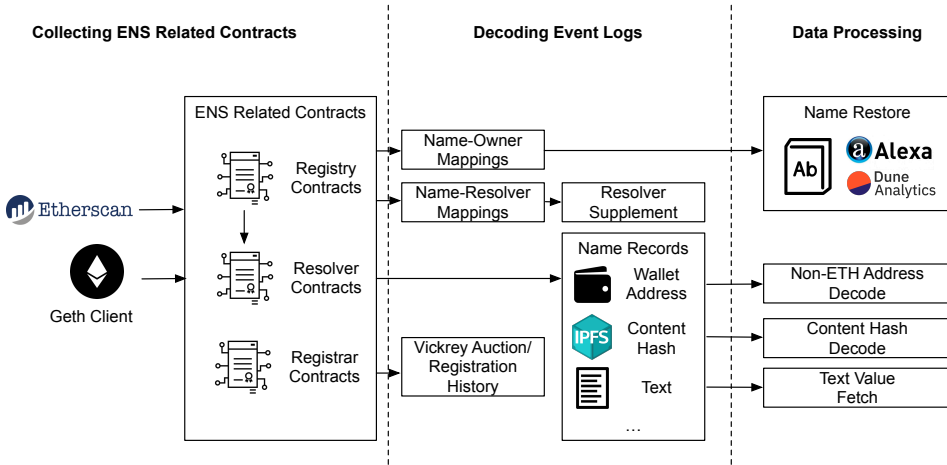
Fig. 3. The workflow of our data collection.

example, the contract used for Vickrey auction[4] is labeled as "Old Registrar". Note that some smart contracts are not related to the core functionalities of ENS, e.g., the "Multisig" contract is used for effect administrative changes. Thus, we only focus on the aforementioned three types of smart contracts that are related to the resolution of ENS, including registry contracts, resolver contracts, registrar contracts (including registrar controller contracts and a short name claim contract). We manually analyzed all these contracts and labelled 14 of them.

4.2.2   Decoding Event Logs. After collecting related contracts, we take advantage of Geth [29], a well-known Ethereum client to synchronize the ledger of Ethereum. Specifically, in order to get the state changes of each contract, we extract event logs[5] from the ledger. Then, since ENS official contracts are open-sourced on Etherscan, we fetch the Application Binary Interface (ABI) [6] of each contract and decode event logs based on their ABIs. Thus, we get name-owner mappings, name-resolver mappings from registry contracts, obtain name records history from resolver contracts, and collect auction/registration history from registrar contracts. Furthermore, in name-resolver mappings, we find that lots of names are pointed to additional resolvers. Thus, we further make effort to include open-source extra resolvers, fetch their event logs, and decode them based on their ABIs, which is shown in Table 7 of Appendix.

4.2.3   Data Processing. In the decoded event logs, some information like Vickrey auction history can be directly used for further research. However, some additional data processing tasks are still needed due to the design of these contracts. Specifically, we need to get the unhashed ENS names from name-owner mappings, decode non-ETH wallet addresses and content hashes based on their encoding rules and fetch the values of text records from corresponding transactions.

As stated in Section 2.2.2, ENS smart contracts store hash values of ENS names instead of names themselves, thus we take efforts to restore these hash values to readable names. First, ENS developers uploaded their name-hash dictionary to Dune Analytics [16], a platform for querying, extracting and visualizing Ethereum data. We fetch the dictionary from the website and update our database based on it. Moreover, we generate the labelhash based on a list of over 460K English words and Alexa [2] top-100K domain list (downloaded on Sept. 18th 2020) and match them with

---

[4]Address: 0x6090A6e47849629b7245Dfa1Ca21D94cd15878Ef
[5]Event logs will record the major activities of smart contracts and this will help track smart contracts' behaviors.
[6]ABI encodes how to interact with the functions of a smart contract.

Table 2. An overview of the ENS event logs we collected.

Contract Type	Etherscan Name Tag	Address	# of event logs
Registry	Eth Name Service	0x314159265dD8dbb310642f98f50C066173C1259b	1,097,965
	Registry with Fallback	0x00000000000C2E074eC69A0dFb2997BA6C7d2e1e	944,486
Registrar	Base Registrar Implementation	0x57f1887a8BF19b14fC0dF6Fd9B2acc9Af147eA85	1,135,019
	Old ENS Token	0xFaC7BEA255a6990f749363002136aF6556b31e04	337,071
	Old Registrar	0x6090A6e47849629b7245Dfa1Ca21D94cd15878Ef	1,979,316
	Short Name Claims	0xf7C83Bd0c50e7A72b55a39FE0DABF5e3A330d749	883
Registrar Controller	Old ETH Registrar Controller 1	0xF0AD5cAd05e10572EfcEB849f6Ff0c68f9700455	14,976
	Old ETH Registrar Controller 2	0xB22c1C159d12461EA124b0deb4b5b93020E6Ad16	20,827
	ETHRegistrarController	0x283Af0B28c62C092C9727F1Ee09c02CA627EB7F5	57,483
Resolver	OldPublicResolver1	0x1da022710dF5002339274AaDEe8D58218e9D6AB5	14,997
	OldPublicResolver2	0x226159d592E2b063810a10Ebf6dcbADA94Ed68b8	19,510
	PublicResolver1	0xDaaF96c344f63131acadD0Ea35170E7892d3dfBA	2,603
	PublicResolver2	0x4976fb03C32e5B8cfe2b6cCB31c09Ba78EBaBa41	61,410
	Additional Resolvers	–	110,869

the hashes in registry event logs (this data is also used in Section 7.1.1 for identifying squatting names). Besides, the "NameRegistered" and "NameRenew" events of new ENS registrar controllers contain the plain texts of newly registered names and we simply add them to our database.

For the name records, since non-ETH addresses and content hashes have been encoded for uniformity, we decode them based on the rules in EIP-2304 [18] and EIP-1577 [17][7]. For the text records, as stated in EIP-634 [19] and in ENS docs [38], the event logs of them only contain the keys but not the values. Thus, we resort to the transaction data related to these event logs from the Ethereum ledger and decode them based on ABIs to get the text values.

4.3 Dataset Overview

The dataset collection is a complicated and time-consuming process, since we need to cover all the cases to create a comprehensive dataset. At last, we get all the ledger information until block $10,746,639$ (i.e., 2020-08-28 03:03:42 UTC) on Ethereum. The overall statistics is shown in Table 2. In total, we get over 2 million registry logs, 3.4 million registrar logs, and 200 thousand resolver logs. In addition to event logs, we also fetch and decode over $3,000$ transactions related to text records. We find $465,827$ ENS names in the registry records[8]. Besides, we restore 373,950 names (including 323,255 .eth names, which accounts for 86.6% of all .eth names) in total. To the best of our knowledge, it is the largest preimage ENS name dataset by the time of the study, which is even larger than the dataset provided by the official team.

5 GENERAL OVERVIEW OF ETHEREUM NAME SERVICE

In this section, we will first depict the general overview of ENS, and then perform a deep analysis on each phase during the evolution of ENS.

5.1 Overall Statistics

5.1.1 Overview. Table 3 shows an overview of the $465,827$ ENS names. $107,617$ addresses have ever participated in the registration of ENS .eth names, and by the study time there are over 183K

---

[7]Hashes in old resolvers' "ContentChanged" events are treated as Swarm hashes as they did not have a uniformed format.
[8]We exclude ENS top-level domain names' (TLDs) records and reverse resolution names because our study is focused on second and higher level ENS names.

Table 3. The distribution of ENS names. Note that, the .eth subdomain owners of expired parent names and expired DNS name owners still have control over their ENS names, which are considered as active ENS names.

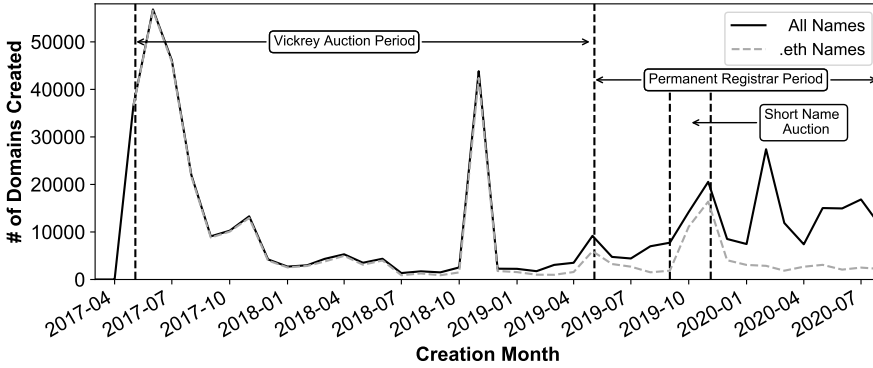| Category	# of Names	Category	# of Names
`.xyz` Names	96	Total ENS Names	465,827
`.club` Names	1	`.eth` Names	373,241
`.luxe` Names	1,914	Unexpired `.eth` Names	90,576
`.art` Names	27	Expired `.eth` Names	282,665
`.kred` Names	216	`.eth` Subdomain Names	90,332
DNS Integrated Names	**2,254**	**ENS Names by Study Time**	**183,162**

Fig. 4. The monthly distribution of ENS names' registrations.

active names, which are related to 74.4% of addresses $(80, 081)$[9]. Besides `.eth` names, there are also $2, 254$ DNS names[10] involved in the registration of ENS, which to some extent shows one of the ENS's vision of being complementary of DNS service [23].

