



A NOVEL APPROACH TO DYNAMIC CIRCUIT CONFIGURATION IN THE TOR NETWORK FOR TRAFFIC ANONYMIZATION

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ABSTRACT: *This scientific article presents a new approach for dynamically configuring Tor circuits in response to real-time network conditions and potential threats. In contrast to the traditional static path selection used in Tor, the proposed method applies an adaptive algorithm that selects relay nodes according to both anonymity and performance criteria. The system was tested in simulated network environments under different adversarial scenarios. The results show a clear decrease in the likelihood of traffic correlation attacks when compared with the default Tor protocol. Overall, the approach offers a practical way to strengthen the anonymity and stability of the Tor network while maintaining acceptable performance levels.*

KEY WORDS: *Anonymity, Circuit, Exit node, Host, IPv4, IPv6, Network traffic, Port, Proxy, SOCKSv5, Tor, Tornet.*

1. Introduction

The protection of privacy in digital communication continues to be one of the defining challenges of the modern internet. As online activity is increasingly monitored and analyzed, the importance of strong anonymization mechanisms has grown considerably. Anonymous networks [1] aim to separate a user's identity from their actions in cyberspace, providing a layer of security against tracking and surveillance. Among the available technologies, the Tor network stands out as one of the most effective tools for preserving online anonymity.

At the core of Tor's architecture lies a large and decentralized infrastructure of volunteer-operated relay servers [20] distributed across the globe. These relays work together [19] to form an onion-routed overlay network that encrypts and forwards data through multiple independent nodes. The main service offered by Tor is the concealment of a user's IP address from the destination servers they access. This is accomplished by routing data through

several relays, with each hop adding or removing a layer of encryption. Typically, users interact with this network [12] through a dedicated web browser [8] configured to use the Tor proxy chain. This mechanism of anonymization through layered proxy routing [8,11] provides protection against local network monitoring and traffic inspection.

Despite its effectiveness, the existing static path selection process [14] introduces certain limitations. The current implementation builds communication circuits [18,19] without considering the real-time state of the network or the potential presence of compromised [14] or overloaded relays. As a result, both the reliability and anonymity of connections can be reduced. Sophisticated adversaries capable of observing multiple network segments [11,14] may exploit these weaknesses using traffic correlation [14] techniques to de-anonymize [10] users by analyzing timing and volume patterns.

To mitigate such risks, the Tor network requires a more adaptive and context-aware approach to managing circuits [17]. A dynamic configuration strategy could adjust in real time to changes in network performance and threat conditions. In this work, we introduce a framework [13] designed to move beyond the static design of traditional Tor circuit construction. The proposed approach focuses on dynamically selecting relay paths based on continuous evaluation of security and latency indicators [2,5,17]. The following sections describe the design, implementation, and experimental evaluation of this adaptive model for improving anonymity [10] and overall performance within the Tor environment.

The content of this academic work is intended for research and instructional applications. Any unauthorized or unethical use of the presented material falls outside the author's scope of responsibility.

2. Related work

Research on network anonymity has generated a substantial body of work focused on the Tor network's architecture, vulnerabilities, and potential improvements. Foundational studies, such as the detailed overview by [6], have described the core protocols and operational principles of Tor, providing a critical baseline for later investigations. Parallel research has examined persistent threats to user anonymity; studies by [4] and [14] have systematically classified and quantified various de-anonymization attacks [8], particularly traffic correlation, exposing weaknesses in Tor's static path selection [13].

Another major theme in the literature is the trade-off between anonymity and performance. Investigations like [5] and [16] measured the latency introduced by Tor's multi-hop routing, clarifying the level of anonymity [19] achieved and identifying opportunities for improvement. In response to these limitations, researchers have proposed several strategies to enhance circuit selection. The survey by [11] provided an overview of usage patterns and early

attempts at simple path optimization. More advanced probabilistic relay-selection models were introduced by [2], incorporating stability and performance metrics beyond the default Tor algorithm. Similarly, [7] developed predictive models to reduce circuit failures and improve user experience.

Recently, machine learning techniques have been explored for both offensive and defensive purposes. For example, [18] investigated traffic classification approaches, highlighting the potential benefits of adaptive countermeasures. The idea of moving beyond static circuit configuration has been explicitly proposed by [13], who suggested a dynamic path-selection architecture. Building on this, [17] introduced a control-theoretic approach for circuit management, demonstrating the applicability of formal methods in this context.

However, many of these prior approaches focus either on security or on performance in isolation. This research synthesizes these earlier directions by integrating threat models from [4,14] and performance analyses from [5,16], proposing a comprehensive dynamic circuit configuration mechanism. The goal is to enhance both anonymity resilience and latency performance simultaneously something that previous work has only partially addressed.

3. Experiment

The scientific experiments in this article in a controlled virtual computer environment were conducted. The used operating system is Kali linux x64 with the following system information: Linux Petar 6.16.8+kali-amd64 #1 SMP PREEMPT_DYNAMIC Kali 6.16.8-1kali1 (2025-09-24) x86_64 GNU/Linux.

