

Saber: Delegating Web Security to Browser

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Abstract

Today, any non-trivial application requires the ability to communicate over the network. Providing a secure connection (i.e., a confidential and authenticated connection) is a difficult task as it involves correctly implementing complex protocols. Having stood the test of time as being the most popular application for network communication, browsers have been able to achieve network security with greater success. However, almost all other non-browser applications have lagged behind. We look at tools that fetch webpages over https (such as *wget*), analyze their connection security, and propose that these tools delegate network security to browsers. Furthermore, we built a prototype version of *wget* to demonstrate the feasibility of building applications that provides security guarantees (confidentiality, integrity, authenticity) without requiring a deep understanding of the TLS protocol.

1. Introduction

Transport Layer Security (TLS) is a cryptographic protocol designed to provide end-to-end communication security between two parties, even in the presence of active man-in-the-middle adversaries [5]. It has since become the standard for providing secure communication on the Internet and is used for most sensitive applications, including online banking, email, instant messaging, shopping, etc. Usage of TLS is most commonly seen in securing web traffic in the form of HTTPS [21]. When implemented correctly, HTTPS guarantees confidentiality, integrity, and authenticity of all web communication between two parties. Furthermore, there are additional mechanisms that improve the security of the entire HTTPS ecosystem.

While browsers are not free from TLS bugs, their implementations of network security protocols are regarded as the state of the art. Additionally, browser vendors are the original pioneers of modern HTTPS standards and have been the first to implement them into practice. Previous work has found that non-browser applications have struggled with validating TLS certificates [11], but usage of this non-browser software is quite prominent. These applications and libraries support communication on top of TLS and provide the impression of giving security to the user, but they fail to live up to that promise.

The issues with improper implementation of TLS for non-browser applications are due to a combination of the complexity of the protocol, lack of general understanding of TLS, and not having the same security expertise and engineering resources that

browsers possess. Individually solving these issues would be a monumental task and would require widespread education of proper implementation of communication security, along with the expense of recruiting security experts for every application that supports HTTPS. This may not be feasible for several applications that are maintained by individual developers but are nonetheless popular.

In this paper, we propose a new way to build command-line HTTP clients that allows developers to use the TLS protocol, but does not demand an intricate understanding of the correct protocol implementation. Our method involves delegating the handling of connection security to browsers, so the non-browser application deals only with application layer logic. This allows non-browser applications to get connection security “for free” from browsers. This also lets them take advantage of any mechanisms that browsers implement to harden TLS security (such as HSTS, HPKP, etc.). We have built a prototype version of *wget* in this fashion. Our secure *wget* (*swget*) application is able to validate proper TLS connections without writing any code that requires a deep knowledge of the TLS protocol, and further provide modern HTTPS security guarantees that only browsers typically provide.

This paper is organized as follows: In Section 2, we discuss the background material related to TLS and HTTPS, the various existing problems with the ecosystem and how browsers have taken steps to solve them. In Section 3 we look at some non-browser applications, in particular *wget* to see how they compare to modern browsers in terms of connection security. In Section 4, we present the design of a library that delegates connection security to the browser. In Section 5, we present *swget* as a prototype implementation of *wget* that provides better connection security by delegating TLS to browsers. In Section 6, we conclude and discuss related work.

2. Background

In this section, we present a brief description TLS, HTTPS, and additional security mechanisms that harden the HTTPS ecosystem.

2.1 TLS

Transport Layer Security (TLS) is a cryptographic protocol that provides the following properties:

- **Confidentiality:** All communication between two parties is encrypted such that no information about the contents of the communication is leaked to an adversary.

- **Integrity:** An adversary must not be able to change the contents of the communication between the two parties in any way.
- **Authenticity:** The two communicating parties can verify the identity of each other (typically only the client verifies the server identity) through a certificate signed by a *trusted third-party*, and ensure that the messages exchanged are from each other. As such, an adversary cannot pretend to be one of the communicating parties.

TLS provides these security guarantees underneath the application layer. Several application layer protocols such as HTTPS, IMAPS, XMPP, and SMTP use TLS to provide end-to-end security.

