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1. INTRODUCTION

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Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Abbreviations such as IEEE, SI, ac, and dc do not have to be defined. Abbreviations that incorporate periods should not have spaces: write “C.N.R.S.,” not “C. N. R. S.” Do not use abbreviations in the title unless they are unavoidable (for example, “IEEE” in the title of this article).

1. OTHER RECOMMENDATIONS

Use one space after periods and colons. Hyphenate complex modifiers: “zero-field-cooled magnetization.” Avoid dangling participles, such as, “Using (1), the potential was calculated.” [It is not clear who or what used (1).] Write instead, “The potential was calculated by using (1),” or “Using (1), we calculated the potential.”

Use a zero before decimal points: “0.25,” not “.25.” Use “cm3,” not “cc.” Indicate sample dimensions as “0.1 cm × 0.2 cm,” not “0.1 × 0.2 cm2.” The abbreviation for “seconds” is “s,” not “sec.” Use “Wb/m2” or “webers per square meter,” not “webers/m2.” When expressing a range of values, write “7 to 9” or “7-9,” not “7~9.”

A parenthetical statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.) In American English, periods and commas are within quotation marks, like “this period.” Other punctuation is “outside”! Avoid contractions; for example, write “do not” instead of “don’t.” The serial comma is preferred: “A, B, and C” instead of “A, B and C.”

If you wish, you may write in the first person singular or plural and use the active voice (“I observed that ...” or “We observed that ...” instead of “It was observed that ...”). Remember to check spelling. If your native language is not English, please get a native English-speaking colleague to carefully proofread your paper.

1. Experimental Setup

To capture network traffic, Network architecture was created as shown in Figure 2. To show the continuous traffic of VPNs moving across the network, a firewall, and a PCs are part of the suggested experimental configuration. The PC under investigation is connected to the internet through the firewall and all the internet traffic is routed through a PC-based PfSense firewall. The PC-based PfSense firewall filtered all internet traffic. Sniffing, capturing, and monitoring all network traffic was the firewall's job. In order to facilitate investigation, the trace files produced by the firewall were stored. The configured firewall filtered out the VPN traffic in controlled environment.

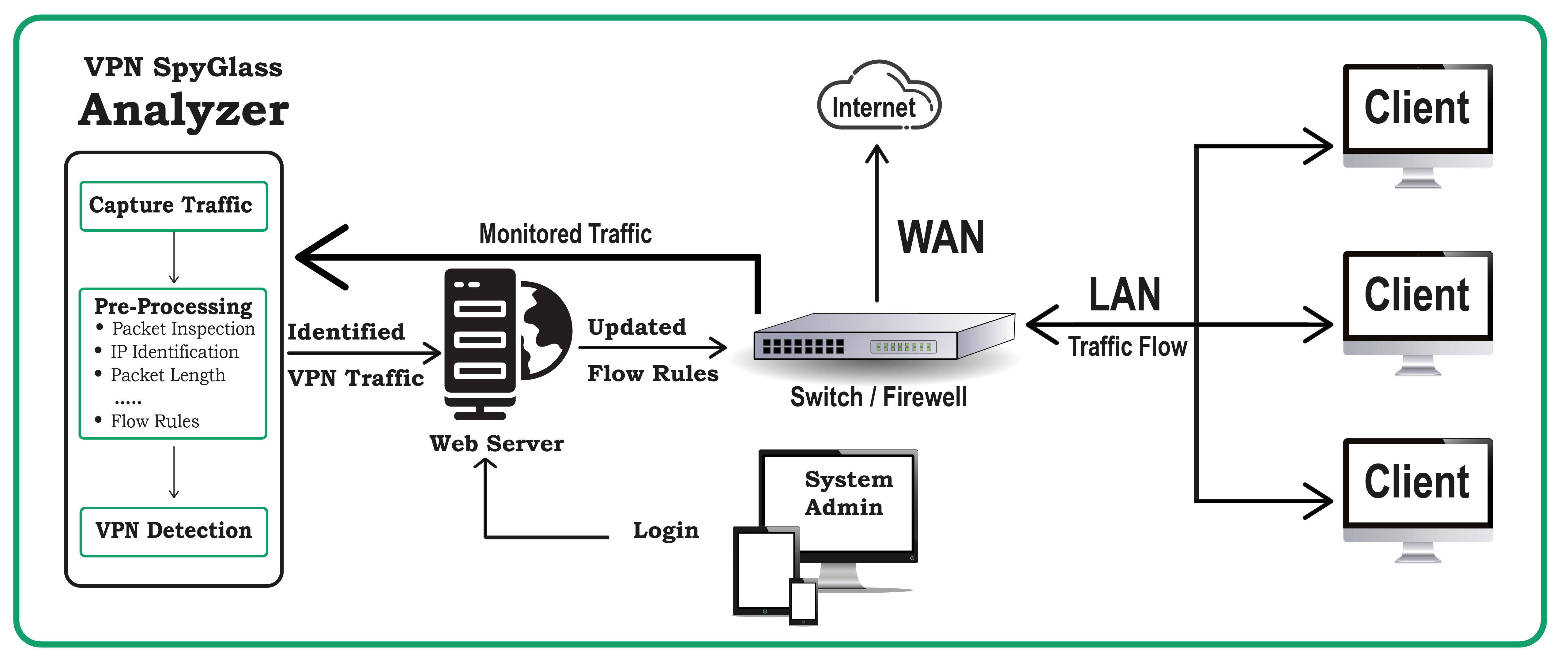


Figure 1: Experimental setup for capturing the network encrypted traffic of VPNs.

In order to monitor the encrypted traffic through the examination of trace files, the Wireshark Software was installed for network traffic analysis. Notably, for privacy and secrecy purposes, the payload was encrypted, but the IP addresses and ports were left in cleartext. The IP addresses and ports made it possible to ascertain the actions taken by VPN applications and how they behaved during the connection. For analytical reasons, we gathered a significant number of trace files during the tests; some of them are accessible on [36] for a clearer understanding. The details of the devices and software tools used in the tests are displayed in Table 2.

**Table 1:**

**DEVICES AND TOOLS SPECIFICATIONS FOR EXPERIMENTAL SETUP**

|  |  |  |  |
| --- | --- | --- | --- |
| **Device/Tool** | **Purpose** | **Company** | **Software/OS** |
| Desktop Computer | To deploy firewall. | Dell | Windows 10, 64- bit Operating system that has an x64-based processor, 4GB RAM, Intel (R) Core (TM) i5-3470 CPU @3.20 GHz. |
| Firewall | Capturing and monitoring packets in the traffic.  Firewall rules | PfSense | pfSense-CE-memstick-2.7.1-RELEASE-amd64 |
| Wireshark | To read the network trace. | Wireshark | Version 4.2.2 |
| Ethernet Wire | Used as bridge. | PTCL |  |
| Laptop | To run VPN applications and perform major activities. | HP | Windows 11, 64-bit operating system, x64-based processor, 16GB RAM, Intel(R) Core (TM) i7-8565U CPU @ 1.80GHz 1.99 GHz |
| Proton VPN | Application under investigation | Proton | Version 2.4.3 |
| Windscribe | Application under investigation | Windscribe Limited | Version 2.8.6 |
| Hide.me | Application under investigation | eVenture Ltd | Version 3.15.1 |
| Tunnel Bear | Application under investigation | McAfee | Version 5.0.0 |
| TurboVPN | Application under investigation | INNOVATIVE CONNECTING PTE. LIMITED | Version 4.0.5.2 |
| Hotspot Shield | Application under investigation | AnchorFree | Version 11.2.1 |
| Cloudflare WARP | Application under investigation | CloudFlare | Version 11.6.0 |

In order to examine the behavior of the VPN application, such as the characteristics of the packets and how client and server communication functions, the suggested method sniffed the encrypted traffic between the client and its servers, displaying a list of several servers along with their IP addresses and ports. Imposing new network rules is made easier with the identification of ports and IP addresses. For instance, we found that several app servers offer distinct response regions and protocols during our studies. The part on results and analysis goes into depth on user activity.

1. Justification of Firewall

By installing a firewall on the investigation network, the control may efficiently identify the behavior of the app.