5.1.2   The evolution of ENS names. Figure 4 shows the monthly registration. We use the first block time of "NewOwner" event of names as their first registration time, and the figure shows the trend of ENS names (all ENS names and `.eth` names) registered for the first time each month. The ENS team once started their service in March 2017, but they encountered two severe bugs and the service went offline [25]. Thus, only basic ENS names like `.eth` or `addr.reverse` were registered on March 2017 and were deregistered soon. On May 4th 2017, ENS relaunched and the first ENS name registered on May 9th (after a 5-day auction period) is `rilxxlir.eth`. The first 7 months after the launch witnessed people's enthusiasm for holding ENS `.eth` names, when $192, 471$ names (51.6% of all `.eth` names) were registered. There is a peak in November 2018, when $43, 832$ were registered. In this month, 4 addresses registered a large number of Chinese pinyin names (e.g., `tianxian.eth`) and names composed of date or numbers (e.g., `20140409.eth`), which resulted in them ranking 2-5 in the registration numbers of the auction period. On May 4th 2019, the ENS team launched a new registration registrar instead of the old auction process. The number of registrations increased slightly until the short name auction started from September to November. The short name auction also affected the registration of other names in October and November[11]. In February, Decentraland, a decentralized virtual reality platform, created over 12K subdomain names for their own naming system [35], which led to a rise in the numbers of names.

---

[9]The owner data is different from ENS home page, which uses the data created by the official in DuneAnalytics. We have checked the source code on it and find its problem, which is confirmed by ENS official team.
[10]ENS introduced traditional DNS TLD `.ceo` on August 26th 2020, and it has no related names in our dataset.
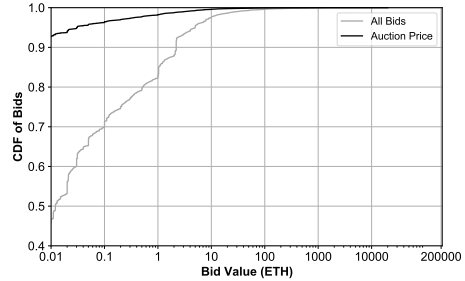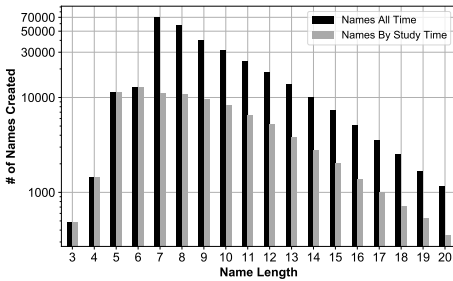[11]The auction period lasted more than 1 month.

Fig. 5. The distribution of `.eth` names' lengths.   Fig. 6. The distribution of bids and auction price.

5.1.3   The owners of ENS names. We track every events related to ownership changes of `.eth` names from ENS registry (i.e., "NewOwner" and "Transfer" events) and analyze the number of `.eth` names held by each addresses. These 373K ENS `.eth` names were ever owned by 42, 154 Ethereum addresses. Over 35% of the addresses have more than one names by the time of this study, indicating that although ENS now has an annual fee mechanism on `.eth` names, there are still a large amount of users holding numerous `.eth` names. The top-10 name owners by the time of this study are shown in Table 8 in Appendix. These top-10 holders have roughly 10% of current registered `.eth` names and it can be inferred that these top holders tend to keep the names they registered for future benefits. The address that holds most names is `0xbcbd4885ee8b2b74249c5ad9b8b668fb256a51b1` with 2,262 names, which registered many words in dictionary (e.g., `plead.eth` and `height.eth`) and famous brands (e.g., `disneyplus.eth`). This address and some other top holders are suspicious to involve in squatting behaviors, which will be analyzed in Section 7.

5.1.4   The length of names. We further analyze the popularity of `.eth` names of different lengths with restored ENS names. Figure 5 shows the distribution of `.eth` names whose length is under 20. ENS initially only accepted name registration with a length larger than 6 and opened shorter name registration after claim and auction. Besides, currently names with a length of less than 5 will be charged more than $160 annually. This explains why `.eth` names that have a length of larger than 6 are more popular. By the time of the study, names with a length ranging from 5 to 8 account for 50.4% of unexpired `.eth` names, which are the major choices of registrations. There have been 2, 705 `.eth` names whose length is over 20 and the longest name has 242 characters of "a".

5.2   The Initial Auction (Vickrey Auction)

5.2.1   Overview of Vickrey auction. In this period, there were 361, 751 names that have been bid. Among them, 274, 052 names were registered with 338, 252 valid bids by 17, 625 addresses. Note that over 80K names did not finish the auction process or the auctions were cancelled due to their short name length found by other users. Figure 6 shows the distribution of the bids and the final auction price. Interestingly, 45.7% of the bids are 0.01 ETH while 92.8% of the auction names valued 0.01 ETH. The highest bid was 201, 709 ETH for `ethfinex.eth` while its auction price is 0.01 ETH.

5.2.2   The most valuable names. The top-10 valuable names in the Vickrey auction are shown in Table 9 of Appendix. The most valuable name is `darkmarket.eth`, which cost the winner over 20K ETH (about $ 5 million). This owner of the name[12] also registered another three valuable names including `openmarket.eth`, `tickets.eth`, and `payment.eth`. The owner is said to be an address

---

[12]`0x8759b0b1d9cba80e3836228dfb982abaa2c48b97`

Table 4. The top-10 popular names and expensive names during the short name auction.

Name	# of Bids	Price in ETH	Name	# of Bids	Price in ETH
amazon	36	100	asset	83	30
wallet	51	75	banker	78	10.5
google	47	52.9	durex	70	1.4
apple	67	51	apple	67	51
sex	44	41	lawyer	66	7.1
porn	44	40	hotel	60	20
com	16	39.8	pussy	58	8
dapp	34	38.7	kering	58	1.4
loan	30	38	foster	58	1.1
jobs	22	35.4	poker	57	33.5

of a well-known cryptocurrency exchange, Bitfinex [6]. Note that 7 of these names had not set any records by the time of this study, indicating that they may be used for squatting purposes.

5.2.3   The holders involved in ENS Vickrey auction. Table 10 in Appendix shows the top-10 name holder addresses and top-10 addresses that spent the most during this period, which do not overlap with each other at all. For name holders, each of the top-10 name holders registered over 2, 000 names, while last 9 of them each spent under 150 ETH in total and the top name holder *0xa7f3659c53820346176f7e0e350780df304db179* ranked 15 among the top spent addresses. For top-10 spent addresses, they each spent over 2, 500 ETH on relatively few names. This suggests that there are two straightforward strategies when people bid for desired ENS names. Some people tended to register as many names as they can with low prices while some other people preferred to bidding for few high-value names that worth lots of money.

5.3   Permanent Registrar, Short Name Claim And Short Name Auction

5.3.1   The Short Name Claim. During this period, 344 requests were submitted and 193 were approved. Among the applications, some famous traditional sites like nba.com, paypal.cn, ebay.net, opera.com and infura.io applied and got the corresponding .eth names, indicating that ENS has received attentions beyond the blockchain community.

5.3.2   The Short Name Auction. Since this auction took place in OpenSea and the details of this auction are not shown in the ENS contracts' event logs, we take advantage of the data shared by OpenSea in ENS blog [41] to analyze the trends of the auction this time. In total, there are over 50K bids and 7, 670 names were sold for 5, 697 ETH during this auction. The price distribution is shown in Figure 7. Roughly 10% of the names have a price of over 1.5 ETH (about $594 by study time) and over 22% of the names were bid for over 10 times. The top-10 popular names and expensive names are shown in Table 4. It is not surprising to see that famous companies like "apple", "google", "amazon" and terms related to sex like "sex" and "porn" are in the popular name list, and we can also find that some blockchain-related ENS names like "assets" and "dapp" have also become the hot pursuit of people. Compared with the name price in the Vickrey auction period, the name price in the short name auction tend to be relatively low since users need to pay the bids actually instead of depositing the payments in the deeds. Considering that there were few brands claiming their corresponding .eth names in the short name claim period, it is possible that bad actors bid for famous brand names and use them for malicious purposes. We will further investigate whether there are some squatters targeting at ENS in Section 7.1.
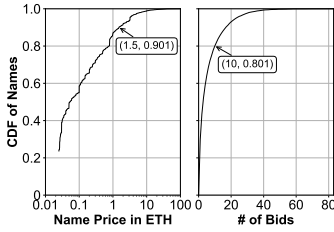
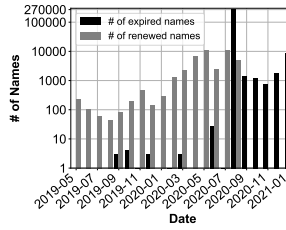Fig. 7. The distribution of short names' price and bids.