2.2 HTTPS

HTTPS (or “HTTP over TLS”) is a protocol which secures HTTP traffic within a connection encrypted by the TLS protocol [21]. It is mainly used for authenticating a website and securing communication between the website and its users. This is done with the use of server certificates [4]. In a normal HTTPS connection, when a client makes a request over HTTPS to some website, the server presents the client with a certificate signed by some certificate authority. This certificate authority may not directly be trusted by the client but may instead be trusted by another entity that the client may trust. The server also responds with a chain of trust listing all the CAs that are part of the chain connecting to a root CA that the client trusts.

A client needs to validate the certificate’s credentials and determine the validity of the certificate. A client may find the certificate to be invalid in cases when it’s expired, has a mismatching common name field, is revoked, uses a weak signature algorithm, etc. We list several different types of client behavior for certificates in Table 1 in the appendix.

2.3 Strict Transport Security

While HTTPS protects users from active man-in-the-middle attackers, the protection only applies if the client actually makes an HTTPS web request.

Secure connection to a domain that does serve over HTTPS can only be guaranteed if the initial web request made by the client was over HTTPS. Unencrypted HTTP requests and responses can be modified freely by an active man-in-the-middle attacker. Even if a web server redirects from HTTP to HTTPS for partial or all of the web requests that it serves, an active man-in-the-middle attacker could intercept that unencrypted redirect response and replace it with a forged accept-response pretending to be the server. As a result, the attacker could make it so that the client never actually switches to an HTTPS connection and remains vulnerable. This class of attacks is commonly known as *SSL Stripping* [18].

To combat this problem, servers serve a *Strict-Transport-Security* (HSTS) header as part of the response that instructs the client to only visit the website over HTTPS connection [15]. A client that respects this HSTS policy would automatically upgrade all HTTP requests made by the user to HTTPS before sending the request over the network. As long as the client can guarantee a secure connection with a domain once and receive an HSTS header, all future communication within a designated timeframe to that

domain is protected. HSTS headers also need to provide a *max-age* policy that determines how long a client enforces the HSTS policy. This policy is continuously updated every time an HSTS header is received, so if a client visits the same website again within the expiry period, the client stays protected. Otherwise, the client loses protection when the max-age policy expires and protection is resumed once the client receives a fresh HSTS header from securely connecting to the domain again. The *max-age* policy allows websites to switch back to HTTP connections should they choose to do so in the future. Without a max-age policy, a client wouldn’t be able to communicate over HTTP with the server again once it has received an HSTS header.

HSTS relies on the *Trust On First Use* (TOFU) principle to harden protection. Today, browsers ship with preloaded list of domains that have HSTS protection turned on by default so that users gain HSTS protection even before they establish a single secure connection. Any domain owner can apply to be a part of this list and the process has seen significant adoption since it was automated by Chrome [1].

2.4 Public Key Pinning

The current HTTPS Public Key Infrastructure relies on trusting all the root CAs and by extension, all intermediate CAs trusted by root CAs. This raises the concern that if one of the CAs was coerced or compromised by some adversary, then that CA could issue a valid rogue certificate for some website without the permission of the owner of the website. This rogue certificate would be trusted by any user that trusts the CA that generated it. Previous work has shown that certificate authorities can be falsely tricked into issuing rogue certificates and in 2010, a commercial software was available for sale to government agencies to use rogue certificates for intercepting traffic [23]. HTTPS and HSTS alone do not protect from this kind of interception.

HTTP Public Key Pinning (HPKP) solves this problem by allowing web servers to serve an HTTP header over HTTPS that lists the hashes of the complete *Subject Public Key Info* field of a certificate for each public key that the domain owner wishes to use to establish a TLS connection. A client that respects the HPKP policy must ensure that while establishing a TLS connection with a website for which there is a cached HPKP entry, at least one key in the certificate chain matches a key stored in the pin set [8].

This allows a domain owner to pin only their own keys. In the case that the owner chooses to only pin leaf-level keys generated by the owner themselves, no CA would be able to generate a rogue certificate for the domain that a client that has already had the keys pinned. The owner can also choose to pin the public keys for specific CAs that they trust (over all CAs), still reducing the surface area for attackers that compromise CAs.

Similar to HSTS, HPKP headers also specify a *max-age* policy which determines how long a client should remember the pinned key. This value also keeps getting continuously updated if the client receives the header again before the policy expires. HPKP headers are not very commonly seen from websites but both Firefox and Chrome provide support for it. Browsers also ship preloaded HPKP lists similar to HSTS that provide this protection by default.

