

Bake in .onion for Tear-free and Stronger Website Authentication

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Abstract—Tor is a communications infrastructure widely used for unfettered and anonymous access to Internet websites. Tor is also used to access sites on the reserved domain .onion. The focus of .onion use and discussion has traditionally been on the offering of hidden services, services that separate their reachability from the identification of their IP addresses. We argue that Tor’s .onion system can be used to provide an entirely separate benefit: basic website authentication. We also argue that not only can onionsites provide website authentication, but doing so can be easier, faster, cheaper, and more secure than existing alternatives. We illustrate this with a general manual technique based on PGP that can be used right now. We also set out an automated approach that can be integrated with traditional TLS certificates—provided that changes we argue for are made to the current rules limiting the kinds of certificates permissible for .onion addresses.

Keywords—Tor, TLS certificates, PGP, traffic security, authentication

I. INTRODUCTION

Tor is a widely popular communications infrastructure for anonymous communication. Millions use its thousands of relays for unfettered traffic-secure access to the Internet. The vast majority of Tor traffic by bandwidth (about 95% at our last check) is on circuits connecting Tor clients to servers that are otherwise accessible on the Internet [1]. Tor also provides protocols for connecting to services on the reserved top level domain .onion, which are only accessible via Tor. In this paper we explore using Tor’s .onion infrastructure so that individuals operating a website can create authentication, integrity and other guarantees more simply, easily, fully, and inexpensively than by other currently available means.

Tor’s onionsites have been advocated since their introduction as a way to protect network location information for servers, not just clients [2]. (Such advocacy actually predates their introduction inasmuch as the same was said for web servers contacted by reply onions [3].) Discussion in the popular press, as well as research to date, has focused almost exclusively on location hiding and associated properties provided by onionsites and the protocols to interact with them. Indeed, these are generally referred to collectively as *Tor Hidden Services* in the research literature and as the *Dark Web* in the popular press. (Although so many importantly distinct things are often subsumed and run together under ‘Dark Web’ as to rob the term of clear significance. Ironically, as spies and criminals attack users from hiding spots throughout the infrastructure on today’s Internet, Tor’s authenticated routing overlay is often the

only direct control and only illumination users have of where their traffic goes.)

We intend to challenge the narrowness of this view of onionsites. In particular we will focus on security protections they readily facilitate that are largely orthogonal to hiding server location and that are stronger and broader than those currently available by other means. We hope by the end of this paper the reader will agree that they should be called *onion services* or at least something more properly inclusive of the security properties they offer.

Overview

After some basics on Tor and onion services, we describe a limitation on their self-authentication protection: onion addresses are not human-meaningful. Certificates for meaningful registered domains have problems as well, however, many of which are particularly disadvantageous to operators of smaller, less global, or less permanent websites. We next describe some of the concerns for such sites and propose a solution based on PGP signatures that combines the usable meaningfulness of registered domain names with the stronger and broader authentication that onion services can provide. This solution is available immediately, albeit manually. We also sketch prospects for its automation and integration into typical-user experience. Because TLS is widely used and its interfaces comparatively well understood, we next propose a way to obtain this combination of properties by leveraging traditional certificates. This requires a change in certificate issuance regulations for onion addresses. We argue that, for our proposed design, such changes are sensible.

We illustrate our points using three running examples of current sites that are available both as ordinary registered-domain websites and as onionsites. Facebook is a large company that possesses a strong form of cert covering both its onion address and its registered-domain. DuckDuckGo is a company that offers an onion address and has a cert, but only for its registered domain name, not for its onion address. Finally, Glenn Sorrentino is an individual who has both types of sites but no TLS cert of any kind.

II. BRIEF BACKGROUND ON TOR AND ONION SERVICES

We sketch out minimal basics of Tor onion services. For further descriptions see the Tor design paper [2], related documentation at the Tor website [4], or a high-level graphical description of onion services [5]. The Tor Rendezvous Specification [6] provides a more up to date, and much more technical, description of onion-service protocols.

Tor clients randomly select three of roughly 6700 relays [7] comprising the current Tor network, and create a cryptographic circuit through these to connect to Internet services. Since only the first relay in the circuit sees the IP address of the client and only the last (exit) relay sees the IP address of the destination, this technique separates identification from routing. To offer an onion service, a web (or other) server creates Tor circuits to multiple *Introduction Points* that await connection attempts from clients. A user wishing to connect to a particular onion service uses the onion address to look up these Introduction Points in a directory system. In a successful interaction, the client and onionsite then both create Tor circuits to a client-selected *Rendezvous Point*. The Rendezvous Point mates their circuits together, and they can then interact as ordinary client and server of a web connection over this rendezvous circuit.