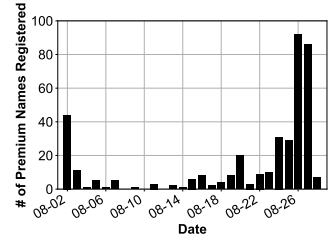Fig. 8. The distribution of expired names and renewed names.

Fig. 9. The distribution of premium name registration.

5.4 The Great Renewal

Figure 8 shows the distribution of expired names and renewed names (status by the time of the study). Note that we take the 90-day grace period into consideration. It can be seen that, most of the names were expired in August 2020 and the renewals occurred mainly around August 2020.

Figure 9 shows the distribution of 389 premium name registration. There were 44 premium names registered on the first day (August 2nd), suggesting that they were registered with almost full premium. For example, decentralised finance (DeFi) related ENS names like makerdao.eth and balancer.eth were registered almost once upon these ENS names released. As design, the first batch of names will be available for registration without premium on August 30th, and that is the reason why we see a spike around the end of August. To some extent, this premium method gives people a greater chance of obtaining the names they strive.

> **Answer to RQ1:** *ENS is showing gradually popularity during its four years' evolution. Over 465K ENS names were registered and 180K of them are active by the time of this study. A number of users are willing to pay high prices for rare ENS names or get as many names as they can.*

6 THE RECORDS OF ENS NAMES

Next, we analyze how people are using ENS names. As aforementioned, besides linking to Blockchain addresses, ENS also provides functions for users to upload text records, web3 content hash, etc.
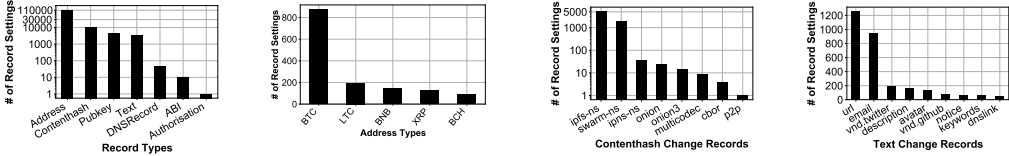
6.1 Overview of ENS records

After decoding the fetched resolver event logs, we find that over 140K names have been set records over 170K times. Figure 10(a) shows the distribution of record settings. It can be seen that the most widespread use of ENS is as alternatives for blockchain addresses, which accounts for over 67.3% of total record changes. Other records include content hash records, public key records text records, etc. The distribution of names that have records is shown in Table 5. It is interesting to see that only 22% of the names have ever had records and .eth names, only 12% (31% unexpired) names have records. In ENS, an address can set multiple records. Specifically, the records could at most contain different blockchain addresses, text records with different keywords and other single records. Table 5 also shows the distribution of the record counts per name. Most names have one record and 98% of records are Ethereum addresses. The names that have most records are brantly.eth and brantly.xyz, which are names of one of ENS developers and are each set 9 text records, one content hash record, and 15 blockchain addresses records.

Table 5. The distribution of names that have records and records per name.

Name Type	# of Names	# of Records Per Name	# of Names
Name that has records	102,557	1	93,361
.eth name that has records	44,297	2	8,353
Unexpired .eth name that has records	27,812	3 - 25	843

6.2 The use of Blockchain address records.

Most of the address settings are relevant to Ethereum and BTC addresses. The former has $114,542$ setting records while the latter has 873 setting records. The distribution of top-5 non-ETH addresses is shown in Figure 10(b). Other types of addresses are set less than 200 times. It can be inferred that although addresses on other blockchains are supported, there are still few people taking advantage of ENS for purposes other than Ethereum addresses.

(a) The distribution of ENS names' records

(b) The distribution of top-5 non-ETH addresses.

(c) The distribution of content hash records.

(d) The distribution of top-9 text records.

Fig. 10. The distribution of all records types and three major record types.

6.3 The use of content hash records

Another major use of ENS is to store content hashes, and roughly $5,300$ names have ever been set to content hash records. Thus, we further analyze how people use these hashes. There are roughly $2,700$ names with non-empty values and the distribution is shown in Figure 10(c). Most of the content hashes (98%) are set for IPFS and Swarm, two prominent solutions for decentralized publication and storage. Specifically, the "ipns-ns" hashes are used for InterPlanetary Name System (IPNS), which is designed for mutable contents [36]. Besides, a few names have been set for Tor .onion addresses while 10 of them have been set by ENS team [40]. For other records, our manual inspection suggests that they are all malformed IPFS hashes. For example, the eight "multicodec" hashes are generated by one user through the way of encoding IPFS hashes twice. The results show that ENS still has some room for dWeb resolutions. We will further investigate the malicious dWebs in Section 7.2.

6.4 The use of text records

ENS allows users to set arbitrary text records in the form of key-value records with pre-defined keys at the same time. We perform an analysis on the keys of text records after excluding empty values, the top-9 of which are shown in Figure 10(d)[13]. Most settings are for URLs, and we find that half of the history records are set to subdomains of OpenSea, suggesting that these names were for sale. Other URLs are used for official sites (e.g., `tokenfactory.global`), personal blog sites (e.g., `marvin-elsen.com`), etc. Besides predefined keywords like "vnd.twitter" (Twitter accounts)

---

[13]The EIP-634 for text records updated on 2021 Jan. 27th, some of these keywords like "vnd.twitter" may be replaced by another keyword later.

and "description" (description for names), etc., there are also some customized keywords in text records. For example, the "dnslink" records are mainly used by DAppNode [9] for their dWebs and the "gundb" records are used for GunDB [31], a P2P database. We identify 44 customized keywords in 214 record settings, indicating that people are exploring new ways to interacting with ENS. We will further analyze security issues related to URL records in Section 7.2.

> **Answer to RQ2:** *ENS is a fully open system where the ENS domain names can be set to any kinds of records. The most common use is for linking to blockchain addresses, which accounts for 67.3% of record changes. Besides, it is also popular to use ENS names for dWebs and traditional websites, etc. We also find that people are exploring new ways to interact with ENS through text records. It suggests that ENS is on its way to becoming a complementary system of DNS.*

7 SECURITY ISSUES AND MISBEHAVIORS ON ENS

In the following, we are committed to investigating whether there are any security issues on ENS, including both traditional issues and new issues introduced by the nature of ENS. For ENS names, we design an approach for searching and identifying possible *squatting ENS names*, which is a common issue in traditional DNS (see Section 7.1). For ENS name records, we are interested in whether there are *malicious addresses or websites* set in ENS names, which corresponds to DNS malicious websites (see Section 7.2 and Section 7.3). In particular, since ENS supports resolutions to dWebs that cannot be taken down easily, we also resort to ENS content hash records to find if there are malicious dWebs. Besides, since DNS and ENS have different designs, we take efforts to check *whether the design of ENS would increase the attack surface* (see Section 7.4).

7.1 Domain Squatting

Domain squatting is an act of registering domains with the same or confusingly similar names with famous landmarks, which is usually used for malicious intents. Domain squatting issues have been extensively studied in traditional DNS. To understand whether this common malicious act is prevalent in ENS, we analyze the registered ENS domain names from three perspectives. First, different with the domain squatting on DNS, where famous brand names with most TLDs are registered by brand owners, the .eth TLD introduced by ENS is a new namespace. As mentioned in Section 5.3, there are few brand claiming their .eth names, which leaves room for explicit domain squatting. Second, as observed in previous research on DNS [74], attackers tend to use domain typo-squatting methods to register domain names that are similar to well-known DNS domains. Thus, the same methods could be exploited to register ENS names. At last, since ENS introduced new .eth TLDs, squatters are more likely to register more ENS names besides the top domain names in the Alexa list. It is interesting to investigate how many squatters have taken such actions.