2.5 Certificate Revocations

In the case that a domain's private key gets leaked (due to server compromise, phishing, etc.) any certificates that were issued for the corresponding public key need to be revoked. Both registering a certificate as revoked and checking the revocation status of a certificate have been tricky challenges for the server and client respectively [17].

One way for checking revoked certificates is to maintain a Certificate Revocation List (CRL) for all revoked certificates which the clients could use to validate the certificate [4]. This list needs to be continuously updated with the latest revocations and clients need to be able to check the revocation status of a certificate dynamically. In a situation where a client is unable to access the revocation list (for example if an adversary runs a denial of service attack that prevents the client from contacting the server), then no further operations that depend upon the validation of the certificate can take place.

Online Certificate Status Protocol (OCSP) is an Internet protocol used to communicate the revocation status of x509 certificates [19]. The protocol works similarly to CRLs but require less bandwidth on the client. A client requests the status of a certificate from an OCSP server, which responds whether the certificate is revoked or not. OCSP still has the same denial of service issues as CRLs and many clients tend to accept a certificate if they cannot successfully get an OCSP response. To address this issue, the original server that presents the certificate can make a request to the OCSP server and staple the OCSP response along with the original certificate, which the client can verify offline. This is known as OCSP stapling and many web servers support it today (although only about 9% of TLS connections use it as of 20.4) [13].

Despite OCSP stapling, an attacker that can compromise a server can simply serve the certificate without a stapled OCSP response which the client may accept. Website owners therefore have an option to issue a certificate with a "Must-Staple" flag [12]. If a client sees this flag in the certificate, the client must not accept the certificate without a stapled response. This is respected by Chrome and Firefox.

Chrome and Firefox have also introduced offline CRLs that they push to user's browsers during updates [13, 14]. This is primarily used for serious incidents (say if an intermediate CA gets compromised) to push emergency updates to the CRLs maintained by the client.

3. Issues with non-browsers

TLS is a complicated protocol to implement correctly and the configuration options in TLS libraries are difficult to understand. Several non-browser softwares have been shown to be insecure against a network attacker not due to using an incorrect protocol, or a broken library, but rather due to incorrect certificate validation arising out of mistakes when configuring TLS options for their application [11].

Further, even a correct implementation of TLS does not protect these applications from SSL stripping, rogue certificates, and revocations, unless all the additional mechanisms such as HSTS, HPKP, and OCSP stapling are also implemented by the application. In our

experiments with wget, curl, and the standard request libraries for Python and Node.js, we found that only wget supports HSTS and has very limited and manual support for public key-pinning. None of the four HTTP clients threw any form of error or warning for a revoked certificate and the request libraries for Python and Node.js, and curl do not have any support for HSTS and HPKP.

Wget provides support for HSTS, but upon investigation, we found that wget was not updating the expiration time for HSTS entries every time it received a valid HSTS header with a valid max-age policy. This breaks the continuity policy of HSTS which is supposed to maintain a secure HSTS entry as long as user visits the domain frequently (i.e. within the specified max-age period). If a domain provides an HSTS max-age policy of 1 day, then the wget client would be vulnerable to interception at least once a day even if the developer visits the domain multiple times within that period. We reported this issue to wget which was then promptly fixed [22].

3.1 Certificate validation results

We tested the behavior of 6 different HTTP clients (2 command-line tools, 2 language request libraries, 2 browsers) when presented with 27 different types of certificates. The complete results are presented in Table 1 in the appendix. Explanation of different types of certificates we tested-

1. **Expired.** The certificate has an expiration date in the past.
2. **Wrong Host.** The certificate is not valid for the website that presented it and should be rejected.
3. **Self Signed.** The certificate is signed by the identity it certifies and should be rejected.
4. **Untrusted Root.** The root authority should not be trusted by the client and should be rejected.
5. **Revoked.** The certificate used to be valid but was revoked by the owner and should be rejected.
6. **Pinning Test.** A different certificate has been pinned (via an HPKP header) and so this certificate should be rejected.
7. **Incomplete Chain.** The certificate chain presented is incomplete. Browsers accept this certificate since the incomplete chain was sufficient to establish trust.
8. **SHA1 Intermediate.** One of the certificates in the chain was signed with a SHA1 signing algorithm and should be rejected.
9. **1000/10000 Subject Alt Names.** The certificate provides 1000 or 10000 alternate subject names. This behavior is acceptable.
10. **RC4-MD5, RC4, 3DES, Null.** These are different types of weak cipher suites used by the respective certificates (and no cipher suite in the Null case). All of these should be rejected.
11. **DH480, DH512, DH1024, DH2048.** These are the different types of Diffie-Hellman key exchange algorithms used by the connection. Only DH2048 is currently considered secure.
12. **DH Small Subgroup, DH Composite.** If the key exchange was performed with a small or non-prime subgroup, then security cannot be guaranteed and these connections should be rejected.