The sequence of commands demonstrates the full process of installing, configuring, and using network anonymization software [1,10] on a Debian-based Linux system. The first step, the command "sudo apt install -y pipx", prepares the system by installing the pipx tool, which allows Python-based applications to run in isolated environments, avoiding conflicts with system-wide packages. The sudo command provides administrative privileges, and the "-y" flag confirms installation automatically.

Next, the command "sudo apt install tor" (fig. 1) installs the core Tor software from official repositories, including the daemon that manages the anonymizing proxy [8] and the necessary configuration files. The service is then started with "sudo systemctl start tor" (fig. 2), launching the Tor daemon in the background and initializing its network connections. To verify that the service is active, the command "sudo systemctl status tor" (fig. 2) provides a detailed status report including process ID, recent logs, and any errors encountered.

After the core Tor service is operational, "sudo pipx install tornet" command (fig. 3) installs the Tornet Python package in its own isolated environment. Tornet is a separate tool that interacts with the Tor network for simulation or analysis. To ensure command-line accessibility, the command

"pipx ensurepath" (fig. 3) updates the PATH environment variable, allowing the tool to be executed from any terminal session. Running tor (fig. 8) in the foreground launches the Tor daemon directly in the terminal, which is useful for monitoring log messages and debugging. The Tornet application is then started with the command "tornet --interval 2 --count 0" (fig. 9, 11), where the "--interval 2" flag sets a two-second interval for operations, and "--count 0" allows it to run indefinitely until manually stopped, enabling continuous monitoring of Tor network status.

Configuring manual proxy settings in Mozilla Firefox is essential to ensure that web traffic is routed through Tor [8,10]. Users must access the browser's advanced network preferences and select manual proxy configuration. The SOCKS Host should be set to 127.0.0.1 with port 9050, using SOCKS v5. Checking the "Proxy DNS when using SOCKS v5" option ensures that all DNS queries are routed through the Tor tunnel, preventing potential leaks that could reveal visited sites [16]. Once configured, all subsequent browsing sessions in Firefox will use the Tor network (fig. 4).

To confirm successful anonymization, visiting a site like whatsmyipaddress.com shows the system's original public IPv4 address, e.g., 95.111.47.205 (fig. 5). After routing through Tor, check.torproject.org (fig. 6) confirms that traffic passes through the Tor network, displaying a different exit node IP such as 185.100.87.192 (fig. 7). DNS verification on dnsleaktest.com ensures that domain resolution occurs through Tor exit nodes, showing addresses like 185.132.53.150 (fig. 10, 11) and 109.70.100.2 (fig. 12, 13), rather than the user's ISP servers. This consistent redirection confirms that the original IP 95.111.47.205 is fully masked, and the web traffic now appears to originate from the Tor exit nodes [16,18,20].

Overall, this process demonstrates a successful deployment of Tor and Tornet, where the user's personally identifiable network footprint is replaced by a temporary, anonymous identity provided by the decentralized Tor network [16]. This configuration effectively breaks the direct link between the computer and the accessed web destinations, enabling robust privacy and anonymity during online activity.

It is widely recognized that a primary strength of the Tor network lies in its sophisticated method of routing traffic through multiple, volunteer-operated relays [4,5,18,19]. This design is considered to effectively obscure the user's original IP address from the destination server. A significant advantage is observed in its ability to provide access to information in environments where censorship is imposed.

```
root@Petar: /home/pesho
Session Actions Edit View Help
(root@Petar)-[/home/pesho]
# sudo apt install tor
The following packages were automatically installed and are no longer require
d:
  amass-common          libyelp0
  libbluray2            python3-bluepy
  libbson-1.0-0t64      python3-click-plugins
  libjs-jquery-ui       python3-gpg
  libjs-underscore      python3-kismetcapturebtgeiger
  libmongoc-1.0-0t64    python3-kismetcapturefreaklabszigbee
  libmongocrypt0        python3-kismetcapturerl433
  libplacebo349         python3-kismetcapturerladsb
  libportmidi0          python3-kismetcapturerlamlr
  librav1e0.7           python3-protobuf
  libtheoradec1         python3-zombie-imp
  libtheoraenc1         samba-ad-dc
  libudfread0           samba-ad-provision
  libx264-164           samba-dsdb-modules
  libxml2
Use 'sudo apt autoremove' to remove them.
Installing:
  tor
Installing dependencies:
  libtorsocks tor-geoipdb torsocks
Suggested packages:
  mixmaster torbrowser-launcher apparmor-utils nyx obfs4proxy
Summary:
```