7.1.1 Explicit Squatting of Known Brands. As stated in Section 4, we have taken advantage of Alexa top-100K name list to match each level of ENS names. In other words, we calculate the labelhash (keccak256 hash of the name, see Section 2.2.2) of each 2LDs in Alexa list and match them with each labelhash in ENS names[14]. Among top-100K names in Alexa, there are 18, 233 top Alexa names that could be found in ENS native 2LDs, i.e., we find that 18, 233 ENS .eth names (only 31 of which were claimed in short name claim period) have the same names with names of Alexa list in total. Note that, not all matching ENS names are squatting names since the name could be registered by the actual owner. Here, our heuristic is that, if one Ethereum address owns more than one known ENS

---

[14]To remove possible false positives, we exclude 119, 764 Alexa names and 15, 701 typo-squatting variants that have a length of less than 4.
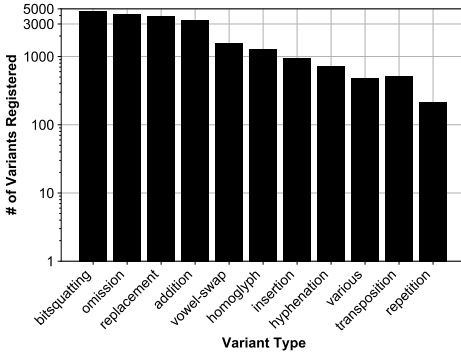
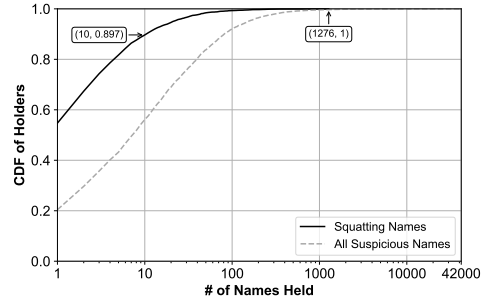Fig. 11. The distribution of squatting variant types.

Fig. 12. The ENS squatting/suspicious name distribution of ENS name holders.

names (e.g., `google.eth` and `facebook.eth`) that belong to different owners in their DNS domain names, we consider these `.eth` names of known brands are explicit squatting names. For example, the address `0x782cf6b6e735496f7e608489b0c57ee27f407e7d` have registered `google.eth`, `mcdonalds.eth`, `redbull.eth`, etc., and these brands are not belonging to the same owner. Thus, we believe this address is involved in the explicit ENS name squatting.

Through this way, 15, 179 ENS `.eth` squatting names controlled by 1, 532 Ethereum addresses are found. Top-10 holders are shown in Table 11 of Appendix. Many famous brands were registered for squatting. Among these explicit squatting ENS `.eth` names, over 42.7% of `.eth` names are active now, suggesting that some attackers tend to hold these explicit squatting names for a long time.

7.1.2 Typo-Squatting ENS Names. To detect typo-squatting ENS names, we take advantage of dnstwist [14], a widely used tool to generate typo-squatting variants of Alexa top-100K names. Dnstwist can generate 12 kinds of squatting variants. Taking domain `google.com` as an example, dnstwist can generate 1, 982 variants on this domain through different methods, such as addition (e.g., `googlea.com`), bitsquatting (e.g., `ggogle.com`), homoglyph (e.g., `googlë.com`), hyphenation (e.g., `g-oogle.com`), insertion (e.g., `g0oogle.com`), omission (e.g., `googe.com`), repetition (e.g., `googgle.com`), replacement (e.g., `googl4.com`), transposition (e.g., `goolge.com`), vowel-swap (e.g., `geogle.com`), and various (e.g., `googlecom.com`). We feed all the domains in Alexa top-100K to dnstwist and get 755, 908, 096 variants. Similarly, we calculate the labelhash of their 2LDs to check whether these squatting names have already been registered on ENS.

As a result, we have identified 18, 483 ENS typo-squatting `.eth` names targeting 13, 450 Alexa domain names, examples of which are shown in Table 12 of Appendix. Figure 11 shows the distribution of variant types. There are roughly 5K bitsquatting variants and 1, 270 homoglyph domains. Over 52% of the typo-squatting ENS `.eth` names are active by the time of our study.

7.1.3 Squatting Names Analysis. In total, we collect 33, 662 unique squatting ENS `.eth` names based on previous heuristics. We next investigate the records and holders of these squatting domains, seeking to identify more suspicious names based on "guilt-by-association" expansion method.

The records of squatting names. Only 4, 474 squatting ENS `.eth` names (3, 775 active ones) have been set records and most (85%) of them were set only blockchain address records. Besides Ethereum addresses, most of their other records are related to sales like Opensea links, IPFS websites posting sale information, etc. It indicates the squatting nature of these identified names.

The relations between addresses. For the identified squatting ENS `.eth` names, we further investigate the *name-to-holder* and *holder-to-holder* relations. Overall, these 33, 662 names have

been ever owned by 6, 548 addresses. Figure 13 shows the relations between names and owners according to the all-time ownership (note that an ENS domain name can change its ownership). It is interesting to see that, some names have ever been owned by more than one address. Further investigation reveals that some addresses also transferred their names. For example, the address 0xbd21109e2bdcb24c4fbcdc16a4c90f34e81228e2 received ENS .eth names from 3 addresses in the figure. It can be also seen that several addresses are holding a large number of ENS .eth names. As shown in Figure 12, over 10% of addresses hold more than 10 squatting ENS .eth names, and these names account for 70% of all squatting ENS names in total.
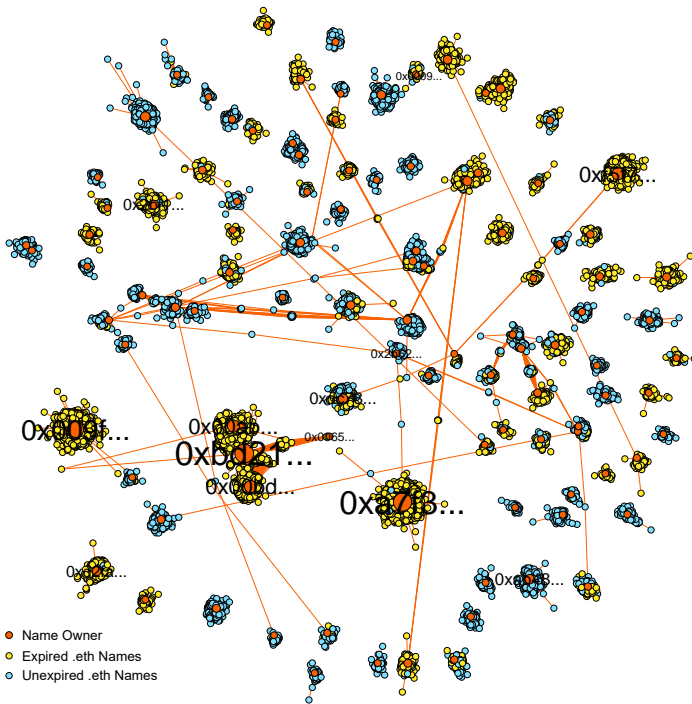

Fig. 13. The distribution of all time ownership of squatting names. Note that we exclude addresses that ever have less than 50 ENS names and their corresponding names for showing the figure clearly.

"Guilt-by-association" Expansion. Our heuristic is that, for the squatters that register squatting domains, it is quite possible that they would hold more squatting domains than we identified, as we only consider the most popular Alexa domains in our previous exploration. We call it the "Guilt-by-association" principle, which has been used in previous work to identify malicious domains and malware [67, 73]. Thus, we analyze all the ENS names held by the identified squatters. In total, we find 279, 193 suspicious squatting .eth names, which we believe are high suspicious to be squatting names too. Figure 12 shows the distribution of these addresses. Over 40% of the squatters have ever held more than 10 ENS .eth names, which account for over 96% of all suspicious names in total. The top-10 holders that have most squatting names are shown in Table 13 of Appendix. The top address 0xbd21109e2bdcb24c4fbcdc16a4c90f34e81228e2 has ever acquired 1, 276 ENS squatting names, and it has ever held more than 40K names in total. Most of the ENS names owned by it contain Chinese pinyin (e.g., jianshu.eth) or numbers (e.g., 8062222.eth), which were transferred from 6 other addresses including the 4 addresses mentioned in Section 5. These top-10 addresses have ever held around 17% of all names, which is not a number that could be ignored.

These observations show that squatters are likely to register more other ENS names even when these names don't rank top in Alexa list.