Since a properly-configured onionsite only communicates over Tor circuits it creates, this protocol hides its network location, the feature that gives it the name ‘hidden service’. But, there are other important features to the .onion system, notably self-authentication. The onion address is actually the hash of the public key of the onionsite. For example, if one wishes to connect to the DuckDuckGo search engine’s onion service, the address is 3g2upl4pq6kufc4m.onion. The Tor client recognizes this as an onion address and thus knows to use the above protocol rather than passing the address through a Tor circuit for DNS resolution at the exit (which protects against leakage of client interests by observation of a DNS lookup as well as against any of the well-known DNS hijinks). The public key corresponds to the key that signs the list of Introduction Points and other service descriptor information provided by the directory system. In this way, onion addresses are self-authenticating.

For services such as DuckDuckGo, the value provided by onion services lies, not in their location hiding, but in this additional authentication and in the greater assurance of improved route security offered to their users by requiring a connection via Tor. The complexity, latency, and network overhead of the several Tor circuits needed to reach Introduction Points and Rendezvous Points is not needed to provide those protections. There are nonetheless, also some performance advantages to providing an onion service to the users wishing to connect to one’s site via Tor (e.g., skirting effects of exit relay bandwidth scarcity). And Tor proposals (the Tor equivalent of IETF RFCs) to standardize further simplified onion services without location hiding are in the works. Facebook already uses such simplifications in offering its onion service.

III. KNOWING TO WHICH SELF TO BE TRUE

Of course the self-authentication described above for DuckDuckGo only binds the service descriptor information to the 3g2upl4pq6kufc4m.onion address. What a user would like to be assured of is that s/he is reaching DuckDuckGo. Presumably the user wants the search results DuckDuckGo offers and not what might be returned by some other, possibly malicious, server. In addition to the integrity guarantee, the user relies on authentication so that queries are revealed only to DuckDuckGo and not to others. The onion address by

itself does not offer this. Making use of the traditional web trust infrastructure, Facebook offers a certificate for its onion addresses issued by DigiCert. This helps ensure that users are not misled by onionsites purporting to be official.

Though cryptographic binding is essential to the technical mechanisms of trust, users also rely on human-readable familiarity, for example, that the browser graphically indicates s/he has made a certified encrypted connection as a result of typing facebook.com into the browser. To some extent, it is at least possible to make use of this in onionspace. By generating many keys whose hash had ‘facebook’ as initial string and then looking among the full hashes for an adequately felicitous result, Facebook was able to obtain facebookcorewwi.onion for its address. Whatever its value for Facebook, this is clearly not something that will work widely, as it is difficult to generate custom addresses in this way.

The Onion Name System (OnioNS) attempts to respond to these concerns by creating a system for globally-unique but still human-meaningful names for onionsites [8]. This has the advantage of not being dependent on any existing naming scheme, such as existing domain registration. On the other hand, through much experience and design, existing approaches to naming have evolved effective usage and infrastructure that we can leverage. We will focus herein on approaches that link onion addresses to already meaningful ways of referring to sites. In particular, we focus on the case where one controls a registered domain name; although binding to other meaningful web locations (such as a Facebook page or WordPress blog) is also possible.

If one has a registered domain name, why not just obtain certificates from traditional authorities as Facebook has done? For many server operators, getting even a basic server certificate is just too much of a hassle. The application process can be confusing. It usually costs money. It’s tricky to install correctly. It’s a pain to update. These are not original observations. Indeed that description is actually a quote from the blog of Let’s Encrypt, a new certificate authority dedicated, among other things, to making TLS certification free and automatic for most websites [9].

Using the existing X.509 system, setting up a certificate can take hours or even days. In cases where the website is operated by a collective or organization, SSL/TLS certificates have been known to take months, due to questions around ownership and authorization. This time cost is in addition to the monetary cost of the certificate, if any. In contrast, setting up an onionsite takes a few minutes and costs nothing. Once Tor is installed, you simply add two lines to your torrc file and start Tor. The Tor Project also provides a brief page with additional tips and advanced options [10]. Even if one follows the option described below of PGP for the binding, and the process of learning how to create a PGP key and signature is taken into account, the time investment is dramatically less than with the current X.509 public-key infrastructure.