1. Configuration
2. Results and Analysis

Encryption methods are used by VPN applications to protect data while communicating. Only packet sizes, frequencies, and recurring patterns of packets may be used for analysis because of the encrypted payload. Consequently, distinct traffic may be identified with the use of particular payload lengths, sizes, port numbers, and IP addresses. Extensive analysis of packet sizes (patterns, frequencies) discloses the significant operations of the applications, even while privacy and secrecy remain unaffected. This study's thorough examination of traffic dumps produced patterns in the bytes and payloads associated with various activities. While patterns did appear, they were predictably ineffective in aiding in the reconstruction of the original data. Regulatory bodies, on the other hand, can ascertain the behaviors of VPN applications by observing constant connectivity patterns, thanks to the experimental setup provided in the previous section. Towards the conclusion of the Results and Analysis section is the comprehensive summary.

The following users were created and given descriptions to facilitate the app operations for better understanding:

**User A:** target user, who’s entire set of activities are monitored.

**User B:** Network Administrator, who monitors the network traffic.

1. Identifying of Ports and Servers’ Range
2. Identification of VPN Traffic

We dumped the network data from the laptop that was the target in order to find the activity related to the VPN apps. Without the cryptographic key, it was impossible to decipher the intercepted traffic since it was encrypted. As a result, in order to identify traffic patterns against the various activities, we thoroughly carried out and recorded the various activities. The target device, User A, is used for a variety of tasks.

To gain a deeper comprehension, we examined and categorized target User A's (device's) app behaviors as follows:

1. Handshake with the VPN server
2. Idel State after connection
3. Accessing Google Site
4. Searching on Google
5. YouTube Video Streaming

Now we move on to individual analysis of each VPN application.

### Proton VPN

The firm behind Proton Mail, Proton AG, is based in Switzerland and runs Proton VPN, which is a VPN service. The IPSEC protocol may be used to implement its service, which is compatible with Windows, MacOS, Linux, Android, iOS, and ChromeOS. It also provides a command-line utility for Linux. Proton VPN employs AES-256 encryption with the OpenVPN (UDP/TCP), IKEv2, and WireGuard protocols.

Now we examine and categorize target application behaviors as follows:

#### Handshake with the VPN server

The Handshake activity of the Proton VPN represents the start of application on the User A’s device. Initially, it was difficult to classify the VPN only traffic from the shared network traffic packets. Therefore, an extensive number of trace files were captured and monitored during the handshake of the Proton VPN application with VPN server. The process of the above activity is as follows:

* Open the VPN application on User A device and Press Connect.
* Wait for 3 to 4s without interacting with the app.
* Click on Disconnect and close the application.

We observed that a Handshake Initiation packet is sent to the VPN Server from User A. In response, a Handshake Response packet with IP addresses was sent back to the client to establish a connection. In addition, it was observed that User A's Proton VPN was connecting to the server 51820 [Table 3] over a random port on their end. The client and server exchanged certificates and session keys.

The following packet patterns with payloads were seen between the server and client endpoints following the negotiation of session keys between the client and server.

* Proton VPN Application (IP: 172.20.10.12) sent packets of (190) bytes with a payload of size (148), to the Proton servers.
* In response, the server (IP: 37.19.205.202) sent packets of (134) bytes to the VPN application with a payload of (92).

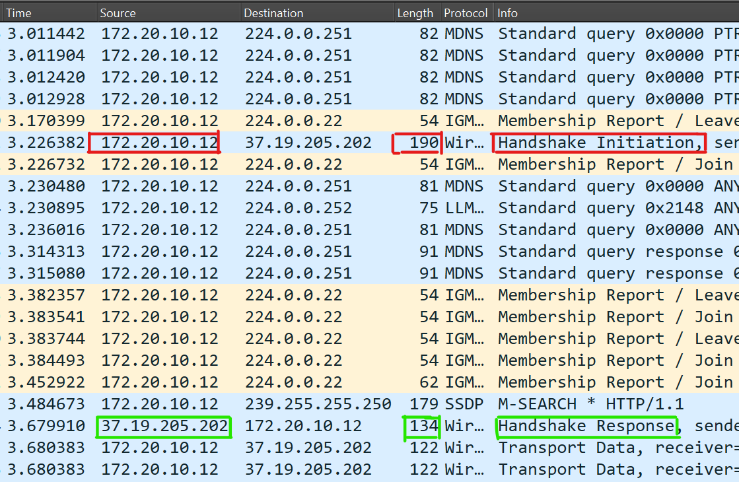
To validate the Proton VPN app's connection patterns, the aforementioned action was repeated several times, as seen in Figure 6. Thus, we deduced that the aforementioned byte transfer patterns signify the launch or establishment of the Proton VPN connection.

Figure 2: **Proton VPN -** Handshake Packets

#### Idel State after Connection

To notify the patterns of the Proton VPN app when target User A is connected and no activity is being performed, certain flow patterns with fixed payload sizes were noticed. To be assured, these patterns were observed several times in trace files to deduce results as shown in Figure 7. Target User A is highlighted with IP 172.20.10.12. It was noticed that when User A with IP 172.20.10.12 started sending packets to server with IP 37.19.205.202 with 122, 154 and 138 bytes of data packets with 80, 112 and 96 payload size. The server replied by sending the Proton VPN client 138 or 1482 bytes of data packets with payload sizes of 96, 1440. In the meantime, it was observed that even though nothing was being done, the Proton VPN app showed the connected status to the corresponding servers.

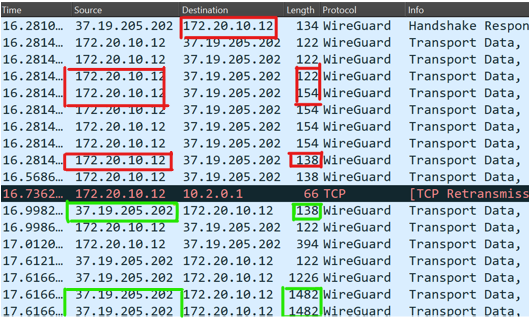


Figure 3: **Proton VPN - Idel State**

#### Accessing Google site

The traffic patterns that User A uses to reach the Google website will be examined in this section. It was always seen that the client at target User A transmitted 138 bytes of the packet in request with 96 bytes of payload to the server after User A accessed the webpage in his or her browser. This request was made to the target server (IP: 45.87.213.226). In answer to the client at target User A's device, the server transmitted 1354 and 122 bytes of packets containing 1312 and 80 bytes of payload. As seen in Figure 8, the server sent the client a series of 1354-byte and 122-byte data packets with payload sizes of 1312 and 80 bytes respectively. This pattern was observed and confirmed repeatedly through multiple iterations.

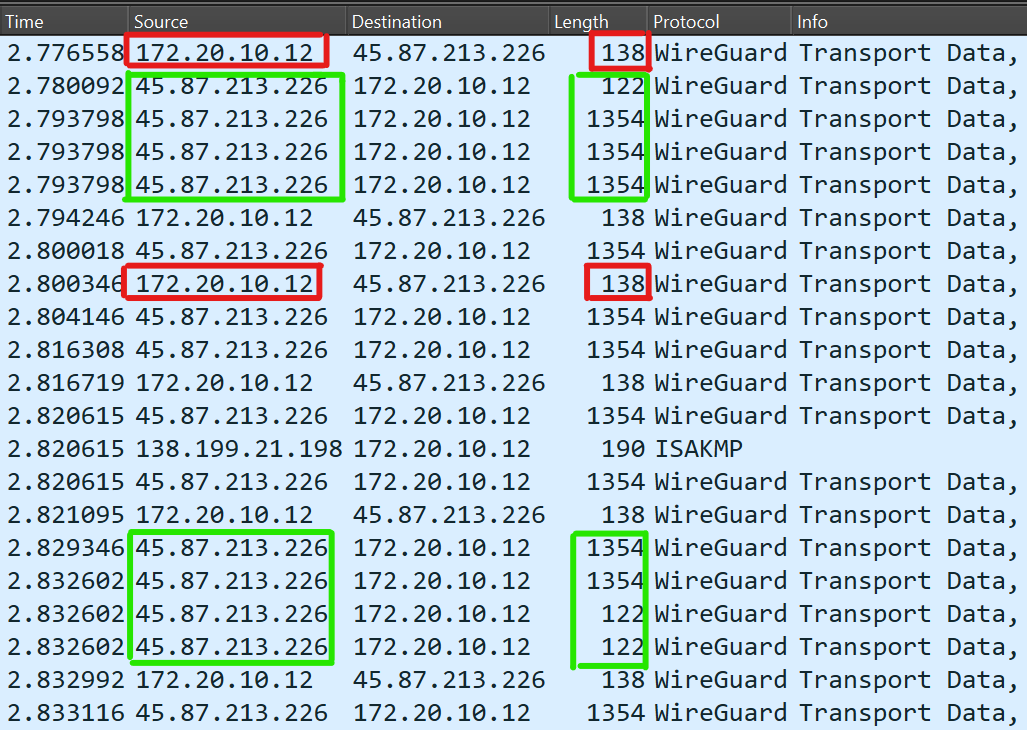


Figure 4: **Proton VPN - Accessing Google Website**

#### Searching on Google

In this section, we will analyze the traffic patterns of User A when he/she performs a search on Google Search Engine. Once User A started searching his/her browser, which would be sent to the target server, it was always noticed that 1354 bytes of packets with 1312 bytes of payload were sent from the server to the client in response to the request. It was also observed that maximum packet length is 1482 byte with 1408 byte of payload. The client at target User A sent 138 bytes of the packet as request with 96 bytes of payload as shown in Figure 9. This pattern was observed and confirmed repeatedly through multiple iterations.

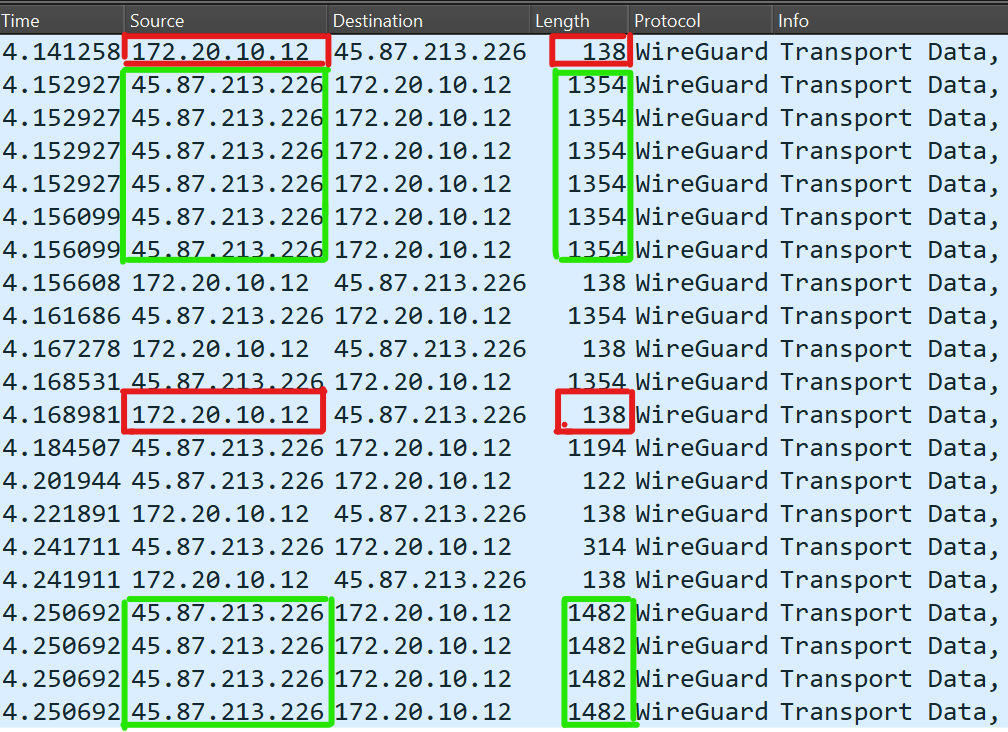


Figure 5: **Proton VPN - Searching on Google**

#### YouTube Video Streaming

To observe the pattern of Proton VPN when a video content was played, as a result certain flow patterns with fixed payload sizes were noticed. Targeted User A sent a request for 138 bytes with payload size of 96 byte for a video. In response, the Proton VPN server responded with 1354-byte packets with 1312 byte of payload. Occasionally, these packets reached the size of 1482 and 138 bytes with payload size of 1408 and 96 bytes. The majority of packets were at size 1354-byte with 1312 byte of payload. This pattern was observed and confirmed repeatedly through multiple iterations as shown in Figure 9.

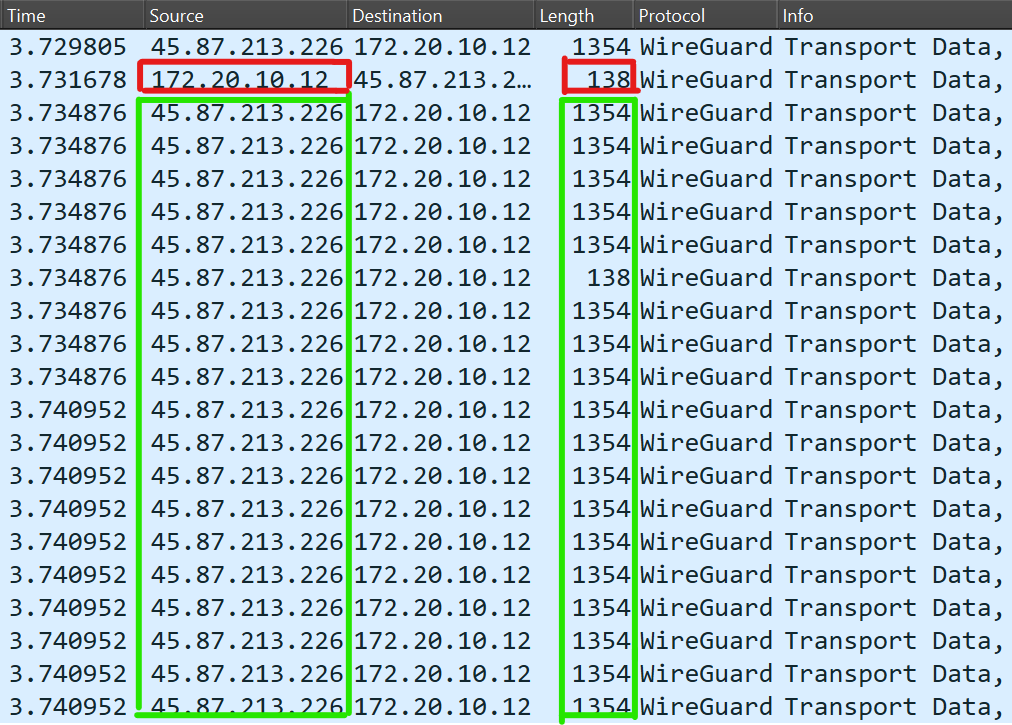


Figure 6: **Proton VPN - YouTube Video Streaming**

### Windscribe VPN

Based in Canada, Windscribe is a cross-platform, commercial virtual private network (VPN) service provider with operations throughout the globe. In its manual setups and applications, Windscribe makes use of the Internet Key Exchange v2/IPsec, WireGuard, and OpenVPN protocols. P2P file sharing is supported on Windscribe servers, who advertise themselves as a no-log VPN service in their privacy statement. Open-source desktop programs for Windows and macOS are available from Windscribe, along with a command-line tool for Linux and open-source mobile programs for iOS, Android, and Android TV. With browser extensions for Firefox and Google Chrome, Windscribe additionally provides encrypted proxy functionality. Users of Windscribe are able to connect an infinite number of devices simultaneously.

Now we examine and categorize target application behaviors as follows:

#### Handshake with the VPN server

The Handshake activity of the Windscribe VPN represents the start of application on the User A’s device. Initially, it was difficult to classify the VPN only traffic from the shared network traffic packets. Therefore, an extensive number of trace files were captured and monitored during the handshake of the Windscribe VPN application with VPN server. The process of the above activity is as follows:

* Open the VPN application on User A device and Press Connect.
* Wait for 3 to 4s without interacting with the app.
* Click on Disconnect and close the application.

We observed that a Handshake Initiation packet is sent to the VPN Server from User A. In response, a Handshake Response packet with IP addresses was sent back to the client to establish a connection. In addition, it was observed that User A's Windscribe VPN was connecting to the server 443 port [Table 3] over a random port on their end. The client and server exchanged certificates and session keys.

The following packet patterns with payloads were seen between the server and client endpoints following the negotiation of session keys between the client and server.

* Windscribe VPN Application (IP: 172.20.10.12) sent packets of (190) bytes with a payload of size (148), to the Windscribe servers.
* In response, the server (IP: 169.150.197.222) sent packets of (134) bytes to the VPN application with a payload of (92).

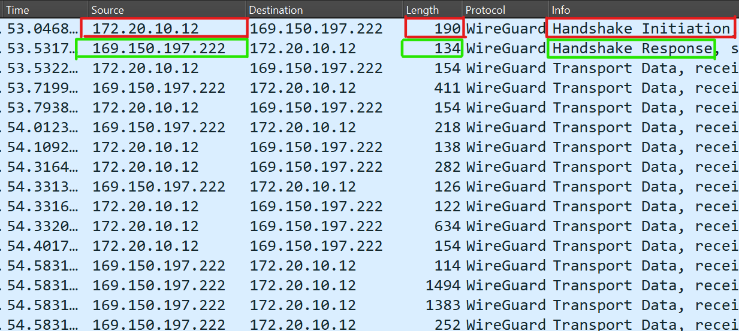
To validate the Windscribe VPN app's connection patterns, the aforementioned action was repeated several times, as seen in Figure 6. Thus, we deduced that the byte transfer patterns signify the establishment of the Windscribe VPN connection.

Figure 7:**Windscribe VPN - Handshake Packets**

#### Idel State after Connection

To notify the patterns of the Windscribe VPN app when target User A is connected and no activity is being performed, certain flow patterns with fixed payload sizes were noticed. To be assured, these patterns were observed several times in trace files to deduce results as shown in Figure 7. Target User A is highlighted with IP 172.20.10.12. It was noticed that when User A with IP 172.20.10.12 started sending packets to server with IP 169.150.197.222 with 122, and 138 bytes of data packets with 80 and 96 payload size being more prominent. The server replied by sending the Windscribe VPN client a large number of Varity of packets with most notable being 494 bytes of data packets with payload sizes of 1452. In the meantime, it was observed that even though nothing was being done, the Windscribe VPN app showed the connected status to the corresponding servers.

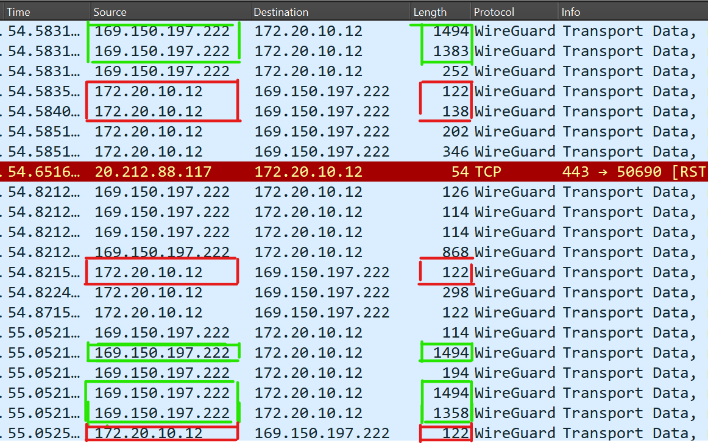


Figure 8: **Windscribe** **VPN - Idel State**

#### Accessing Google site

The traffic patterns that User A uses to reach the Google website will be examined in this section. It was always seen that the client at target User A transmitted 122 bytes of the packet in request with 96 bytes of payload to the server after User A accessed the webpage in his or her browser. This request was made to the target server (IP: 27.122.12.228). In answer to the client at target User A's device, the server transmitted 1494 bytes of packets containing 1452 bytes of payload. As seen in Figure 8, this pattern was observed and confirmed repeatedly through multiple iterations.

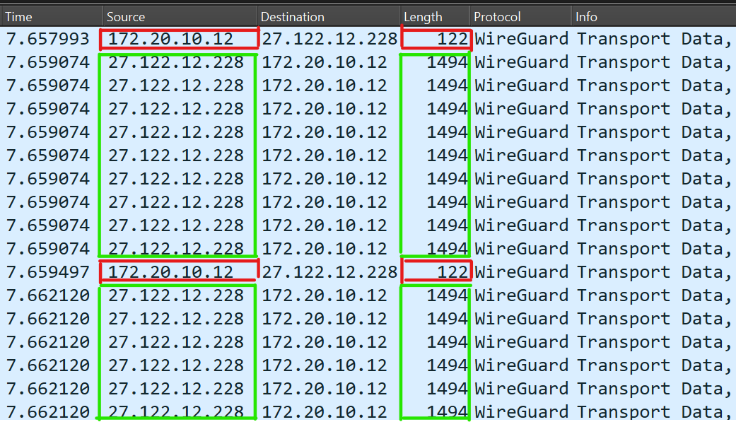


Figure 9: **Windscribe** **VPN - Accessing Google Website**

#### Searching on Google

In this section, we will analyze the traffic patterns of User A when he/she performs a search on Google Search Engine. Once User A started searching his/her browser, which would be sent to the target server, it was always noticed that 114 and 1494 bytes of packets with 72 and 1452 bytes of payload were sent from the server to the client in response to the request. It was also observed that maximum packet length is 1494 byte with 1452 byte of payload. The client at target User A sent 122 bytes of the packet as requested with 80 bytes of payload as shown in Figure 9. This pattern was observed and confirmed repeatedly through multiple iterations.

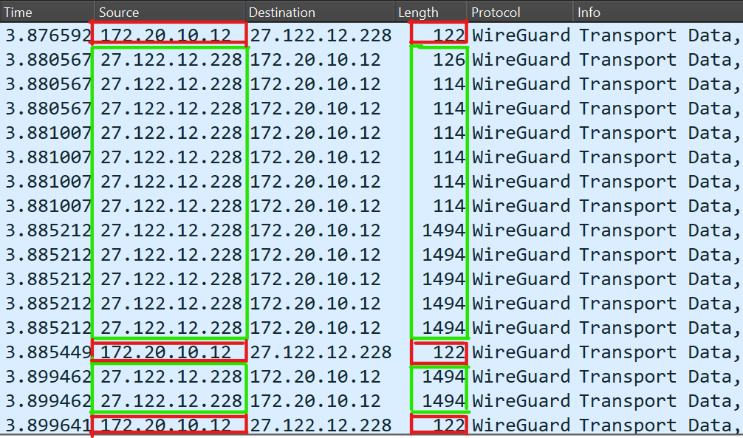


Figure 10: **Windscribe** **VPN - Searching on Google**

#### YouTube Video Streaming

To observe the pattern of Windscribe VPN when a video content was played, as a result certain flow patterns with fixed payload sizes were noticed. Targeted User A sent a request for 154 and 138 byte with payload size of 112 and 96 byte for a video. In response, the Windscribe VPN server responded with 1494-byte packets with 1454 byte of payload. This pattern was observed and confirmed repeatedly through multiple iterations as shown in Figure 9.

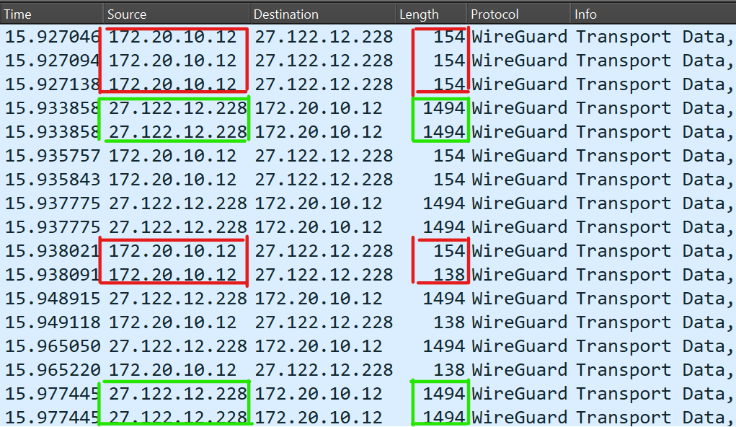


Figure 11: **Windscribe** **VPN - YouTube Video Streaming**

### Hide.me VPN

Hide.me VPN provides encryption, wi-fi security, and privacy protection for a genuinely private online browsing experience, no matter where you are. It makes use of SSTP, WireGuard, OpenVPN, SoftEther VPN, and IKEv2.

Now we examine and categorize target application behaviors as follows:

#### Handshake with the VPN server

The Handshake activity of the Hide.me VPN represents the start of application on the User A’s device. Initially, it was difficult to classify the VPN only traffic from the shared network traffic packets. Therefore, an extensive number of trace files were captured and monitored during the handshake of the Hide.me VPN application with VPN server. The process of the above activity is as follows:

* Open the VPN application on User A device and Press Connect.
* Wait for 3 to 4s without interacting with the app.
* Click on Disconnect and close the application.

We observed that a standard DNS query was sent to access the Hide.me server from the client end, i.e., free-nl-ds.hideservers.net. In response, a server’s IP address was sent back to the client to establish a connection as shown in Figure 15. Three stages were used to create a TCP connection between the client and server: SYN, SYN ACK, and ACK. Following that, a TLS handshake with TLSv1.2 took place. The client and server exchanged session keys and certificates. Subsequently, the client transmitted an encrypted handshake message to the server and exchanged the key change cypher specifications. In response, the server updated the cypher specifications, provided a new session ticket, and used TLS to encrypt a handshake message to the client device.

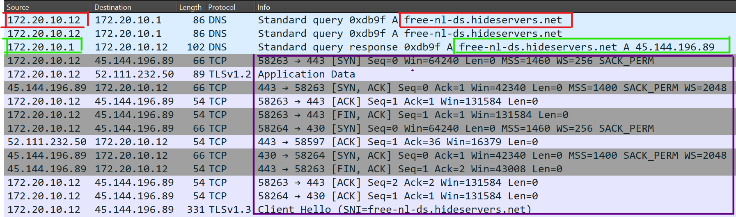


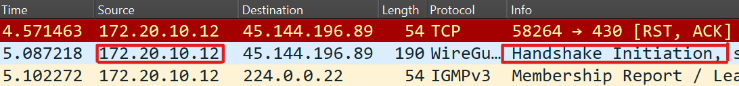
Figure 12: **Hide.me VPN - DNS Query**

We observed that a Handshake Initiation packet was sent to the VPN Server from User A. In response, a Handshake Response packet with IP addresses was sent back to the client to establish a connection. In addition, it was observed that User A's Hide.me VPN was connecting to the server 432 port [Table 3] over a random port on their end. The client and server exchanged certificates and session keys.

The following packet patterns with payloads were seen between the server and client endpoints following the negotiation of session keys between the client and server.

* Hide.me VPN Application (IP: 172.20.10.12) sent packets of (190) bytes with a payload of size (148), to the Hide.me servers.
* In response, the server (IP: 45.144.196.89) sent packets of (134) bytes to the VPN application with a payload of (92).

To validate the Hide.me VPN app's connection patterns, the aforementioned action was repeated several times, as seen in Figure 6. Thus, we deduced that the byte transfer patterns signify the establishment of the Hide.me VPN connection.



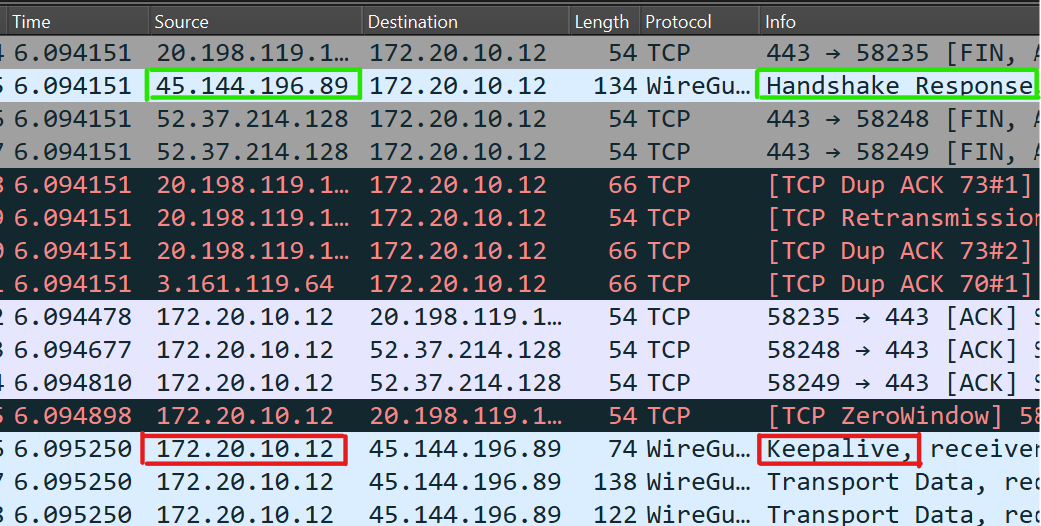


Figure 13:**Hide.me VPN - Handshake Packets**

#### Idel State after Connection

To notify the patterns of the Hide.me VPN app when target User A is connected and no activity is being performed, certain flow patterns with fixed payload sizes were noticed. To be assured, these patterns were observed several times in trace files to deduce results as shown in Figure 7. Target User A is highlighted with IP 172.20.10.12. It was noticed that when User A with IP 172.20.10.12 started sending packets to server with IP 45.144.196.89 with 154, and 138 bytes of data packets with 112 and 96 payload size being more prominent. The server replied by sending the Hide.me VPN client large number of Varity of packets with most notable being 1466 bytes of data packets with payload sizes of 1424. In the meantime, it was observed that even though nothing was being done, the Hide.me VPN app showed the connected status to the corresponding servers.

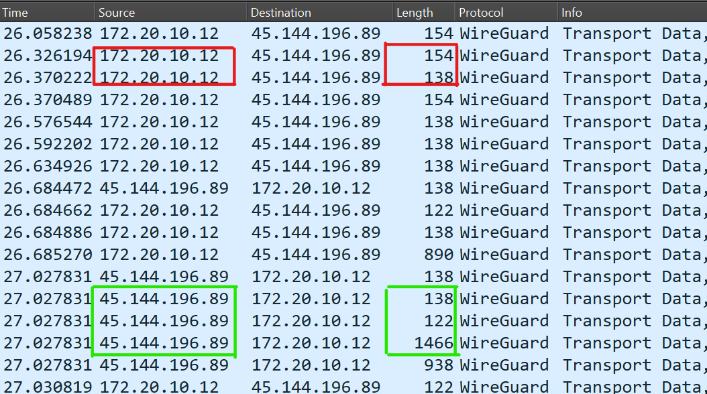


Figure 14: **Hide.me** **VPN - Idel State**

#### Accessing Google site

The traffic patterns that User A uses to reach the Google website will be examined in this section. It was always seen that the client at target User A transmitted 122, 138 and 154 bytes of the packet in request with 80, 96 and 112 bytes of payload to the server after User A accessed the webpage in his or her browser. This request was made to the target server (IP: 45.144.196.89). In answer to the client at target User A's device, the server transmitted 1466 bytes of packets containing 1424 bytes of payload. We also observe packets of length 1354, 138 and 122 bytes with a payload of 1312, 122and 80. As seen in Figure 8, this pattern was observed and confirmed repeatedly through multiple iterations.

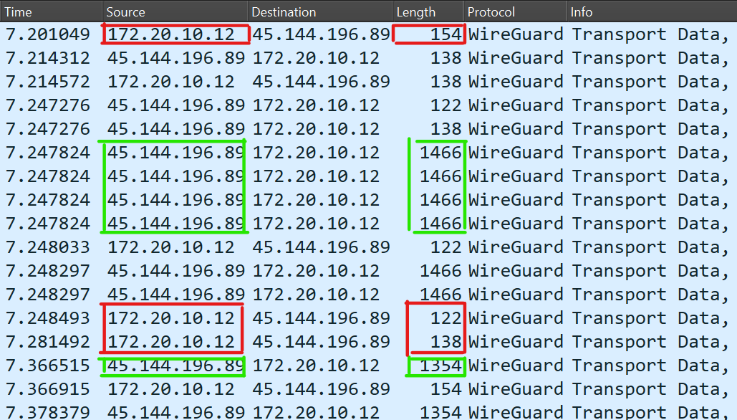


Figure 15: **Hide.me** **VPN - Accessing Google Website**

#### Searching on Google

In this section, we will analyze the traffic patterns of User A when he/she perform a search on Google Search Engine. Once User A started searching his/her browser, which would be sent to the target server, it was always noticed that 114 and 1494 bytes of packets with 72 and 1452 bytes of payload were sent from the server to the client in response to the request. It was also observed that maximum packet length is 1494 byte with 1452 byte of payload. The client at target User A sent 122 bytes of the packet as request with 80 bytes of payload as shown in Figure 9. This pattern was observed and confirmed repeatedly through multiple iterations.

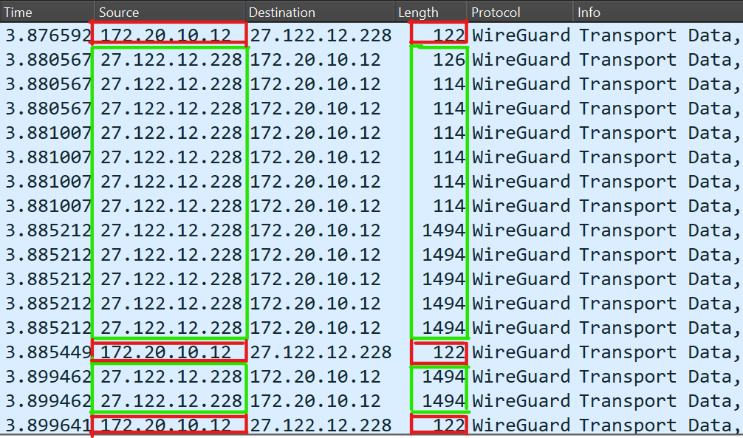


Figure 16: **Hide.me** **VPN - Searching on Google**

#### YouTube Video Streaming

To observe the pattern of Hide.me VPN when a video content was played, as a result certain flow patterns with fixed payload sizes were noticed. Targeted User A sent a request of 154 and 138 byte with payload size of 112 and 96 byte for a video. In response, the Hide.me VPN server responded with 1494-byte packets with 1454 byte of payload. This pattern was observed and confirmed repeatedly through multiple iterations as shown in Figure 9.

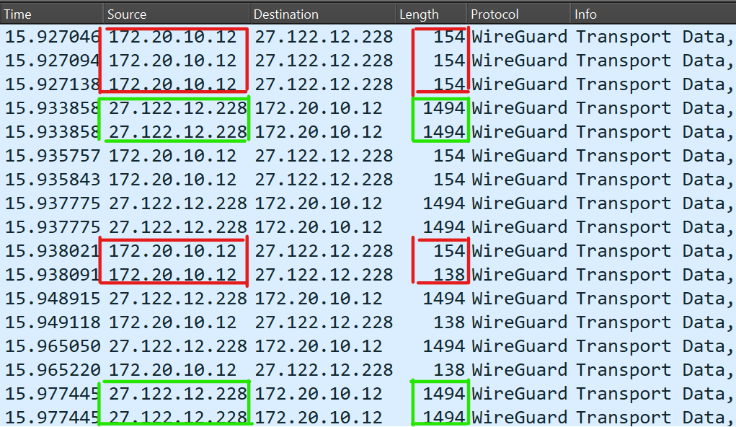


Figure 17: **Hide.me** **VPN - YouTube Video Streaming**

1. Performance Comparison
2. Discussion and Use Cases

MATH

If you are using Word, use either the Microsoft Equation Editor or the MathType add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation or MathType Equation). “Float over text” should not be selected.

1. EQUATIONS

Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First use the equation editor to create the equation. Then select the “Equation” markup style. Press the tab key and write the equation number in parentheses. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Use parentheses to avoid ambiguities in denominators. Punctuate equations when they are part of a sentence, as in

(1)

Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize symbols (T might refer to temperature, but T is the unit tesla). Refer to “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ... .”

UNITS

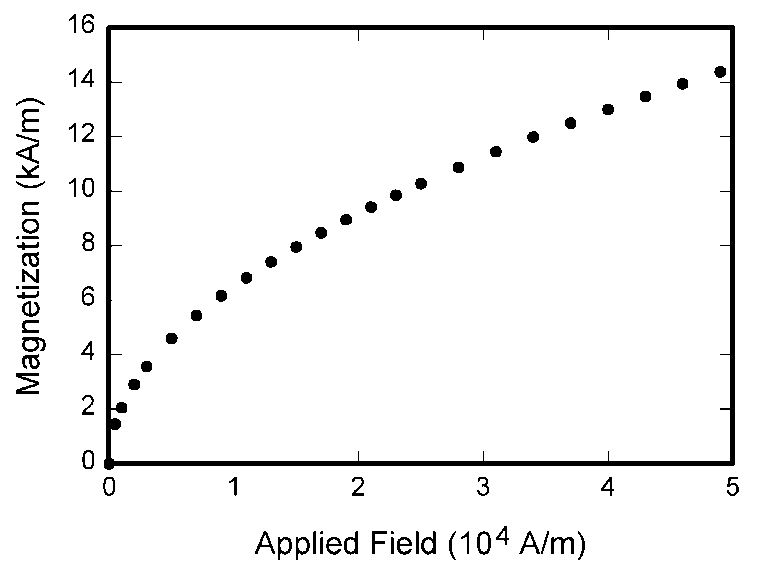
Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). This applies to papers in data storage. For example, write “15 Gb/cm2 (100 Gb/in2).” An exception is when English units are used as identifiers in trade, such as “3½-in disk drive.” Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as µ0H. Use the center dot to separate compound units, e.g., “A·m2.”

SOME COMMON MISTAKES

The word “data” is plural, not singular. The subscript for the permeability of vacuum µ0 is zero, not a lowercase letter “o.” The term for residual magnetization is “remanence”; the adjective is “remanent”; do not write “remnance” or “remnant.” Use the word “micrometer” instead of “micron.” A graph within a graph is an “inset,” not an “insert.” The word “alternatively” is preferred to the word “alternately” (unless you really mean something that alternates). Use the word “whereas” instead of “while” (unless you are referring to simultaneous events). Do not use the word “essentially” to mean “approximately” or “effectively.” Do not use the word “issue” as a euphemism for “problem.” When compositions are not specified, separate chemical symbols by en-dashes; for example, “NiMn” indicates the intermetallic compound Ni0.5Mn0.5 whereas “Ni–Mn” indicates an alloy of some composition NixMn1-x.

Be aware of the different meanings of the homophones “affect” (usually a verb) and “effect” (usually a noun), “complement” and “compliment,” “discreet” and “discrete,” “principal” (e.g., “principal investigator”) and “principle”



1. Magnetization as a function of applied field. Note that “Fig.” is abbreviated. There is a period after the figure number, followed by two spaces. It is good practice to explain the significance of the figure in the caption.

(e.g., “principle of measurement”). Do not confuse “imply” and “infer.”

Prefixes such as “non,” “sub,” “micro,” “multi,” and “ultra” are not independent words; they should be joined to the words they modify, usually without a hyphen. There is no period after the “et” in the Latin abbreviation “et al.” (it is also italicized). The abbreviation “i.e.,” means “that is,” and the abbreviation “e.g.,” means “for example” (these abbreviations are not italicized).

A general IEEE styleguide is available at www.ieee.org/authortools.

GUIDELINES FOR GRAPHICS PREPARATION   
AND SUBMISSION

1. TYPES OF GRAPHICS

The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color / shades of gray:

1. Color/Grayscale figures

Figures that are meant to appear in color, or shades of black/gray. Such figures may include photographs, illustrations, multicolor graphs, and flowcharts.

1. Line Art figures

Figures that are composed of only black lines and shapes. These figures should have no shades or half-tones of gray, only black and white.

1. Author photos

Head and shoulders shots of authors that appear at the end of our papers.

1. Tables

Data charts which are typically black and white, but sometimes include color.

TABLE I

Units for Magnetic Properties

|  |  |  |
| --- | --- | --- |
| Symbol | Quantity | Conversion from Gaussian and  CGS EMU to SI a |
| Φ | magnetic flux | 1 Mx → 10−8 Wb = 10−8 V·s |
| *B* | magnetic flux density,  magnetic induction | 1 G → 10−4 T = 10−4 Wb/m2 |
| *H* | magnetic field strength | 1 Oe → 103/(4π) A/m |
| *m* | magnetic moment | 1 erg/G = 1 emu  → 10−3 A·m2 = 10−3 J/T |
| *M* | magnetization | 1 erg/(G·cm3) = 1 emu/cm3  → 103 A/m |
| 4π*M* | magnetization | 1 G → 103/(4π) A/m |
| σ | specific magnetization | 1 erg/(G·g) = 1 emu/g → 1 A·m2/kg |
| *j* | magnetic dipole  moment | 1 erg/G = 1 emu  → 4π × 10−10 Wb·m |
| *J* | magnetic polarization | 1 erg/(G·cm3) = 1 emu/cm3  → 4π × 10−4 T |
| χ*,* κ | susceptibility | 1 → 4π |
| χρ | mass susceptibility | 1 cm3/g → 4π × 10−3 m3/kg |
| μ | permeability | 1 → 4π × 10−7 H/m  = 4π × 10−7 Wb/(A·m) |
| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

aGaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

1. MULTIPART FIGURES

Figures compiled of more than one sub-figure presented side-by-side, or stacked. If a multipart figure is made up of multiple figure types (one part is lineart, and another is grayscale or color) the figure should meet the stricter guidelines.

1. FILE FORMATS FOR GRAPHICS

Format and save your graphics using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (.EPS), Tagged Image File Format (.TIFF), Portable Document Format (.PDF), or Portable Network Graphics (.PNG) sizes them, and adjusts the resolution settings. If you created your source files in one of the following programs you will be able to submit the graphics without converting to a PS, EPS, TIFF, PDF, or PNG file: Microsoft Word, Microsoft PowerPoint, or Microsoft Excel. Though it is not required, it is strongly recommended that these files be saved in PDF format rather than DOC, XLS, or PPT. Doing so will protect your figures from common font and arrow stroke issues that occur when working on the files across multiple platforms. When submitting your final paper, your graphics should all be submitted individually in one of these formats along with the manuscript.

1. SIZING OF GRAPHICS

Most charts, graphs, and tables are one column wide (3.5 inches / 88 millimeters / 21 picas) or page wide (7.16 inches / 181 millimeters / 43 picas). The maximum depth a graphic can be is 8.5 inches (216 millimeters / 54 picas). When choosing the depth of a graphic, please allow space for a caption. Figures can be sized between column and page widths if the author chooses, however it is recommended that figures are not sized less than column width unless when necessary.

There is currently one publication with column measurements that do not coincide with those listed above. Proceedings of the IEEE has a column measurement of 3.25 inches (82.5 millimeters / 19.5 picas).

The final printed size of author photographs is exactly   
1 inch wide by 1.25 inches tall (25.4 millimeters x 31.75 millimeters / 6 picas x 7.5 picas). Author photos printed in editorials measure 1.59 inches wide by 2 inches tall (40 millimeters x 50 millimeters / 9.5 picas x 12 picas).

1. RESOLUTION

The proper resolution of your figures will depend on the type of figure it is as defined in the “Types of Figures” section. Author photographs, color, and grayscale figures should be at least 300dpi. Line art, including tables should be a minimum of 600dpi.

1. VECTOR ART

In order to preserve the figures’ integrity across multiple computer platforms, we accept files in the following formats: .EPS/.PDF/.PS. All fonts must be embedded or text converted to outlines in order to achieve the best-quality results.

1. COLOR SPACE

The term color space refers to the entire sum of colors that can be represented within the said medium. For our purposes, the three main color spaces are Grayscale, RGB (red/green/blue) and CMYK (cyan/magenta/yellow/black). RGB is generally used with on-screen graphics, whereas CMYK is used for printing purposes.

All color figures should be generated in RGB or CMYK color space. Grayscale images should be submitted in Grayscale color space. Line art may be provided in grayscale OR bitmap colorspace. Note that “bitmap colorspace” and “bitmap file format” are not the same thing. When bitmap color space is selected, .TIF/.TIFF/.PNG are the recommended file formats.

1. ACCEPTED FONTS WITHIN FIGURES

When preparing your graphics IEEE suggests that you use of one of the following Open Type fonts: Times New Roman, Helvetica, Arial, Cambria, and Symbol. If you are supplying EPS, PS, or PDF files all fonts must be embedded. Some fonts may only be native to your operating system; without the fonts embedded, parts of the graphic may be distorted or missing.

A safe option when finalizing your figures is to strip out the fonts before you save the files, creating “outline” type. This converts fonts to artwork what will appear uniformly on any screen.

1. USING LABELS WITHIN FIGURES
2. Figure Axis labels

Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity “Magnetization,” or “Magnetization M,” not just “M.” Put units in parentheses. Do not label axes only with units. As in Fig. 1, for example, write “Magnetization (A/m)” or “Magnetization (Am−1),” not just “A/m.” Do not label axes with a ratio of quantities and units. For example, write “Temperature (K),” not “Temperature/K.”

Multipliers can be especially confusing. Write “Magnetization (kA/m)” or “Magnetization (103 A/m).” Do not write “Magnetization (A/m) × 1000” because the reader would not know whether the top axis label in Fig. 1 meant 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 10 point type.

1. Subfigure Labels in Multipart Figures and Tables

Multipart figures should be combined and labeled before final submission. Labels should appear centered below each subfigure in 8 point Times New Roman font in the format of (a) (b) (c).

1. FILE NAMING

Figures (line artwork or photographs) should be named starting with the first 5 letters of the author’s last name. The next characters in the filename should be the number that represents the sequential location of this image in your article. For example, in author “Anderson’s” paper, the first three figures would be named ander1.tif, ander2.tif, and ander3.ps.

Tables should contain only the body of the table (not the caption) and should be named similarly to figures, except that ‘.t’ is inserted in-between the author’s name and the table number. For example, author Anderson’s first three tables would be named ander.t1.tif, ander.t2.ps, ander.t3.eps.

Author photographs should be named using the first five characters of the pictured author’s last name. For example, four author photographs for a paper may be named: oppen.ps, moshc.tif, chen.eps, and duran.pdf.

If two authors or more have the same last name, their first initial(s) can be substituted for the fifth, fourth, third... letters of their surname until the degree where there is differentiation. For example, two authors Michael and Monica Oppenheimer’s photos would be named oppmi.tif, and oppmo.eps.

1. REFERENCING A FIGURE OR TABLE WITHIN YOUR PAPER

When referencing your figures and tables within your paper, use the abbreviation “Fig.” even at the beginning of a sentence. Do not abbreviate “Table.” Tables should be numbered with Roman Numerals.

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you do not need to position figures and tables at the top and bottom of each column. In fact, all figures, figure captions, and tables can be placed at the end of your paper. In addition to, or even in lieu of submitting figures within your final manuscript, figures should be submitted individually, separate from the manuscript in one of the file formats listed above in section VI-J. Place figure captions below the figures; place table titles above the tables. Please do not include captions as part of the figures, or put them in “text boxes” linked to the figures. Also, do not place borders around the outside of your figures.

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All IEEE Transactions, Journals, and Letters allow an author to publish color figures on IEEE Xplore® at no charge, and automatically convert them to grayscale for print versions. In most journals, figures and tables may alternatively be printed in color if an author chooses to do so. Please note that this service comes at an extra expense to the author. If you intend to have print color graphics, include a note with your final paper indicating which figures or tables you would like to be handled that way, and stating that you are willing to pay the additional fee.

CONCLUSION

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

APPENDIX

Appendixes, if needed, appear before the acknowledgment.

ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” In most cases, sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.

REFERENCES AND FOOTNOTES

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References need not be cited in text. When they are, they appear on the line, in square brackets, inside the punctuation. Multiple references are each numbered with separate brackets. When citing a section in a book, please give the relevant page numbers. In text, refer simply to the reference number. Do not use “Ref.” or “reference” except at the beginning of a sentence: “Reference [3] shows ... .” Please do not use automatic endnotes in Word, rather, type the reference list at the end of the paper using the “References” style.

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1. FOOTNOTES

Number footnotes separately in superscripts (Insert| Footnote).[[1]](#footnote-1) Place the actual footnote at the bottom of the column in which it is cited; do not put footnotes in the reference list (endnotes). Use letters for table footnotes (see Table I).

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REFERENCES

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J. K. Author, “Title of chapter in the book,” in *Title of His Published Book, x*th ed. City of Publisher, (only U.S. State), Country: Abbrev. of Publisher, year, ch. *x*, sec. *x*, pp. *xxx–xxx.*

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1. G. O. Young, “Synthetic structure of industrial plastics,” in *Plastics,* 2nd ed., vol. 3, J. Peters, Ed. New York, NY, USA: McGraw-Hill, 1964, pp. 15–64.
2. W.-K. Chen, *Linear Networks and Systems.* Belmont, CA, USA: Wadsworth, 1993, pp. 123–135.

*Basic format for periodicals:*

J. K. Author, “Name of paper,” *Abbrev. Title of Periodical*, vol. *x, no*. *x,* pp*. xxx-xxx,* Abbrev. Month, year, DOI. 10.1109.*XXX*.123456.

*Examples:*

1. J. U. Duncombe, “Infrared navigation—Part I: An assessment of feasibility,” *IEEE Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34–39, Jan. 1959, 10.1109/TED.2016.2628402.
2. E. P. Wigner, “Theory of traveling-wave optical laser,”   
   *Phys. Rev*.,   
   vol. 134, pp. A635–A646, Dec. 1965.
3. E. H. Miller, “A note on reflector arrays,” *IEEE Trans. Antennas Propagat*., to be published.

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1. E. E. Reber, R. L. Michell, and C. J. Carter, “Oxygen absorption in the earth’s atmosphere,” Aerospace Corp., Los Angeles, CA, USA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.
2. J. H. Davis and J. R. Cogdell, “Calibration program for the 16-foot antenna,” Elect. Eng. Res. Lab., Univ. Texas, Austin, TX, USA, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

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*Name of Manual/Handbook, x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, Country, year, pp. *xxx-xxx.*

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1. *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, USA, 1985, pp. 44–60.
2. *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, USA, 1989.

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J. K. Author, “Title of chapter in the book,” in *Title of Published Book*, *x*th ed. City of Publisher, State, Country: Abbrev. of Publisher, year, ch.*x*, sec. *x*, pp. *xxx–xxx*. [Online]. Available: http://www.web.com

*Examples:*

1. G. O. Young, “Synthetic structure of industrial plastics,” in Plastics, vol. 3, Polymers of Hexadromicon, J. Peters, Ed., 2nd ed. New York, NY, USA: McGraw-Hill, 1964, pp. 15-64. [Online]. Available: http://www.bookref.com.
2. *The Founders’ Constitution*, Philip B. Kurland and Ralph Lerner, eds., Chicago, IL, USA: Univ. Chicago Press, 1987. [Online]. Available: http://press-pubs.uchicago.edu/founders/
3. The Terahertz Wave eBook. ZOmega Terahertz Corp., 2014. [Online]. Available: http://dl.z-thz.com/eBook/zomega\_ebook\_pdf\_1206\_sr.pdf. Accessed on: May 19, 2014.
4. Philip B. Kurland and Ralph Lerner, eds., *The Founders’ Constitution.* Chicago, IL, USA: Univ. of Chicago Press, 1987, Accessed on: Feb. 28, 2010, [Online] Available: http://press-pubs.uchicago.edu/founders/

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*Examples:*

1. J. S. Turner, “New directions in communications,” *IEEE J. Sel. Areas Commun*., vol. 13, no. 1, pp. 11-23, Jan. 1995.
2. W. P. Risk, G. S. Kino, and H. J. Shaw, “Fiber-optic frequency shifter using a surface acoustic wave incident at an oblique angle,” *Opt. Lett.*, vol. 11, no. 2, pp. 115–117, Feb. 1986.
3. P. Kopyt *et al., “*Electric properties of graphene-based conductive layers from DC up to terahertz range,” *IEEE THz Sci. Technol.,* to be published. DOI: 10.1109/TTHZ.2016.2544142.

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1. PROCESS Corporation, Boston, MA, USA. Intranets: Internet technologies deployed behind the firewall for corporate productivity. Presented at INET96 Annual Meeting. [Online]. Available: http://home.process.com/Intranets/wp2.htp

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J. K. Author. “Title of report,” Company. City, State, Country. Rep. no., (optional: vol./issue), Date. [Online] Available: site/path/file

*Examples:*

1. R. J. Hijmans and J. van Etten, “Raster: Geographic analysis and modeling with raster data,” R Package Version 2.0-12, Jan. 12, 2012. [Online]. Available: http://CRAN.R-project.org/package=raster
2. Teralyzer. Lytera UG, Kirchhain, Germany [Online]. Available: http://www.lytera.de/Terahertz\_THz\_Spectroscopy.php?id=home, Accessed on: Jun. 5, 2014

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Legislative body. Number of Congress, Session. (year, month day). *Number of bill or resolution*, *Title*. [Type of medium]. Available: site/path/file

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*Example:*

1. U.S. House. 102nd Congress, 1st Session. (1991, Jan. 11). *H. Con. Res. 1, Sense of the Congress on Approval of Military Action*. [Online]. Available: LEXIS Library: GENFED File: BILLS

*Basic format for patents (when available online):*

Name of the invention, by inventor’s name. (year, month day). Patent Number[Type of medium]. Available: site/path/file

*Example:*

1. Musical toothbrush with mirror, by L.M.R. Brooks. (1992, May 19). Patent D 326 189

[Online]. Available: NEXIS Library: LEXPAT File: DES

*Basic format for conference proceedings (published):*

J. K. Author, “Title of paper,” in *Abbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), Country, year, pp. *xxxxxx.*

*Example:*

1. D. B. Payne and J. R. Stern, “Wavelength-switched pas- sively coupled single-mode optical network,” in *Proc. IOOC-ECOC,* Boston, MA, USA,1985,   
   pp. 585–590.

*Example for papers presented at conferences (unpublished):*

1. D. Ebehard and E. Voges, “Digital single sideband detection for interferometric sensors,” presented at the *2nd Int. Conf. Optical Fiber Sensors,* Stuttgart, Germany, Jan. 2-5, 1984.

*Basic format for patents:*

J. K. Author, “Title of patent,” U.S. Patent *x xxx xxx*, Abbrev. Month, day, year.

*Example:*

1. G. Brandli and M. Dick, “Alternating current fed power supply,” U.S. Patent 4 084 217, Nov. 4, 1978.

*Basic format**for theses (M.S.) and dissertations (Ph.D.):*

a) J. K. Author, “Title of thesis,” M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

b) J. K. Author, “Title of dissertation,” Ph.D. dissertation, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

*Examples:*

1. J. O. Williams, “Narrow-band analyzer,” Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, USA, 1993.
2. N. Kawasaki, “Parametric study of thermal and chemical nonequilibrium nozzle flow,” M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

*Basic format for the most common types of unpublished references:*

a) J. K. Author, private communication, Abbrev. Month, year.

b) J. K. Author, “Title of paper,” unpublished.

c) J. K. Author, “Title of paper,” to be published.

*Examples:*

1. A. Harrison, private communication, May 1995.
2. B. Smith, “An approach to graphs of linear forms,” unpublished.
3. A. Brahms, “Representation error for real numbers in binary computer arithmetic,” IEEE Computer Group Repository, Paper R-67-85.

*Basic formats for standards:*

a) *Title of Standard*, Standard number, date.

b) *Title of Standard*, Standard number, Corporate author, location, date.

*Examples:*

1. IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.
2. Letter Symbols for Quantities, ANSI Standard Y10.5-1968.

*Article number in reference examples:*

1. R. Fardel, M. Nagel, F. Nuesch, T. Lippert, and A. Wokaun, “Fabrication of organic light emitting diode pixels by laser-assisted forward transfer,” *Appl. Phys. Lett.*, vol. 91, no. 6, Aug. 2007, Art. no. 061103.
2. J. Zhang and N. Tansu, “Optical gain and laser characteristics of InGaN quantum wells on ternary InGaN substrates,” *IEEE Photon. J.*, vol. 5, no. 2, Apr. 2013, Art. no. 2600111.

*Example when using et al.:*

1. S. Azodolmolky *et al.*, Experimental demonstration of an impairment aware network planning and operation tool for transparent/translucent optical networks,” *J. Lightw. Technol.*, vol. 29, no. 4, pp. 439–448, Sep. 2011.

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