The evolution of squatting names. Further, we also investigate the evolution of all these suspicious ENS squatting names, as shown in Figure 14. The first batch of squatting names (e.g., `zhifubao.eth`, pinyin of Alipay) were registered around 2017 May 9th, almost at the same time as the initial auction start. Furthermore, the overall squatting trend follows the trend of general names we study in Section 5, suggesting to some extent that there have been certain squatting behaviors in each period of ENS. However, after ENS team launched the permanent registrar, most expired names were given up by these squatters but $67,614$ suspicious ENS squatting names (75% of all active ENS `.eth` names by the time of the study) are still held. For example, when the massive squatting behaviour happened on 2018 Nov., the address `0xbd21109e2bdcb24c4fbcdc16a4c90f34e81228e2` registered more than 40K names while by the study time he owns only one name.
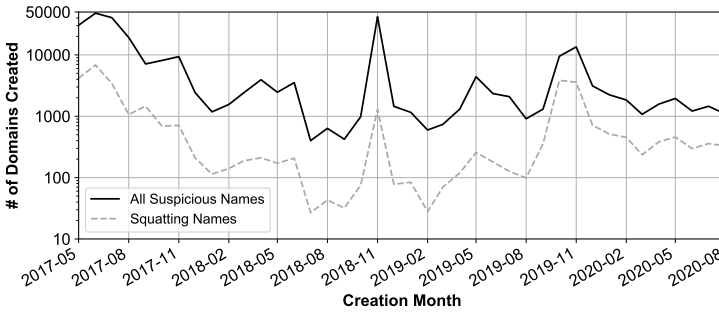

Fig. 14. The evolution of squatting names we identified.

7.2   Websites with Misbehaviors

Since ENS provides the functionality to store URL information in "TextRecord" or "DNSRecord", and store decentralized web identifiers or onion website hashes in "ContentHash", there is a possibility that some bad actors can exploit these functions to deliver malicious or illegal web contents. Thus we attempt to perform an analysis on websites that have ever been stored in ENS. As mentioned in Section 6, we get 5,879 unique dWeb hashes, 34 onion hashes and 620 URLs.

7.2.1   Method. We first upload all the URLs to VirusTotal [49], which is a famous anti-virus service that providing over 70 anti-virus engines, for scanning malicious websites. Following previous studies [63, 72], if a URL is reported by 2 or more anti-virus engines, it will be marked as a malicious URL. Second, we use Eyewitness [28] to get the screenshots and source codes of all these websites, which will be uploaded to Google Cloud Natural Language API and Vision API [50] to check whether they contain censored (e.g., adult and gambling) contents. Besides, we also mark the URLs that have keywords like "casino" or "generator" in their names or contents as suspicious URLs. All the suspicious URLs will be manually inspected to reduce false positives.

7.2.2   Result. In total, we get 19 (17 second-level ENS names) malicious dWeb URLs. Examples are shown in Figure 17 of Appendix. The malicious websites we find are involving in gambling (7), adult (5) or scam activities (7). Note that, since dWebs may not store the data online persistently, some content cannot be reached during the analysis period. Thus, the actual number of malicious dWebs should be higher than we identified. Nevertheless, due to the decentralized nature, these malicious dWebs have the ability to exist online for a long time, causing certain losses to users. For traditional URLs in text records, although we do not find any malicious traditional DNS websites

Table 6. Identified suspicious scam addresses in ENS.

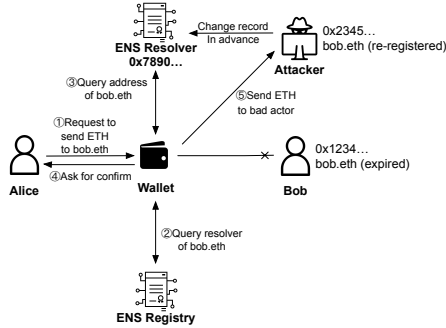| ENS names	Address	Description
valus.smartaddress.eth	ETH: 0x903bb9cd3a276d8f18fa6efed49b9bc52ccf06e5	An airdrop scam
four7coin.eth	BTC: 385cR5DM96n1HvBDMzLHPYcw89fZAXULJP	Reported as a Ponzi scheme by BitcoinAbuse, actually is a Bittrex cold wallet [45]
jessica.chainlinknode.eth, jessica.atethereum.eth, crunk.eth	BTC: 1F1tAaz5x1HUXrCNLbtMDqcw6o5GNn4xqX	Reported to be ransomware address, actually is a old Silkroad seized wallet [4]

Fig. 15. An Example of the attack scenario that exploits the record persistence issue.

Fig. 16. Some people are still using thisisme.eth names.

on ENS and there is currently no convenient way to access DNS domains through ENS, there may be a risk of malicious use of this feature in the future.

7.3 Scam Address

As mentioned in Section 6, ENS is used mainly for storing Blockchain address records. Thus, we further seek to analyse whether any addresses are used for malicious purpose.

7.3.1 Method. Considering that there is no available comprehensive dataset of scam blockchain addresses, we first compile a scam address list from various sources. Etherscan and Bloxy [7] have labelled a list of "phishing" or "hacked" Ethereum addresses. BitcoinAbuse [5] and CryptoScamDB [33] are hosting websites for tracking malicious blockchain addresses. We crawl all the addresses above and get over 58K scam addresses in total. Then, we match the addresses stored in ENS with the scam address list.

7.3.2 Result. We find three scam addresses that have been registered in the ENS, which is shown in Table 6. Figure 18 in Appendix shows the screenshot of an airdrop scam using ENS name valus.smartaddress.eth to promote their scam token. Our manual inspection suggests that the second address may not be a scam address, but its ENS name was linked to a Ponzi-like website. Despite few occurrences, malicious actors are finding a way to exploit ENS in malicious activities.

7.4 Record Persistence

7.4.1 Attack Scenario. We find that when an ENS name expires, the name and its subdomain names' records would be kept and some ENS-supported wallets could still resolve them to blockchain addresses or other records. This may lead to scams when previous users are still using these expired ENS names. An example of the possible attack is shown in Figure 15. When an attacker re-registers the expired name that has records and changes the name's records to his address in advance, people who are unaware of this change and do not check the recipient addresses (this is originally one of the purposes using ENS) would eventually send money to the attacker.

7.4.2   Vulnerable ENS Names. We further make an attempt to find how many ENS names are vulnerable to such kind of attacks, i.e., the expired ENS names that have records. After resorting to history records, we find that 16, 017 expired `.eth` names have records within them or their subdomains (3, 116 subdomains), examples of which are shown in Table 14 of Appendix. These names contain not only blockchain addresses but also dWeb hashes that may direct users to phishing/malicious websites if abused. In particular, the ENS name `thisisme.eth` has 706 subdomain names and all of them have Ethereum address records. It was listed in `enslisting.com` for free registration and was transferred to a smart contract to ensure that subdomain name records of this name would not be modified easily. Also, the ENSListing team claimed that they would cover the cost of annual renewals [1]. However, the name was expired on May 4th 2020, and we re-registered it for protection. Note that there are still some people using subdomain names of this name. Figure 16 shows an example, where a man was taking part in an airdrop activity with his `thisisme.eth` names. As we mentioned, attackers can identify the vulnerable ENS names and re-register them for making a profit. Although ENS team has proposed a new function of email notifications to remind people to renew their names on June 2020 [44], it is still a severe security concern of ENS names.

> **Answer to RQ3:** *Although the working mechanism of ENS has been improved greatly during the evolution, there still leaves room for attackers to abuse the system. We have identified several security issues and misbehaviors including traditional DNS security issues and new issues introduced by ENS smart contracts. A few squatters are found holding a lot of famous brand names and their variants, which could be used for malicious purposes. Some malicious decentralized websites and scam addresses are found in records of ENS names. Besides, a record persistence issue is found that may cause potential attacks, which could lead to financial loss to users.*

8   DISCUSSION

Implications Our findings are very important to the stakeholders in the ecosystem. Considering the certain number of active addresses and users on ENS, along with the integrated dApps and DNS TLDs, ENS still has a relatively healthy ecosystem. According to the official team [53, 54], they have deployed a smart contract on Ropsten testnet to enable the integration of most DNS 2LDs and planned to make many improvements including scaling on Layer 2 [55], etc., which will greatly facilitate the daily use and reduce the cost of ENS users. However, since we find several security issues on ENS, the ENS team may consider solutions to enhance the security of ENS. Considering the difficulty and cost of making changes to the deployed smart contracts, developers of dAPP or blockchain wallets that support ENS may deploy similar methods used in this work to detect squatting names or malicious records and give reminders to users who are trying to interact with these suspicious ENS names. For ENS users, it could be better to check the real addresses under ENS names when interacting with them. Besides, as BNS shares some common properties like tamper-resistant records, methods used in this work could be extended to study other BNS systems. **Limitations** First, we have only restored 86.6% of all `.eth` names to their readable names (see §4.2), which could bring limitations when we identify squatting names since we may not detect some combo-squatting [68] ENS names. Nevertheless, our dataset of recovered names is the largest dataset, which has no effect on our study of explicit name squatting and typo-squatting since we could calculate their hash values. Besides, there are many cyber attacks targeting at DNS, while some attacks like DDoS are not studied due to time or cost, which could be explored in future work.