13. **Invalid Expected SCT.** The certificate for this site uses a CA that Chrome requires valid Signed Certificate Timestamps (SCTs) for, but contains an invalid SCT. Only Chrome enforces this check.
14. **Superfish, eDellRoot, DSD Test Provider.** These are certificates issued known bad certificate authorities and should be rejected.

3.2 Why do these problems exist?

HSTS and HPKP are relatively recent standards that have been pioneered by web browsers, so it was not surprising for us to find that non-browser software do not implement them. However, this supports the argument that browsers are ahead of other applications when it comes to providing connection security. Browsers are also more frequently updated when compared to non-browsers allowing them to fix any discovered vulnerabilities faster.

Both Chrome and Firefox have dedicated security teams working on ensuring the safety of the respective browsers. It is difficult to for every single HTTP client implementation to afford the same attention to security as browsers can even when the applications have similar connection requirements. While we can encourage safe defaults and better tutorials, developers who implement such http clients are still prone to making mistakes when using TLS libraries. These mistakes would be difficult to eliminate since developers quite often do not have the security expertise to understand these mistakes. This can be seen by comments from developers on stack overflow, with one particular response suggesting disabling certificate validation being a top answer with hundreds of votes [2].

3.3 Non-browsers have a representation issue

Due to the nature of most command-line HTTP clients and their lack of a graphical user interface, they do not convey the same information about the security of the connection to the user as browsers do. There has been a lot of work involved in presenting appropriate security warnings to the user when a certificate error occurs [10]. Further, the “green lock” symbol is also a useful indicator to users about the security of their connection to some website. All of these advantages are application specific and traditionally exclusive to browsers.

Redirects, in particular, can be easily overlooked without appropriate indicators. Browsers consider HTTPS to HTTP redirect for top-level pages as acceptable behavior since the user can look for insecure connection indicators next to the url. This behavior however may not be appropriate for an application like wget. In the case of such a redirect, wget would follow the redirect and download the resource. The redirect to HTTP is easily overlooked by an average user. Considering the original request was for an HTTPS url, the user’s security may have been undermined without the knowledge of the user. If the user was downloading code and piping it to bash, a common practice, then an HTTPS to HTTP redirect could allow a man-in-the-middle attacker to run code directly on the user’s machine.

4. Delegating connection security to browser

We propose a new way to build non-browser applications that allows developers to use the TLS protocol as implemented for web security but does not require the expertise needed to implement TLS verification correctly. We achieve this by delegating the actual network request/response handling to Chrome. Instead of directly interfacing with TLS, all requests are forwarded to Chrome, which would handle proper certificate checking on behalf of the application. This allows HTTP clients to capitalize on the security, reliability, and update frequency of Chrome, while only having to worry about the correctness of application layer logic. Another huge benefit to this approach is that the benefits are not restricted to just establishing a TLS connection. Chrome also implements HSTS, HPKP, and revocation verification, and HTTP clients delegating requests to Chrome gain all of these advantages for free as well. Chrome also provides protection from websites marked as containing malware, phishing attacks, and dangerous binaries. These are pages that may be served over a secure connection, but are flagged as malicious (which may happen due to a server compromise, or a malicious hosting site). Delegating requests to Chrome allows other HTTP clients to avoid downloading malware as well.

4.1 Remote debugging protocol

We built a prototype version of *wget* that we discuss in Section 5. For our prototype implementation, we utilize the Chrome *remote debugging protocol*. When remote debugging is enabled for Chrome, it allows other applications to communicate with the browser over a web socket. This feature has mainly been used for debugging Chrome, but we use it to issue network requests and fetch responses. Since the network request is made by Chrome, it performs all the usual HTTPS security checks and the request only succeeds if the connection is secure, we only add additional logic for redirects. Figure 1 shows the design for this approach.