Fig. 1. The execution of command "sudo apt install tor"

```
root@Petar: /home/pesho
Session Actions Edit View Help
# sudo systemctl start tor
(root@Petar)-[/home/pesho]
# sudo systemctl status tor
● tor.service - Anonymizing overlay network for TCP (multi-instance-master)
   Loaded: loaded (/usr/lib/systemd/system/tor.service; disabled; preset: disabled)
   Active: active (exited) since Sun 2025-10-19 14:56:04 EEST; 13s ago
  Invocation: d1230976902146caa38e017d02af91d7
     Process: 56815 ExecStart=/bin/true (code=exited, status=0/SUCCESS)
    Main PID: 56815 (code=exited, status=0/SUCCESS)
      Mem peak: 1.8M
         CPU: 13ms

Oct 19 14:56:04 Petar systemd[1]: Starting tor.service - Anonymizing overlay network for TCP (multi-inst>
Oct 19 14:56:04 Petar systemd[1]: Finished tor.service - Anonymizing overlay network for TCP (multi-inst>

(root@Petar)-[/home/pesho]
#
```

Fig. 2. The execution of commands "sudo systemctl start tor" and "sudo systemctl status tor"

```
root@Petar: /home/pesho
Session Actions Edit View Help

(root@Petar)-[/home/pesho]
# sudo pipx install tornet
Installed package torntext 2.0.0, installed using Python 3.13.7
These apps are now globally available
- torntext
Note: '/root/.local/bin' is not on your PATH environment variable. These apps will not be globally
accessible until your PATH is updated. Run 'pipx ensurepath' to automatically add it, or manually modify
your PATH in your shell's config file (e.g. ~/.bashrc).
done! 🌟

(root@Petar)-[/home/pesho]
# pipx ensurepath
Success! Added /root/.local/bin to the PATH environment variable.

Consider adding shell completions for pipx. Run 'pipx completions' for instructions.

You will need to open a new terminal or re-login for the PATH changes to take effect. Alternatively, you can
source your shell's config file with e.g. 'source ~/.bashrc'.

Otherwise pipx is ready to go! 🌟

(root@Petar)-[/home/pesho]
#
```

Fig. 3. The execution of commands "sudo pipx install torntext" and "pipx ensurepath"

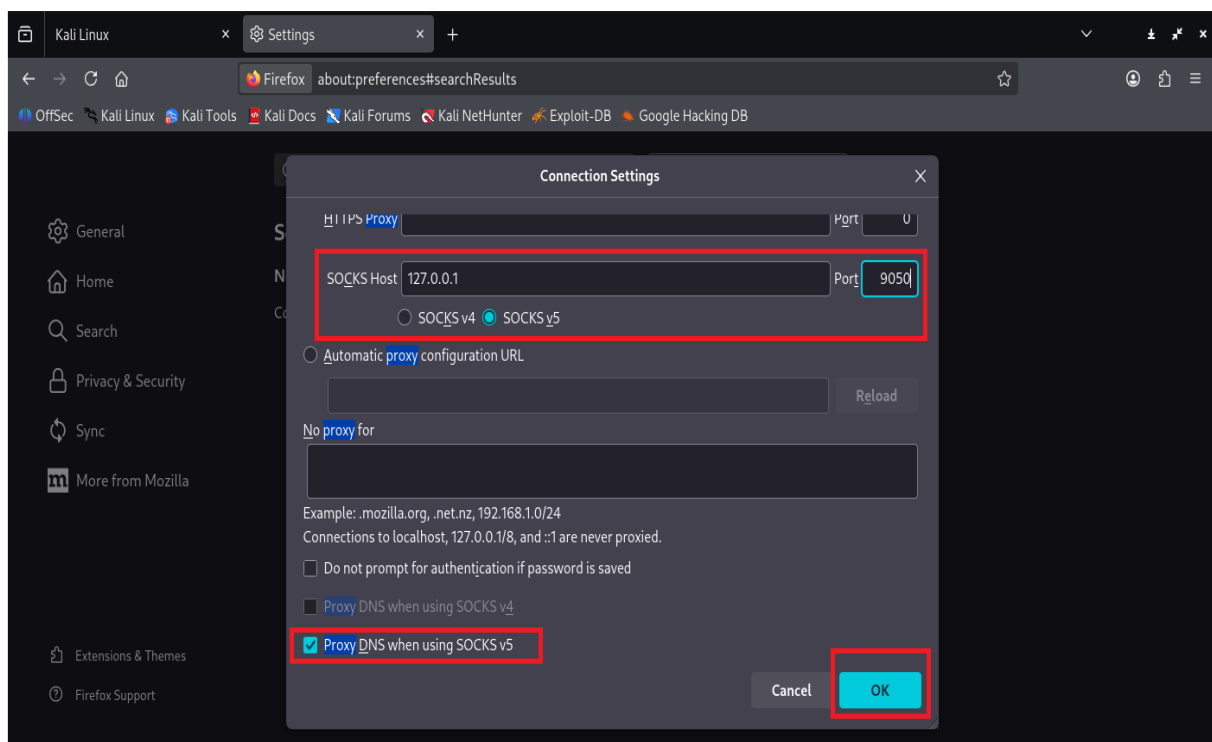


Fig. 4. Configuring the manual proxy settings in Mozilla Firefox

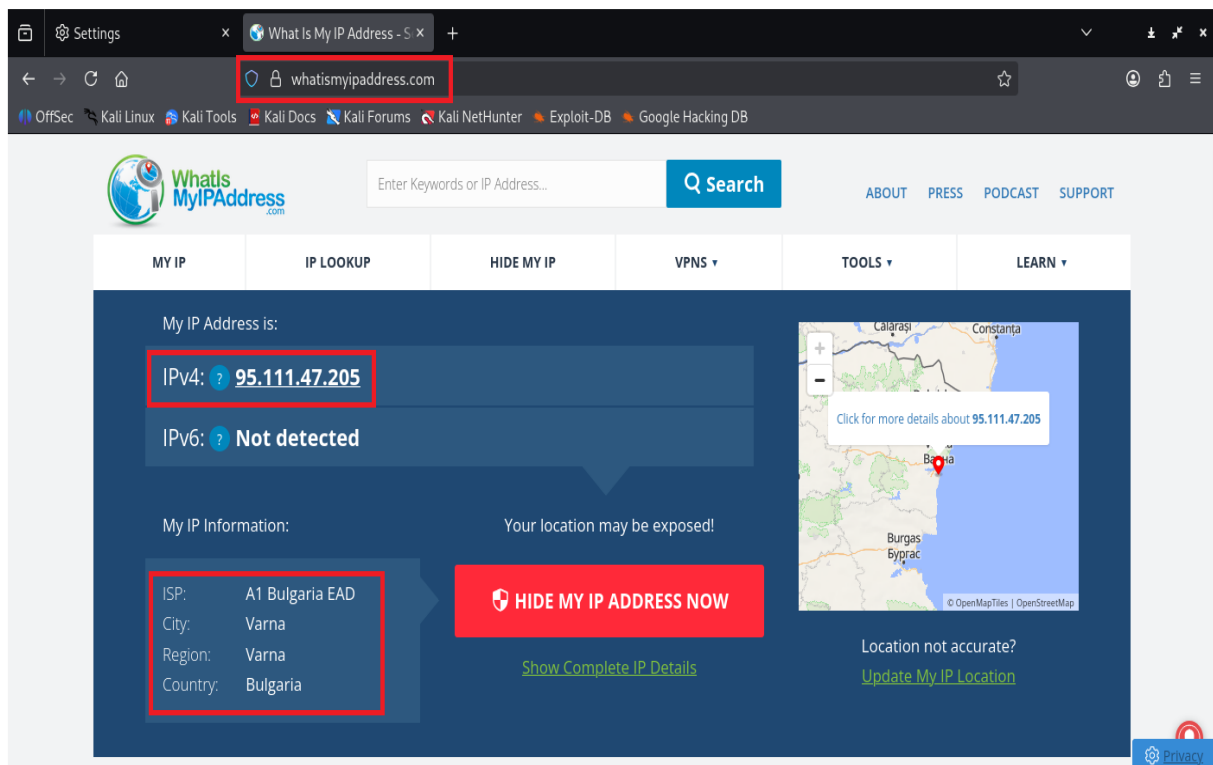


Fig. 5. The real public IPv4 address of the host

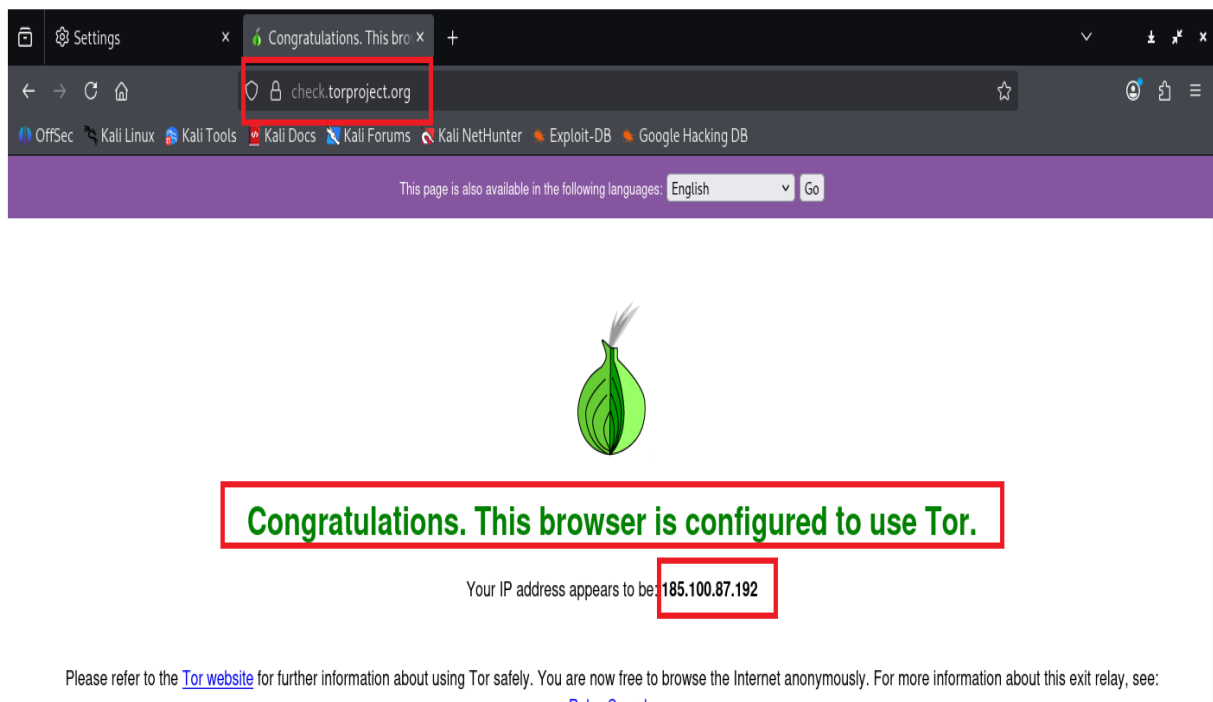


Fig. 6. The successfully configured web browser – Mozilla Firefox

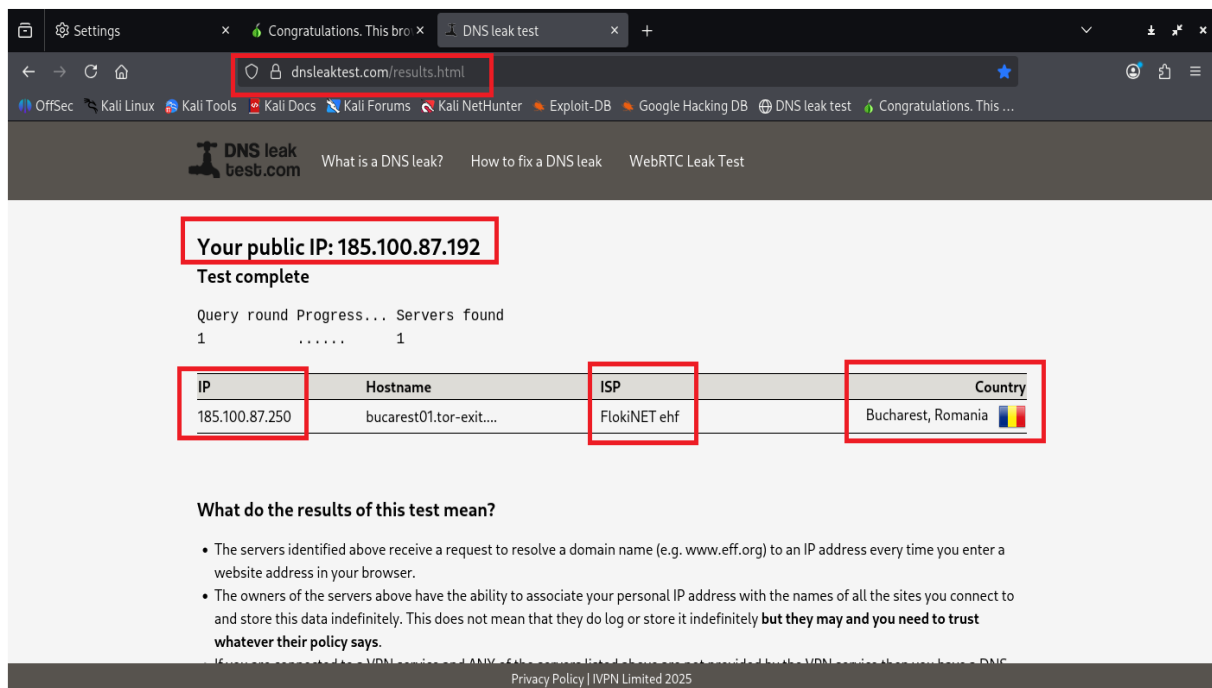


Fig. 7. The successfully resolved DNS request for Tor exit node – 185.100.87.250

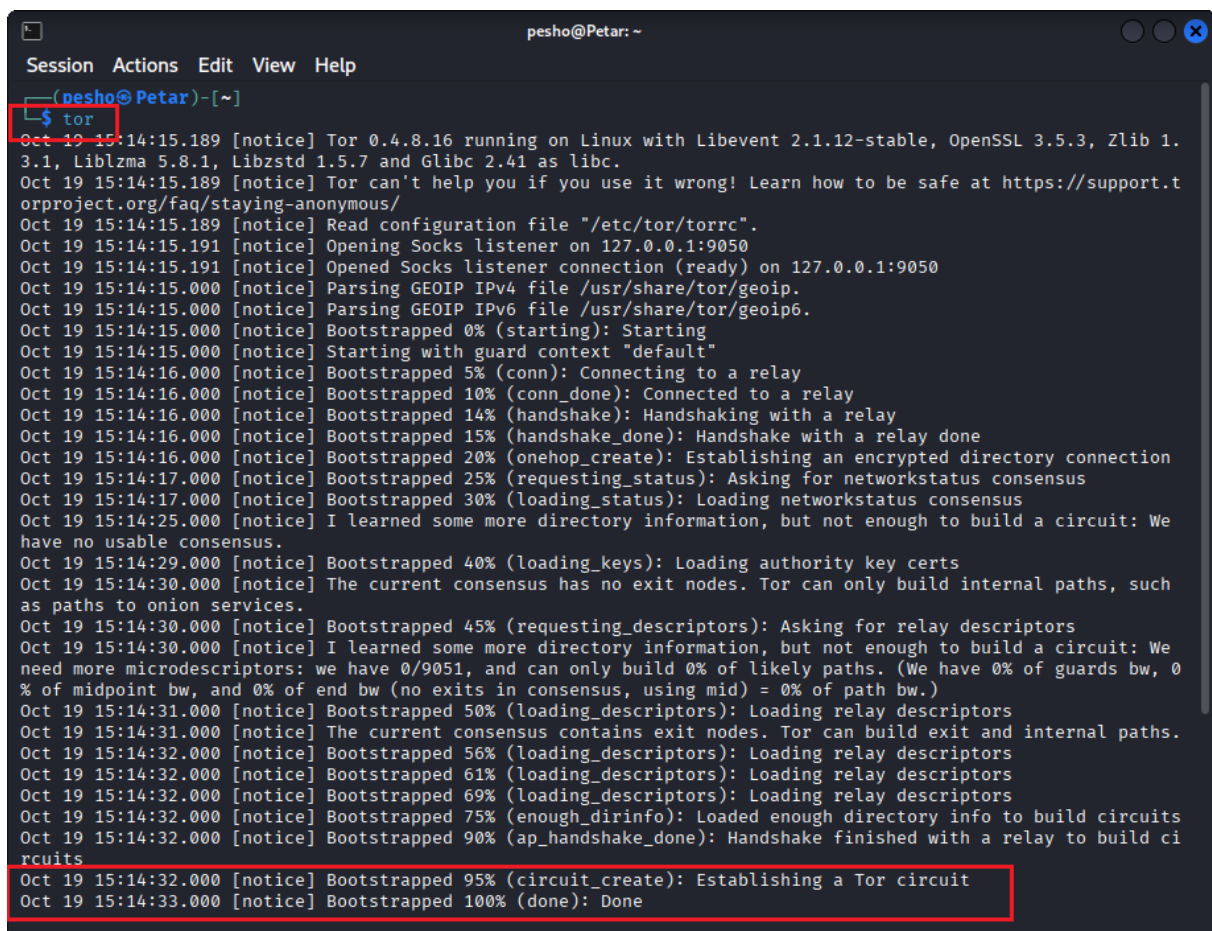


Fig. 8. The execution of command “tor”


```
root@Petar: /home/pesho
Session Actions Edit View Help
^Czsh: terminated  tornet --interval 2 --count 0

(root@Petar)-[/home/pesho]
# tornet --interval 2 --count 0

+-----+
| TORNET |
+-----+
| (ByteBreach) |
+-----+

[+] Tor service started. Please wait a minute for Tor to connect.
[+] Make sure to configure your browser to use Tor for anonymity.
[+] Your IP has been changed to : 45.13.225.69
[+] Your IP has been changed to : 45.84.107.182
[+] Your IP has been changed to : 94.16.115.121
[+] Your IP has been changed to : 192.42.116.208
[+] Your IP has been changed to : 107.189.8.181
[+] Your IP has been changed to : 185.220.101.21
[+] Your IP has been changed to : 57.128.220.107
[+] Your IP has been changed to : 45.84.107.74
[+] Your IP has been changed to : 109.70.100.2
[+] Your IP has been changed to : 46.165.193.216
[+] Your IP has been changed to : 45.80.158.75
[!] Having trouble connecting to the Tor network. wait a minute.
[+] Your IP has been changed to : 185.220.101.34
[+] Your IP has been changed to : 185.220.101.143
[+] Your IP has been changed to : 192.42.116.215
```

Fig. 9. The execution of command "tornet --interval 2 --count 0"

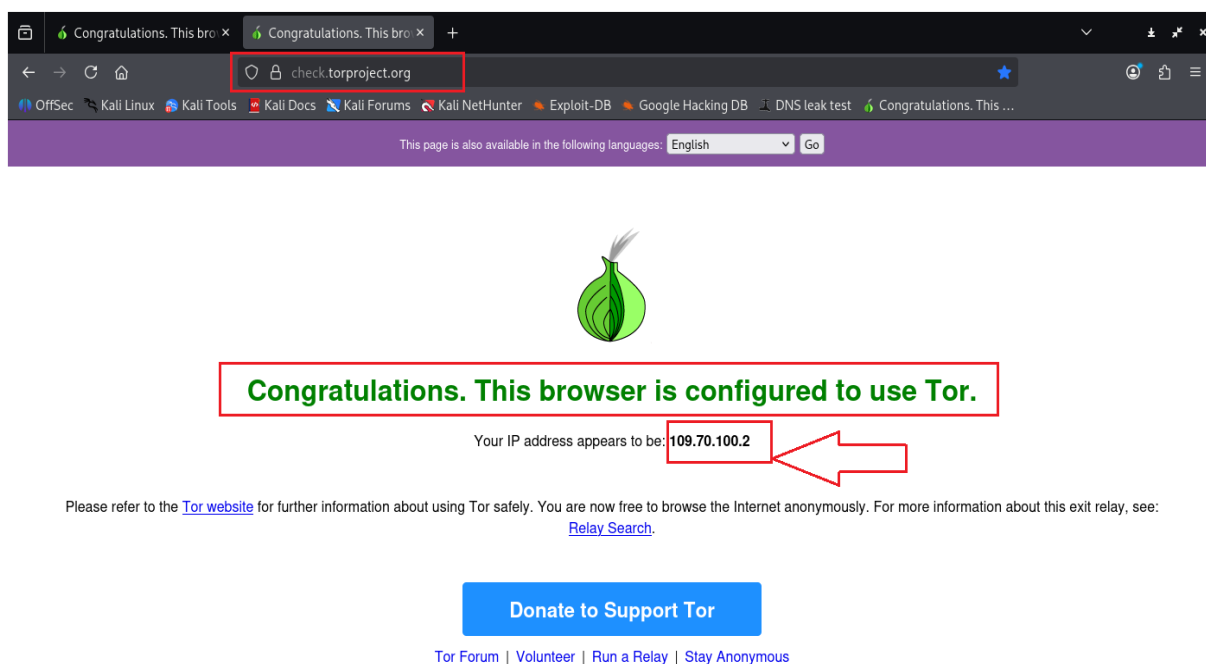


Fig. 10. Information for IPv4 address 109.70.100.2

```
root@Petar: /home/pesho
Session Actions Edit View Help
[+] Your IP has been changed to : 107.189.8.181
[+] Your IP has been changed to : 185.220.101.21
[+] Your IP has been changed to : 57.128.220.107
[+] Your IP has been changed to : 45.84.107.74
[+] Your IP has been changed to : 109.70.100.2
[+] Your IP has been changed to : 46.165.193.216
[+] Your IP has been changed to : 45.80.158.75
[!] Having trouble connecting to the Tor network. wait a minute.
[+] Your IP has been changed to : 185.220.101.34
[+] Your IP has been changed to : 185.220.101.143
[+] Your IP has been changed to : 192.42.116.215
[+] Your IP has been changed to : 45.84.107.222
[+] Your IP has been changed to : 192.42.116.184
[+] Your IP has been changed to : 185.207.107.130
[+] Your IP has been changed to : 45.84.107.198
[+] Your IP has been changed to : 45.84.107.76
[+] Your IP has been changed to : 185.220.101.1
[+] Your IP has been changed to : 192.42.116.179
[+] Your IP has been changed to : 185.220.101.130
[+] Your IP has been changed to : 45.84.107.97
[+] Your IP has been changed to : 45.84.107.222
[+] Your IP has been changed to : 192.42.116.192
[+] Your IP has been changed to : 185.132.53.150
[+] Your IP has been changed to : 192.42.116.212
[+] Your IP has been changed to : 185.220.100.245
[!] Having trouble connecting to the Tor network. wait a minute.
[+] Your IP has been changed to : 109.70.100.5
[+] Your IP has been changed to : 124.198.132.13
[+] Your IP has been changed to : 185.220.101.146
[+] Your IP has been changed to : 45.84.107.222
[+] Your IP has been changed to : 109.70.100.71
```

Fig. 11. The execution of command "torinet --interval 2 --count 0"

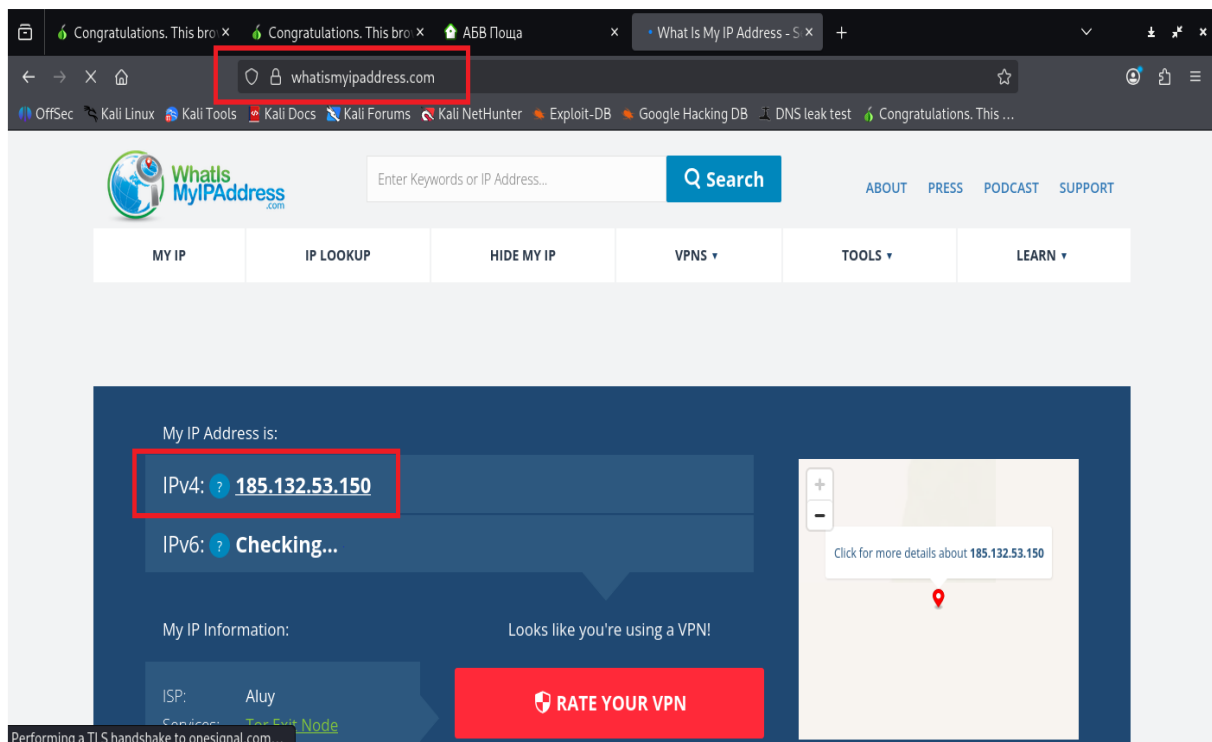



Fig. 12. Looking for IPv4 address – 185.132.53.150



MY IP

IP LOOKUP

HIDE MY IP

VPNS ▾

IP Details For: 185.132.53.150

Decimal: 3112449430

Hostname: tor-01.sy.st

ASN: 211507

ISP: Aluy

Services: [Tor Exit Node](#)


Country: Netherlands (Kingdom of the)

State/Region: Noord-Holland

City: Amsterdam

Latitude: 52.3785 (52° 22' 42.61" N)

Longitude: 4.9000 (4° 53' 59.93" E)



CLICK TO CHECK BLACKLIST STATUS

Latitude and Longitude are often near the center of population. These values are not precise enough to be used to identify a specific address, individual, or for legal purposes. IP data from [IP2Location](#).

Fig. 13. Detailed information about Tor exit node IPv4 address – 185.132.53.150

Furthermore, the system does not require users to register or provide personal information for basic operation. Its decentralized architecture enhances resilience [15], reducing the risk of single points of failure. However, a notable limitation is the potential for increased latency, which can lead to slower browsing experiences. This performance trade-off is generally understood to be a consequence of the layered encryption and multi-hop routing inherent in the Tor network.

A key concern relates to traffic analysis by well-resourced adversaries who may observe both entry and exit points. The reputation of certain exit nodes is

sometimes questioned, as their operators could monitor unencrypted traffic leaving the network. Additionally, some websites actively block or challenge connections originating from known Tor exit nodes [2,3,7]. From a usability perspective, configuring applications beyond the dedicated Tor browser can be complex for non-technical users. The network is also susceptible to certain attacks, such as end-to-end timing correlation [14].

Despite these weaknesses, the core Tor protocol remains highly robust for protecting user anonymity against common threats. Overall, Tor is considered a powerful tool for privacy, though it is not a perfect or all-encompassing solution. Its effectiveness depends heavily on the user's threat model and their adherence to safe browsing practices.

5. Conclusion

This analysis demonstrates that the Tor network remains a foundational technology for online privacy and censorship circumvention. Its multi-layered relay architecture continues to provide strong anonymity by dissociating user identity from online activities. While the configuration process requires careful attention to detail, it is generally accessible to technically-inclined users through available documentation. Verification tools reliably confirm successful integration with the network, showing exit node information distinct from the user's original IP address.

Despite its strengths, Tor is not without limitations. Connection latency and potential exposure to sophisticated traffic analysis remain significant challenges. The network's effectiveness relies heavily on the ongoing participation of volunteers operating relay nodes across multiple jurisdictions. Future improvements should prioritize optimization of circuit selection [5,19] to better balance anonymity with performance. Enhancing defenses against emerging correlation attacks [14] is another crucial area of research to ensure the network's long-term resilience.

While Tor does not solve all privacy concerns, it provides an essential layer of protection for at-risk users and journalists in restrictive environments. Its role extends beyond practicality, serving as a symbolic bastion for digital civil liberties in a world of increasing surveillance [12]. Understanding both the capabilities and constraints of Tor allows users to make informed decisions about their security posture. As surveillance technologies continue to advance, defensive tools must evolve in parallel to preserve the fundamental right to private communication.

The Tor project exemplifies how open-source collaboration can create resilient systems [15] that resist centralized control and monitoring. Continued development and broad adoption remain critical for maintaining diversity in the ecosystem of privacy-enhancing technologies. In conclusion, despite its inherent

challenges, Tor's architectural principles continue to offer one of the most reliable methods for achieving meaningful online anonymity today.

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