9 RELATED WORK

Design of BNS Systems. Many researchers have been studying the design of blockchain-based DNSs. Hari et al.'s work [61] is one of the first works to propose the design of blockchain-based DNS. They analyzed the limitations of the traditional DNS and their dependencies on Public Key Infrastructures (PKIs). Then, they proposed a distributed, tamper-resistant DNS infrastructure. Similarly, Guan et al. [60] presented a domain authentication scheme named AuthLedger to reduce the level of trust in certificate authorities (CAs). On the other hand, some studies are focused on improving the security of the DNS nodes [62, 69, 75, 77]. For example, He et al. [62] proposed a trustworthy decentralised DNS root management architecture based on permissioned blockchain. Besides, Gourley et al. [59] proposed an improved DNSSEC based on blockchain, which provides the same security benefits as DNSSEC whilst addressing its drawbacks.

Analysis of BNS Systems. A few studies have analyzed different kinds of blockchain-based DNS systems [56–58, 65, 66, 70, 71, 76]. Kalonder et al. [65] firstly performed a empirical analysis on Namecoin. After that, some other studies have characterized mainly on the properties of different kinds of blockchain-based DNS. Patsakis et al. [71] surveyed the threat of blockchain-based DNS including malware, underlying registrar mechanism, domain market, phishing, motivation and immutability. Very few studies have mentioned ENS. For example, Liu et al. [70] and Karaarslan et al. [66] compared the designs of several blockchain-based DNSs including ENS. However, there lacks a systematic study of ENS, including the status quo of ENS, security issues, etc.

10 CONCLUSION

We take the first step to systematically characterize Ethereum Name Service. By collecting and analyzing large-scale ENS event logs, we obtain a number of interesting observations and reveal security issues related to ENS. We believe ENS is a promising system on its way to being complementary to DNS, but the spams and security issues may impede its progress. Our efforts in this paper can positively contribute to the BNS ecosystem and offer practical insights.

REFERENCES

[1] Ensnow soft launch! get an instant ens name for your wallet for free! https://medium.com/@enslisting.com/ensnow-soft-launch-get-an-instant-ens-name-for-your-wallet-for-free-3b56ace6b60a, 2017.

[2] Alexa top 1 million sites. http://s3.amazonaws.com/alexa-static/top-1m.csv.zip, 2020.

[3] Announcing support for .xyz on ens. https://medium.com/the-ethereum-name-service/announcing-support-for-xyz-on-ens-7f5bc7fe1b24, 2020.

[4] As feds fumble with bitcoin, the internet trolls the fbi's "private" wallet. https://techcrunch.com/2013/10/07/as-feds-fumble-with-bitcoin-the-internet-trolls-the-fbis-private-wallet/, 2020.

[5] Bitcoin abuse database. https://www.bitcoinabuse.com/, 2020.

[6] Bitfinex | cryptocurrency exchange | bitcoin trading | futures ... https://www.bitfinex.com/, 2020.

[7] Bloxy. https://bloxy.info, 2020.

[8] Cybersquatting. https://en.wikipedia.org/wiki/Cybersquatting, 2020.

[9] dappnode.io. https://dappnode.io/, 2020.

[10] A decaying price premium for newly released .eth names. https://medium.com/the-ethereum-name-service/new-decaying-price-premium-for-newly-released-names-72080a650c15, 2020.

[11] Disadvantages of dnssec. https://dnsinstitute.com/documentation/dnssec-guide/ch06s06.html, 2020.

[12] Dns over https. https://en.wikipedia.org/wiki/DNS_over_HTTPS, 2020.

[13] Dns over tls. https://en.wikipedia.org/wiki/DNS_over_TLS, 2020.

[14] Domain name permutation engine for detecting typo squatting, phishing and corporate espionage. https://github.com/elceef/dnstwist, 2020.

[15] Domain name system security extensions. https://en.wikipedia.org/wiki/Domain_Name_System_Security_Extensions, 2020.

[16] Dune analytics. https://duneanalytics.com, 2020.

[17] Eip-1577: contenthash field for ens. https://eips.ethereum.org/EIPS/eip-1577, 2020.

[18] Eip-2304: Multichain address resolution for ens. https://geth.ethereum.org/, 2020.

[19] Eip-634: Storage of text records in ens. https://eips.ethereum.org/EIPS/eip-634, 2020.

[20] Emerdns. https://emercoin.com/en/emerdns, 2020.

[21] English auction - wikipedia. https://en.wikipedia.org/wiki/English_auction, 2020.

[22] Ens. https://ens.domains/, 2020.

[23] Ens + .kred: Major integration of dns and ens launches. https://medium.com/the-ethereum-name-service/ens-kred-major-integration-of-dns-and-ens-launches-e7efb4dd872a, 2020.

[24] The ethereum name service. https://medium.com/the-ethereum-name-service, 2020.

[25] Ethereum name service launch postmortem. https://medium.com/the-ethereum-name-service/ethereum-name-service-launch-postmortem-a941864f4b5, 2020.

[26] Etherscan. https://etherscan.io/, 2020.

[27] Exclusive: Hackers acting in turkey's interests believed to be behind recent cyberattacks - sources. https://www.reuters.com/article/us-cyber-attack-hijack-exclusive/exclusive-hackers-acting-in-turkeys-interests-believed-to-be-behind-recent-cyberattacks-sources-idUSKBN1ZQ10X, 2020.

[28] Fortynorthsecurity/eyewitness. https://github.com/FortyNorthSecurity/EyeWitness, 2020.

[29] Go ethereum. https://geth.ethereum.org/, 2020.

[30] The great renewal: It's time to renew your .eth names — or else lose them. https://medium.com/the-ethereum-name-service/the-great-renewal-its-time-to-renew-your-eth-names-or-else-lose-them-afccea4852cb, 2020.

[31] Gun — the database for freedom fighters. https://gun.eco/, 2020.

[32] Handshake. https://handshake.org/, 2020.

[33] Home | cryptoscamdb. https://cryptoscamdb.org/, 2020.

[34] Home | ethereum.org. https://ethereum.org/en/, 2020.

[35] Id goes di. https://decentraland.org/blog/announcements/id-goes-di/, 2020.

[36] Interplanetary name system (ipns). https://docs.ipfs.io/concepts/ipns/#interplanetary-name-system-ipns, 2020.

[37] Introducing .luxe on ens. https://medium.com/@weka/introducing-luxe-on-ens-35a9ee2383ce, 2020.

[38] Introduction - ethereum name service. https://docs.ens.domains/, 2020.

[39] The invisible internet project. https://geti2p.net/en/, 2020.

[40] List of ens names that resolve to tor .onion websites. https://medium.com/the-ethereum-name-service/list-of-ens-names-that-resolve-to-tor-onion-websites-99140a4c674f, 2020.

[41] The most popular .eth names in the ens short name auction (final). https://medium.com/the-ethereum-name-service/the-most-popular-eth-names-in-the-ens-short-name-auction-final-5d3466dd8837, 2020.

[42] Namecoin. https://www.namecoin.org/, 2020.

[43] Opensea: Buy crypto collectibles, cryptokitties ... https://opensea.io/, 2020.

[44] Receive email notifications to renew your .eth names with new tool from buidlhub. https://medium.com/the-ethereum-name-service/receive-email-notifications-to-renew-your-eth-names-with-new-tool-from-buidlhub-72aaba226194, 2020.

[45] Tokenview. https://btc.tokenview.com/en/address/385cR5DM96n1HvBDMzLHPYcw89fZAXULJP, 2020.

[46] Tor project | anonymity online. https://www.torproject.org/, 2020.

[47] Unstoppable domains. https://unstoppabledomains.com/, 2020.

[48] Vickrey auction - wikipedia. https://en.wikipedia.org/wiki/Vickrey_auction, 2020.

[49] Virustotal. https://www.virustotal.com/gui/, 2020.

[50] Vision ai | derive image insights via ml | cloud vision api. https://cloud.google.com/vision, 2020.

[51] What is dns, how it works + vulnerabilities. https://www.varonis.com/blog/what-is-dns/, 2020.

[52] Zooko's triangle - wikipedia. https://en.wikipedia.org/wiki/Zooko%27s_triangle, 2020.

[53] 2021 ens roadmap - feedback welcome! https://discuss.ens.domains/t/2021-ens-roadmap-feedback-welcome/328, 2021.

[54] Dns namespace integration on testnet, ethereum classic labs sponsors with grant. https://medium.com/the-ethereum-name-service/dns-namespace-integration-on-testnet-ethereum-classic-labs-sponsors-with-grant-19d57bf16a8b, 2021.

[55] Layer 2 scaling. https://ethereum.org/en/developers/docs/layer-2-scaling/, 2021.

[56] Saif Al-Mashhadi and Selvakumar Manickam. A brief review of blockchain-based dns systems. *International Journal of Internet Technology and Secured Transactions*, 10(4):420–432, 2020.

[57] Faizan Safdar Ali and Alptekin Kupcu. Improving pki, bgp, and dns using blockchain: A systematic review. *arXiv preprint arXiv:2001.00747*, 2020.