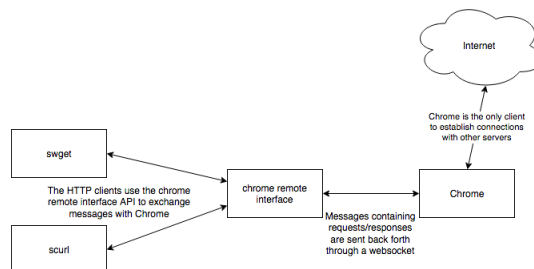


Figure 1. Prototype approach: Applications issue requests and fetch responses from Chrome through the Chrome remote debugging protocol. Chrome makes the request on the application’s behalf and fetches handles all connection security specifics.

4.2 Linking directly to Chrome’s networking code

Using the remote debugging protocol to delegate requests to Chrome is inefficient since serialized messages are exchanged over a web socket between the HTTP client and the browser. A more optimized and secure approach would be to link directly with Chrome’s networking library. This could potentially be more lightweight as it

would only require a small subset of Chrome wrapped with a thin request API that applications could interface with. Figure 2 shows a potential design for this approach. We leave this approach for future work.

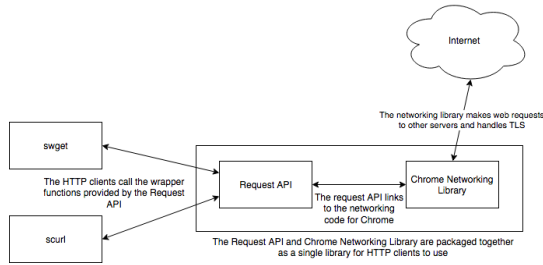


Figure 2. Optimal approach: The network request library from Chrome is exported (along with any security handling logic) and wrapped up in a library with an exposed Request API that non-browser applications interface with.

4.3 Motivation

The motivation behind our delegation approach is based on two key facts: (1) Browsers are already pioneers of providing secure communication and other applications can capitalize on that. (2) Writing security critical code is difficult and we want to minimize the amount of such code that needs to be written by developers. Currently, any HTTP client would have to include its own code that either correctly implements the TLS protocol, or uses a TLS library correctly, both of which have proven to be difficult [11]. As an example of our delegation approach, we implement *swget*, a prototype of *wget* that provides connection security without writing any TLS verification code. This pattern can also be used to create a library that provides a simple Fetch API that any HTTP client could interface with easily.

5. wget

wget is a popular command line tool for downloading files from a webserver. It is frequently used by developers to crawl web pages, download scripts, and sometimes directly pipe such scripts to the shell (for example, when installing software such as Node or Bower). While such a practice of executing code obtained remotely can be dangerous in itself, it is especially a problem if the security of the connection is compromised by a man-in-the middle attacker.

```
atyansh@caster ~$ ./swget google.com
Redirecting from http://google.com/ to http://www.google.com/
Redirecting from http://www.google.com/ to https://www.google.com/
Writing contents to index.html
atyansh@caster ~$ ./swget facebook.com
Redirecting from http://facebook.com/ to https://facebook.com/
Redirecting from https://facebook.com/ to https://www.facebook.com/
Writing contents to index.html
atyansh@caster ~$
```

Figure 3. *swget* fetches and saves the webpage similar to *wget* in the normal case

We wrote our own prototype version of *secure wget* that has the same basic functionality as *wget*, but uses Chrome to make

network requests. Figure 3 shows standard behavior of *swget* when fetching a webpage. Looking at *wget*’s source code, we see it has 994 lines of code for interfacing with the *OpenSSL* library. Our version of *swget* does not require any code to interface with a TLS library. Only 8 lines of code are needed to add a certificate handler since Chrome would already throw an event in case any abnormal certificate is encountered. We override Chrome’s certificate handling settings using the remote debugging protocol to grab the certificate error determined by Chrome and cancel the request. We used the Chrome remote interface Node.js library to construct our messages to Chrome which also contributed to the decreased code size. Figure 4 shows how *swget* responds when it catches a certificate error.

```
atyansh@caster ~$ ./swget https://expired.badssl.com/
Certificate Error: ERR_CERT_DATE_INVALID
atyansh@caster ~$ ./swget https://wrong-host.badssl.com/
Certificate Error: ERR_CERT_AUTHORITY_INVALID
atyansh@caster ~$ ./swget https://pinning-test.badssl.com/
Certificate Error: ERR_SSL_PINNED_KEY_NOT_IN_CERT_CHAIN
atyansh@caster ~$
```

Figure 4. *swget* catches any certificate errors caught by Chrome. In the figure, we see an example of domains with expired certificate, mismatched hostname, and an example of website that serves a valid certificate that was not pinned as part of the HPKP policy.