As of this writing, Let’s Encrypt services are still only available in beta release. Should they be willing to offer certificates for onion domains, Let’s Encrypt could be an easy way for onionsite operators to take advantage of the traditional certification infrastructure. We will return to this below.

Traditional SSL certificates have more problems than the above cost and convenience questions. The trust hierarchy is opaque to direct usage, and the sheer number of trusted authorities is large enough to be of concern. In particular, there have been numerous cases of man-in-the-middle (MitM) attacks through certificate manipulation, as well as hacking of certificate authorities or certificate validation software leading to use of fraudulent certificates for some of the most popular websites [11].

EFF's SSL Observatory [12] monitors for such problems and documents their occurrence. Google's Certificate Transparency Effort [13] is similar but broader, adding (amongst other things) append-only signed public logs that make certificate shenanigans all the harder to bring off undetectably.

The problems with certificates raised above and below, though real, are largely moot at the moment for most of those who might wish to create onion services. As of this writing, the CA/Browser Forum has approved only EV (Extended Validation) Certificates for .onion addresses. This limits their use to those with the significant amount of time, money, and desire to follow the extensive identity validation process required. EV Certificates are primarily used by large businesses [14]. More common for individuals, organizations, and small business that obtain certificates for their sites are Domain Validation (DV) Certs. These typically require a simple email confirmation based on information in the WHOIS database.

Further, the .onion top-level domain itself was without official status until recently, which is part of why the approval to issue EV Certs was initially temporary. An IETF RFC reserving .onion as one of the handful of special-use domain names was, however, approved in October 2015 as a proposed standard [15]. With the official release of this RFC, the approval of certs for .onion addresses is now on firmer footing [16].

IV. OUR ONIONS OURSELVES

As noted, onionsites already provide a self-authenticated binding of public key to onion address but do not bind that public key to something recognizably associated with that site. We seek a solution that will work for all kinds of sites, but in this section we are especially interested in providing authentication for only moderately popular and/or short-lived websites, e.g., personal web pages, hometown sports teams, sites for local one-time events, small businesses, municipal election campaigns, etc. Though not such large targets as more popular long-lived sites, they are still subject to controversy and have been subject to many of the same sorts of attacks as more well-known sites. They might also not be the target of attacks but simply collateral victims.

Some users of this kind may not even have Internet accounts that allow them to set up servers. Onionsites are generally compliant with such a limitation since they actually only make outbound client connections. A related existing usage is for administering systems behind restrictive firewalls that only permit outbound connections. Even if the user has an Internet account that permits setting up a web page, HTTPS may not be available from that provider or only available for an additional fee.

Website owners may also wish to simply make sure their sites are available to Tor users. With a growing userbase already in the millions, this is understandable. Some sites, such as Facebook, use an onion service to provide better performance, security, and user experience for Tor users than they are able to offer simply having those users connect to their site over a simple Tor circuit connecting to facebook.com [16]. On the other hand, those with a small personal site may discover that access to it from Tor exits is blocked by their hosting provider. Thus, when Glenn Sorrentino, a product designer, realized this was true of his site glennsorrentino.com, he set up a version of that site on a small personal system at at3o24mj2rfabkca.onion. This provides other benefits as well, but his motivation was to allow reachability for Tor users. (Since the Tor network is designed to be reached even by users experiencing censorship, another possible way to solve this same problem would be to run the site as an onion service from the same web server but connecting to Tor via bridges and obfuscating pluggable transports [17].)

We are primarily focused on improvements to authentication using onionsites and thus mostly leave properties of network location hiding aside as orthogonal to our goals. They can be complementary, however. Authenticated hidden services are also an appealing option for those who'd like to secure their onionsites for personal use. Unlike traditional websites that appear online prior to authentication, users lacking authentication information for such a site will not be easily able to determine that it even exists, nor will they be able to probe it for vulnerabilities. These qualities make an ideal environment for operating a personal cloud service. With privacy and cost in mind, many people are operating their own cloud infrastructure to store files and calendar entries using open-source systems such as Cozy and OwnCloud [18]. Another common use of authenticated hidden services is as a personal RSS reader, as onionsites ensure some level of feed integrity (particularly important when fetching news feeds that do not utilize TLS).

One can always create a Facebook page or something similar that is protected by HTTPS and TLS certificates, and this is often done. But this makes the service dependent on the reputation, trust, policies, and protections of such a host, not to mention the dynamics thereof, rather than allowing the user to readily understand and control these aspects of his own service.

A very simple way to add binding of the onionsite public key to a known entity using widely available mechanisms is to provide a signature on the onion address, such as a PGP/GPG signature. The signed text can be included on the onionsite, making it self-authenticating in this sense as well. The trust in the authentication will then be whatever trust is associated with the public key that does the signing. Such techniques are already used for signing code. For example, the Tor Project offers signatures on all source and binaries it makes available for download.

If the signer wishes, she can also post the signed onion address to a public site such as her Facebook page (An advantage of doing so will be discussed below.) Indeed, a useful public site for doing this would be an unauthenticated version of the same exact service as the one being offered at

the onionsite. The unauthenticated version and the onionsite version should both contain a signed pointer to both versions. It is then easy for anyone who desires to check their association. For example, by posting his PGP signature on both addresses at both <http://glennsorrentino.com/onion-binding.php> and <http://at3o24mj2rfabkca.onion/onion-binding.php> Glenn Sorrentino binds the addresses of the insecure and authenticated versions of his site.

Another natural place to post the association would be to Keybase, which is in beta and a somewhat similarly motivated “people directory” [19]. Keybase lets one look up via usernames on github, reddit, twitter, bitcoin etc. identifiers signed with the same PGP key. Keybase is, incidentally, another commercial site with an onion address (<http://fncuwbiisyh6ak3i.onion/>) for its registered-domain address (<https://keybase.io/>), although at last check they have not recursively listed this itself within Keybase.

Given the authentication benefits onionsites provide, why even bother with a non-onionsite version? Providing a site at the registered domain is a way to make it available to users not coming over Tor. An onionsite could typically still be accessed via Tor2web, a website that proxies connections from non-Tor clients to onionsites [20]. But, whatever availability such proxying services provide, they inherently operate as at best an overtly acknowledged man-in-the-middle on connections to onionsites. Since we are focused on not merely maintaining but improving authentication in this paper, we will say no more about such possibilities. We thus limit ourselves to *secure* onionsite access for the millions of current Tor users and those who become users. Site operators wishing to provide access more widely if less securely should do so via connection to the registered domain name—hopefully at least protected by HTTPS.

Finally, traditional search and indexing engines such as Google do not generally reflect links to onionsites. One can get them to list onionsites associated with registered domains by including these in site metadata, as in our running example of glennsorrentino.com. The search engine ahmia.fi [21] is limited to onionsites and known primarily to those familiar with them. Ahmia creator Juha Nurmi has, however, agreed to incorporate linking of onion and registered-domain addresses into Ahmia, together with the GPG signatures binding that linking. He has also suggested to us that Ahmia could automatically test the signatures and check the registered-domain and onion sites. Thus, a user who trusts Ahmia (and her connection to Ahmia) on this can verify that a pair of websites is operated by the same party, even if personally inexperienced with manual PGP verification. Crawling and indexing of onionsites is also in its infancy and can thus not be expected to be as appropriately representative as the much more mature indexing of the surface web by Google and similar sites.

V. USABILITY, CONVENIENCE, AND SECURITY

As most onionsite visitors use the Tor Browser, deployment and debugging of hidden services can be faster than their registered-domain counterparts because there is only one browser to test, with only minor variation across users. Website

operators can assume that users do not have Adblock or other browser extensions that may impact how content is displayed. However, plugins that may mitigate Tor Browser’s privacy protections, such as Java and Flash, have been disabled by default. Many privacy-conscious users do enable the NoScript extension to block javascript as well. Despite this, rich content such as video, audio, and interactive storytelling are still available for designers willing to use HTML5 and CSS3. And since Tor Browser is generally somewhat more restricted than other browsers in what it will process, if operators do wish to offer access to their Tor-Browser-tested site at a registered domain, no change should typically be needed for successful access using other browsers.

What we have described so far implies a relatively manual authentication of PGP/GPG signatures. It would be natural and straightforward to create a plugin that verifies the signature and provides different indications to the user depending on the trust in it. There are already related tools, e.g., Monkeysphere, a Firefox plugin that uses the PGP trust infrastructure for validation only when the browser does not default accept the TLS certificate validation [22]. A simpler plugin could also just check the planned Ahmia validation mentioned above.

Our PGP approach also can be used (at least in manual form) right now by website operators. It would benefit from usability developments and simplification, and it can complement other approaches. It does not, however, rely fundamentally on the deployment and continued commitment to new infrastructure that is specific to it. It can instead rely on whatever authentication infrastructure might be popular and likely to be maintained for independent reasons, rather than needing to grow and maintain interest in its approach.

In the PGP web of trust, signature authority is built up in a decentralized manner from direct personal connections and introductions. This more naturally fits with many of the kinds of websites that we have suggested could most benefit from our approach, for which local or personal trust relationships are important [23]. The X.509 trust model currently in general use to support TLS certificates is by contrast primarily a hierarchical centralized chain of trust delegated down from some ultimate national or global corporate trust anchor.

PGP remains much less familiar than TLS. Popular familiarity is, however, not so much with TLS as with interfaces that tell the user little more than whether or not TLS and certs from default accepted authorities are in operation at all, which is roughly as it should be for usable security. As noted, similar interfaces for PGP have been designed but have not yet received the extensive development of TLS interfaces, unsurprising given the fundamental role of TLS in global ecommerce. For those who do not otherwise rely on the social or local protections of PGP’s web of trust, TLS certificates are likely to remain the primary ground of linking public, human-readable domain names to the signatures authenticating websites.

VI. LET’S AUTHENTICATE

Unlike conventional web URLs, onion addresses are inextricably connected to the site authentication key. Thus, if one

has publicized the onion address, e.g., through blogs, Twitter, or Facebook, people following those address links will not be vulnerable to hijack or MitM by a subverted CA, as they would be by a link to a registered-domain URL. This significantly raises the bar on the hijacker fairly automatically and easily. Further, non-CA-based MitM techniques such as forcing the site to fall back to a non-SSL version (e.g., SSLStrip) or to use a weaker cipher to communicate (e.g, BEAST and FREAK) are also not possible as the address and key are inextricably linked and generated cryptographically.

Assuming Let's Encrypt is successful, we can envisage eventual incorporation of TLS with onionsites for even the "everyman" users described above. While certificate transparency and the like will help increase trust in authenticating such sites via their certificates, the self-authentication of onion addresses also adds to this trust: in the conventional sense that certificate transparency addresses, in authentication of the route not just the destination, and both of these in a way more directly under website owner control. But, it is not just the little guy. We have already noted a few of the increasing number of prominent companies that offer onion services. Also, the General Services Administration negotiates federal-friendly Terms of Service amendments for the rest of the U.S. government [24]. As of this writing, it is negotiating a federal-friendly amendment for the current Let's Encrypt ToS agreement.

In addition to the PGP-based approach given above, we now sketch a description of incorporating onion addresses into certificates for registered domains. We also describe how to incorporate these into a relatively transparent and simple system for website access with improved security.

Creating the Domain Validation Certificate

We assume the cert to be obtained will have the onion address listed as a SAN (subjectAltName) in the certificate issued for the registered domain name. This is currently ruled out for most by CA/Browser Forum policy, which only allows registered domain names and wildcards thereof, such as *.duckduckgo.com. The only exception is for EV certificates. As noted above, these are prohibitive for many site owners, hence problematic. Nonetheless, DigiCert has provided instructions for ordering .onion certs, in response to a large volume of requests [25]. We will explore below some of the concerns and reasons why the novel approach herein supports a change from the current restrictions. But first we describe how this approach will work, assuming onion addresses are allowed as names in DV certs in the setting we describe.

(One could simply create a self-signed certificate with this binding of onion and registered domain names. A pop-up would then warn users going to the site because the signing authority is not trusted by the browser. Such warnings are important, especially since the overwhelming majority of current Tor usage is for safer connections to registered-domain addresses. And, in this section we pursue a strengthening of, not an alternative to, the current authority-based web authentication infrastructure. This centrally includes the user experience thereof. We thus want to avoid both accepting self-signed certs without warning and adding to circumstances where pop-up warnings superfluously occur.)

At least the same DV level of checking should occur as is currently done when issuing certificates to registered domain names. The latest ballot-approved CA/B Forum Baseline Requirements list several ways that control of a domain can be demonstrated [26]. The most familiar is probably via response to email to administrator@[registered domain] or similar address. The Baseline Requirements also permit that the applicant for a certificate can demonstrate the ability to make a requested change, e.g. adding a nonce, to a page under a domain name that terminates in the requested domain name. So, a validation query protocol can be used that freshly connects to the onionsite and asks if it is acceptable to certify association of the onionsite with the registered domain. This can also serve as a check that an onionsite the user just set up is properly configured and thus the certification process can continue. Only if all DV checks complete successfully should the CA be willing to issue the Cert.

An email or other check of the registered domain must also include the onion name that is being bound as well as the registered domain name. If someone were to obtain a certificate for multiple registered domain names by showing control of only one, they could thereby fraudulently authenticate others covered by the certificate. The self-authentication of onion addresses limits this damage. This check alone would not prevent someone from obtaining certificates for onion addresses not under her control. But, since she would not possess the private key for the onion address, people thereby tricked into going to that address thinking it was authenticated by the cert or thereby associated with the registered domain name would simply experience a failure to successfully complete a connection. Nonetheless, many subtle attacks on authentication are possible when parties are confused about who they are connecting to and in what role, especially if authentication protocol runs are interleaved [27]. It is therefore advisable to have a similar check that someone with control over the onion address authorizes binding of the registered domain name to the onion address.

Connecting to an onionsite by the client

Assuming an onionsite has been configured and certificate issued for it, how should a client connect to the onionsite? If connection to the onion address has been requested, e.g., by the user clicking on a link to that address, then the connection should proceed as normal and the browser should display appropriately for a DV-certified destination. But a client may request a connection to the registered-domain address associated in the certificate and be automatically redirected to the onionsite as a security enhancement. This could be done by additions to the HTTPS Everywhere ruleset.

HTTPS Everywhere is a browser extension incorporated by default in Tor Browser and currently available for Firefox, Chrome, and Opera [28]. It rewrites requests to visit sites via unencrypted HTTP to HTTPS requests. This does more than simply add an "S" to the request. Sometimes the encrypted version of a site and the unencrypted version are at different locations in the domain. Conversely, sometimes adding an "S" to an HTTP request will succeed, but will connect to a page intended by the domain owner for an entirely different purpose

than offering a secure version of the site at the unencrypted address. Like HSTS, HTTPS Everywhere also helps guard against SSLStrip and similar attacks. HTTPS Everywhere also includes the SSL Observatory mentioned above. (Though it would be a much more significant difference from current HTTPS Everywhere, note that the ruleset could be expanded to allow redirection to onionsites that are using the GPG approach to binding described above.)

Another advantage of relying on HTTPS Everywhere for directing registered-domain requests to onionsites is that there will be no DNS lookup of IP address associated with the domain name. This means that no attacks on DNS resolution or even observations of DNS lookups exiting the Tor network can affect such connections.

An onion by any other name would cert as sweet

Why not permit onion addresses as names in certificates in the above setting? Two broad classes of objections have been raised to us in CA/B Forum discussions and discussions with CA/B Forum members.

First, currently deployed onion addresses and protocols rely on SHA-1 and RSA-1024, both of which are recognized to have reached their effective cryptographic security end-of-life. But, Tor client and relay software has already transitioned in stable releases to SHA-256 and ed25519, which are generally accepted as adequate for the foreseeable future. And Tor is expected to transition onion services to these within the year. So any valid objections based on this concern must be very short-lived. More importantly, when combined as described above, onion protections can only add to the protections offered by TLS and certificates. Breaking the private RSA-1024 key associated with an onion address that has an appropriately stronger TLS key and cert does not by itself allow one to subvert a certified TLS session with the onionsite. Conversely, MitM, cipher degradation, or other attacks on the cert or TLS instance are not possible when connecting to an onion address unless one also breaks the self-authentication.

Second, for various reasons there is some desire to support CA's being able to link "real-world" identities to issued certificates as occurs when validating registered domain names, which is why only EV certs have been approved for onion addresses. But the above only proposes that DV certs for onion addresses be issued when fully bound to a registered domain name by the same validation that would permit the cert issuance for the registered domain name; whatever benefits such linking provides is just as strongly supported for the onion address as would be supported when issuing a cert for the registered domain name by itself.

VII. CONCLUSION

In this paper we have described how Tor's onion services can be used, not for the usual stated purpose of hiding server network location, but for website authentication. We have also described how securely combining onion services with registered domains allows site operators to offer a simple, effective, and inexpensive means of providing authentication with security advantages not currently otherwise available. We have described two approaches to this: One, based on

PGP, is feasible for immediate albeit manual use. The other enhances existing authority-based TLS and has the potential for simple setup and use in conjunction with the Let's Encrypt infrastructure.

A decade ago, websites available via encrypted and authenticated connections were relatively rare, rather than ubiquitous as they are today. At the time, the need to provide users with such options seemed the province of the paranoid rather than standard good practice. Whether or not our specific design recommendations are adopted, we hope readers can see in our proposals similar prospects for general adoption in the years to come of the stronger and broader authentication and confidentiality offered by onionsites. We also hope our expanded view of the possibilities created by Tor's onion services will encourage others to explore this fascinating system for other interesting properties and applications.

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