[58] Dmitry Bagay. Blockchain-based dns building. *Procedia Computer Science*, 169:187–191, 2020.

[59] Scarlett Gourley and Hitesh Tewari. Blockchain backed dnssec. In *International Conference on Business Information Systems*, pages 173–184. Springer, 2018.

[60] Zhi Guan, Abba Garba, Anran Li, Zhong Chen, and Nesrine Kaaniche. Authledger: A novel blockchain-based domain name authentication scheme. In *ICISSP*, pages 345–352, 2019.

[61] Adiseshu Hari and TV Lakshman. The internet blockchain: A distributed, tamper-resistant transaction framework for the internet. In *Proceedings of the 15th ACM Workshop on Hot Topics in Networks*, pages 204–210, 2016.

[62] Guobiao He, Wei Su, Shuai Gao, and Jiarui Yue. Td-root: A trustworthy decentralized dns root management architecture based on permissioned blockchain. *Future Generation Computer Systems*, 102:912–924, 2020.

[63] Ren He, Haoyu Wang, Pengcheng Xia, Liu Wang, Yuanchun Li, Lei Wu, Yajin Zhou, Xiapu Luo, Yao Guo, and Guoai Xu. Beyond the virus: A first look at coronavirus-themed mobile malware, 2020.

[64] Zhangrong Huang, Ji Huang, and Tianning Zang. Leopard: Understanding the threat of blockchain domain name based malware. In *International Conference on Passive and Active Network Measurement*, pages 55–70. Springer, 2020.

[65] Harry A Kalodner, Miles Carlsten, Paul Ellenbogen, Joseph Bonneau, and Arvind Narayanan. An empirical study of namecoin and lessons for decentralized namespace design. In *WEIS*. Citeseer, 2015.

[66] Enis Karaarslan and Eylul Adiguzel. Blockchain based dns and pki solutions. *IEEE Communications Standards Magazine*, 2(3):52–57, 2018.

[67] Issa M Khalil, Bei Guan, Mohamed Nabeel, and Ting Yu. A domain is only as good as its buddies: Detecting stealthy malicious domains via graph inference. In *Proceedings of the Eighth ACM Conference on Data and Application Security and Privacy*, pages 330–341, 2018.

[68] Panagiotis Kintis, Najmeh Miramirkhani, Charles Lever, Yizheng Chen, Rosa Romero-Gómez, Nikolaos Pitropakis, Nick Nikiforakis, and Manos Antonakakis. Hiding in Plain Sight: A Longitudinal Study of Combosquatting Abuse. In *Proceedings of the 2017 ACM SIGSAC Conference on Computer and Communications Security*, CCS '17, pages 569–586, 2017.

[69] Jingqiang Liu, Bin Li, Lizhang Chen, Meng Hou, Feiran Xiang, and Peijun Wang. A data storage method based on blockchain for decentralization dns. In *2018 IEEE Third International Conference on Data Science in Cyberspace (DSC)*, pages 189–196. IEEE, 2018.

[70] Yang Liu, Yuwen Zhang, Siyu Zhu, and Cheng Chi. A comparative study of blockchain-based dns design. In *Proceedings of the 2019 2nd International Conference on Blockchain Technology and Applications*, pages 86–92, 2019.

[71] Constantinos Patsakis, Fran Casino, Nikolaos Lykousas, and Vasilios Katos. Unravelling ariadne's thread: Exploring the threats of decentralised dns. *IEEE Access*, 8:118559–118571, 2020.

[72] Peng Peng, Limin Yang, Linhai Song, and Gang Wang. Opening the blackbox of virustotal: Analyzing online phishing scan engines. In *Proceedings of the Internet Measurement Conference*, pages 478–485, 2019.

[73] Silvia Sebastian and Juan Caballero. Towards attribution in mobile markets: Identifying developer account polymorphism. In *Proceedings of the 2020 ACM SIGSAC Conference on Computer and Communications Security*, pages 771–785, 2020.

[74] Janos Szurdi, Balazs Kocso, Gabor Cseh, Jonathan Spring, Mark Felegyhazi, and Chris Kanich. The Long "Taile" of Typosquatting Domain Names. In *Proceedings of the 23rd USENIX Conference on Security Symposium*, SEC'14, pages 191–206, USA, 2014. USENIX Association.

[75] Wentong Wang, Ning Hu, and Xin Liu. Blockzone: A blockchain-based dns storage and retrieval scheme. In *International Conference on Artificial Intelligence and Security*, pages 155–166. Springer, 2019.

[76] Hu Wei-hong, A. Meng, Shi Lin, Xie Jia-gui, and L. Yang. Review of blockchain-based dns alternatives. 2017.

[77] Jichuan Zhang, Jianhong Zhai, Ru Yang, and Shuyan Liu. Research on enterprise dns security scheme based on blockchain technology. In *International Conference on Blockchain and Trustworthy Systems*, pages 690–701. Springer, 2019.

Appendix 1   APPENDIX FOR STUDY DESIGN IN SECTION 4

Appendix 1.1   The additional resolvers.

Table 7 shows eight open-source additional resolvers we add, the names of which were fetched from Etherscan labels and search engines.

Appendix 2   APPENDIX FOR GENERAL OVERVIEW IN SECTION 5

Appendix 2.1   Top-10 .eth name owners by study time.

Table 8 shows top-10 owners that hold most of `.eth` names by the time of the study.

Appendix 2.2   Top-10 valuable ENS names.

During the Vickrey auction period, the top-10 valuable ENS names are shown in Table 9.

Table 7. The eight additional resolvers we add.

Resolver Name	Address	# of Event Logs
ArgentENSResolver1	0xDa1756Bb923Af5d1a05E277CB1E54f1D0A127890	67,068
OldPublicResolver3	0x5FfC014343cd971B7eb70732021E26C35B744cc4	27,693
OldPublicResolver4	0xD3ddcCDD3b25A8a7423B5bEe360a42146eb4Baf3	6,610
AuthereumEnsResolverProxy	0x4DA86a24e30a188608E1364A2D262166a87fCB7C	8,406
OpenSeaENSResolver	0x9C4e9CCE4780062942a7fe34FA2Fa7316c872956	226
ArgentENSResolver2	0xb23267e7a0DEe4DCBA80C1D2FFDb0270aF76fe80	478
PortalPublicResolver	0x0B3eBEccC00E9CEae2BF3235d558EdA7398BE91E	236
TokenResolver	0x074d58C0a0903d4C7DB9388205232602a0bF9Bf0	152

Table 8. The top-10 .eth name owners by the time of this study.

Owner Address	.eth Names Owned (By Study Time)	.eth Names Owned (All Time)
0xbcbd4885ee8b2b74249c5ad9b8b668fb256a51b1	2262	2367
0xea32bf2135888c46157320f9fe3539211945cbae	1388	1388
0x8124b02b4967bd7338a450420a572d574915ff9c	916	1040
0xe2faa63f2351c6f2b88659f2fffc2167172d329a	806	906
0xddd3964d75d59b6b6d5c31eb313bba5ebf076364	704	757
0xab48edd90bdf367d326d827758bacd2460c59d17	655	657
0x1d6f2f0356b3defadf14b1a0f8a3dcda89367d68	634	642
0xf14955b6f701a4bfd422dcc324cf1f4b5a466265	567	766
0xdc784458e2516a9d0531509f784dcf21983a60d7	543	1308
0x813ec5facf289bd41365a8f1c9038a1228e95201	530	542

Table 9. Top-10 valuable ENS names.

Name	Auction Price (ETH)	# of Valid Bids	Owner
darkmarket.eth	20,103	4	0x8759b0b1d9cba80e3836228dfb982abaa2c48b97
openmarket.eth	10,055	10	0x8759b0b1d9cba80e3836228dfb982abaa2c48b97
exchange.eth	6,660	72	0xdc9fbececa49457fbcb2ee1dfd576a8be06a5c30
blackjack.eth	5,910	48	0x217ad132e6271a9a19a818bde4cb6498888a3ba2
tickets.eth	2,977	39	0x8759b0b1d9cba80e3836228dfb982abaa2c48b97
payment.eth	2,600	66	0x8759b0b1d9cba80e3836228dfb982abaa2c48b97
trading.eth	2,563	37	0x752975f5990c33da38c4cd50f0a41b70b3a6796c
registry.eth	2,509	12	0x352f25babf4a690673e35195efa8f79d05848aad
jackpot.eth	2,123	21	0x352f25babf4a690673e35195efa8f79d05848aad
lottery.eth	1,700	26	0x9a02ed4ca9ad55b75ff9a05debb36d5eb382e184

Appendix 2.3 Top-10 most spent addresses and top-10 name owners in Vickrey auction period.