Since Chrome does certificate validation, *swget*’s connection security is at least as restrictive as that of Chrome by default. We can manually increase or decrease restrictions based on user supplied arguments to *swget*. This also includes protection from revoked certificates, something which *wget* does not provide today. A full list of our certificate testing for various clients can be found in Table 1 in the appendix.

5.1 Secure redirects

```
atyansh@caster ~$ ./swget --allow-insecure-redirects vm150.sysnet.ucsd.edu
Redirecting from http://vm150.sysnet.ucsd.edu/ to https://vm150.sysnet.ucsd.edu/
Redirecting from https://vm150.sysnet.ucsd.edu/ to https://www.atyansh.com/
Redirecting from https://www.atyansh.com/ to http://eduardo.me/
Writing contents to index.html
atyansh@caster ~$ ./swget vm150.sysnet.ucsd.edu
Redirecting from http://vm150.sysnet.ucsd.edu/ to https://vm150.sysnet.ucsd.edu/
Redirecting from https://vm150.sysnet.ucsd.edu/ to https://www.atyansh.com/
ERROR: Redirecting from https://www.atyansh.com/ to http://eduardo.me/
Unsafe redirect, connection closed
atyansh@caster ~$
```

Figure 5. Preventing unsafe https to http redirects

The default redirect behavior for Chrome is for top level requests is to follow redirects. While this behavior is okay for Chrome, this may not be ideal for an application like *wget*. Users use *wget* to fetch and download files. If a request to fetch was made for an https link which was then redirected to HTTP, security of the connection could be compromised by an attacker. While browsers can display the current security status to the user, there’s no convenient way to check whether a file downloaded with *wget* was actually downloaded securely or not, once the file has already been fetched. We disable HTTPS to HTTP redirects by default in our implementation of *swget*. As seen from Figure 5 a connection is terminated if the application encounters an unsafe redirect. Command-line HTTP clients such as *wget* and *curl* do not currently provide secure redirects.

5.2 Warning messages

Non-browser applications have suffered from having poor UI in comparison to browsers. Previous research has shown that better browser TLS warnings decreased user click-through [9]. We believe that users that use non-browser applications would similarly benefit from improved warning messages and have included more visual indicators (such as lock symbols) to convey the security state of the connection. This is especially noticeable in the case of redirects (Figure 5) and malware warnings (Figure 6). Further work needs to be done to measure the effectiveness of these warnings.

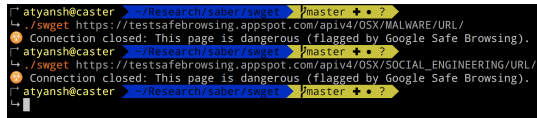


Figure 6. Malware detection as flagged by Chrome

5.3 Cookies and basic authentication

Since swget uses Chrome to issue web requests, it can take advantage of Chrome’s session management. This allows us to enable/disable cookies for swget. Depending on the behavior the user wants, the user’s Chrome profile can be used if the client needs to access the browser cookies, otherwise, a fresh Chrome user profile could be created that doesn’t share any session state with the user’s actual browser.

Cookie authentication can be pretty useful, especially to download web pages that require authentication (for example, Facebook). In standard wget, the user would have to provide their login credentials to wget or create a special authentication token for wget. In case of swget, the browser is already authenticated with the web server hence no further authentication is needed.

To demonstrate this, we provide an example of HTTP basic authentication by using swget on a website that requires a user to provide login credentials before visiting the website. Using wget on this website would return a *401 Unauthorized* error unless the credentials are provided along with the url. We used a simple username/password prompt to allow an swget user to provide credentials dynamically if a website requests for them. Since Chrome remembers the authentication credentials for the session, any further requests would automatically have the credentials filled by Chrome. This can be seen in Figure 7. The user is prompted again if the credentials did not match correctly.