During Vickrey auction period, the addresses that spent most ETH and that owned most ENS names are shown in Table 10.

Table 10. Top-10 most spent addresses and top-10 ENS name owners in the Vickrey auction period.

Top-10 Most Spent Addresses in ETH	Total Sepnt (ETH)	# of Names Owned	Top-10 ENS Name Owner Addresses	# of Names Owned	Total Spent (ETH)
0x8759b0b1d9cba80e3836228dfb982abaa2c48b97	39,712	32	0xa7f3659c53820346176f7e0e350780df304db179	26,257	1,686
0x752975f5990c33da38c4cd50f0a41b70b3a6796c	22,881	163	0x00bda1105ce38848b890c138d3d23a0435790a39	13,233	132
0x9ef56cdfc51154a4bb25888a879560e08ad80795	13,073	215	0x001e28376ebe0982a50b0ad4a076a39aa0264bcc	12,633	126
0x352f25babf4a690673e35195efa8f79d05848aad	7,928	56	0x00ab424d2019bc0f4c648232c6e7d181a34034b8	9,344	93
0x217ad132e6271a9a19a818bde4cb6498888a3ba2	7,047	22	0x002acd20810b405fc4d01896871a6a7ba4b279fa	5,481	55
0xdc9fbececa49457fbcb2ee1dfd576a8be06a5c30	6,660	1	0xae18d320383a3598c65767dfd97c8df8ab465d26	4,627	47
0x5807a8b404c71cf22eb0bac2e5f2a6c202ebe0a1	3,214	289	0xf5f700e1912b93ad09597bfa22484e01c0035b04	3,394	37
0x00f2aaa26fa8a6aada2afa7f545b141c8aca983f	3,139	65	0x000fb8369677b3065de5821a86bc9551d5e5eab9	3,071	31
0xa37e710865314998ed47c3a24c8d1daaa58b1d07	2,695	8	0x64372db6405879214a0a76a7f1e9c013fd2fd84b	2,307	23
0xf14955b6f701a4bfd422dcc324cf1f4b5a466265	2,647	760	0x94048eb0db0ccb7d38219f28ed6522937b339aaf	2,277	24

Appendix 3 APPENDIX FOR SECURITY ISSUES AND MISBEHAVIORS IN SECTION 7

Appendix 3.1 Top-10 holders of explicit squatting names.

Table 11 shows top-10 holders that registered most the known brands, which is a explicit squatting behavior.

Table 11. Top-10 holders of explicit squatting names.

Address	# of Names Owned	Highest Alexa Rank	Example	First Registration Time
0x009fde04525832da85a240d68c82421ca249a5b8	933	140	ilovepdf.eth	2017/8/12
0xf5f700e1912b93ad09597bfa22484e01c0035b04	478	23	okezone.eth	2017/5/12
0xa7f3659c53820346176f7e0e350780df304db179	262	425	pearson.eth	2017/5/22
0xaa0ea472b51ae4c5f77d50de5c91cbd932120b96	233	330	gamepedia.eth	2017/9/3
0xd2fa59b040852952bf4b4639edd4d8a718a4598a	211	2053	eonline.eth	2017/6/9
0xc67247454e720328714c4e17bec7640572657bee	206	662	wiktionary.eth	2017/5/20
0xdc784458e2516a9d0531509f784dcf21983a60d7	184	162	slideshare.eth	2017/5/21
0xd8c958f774de4b671e43f78fd0a04255e2291a13	160	34	naver.eth	2017/6/12
0x776efc479eeed9cb4fbc5e743aeb943313457bb5	153	358	allegro.eth	2017/5/23
0xf14955b6f701a4bfd422dcc324cf1f4b5a466265	136	35	bongacams.eth	2017/5/16

Appendix 3.2 Top-10 holders of typo-squatting names.

Figure 12 shows the top-10 holders of typo-squatting names.

Appendix 3.3 Top-10 holders of ENS squatting names.

After combining explicit ENS squatting names and typo-squatting names, the top-10 ENS squatting name holders are shown in Table 13.

Table 12. Top-10 holders of typo-squatting names

Address	# of Names Owned	Max Alexa Rank	Example	First Registration Time
0xbd21109e2bdcb24c4fbcdc16a4c90f34e81228e2	1225	33	zhuanqi.eth	2018/10/30
0xa7f3659c53820346176f7e0e350780df304db179	948	70	forbess.eth	2017/5/19
0xbcbd4885ee8b2b74249c5ad9b8b668fb256a51b1	267	249	brillo.eth	2017/5/13
0x000fb8369677b3065de5821a86bc9551d5e5eab9	194	292	allegri.eth	2017/5/15
0xab48edd90bdf367d326d827758bacd2460c59d17	192	395	hermès.eth	2019/9/29
0x2bf1c1aedf56f2d1c413241d37f03c71b8793832	186	49	live-jasmin.eth	2017/6/10
0x1d6f2f0356b3defadf14b1a0f8a3dcda89367d68	172	71	facet.eth	2017/6/5
0xddd3964d75d59b6b6d5c31eb313bba5ebf076364	159	378	ubers.eth	2018/5/6
0x813ec5facf289bd41365a8f1c9038a1228e95201	130	30	bittrix.eth	2019/2/2
0xf5f700e1912b93ad09597bfa22484e01c0035b04	123	1	googlecom.eth	2017/5/26

Table 13. The top-10 holders of ENS squatting names.

Address	Owned Squatting Names (Unexpired)	First Registraion	Owned Suspicious Names (Unexpired)
0xbd21109e2bdcb24c4fbcdc16a4c90f34e81228e2	1276 (0)	2018/10/30	41370 (1)
0xa7f3659c53820346176f7e0e350780df304db179	1210 (2)	2017/5/19	26199 (10)
0x009fde04525832da85a240d68c82421ca249a5b8	974 (0)	2017/8/12	1491 (0)
0xf5f700e1912b93ad09597bfa22484e01c0035b04	601 (0)	2017/5/12	3408 (0)
0xbcbd4885ee8b2b74249c5ad9b8b668fb256a51b1	345 (340)	2017/5/13	2366 (2262)
0xab48edd90bdf367d326d827758bacd2460c59d17	318 (318)	2019/9/29	655 (655)
0xdc784458e2516a9d0531509f784dcf21983a60d7	304 (174)	2017/5/11	1306 (543)
0xd2fa59b040852952bf4b4639edd4d8a718a4598a	271 (1)	2017/6/9	2078 (1)
0x2bf1c1aedf56f2d1c413241d37f03c71b8793832	259 (22)	2017/5/24	1532 (90)
0xc67247454e720328714c4e17bec7640572657bee	254 (4)	2017/5/20	1206 (13)

Appendix 3.4 Examples of websites with misbehaviors.

Figure 17 shows some examples of websites with misbehaviors we find in records of ENS.

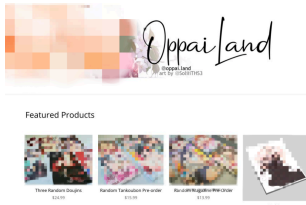## Appendix 3.5 The screenshot of an airdrop scam using ENS.

Figure 18 shows the screenshot of an airdrop scam using valus.smartaddress.eth

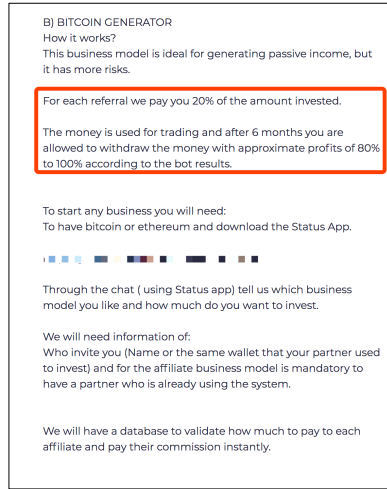## Appendix 3.6 Some examples of expired (sub) domains with records.

We have found 16,017 expired ENS names that have records in them or in their subdomains, examples of which are shown in Table 14.

(a) bobabet.dcl.eth (a gambling site)

(b) oppailand.eth (an adult book shop)

(c) bitcoingenerator.eth (a Ponzi scheme site)

Fig. 17. Examples of websites with misbehaviors.

Fig. 18. The screenshot of airdrop scam using `valus.smartaddress.eth`.

Table 14. Some examples of expired (sub) domains with records.

.eth Name	Record Type	.eth Name with Subdomains	# of subdomains	Record Type
ammazon.eth	ETH Address	thisisme.eth	708	ETH Address
wikipediaa.eth	ETH Address	tenzorum-id.eth	539	ETH Address
pay-pal.eth	ETH Address	[unknown].eth	360	Swarm Hash
investing.eth	ETH Address, Swarm Hash	portalid.eth	113	ETH address, Swarm hash, Email
babytree.eth	ETH Address	eth2phone.eth	61	ETH address