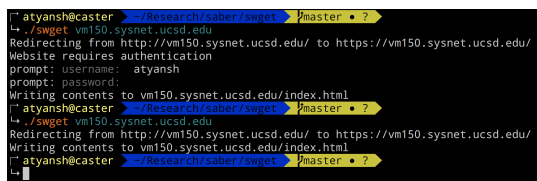


Figure 7. HTTP Basic Auth

5.4 Centralized HSTS and HPKP

When Chrome receives an HSTS or HPKP header from a domain, it would record the header and provide protection for the website.

Wget provides a similar HSTS protection for a domain. However, if an HSTS entry is recorded for a website by Chrome, the user gets HSTS protection only for Chrome, and not wget, and vice versa. In fact, any two different clients do not share these protections with each other. As such, the user is vulnerable every time they make an HTTP request for a website from a new client even though they have previously received an HSTS header for the domain via different client. The same problem exists for HPKP.

The model of delegating connection security to a single client—Chrome in our prototype—provides a centralized way to maintain HSTS and HPKP records. As such, any clients (such as swget) automatically share these protections with the browser. In fact, all clients that use this model would share these protections.

5.5 Future Work

Browsers provide protection against mixed-content in webpages (for example, HTTP hyperlinks on a webpage served over HTTPS) through security warnings. They also disable loading HTTP iframes when the top level page is served over HTTPS. Further, if a *Content-Security-Policy* header is served by the server that specifies the client to upgrade insecure requests, browsers will upgrade insecure HTTP requests to HTTPS. Swget currently does not support these mechanisms but we plan to implement CSP request upgrades in the future.

We also plan to add subresource integrity checking to swget. Browsers can verify the integrity of subresources downloaded over HTTP, commonly seen for media downloaded from a CDN, by checking the cryptographic hash of the subresource obtained over HTTPS. Command-line HTTP clients can benefit greatly from subresource integrity.

6. Conclusion

Today, non-browser HTTP clients are weak to network adversaries in ways that browsers aren’t. Our successful implementation of swget shows that this is a feasible strategy of building non-browser HTTP clients that require connection security without interfacing directly with a TLS library.

Another approach involves retrofitting implementations of SSL Libraries through dynamic linking [3]. The benefits of this approach is that it doesn’t require existing applications to be changed. However, this mechanism only improves proper certificate validation, it doesn’t provide further protections such as malware detection, HSTS upgrade, browser maintained CRLs, etc. In contrast, our approach also address protection sharing across clients through a centralized protection mechanism.

7. Acknowledgments

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A. Certificate Results

Table 1: Behavior of different clients when presented with different certificates. A green entry indicates that behavior is safe. A red entry indicates that the behavior is not ideal.

Certificate	wget	curl	python	node	firefox	chrome
Expired	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
Wrong Host	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
Self Signed	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
Untrusted Root	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
Revoked	Accepted	Accepted	Accepted	Accepted	Rejected	Rejected
Pinning Test	Accepted	Accepted	Accepted	Accepted	Rejected	Rejected
Incomplete Chain	Rejected	Accepted	Rejected	Rejected	Accepted	Accepted
SHA1 Intermediate	Accepted	Accepted	Accepted	Accepted	Rejected	Rejected
1000 Subject Alt Names	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
10000 Subject Alt Names	Rejected	Accepted	Rejected	Rejected	Rejected	Rejected
RC4-MD5	Accepted	Rejected	Rejected	Rejected	Rejected	Rejected
RC4	Accepted	Rejected	Rejected	Rejected	Rejected	Rejected
3DES	Accepted	Accepted	Rejected	Rejected	Accepted	Accepted
Null	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
DH480	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
DH512	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
DH1024	Accepted	Accepted	Accepted	Accepted	Accepted	Rejected
DH2048	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
DH Small Subgroup	Accepted	Accepted	Accepted	Accepted	Accepted	Rejected
DH Composite	Accepted	Accepted	Accepted	Accepted	Accepted	Rejected
Invalid Expected SCT	Accepted	Accepted	Accepted	Accepted	Accepted	Rejected
Superfish	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
eDellRoot	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
DSD Test Provider	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected