Avoiding recording user activities: TOR, Linux Tails

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Abstract

The Tor (The Onion Router) network is a virtual computer network that provides anonymisation and access to often illegal data or for those avoiding censorship. Linux Tails (The Amnesic Incognito Live System), on the other hand, is an operating system bootable only from a removable media (e.g.: flash drive, memory card or DVD) or run in a virtualized manner. Tails, as one of the tools, offers access to the Tor network providing, in addition, far sophisticated mechanisms to avoid leaving digital traces on the user's machine. Despite the different intentions of the developers of the two tools discussed above, they have also become the favorite package of a huge group of criminals around the world. In this publication, the author focuses on discussing both the areas of formation of digital traces of Tor and Tails usage, as well as the research possibilities and inference possibilities based on them. The first part of the article describes the mechanism of the Tor anonymizing network. The author then introduces the reader to the Linux Tails environment and refers to actual use cases.

Keywords: anonymisation, Tor, Tails, Linux, routing, virtual

Until recently, the burglar's sleep was spent on the problem of how to leave as few traces as possible at the scene of the crime. Today, in the digital age, perpetrators use a variety of tools to gain unauthorized access, fake identities or perform other actions, leaving virtually no traces other than digital. They try to hide in the shadows of ordinary network traffic, mask their activities, and encrypt data that constitutes digital evidence. Sometimes they may even return to the crime scene and continue to obliterate traces or verify their existence without the knowledge of law enforcement. Although the idea of anonymizing networks or flexible live operating systems did not originate with the criminal world in mind, its fruits are increasingly becoming such tools. This prompted the author to describe in this article the Linux Tails operating system as a tool and the anonymizing programs it contains, including those using the Tor network in the context of computer forensics. However, it is important to remember that these types of tools are also used by, among others, people living in authoritarian systems, or people who want to maintain their privacy. All readers who have had the opportunity to read the book „Non-Volatile Memory" by Edward Snowden know that during his work for the NSA, he used the Tails operating system to contact the press. And most importantly, he was not caught at it, which is a special recommendation.

The Tor (The Onion Router) network is a virtual computer network that implements second-generation onion routing, which prevents network traffic analysis and provides its users with almost anonymous access to Internet resources.

The Tor project was initially sponsored by the U.S. Naval Research Laboratory and developed as a military project to protect U.S. intelligence communications on the Internet. It was meant to mask the activities of intelligence agents on the Internet.

The initiators of the Tor network were programmers Roger Dingledine, Nick Mathewson and Paul Syverson, who began work on the project in 2002 with the support of the US Naval Research Center. In 2004 at the 13th. Security Symposium of the USENIX Association presented the paper „Tor: The Second-Generation Onion Router". In late 2004 to November 2005, it became a project branded by the Electronic Frontier Foundation (EFF). Today, Tor software development is handled by the Tor Project, a non-profit research and education organisation based in the United States, supported by volunteers and network users around the world. The project currently operates under a BSD license, but has been indirectly sponsored by the US Navy all along (Mider, 2019).

The Onion Router was made available for civilian use in 2003. The servers making up the Tor network in its early days were located only in the United States and Germany.

The name of the Tor network is an acronym for „The Onion Router". It is derived from a technique that involves sending independent and multilayered encrypted packets, hence the term „onion routing". The devices that make up this network, perform a process called onion routing, different from classic routing by routers using the TCP/IP model (Mider, 2019; Casad, 2017).

In the Tor network, data is sent in encrypted layers, analogous to the layers of an onion. The data thus encrypted is sent through a series of network relays (onion routers, or onion routers), each of which removes („peels off") a single layer, revealing the next destination of the transmitted data. Once the last layer is decrypted, the data arrives at its destination. The sender remains anonymous, as each relay only knows the location of the immediately preceding and following relays. The router at each layer knows only what it needs to operate. The IP addresses of all requests and responses change at each relay (Ortega, 2022).

Onion routing is a data structure created by encapsulating („wrapping") data in successive layers of encryption, which can be decrypted by as many intermediary computers as there are layers before it reaches its destination. The connection between each relay (proxy server) is encrypted. The original data (and its sender) remain hidden because the data is transmitted between intermediate relays, and no intermediate relay knows both the origin and destination of the data, so the sender remains anonymous.

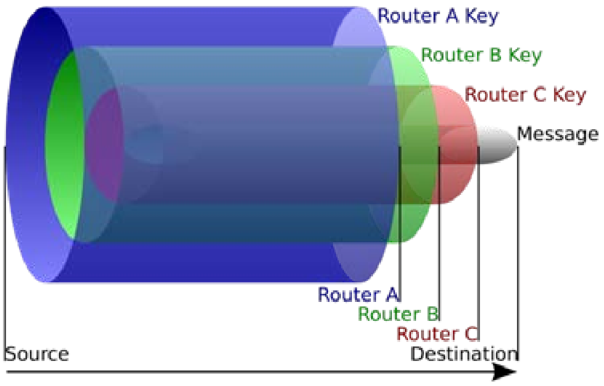


Fig. 1. Onion routing mechanism: the source sends data to Router A, which removes the encryption layer to find out just where to send it next and where it came from (although it doesn't know if the sender is the source or just another relay). Router A sends it to router B, which decrypts the next layer to learn its next data destination. Router B sends the data to Router C, which removes the last layer of encryption and sends the original message to its destination

Observation of such network traffic makes it impossible to tell what is being transmitted in it.

The Tor network provides TCP-based anonymity with relatively low latency and high bandwidth. The mechanisms implemented in the Tor network protocol impose a layer of anonymity on the TCP layer and create a (default minimum) three-point path through which Tor network routers layer encryption. Routing information is sent by a group of authoritative servers. In simple terms: all of a user's TCP communications are tunneled into a single relay, rotating in time, and to ensure low latency, the Tor network does not force retransmission of lost packets.

From a privacy perspective, the Tor network has two purposes:

1. hiding the location of users accessing the Internet – tracing the IP addresses and locations they use is supposed to be impossible;
2. encryption of transmitted data – the Tor network, by encrypting data and sending it via onion routing, hides the IP addresses of users and transmitted data, and hides the IP addresses of the ISPs through which users connect to the Tor network (Ortega, 2022).

The relays that make up the Tor network have different tasks, and depending on their characteristics and configuration, we distinguish:

1. guard relays – communicating with users, connected to the rest of the Tor network. Used for a long time. They have large throughputs;
2. middle relays – which communicate only with other relays. The data that comes out of them does not leave the Tor network;
3. exit relays – the end (edge) points of the Tor network. They receive the requests, send them to the recipients, receive the responses and send them across the network toward the sender;
4. bridge relays – which are relays about which there is no information in the public directory of Tor network relays, which are much more difficult to block. They are used when the ISP blocks the Tor network. The list is available at https://bridges.torproject.org (Ortega, 2022).

The use of the Tor network is as follows:

1. A host connecting to the Tor network retrieves a list of available relays and selects three of them: guard, relay and output;
2. The data to be sent over the Tor network is first encrypted. Only the originating relay knows the address of the requested network service and has insight into the data packets being transmitted, but

their origin is not known to it, thus providing privacy to the user;

3. The encrypted data is re-encrypted and only the relay relay knows which output relay to send it to. With double encryption, only the guard relay knows where the relay relay is located (Ortega, 2022).

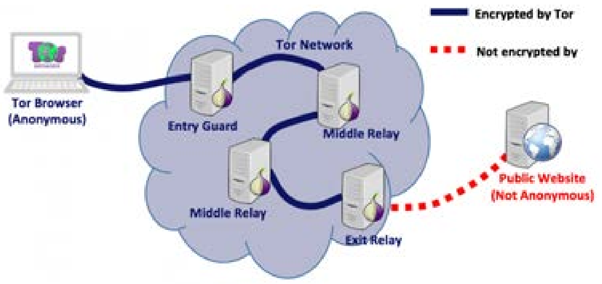


Fig. 2. Diagram showing a typical scenario of a Tor client accessing a public site on the Internet

The data is encrypted before it leaves the user's computer:

1. If there is a system that monitors the Internet connection (the ISP may do so), it only sees the encrypted data exchanged with the watchdog relay;
2. Only the guard relay sees the user's IP and knows where the relay relay is located;
3. Only the relay relay knows where the guard and output relays are. However, it does not know where the user is or the requested website (or other web service). Relay relays do not know their places in the network;
4. The output relay knows where the requested website (or other web service) and relay relay are. But it doesn't know where the user and the guard relay are (Ortega, 2022).

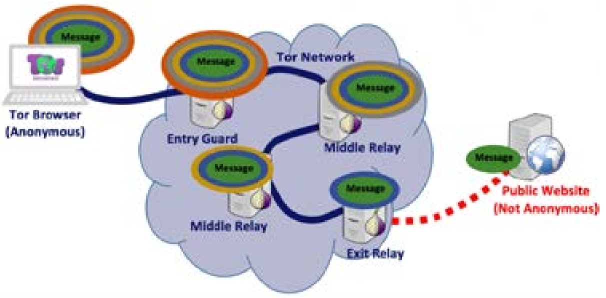


Fig. 3. A diagram showing how a message travels through the Tor network until it reaches a public website. The Tor network client (Tor Browser) adds as many layers as there are relays in the chain

Some networks block outbound traffic on the TCP port 9050 used by the Tor network, and even dynamically blacklist all Tor network relays, making it impossible to use the network. This restriction can be circumvented by using so-called network bridges, i.e. Tor network relays that are not visible in the public Tor network directory (Allsopp, 2017).

In addition to connecting to services on the Internet, the Tor network enables the use of so-called hidden services, provided on completely anonymous web servers, locked into and visible only within the Tor network ecosystem, which use their own distributed addressing system (Allsopp, 2017).

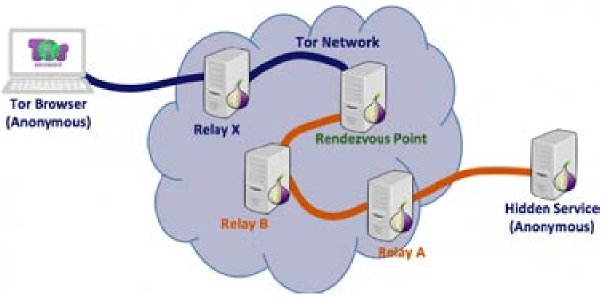


Fig. 4. Diagram showing the mechanism for accessing a web server hidden in the Tor network (hidden service): (1) one Tor Relay (relay) server will be selected as (relay) Rendezvous Point; (2) two connections are established: one from the Tor network client to the Rendezvous Point relay, and the other from a hidden server in the Tor network to the Rendezvous Point relay. The author leaves it to the attentive reader to consider whether the „Hidden Service" in the diagram above should not be covered by the „Tor Network" image cloud area

Unlike regular websites, which are accessed via their URLs, hidden services are accessed via a special type of onion address that contains a random, non-mnemonic string and is not part of the Internet's typical DNS system. Random characters in the address of a site on the TOR network (e.g.: https://zqktlwi4fecvo6ri.onion/wiki/index.php/Main_Page) make it even more difficult to find the right site – access is available to those who know how to look for them.

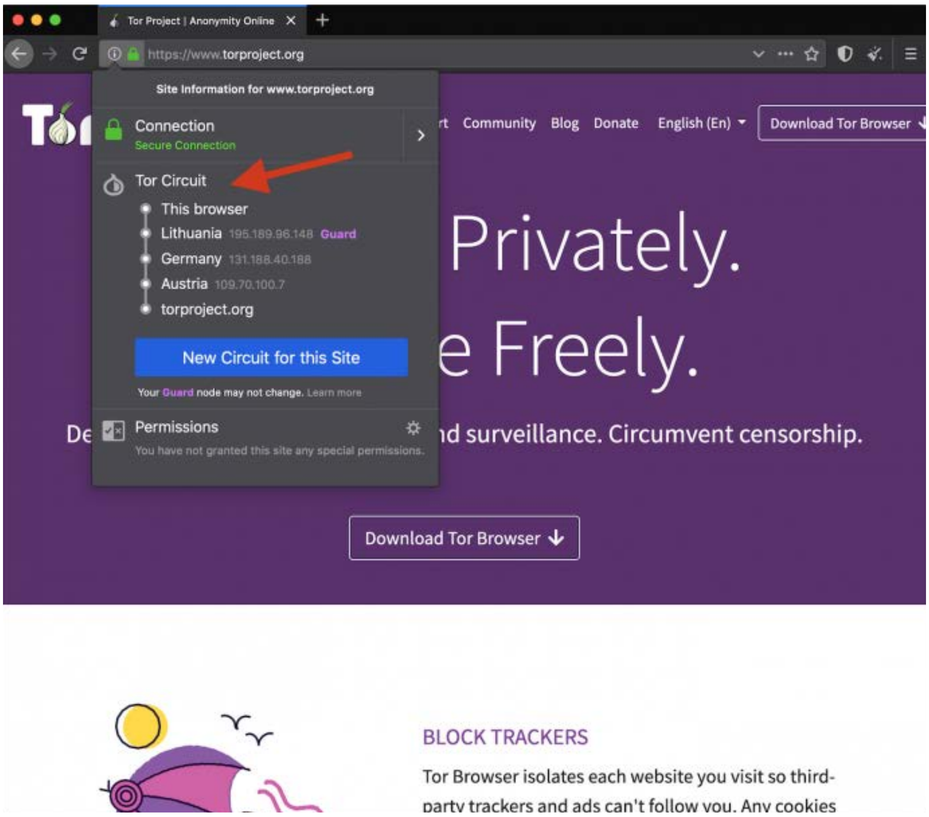
The most popular program for browsing the Tor network is the Tor Browser Bundle, integrated into the Mozilla Firefox web browser. The program provides protection to the user if he only uses the built-in Firefox browser. Once you are connected to the Tor network, you can freely browse the web, as well as chat using instant messaging. The program has a huge number of different configuration options, with which we can set up a connection to the Tor network and establish a new TCP connection by entering a different IP address. Tor Browser provides security at three levels, which we can set ourselves at any time. These levels are: Standard (all Tor browser and page features are enabled); Safer (JavaScript support on pages without HTTPS is disabled, likewise some fonts and symbols, HTML5 media (audio and video) run only after we click) and Safest (same situation with HTML5 as above, and JavaScript disabled by default on all pages, likewise some fonts, symbols and images).

As you can learn from the above analysis of the operation of the Tor virtual network, specialized software is required to operate it. User safety increases when it operates in an environment that minimizes the creation of digital artifacts. The best such environment is a computer memory-only operating system or a virtual system. The Tails system described later in this article is not the only Linux distribution designed for similar purposes. Among the popular ones can also be mentioned: Qubes OS, minimalist Alpine Linux, IprediaOS, Whonix and Kodachi Linux, however, the author focused on the distribution in question due to its popularity in the evidence submitted for the study.

„The Amnesic Incognito Live System", or Tails for short, is a Debian-based Linux distribution based on Debian and the Gnome desktop environment designed exclusively for use as a Live USB, Live DVD or for a virtual environment. The first version of this operating system was created in 2009 by the developers of „The Tails project" with security, privacy and user anonymity in mind. Up to version 5.2 on July 12, 2022, the functionality of which will be discussed in this part of the article (the author's paper focuses on functionality particularly relevant to digital forensics and therefore does not include a full description of Linux Tails 5.2), the project has undergone an impressive evolution that has also significantly affected the modus operandi of the criminals using it. Of particular relevance from the point of view of a computer forensic investigator seems to be the evolution of the system developers' policy on methods of accessing the area made available for data recording.

Currently, according to the distributor, Tails is a system aimed at users such as activists, journalists and their sources, people experiencing excessive scrutiny in their environment, and anyone in need of privacy in the digital world. It is free software under the GNU/GPL license, so the source of funding for the aforementioned group of developers includes sponsors among whom the participation of organisations such as: U. S. Department of State (over $100,000); ProtonMail, RIPE NCC ($50,000-$99,999 each) or Tor.

The operating system in question needs a 64-bit processor and at least 2 GB of RAM to operate and the manufacturer claims compatibility with most personal computers manufactured after 2006. As mentioned earlier, using a USB flash drive or DVD, it runs on the computer bypassing the use of the native



Tor Project | Anonymity Online
https://www.torproject.org
Site Information for www.torproject.org
Connection
Secure Connection
Tor Circuit
This browser
Lithuania 195.189.96.148 Guard
Germany 131.188.40.188
Austria 109.70.100.7
torproject.org
New Circuit for this Site
Your Guard node may not change. Learn more
Permissions
You have not granted this site any special permissions.
rt Community Blog Donate English (En)
Download Tor Browser
Privately.
e Freely.
De
nd surveillance. Circumvent censorship.
Download Tor Browser
BLOCK TRACKERS

Tor Browser isolates each website you visit so third-party trackers and ads can't follow you. Any cookies

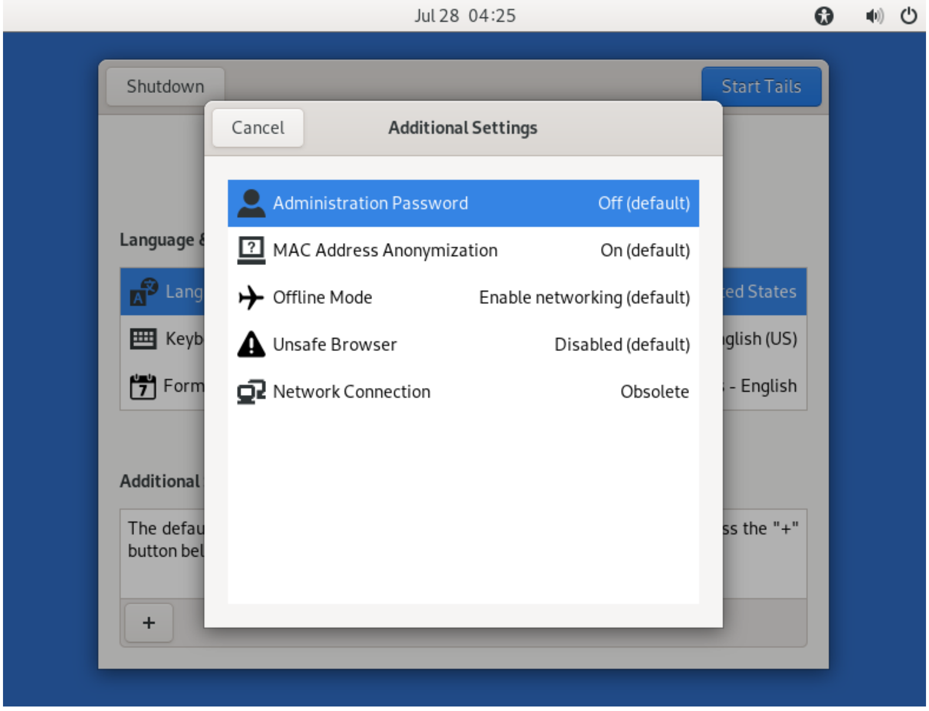
Fig. 5. Tor Browser window with visible addresses of Tor network relays and options for changing the circuit

operating system while guaranteeing read-only access to the mounted storage media. Even at this stage of the user's action, no artifacts indicating the use of Tails are created on the computer, since the only non-standard command during startup is the use of the boot media selection interface, and as the practice of the article's author confirms, on most of the devices tested and submitted for testing in the course of the implementation of the provisions for the expert opinion, this operation does not require permanent modification of the BIOS settings.

After selecting the standard startup mode, the user has the option to preconfigure parameters, among others that significantly affect security.

These settings include the ability to specify an administrative password. Skipping this step significantly limits certain functionality while giving the less sophisticated user a greater guarantee of avoiding digital evidence artifacts. Other pre-configuration options worth mentioning are the ability to automatically anonymize the physical MAC address of network interfaces, enforced offline mode, provision of the so-called Unsafe Browser function, i.e. a web browser with the ability to use the Internet bypassing Tor, which is blocked by default for security reasons. Previous development versions of Linux Tails at the pre-configuration level even offered, at a minimum, camouflage in the form of a graphical interface resembling the MS Windows desktop.

The Linux Tails operating system running with the parameters described above, as mentioned earlier, allows access to mounted storage media in „read-only" mode. The correct operation of the Tails system's software write blocker was confirmed by the author's numerous tests, which consisted of mounting various media, both removable memory and disks installed in the tested units, reviewing their contents, attempting to write to these media using GUI software distributed with the live USB compilation LinuX Tails 5.2 and running this system, and then verifying their SHA-1 and MD5 hash function values. It should be noted that for file systems other than those based on GNU/Linux, the built-in file viewer automatically ignores access permission restrictions to view the contents of storage media. Thus, in the absence of encryption, it is possible to access, read or make copies of any personal computer user's files, even if the native operating system is protected from unauthorized access (A simple way to prevent unauthorized booting of Tails on a computer is to protect the boot source selection panel with a BIOS-level password). In addition, no digital evidence artifacts related to this fact are observed on the computer in use. Although the operations are performed using RAM, however, the Tails system architecture has a built-in mechanism that immediately overwrites the allocated area when the process finishes, the system also blocks the standard methods of performing a RAM dump. The execution of such a snapshot is



Administration Password Off (default)
MAC Address Anonymization On (default)
Offline Mode Enable networking (default)
Unsafe Browser Disabled (default)
Network Connection Obsolete

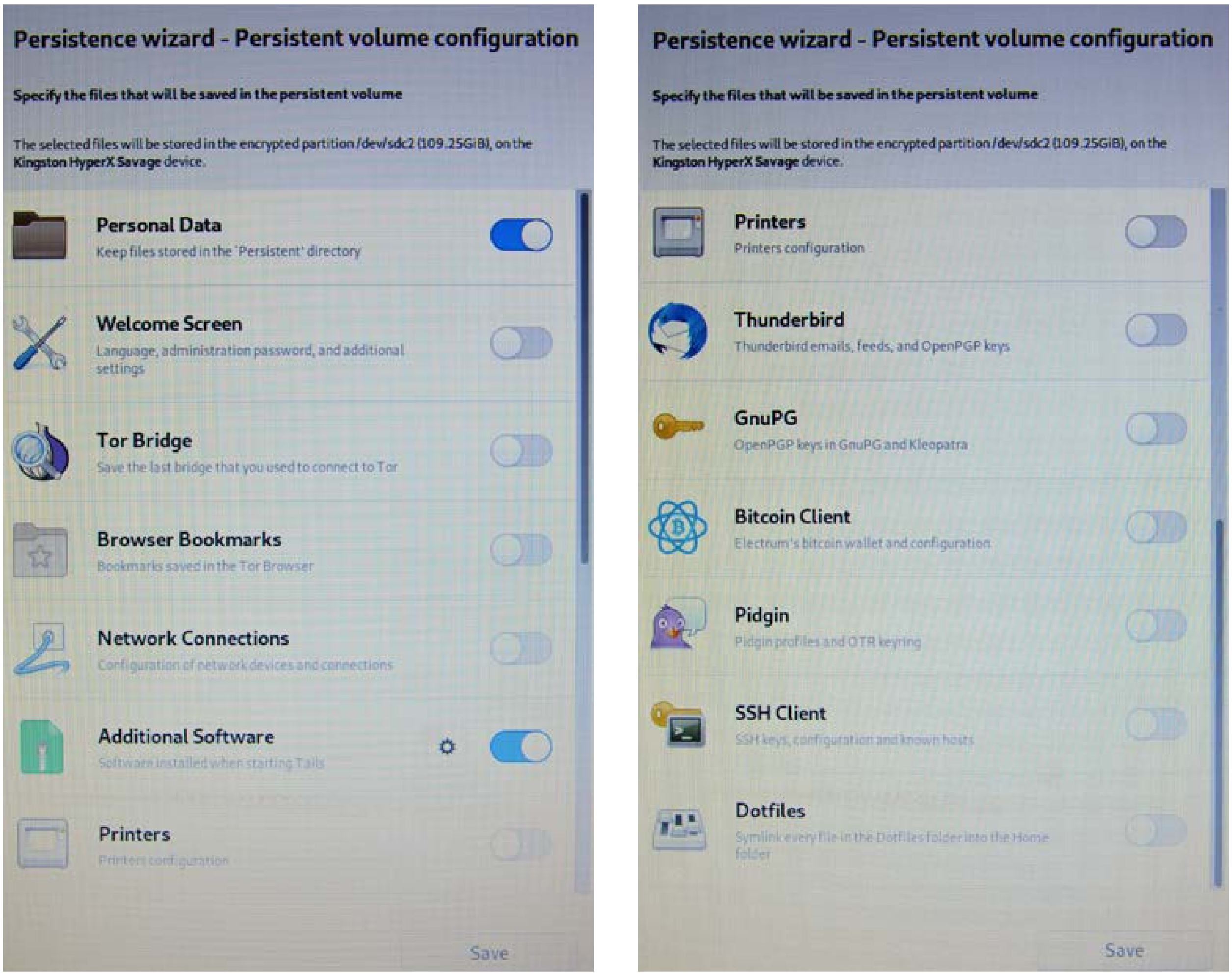
The defau
button bel
ss the "+"

Fig. 6. View of Linux Tails session pre-configuration panel selection windows taken as a screenshot of a session on a virtual machine

possible, for example, with the help of AVML software, however, due to the limitation of the possibility of saving the result only in the „Persistent Storage" area (See the further part of the article) or with the help of a web interface, it represents, besides the analysis of the content of the snapshot itself, an interesting and important research problem to be solved in the course of further author's own analysis. In addition, when Talils is properly terminated, all of its ephemeral memory is overwritten, making it invulnerable to the use of investigative „cold boot attack" methods.

In earlier development versions of Linux Tails, an intermediate user could mount storage media in „read-write" mode, so to the capabilities described above, the ability to tamper with data could be added. In the described version 5.2 from the level of standard system settings and attached applications, there is no such functionality, which, despite the increase in the level of confidentiality of use, causes a significant hindrance, i.e. no storage for data produced during the work. Among other things, the developers have implemented a feature called: „Persistent Storage" – encrypted permanent storage. This feature is available to configure from Linux Tails, which is running from a USB stick. With its help, the user sets up a partition encrypted with the Linux LUKS standard in the free storage area of the carrier („Persistent Storage" can only be installed on the carrier with Linux Tails). During the next boot of the Live system, the partition is recognized and, after entering the password in read-write mode, an encrypted space is made available, where, in addition to user files, applications can be installed or Tails configuration settings stored, among other things.

It is telling that the operating system in question does not force the creation of a password of high complexity (it even allows one arbitrary character as an access password), which makes the created partition vulnerable to dictionary or „brute force" attacks using mini-software such as „Passware Kit Forensics". In addition, the LUKS encryption standard allows the encrypted partition to be read with a known access password on any computer with the appropriate software. This activity can easily lead to artifacts in the operating system of the computer used, containing, for



Persistence wizard - Persistent volume configuration

Specify the files that will be saved in the persistent volume

The selected files will be stored in the encrypted partition /dev/sdc2 (109.25GiB), on the **Kingston HyperX Savage** device.

- **Personal Data** – Keep files stored in the 'Persistent' directory ●
- **Welcome Screen** – Language, administration password, and additional settings ○
- **Tor Bridge** – Save the last bridge that you used to connect to Tor ○
- **Browser Bookmarks** – Bookmarks saved in the Tor Browser ○
- **Network Connections** – Configuration of network devices and connections ○
- **Additional Software** – Software installed when starting Tails ⚙ ●
- **Printers** – Printers configuration ○

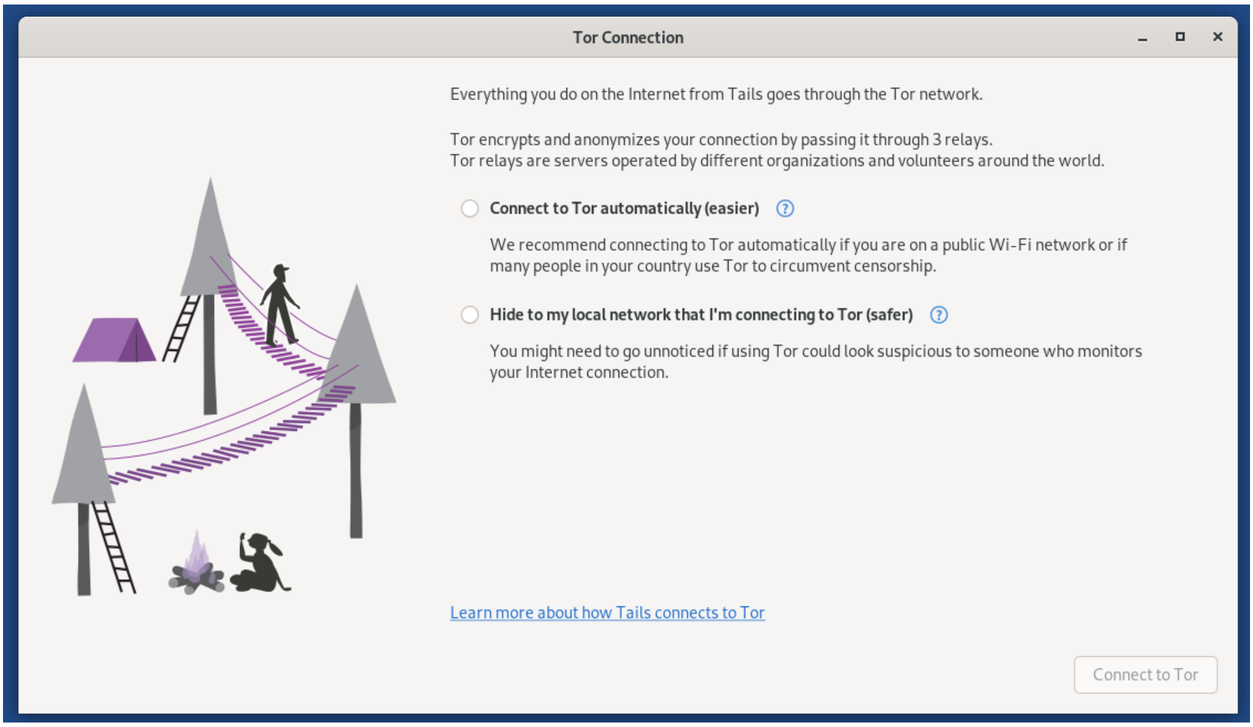
Persistence wizard - Persistent volume configuration

Specify the files that will be saved in the persistent volume

The selected files will be stored in the encrypted partition /dev/sdc2 (109.25GiB), on the **Kingston HyperX Savage** device.

- **Printers** – Printers configuration ○
- **Thunderbird** – Thunderbird emails, feeds, and OpenPGP keys ○
- **GnuPG** – OpenPGP keys in GnuPG and Kleopatra ○
- **Bitcoin Client** – Electrum's bitcoin wallet and configuration ○
- **Pidgin** – Pidgin profiles and OTR keyring ○
- **SSH Client** – SSH keys, configuration and known hosts ○
- **Dotfiles** – Symlink every file in the Dotfiles folder into the Home folder ○

Fig. 7. Images of the „Persistent Storage" configuration window



Everything you do on the Internet from Tails goes through the Tor network.

Tor encrypts and anonymizes your connection by passing it through 3 relays.
Tor relays are servers operated by different organizations and volunteers around the world.

○ Connect to Tor automatically (easier)

We recommend connecting to Tor automatically if you are on a public Wi-Fi network or if many people in your country use Tor to circumvent censorship.

○ Hide to my local network that I'm connecting to Tor (safer)

You might need to go unnoticed if using Tor could look suspicious to someone who monitors your Internet connection.

Learn more about how Tails connects to Tor

Fig. 8. View of the Tor connection configuration window taken as a screenshot of a session on a virtual machine

example: thumbnails or copies of multimedia content, file indexes and their metadata, having the meaning of digital traces.

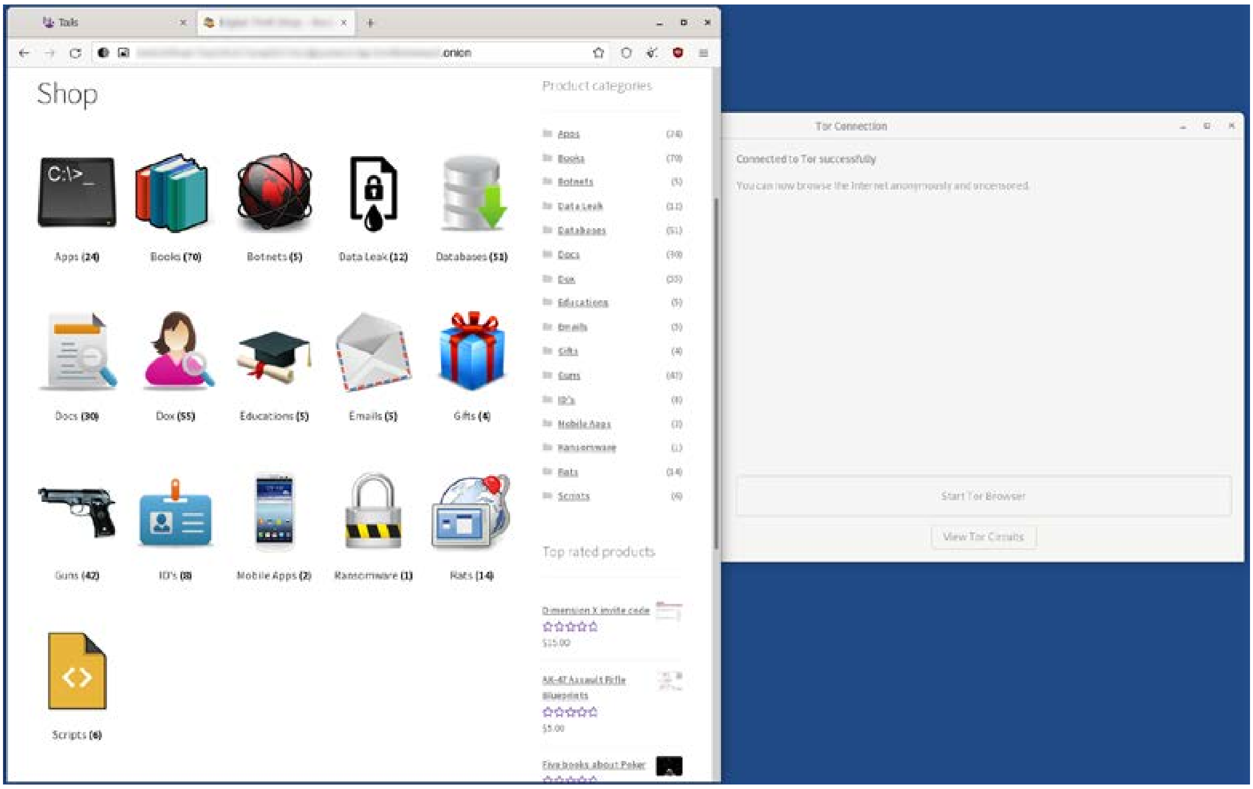
Another layer of usability for Linux Tails is the web interface. As described earlier, the „Unsafe Browser" is available only upon explicit request by the user. Otherwise, all communication with the Internet or hidden services on the Tor network is carried out via the Tor network. In addition, the system offers the use of „Tor bridge", or specialized relays that hide traffic as described earlier in this article. This method also makes it possible to access the Tor network through access points where such Internet connection is blocked or to hide such activity.

With the additional assumption of the use of a VPN, the absence of the creation of non-fleeting artefacts on the computer that are associated with network usage, the encryption of data packets and their metadata, the lack of direct access by investigators to the computer in use with an open Tails session, the analysis of network traffic and its tracking becomes extremely difficult and laborious, not to say impossible. However, it should be noted that there are tools based on analysis of anomalies in network traffic that allow typing users who use the described techniques.

The described version 5.2 also has a built-in „Thunderbird" mail client with support for encrypted e-mails, a „KeePassXC" application supporting the creation and storage of access passwords, the „LibreOffice" office suite, a very interesting „OnionShare" application supporting file transfer via the Tor network, a suite of graphics and sound processing tools, and other utility programs, including diagnostics.

Also noteworthy is the fact, confirmed by tests and analysis of materials submitted for testing, of satisfactory stability of system operation. At the same time, if the media containing a running session of Linux Tails 5.2 is suddenly removed from the USB port, the GUI is immediately shut down and, after a brief listing of errors and several system processes, the computer shuts down. The significance of the mechanism described above for law enforcement agencies, the author allows himself to leave to the reader's free thought. In addition, Tails works stably in a virtual environment such as VMware Workstation, where the only limitation of functionality is the lack of support for „Persistent Storage"(according to the distributor, full functionality on the machine is available in the „virt-manager" application running in a Linux environment).

In the practice of expert IT investigators, one encounters ingenious combinations of sophisticated tools that make data analysis difficult, such as Linux Tails, and a variety of physical hardware modifications designed to further secure data from law enforcement access. The material provided for testing in one such case was a laptop computer in which part of the case had been cut out to facilitate quick removal of the hard drive, while the optical media reader revealed one of the Tails distributions recorded on a DVD, as illustrated in the photos below:



Connected to Tor successfully

You can now browse the Internet anonymously and uncensored.

Fig. 9. View of a browser window with a preview site running, accessible only from Tor, taken as a screenshot of a session on a virtual machine

In another more analytically challenging case, the author, despite detailed research using X-Ways Forensics software, Magnet AXIOM or virtualisation of the operating system installed on the computer unit submitted for testing, failed to reveal, according to the investigator's question: documentation, web browsing history entries or the contents of correspondence regarding the marketing of certain illegal substances. Although the history revealed in the memory of the web browsers and the contents of the files did not even indicate the user's interest in the issues in question, they became crucial in pointing out the further course of the case. This is because a detailed analysis of search history for phrases on the Internet indicated that the user's interest in anonymisation tools and access to the Tor network was sudden and ran over a short period of time. Digital traces indicating the download of one of the Linux Tails distributions from the Internet were also found. An earlier analysis on the partition responsible for booting MS Windows (write access from the MS Windows user level is blocked on such a partition) also revealed the presence of an unusual text file. Correlation of the timestamps of the artifact sets described above indicated the order of operations described below. As a first step, the user searched for and then downloaded and installed Linux Tails on removable media. In order to hide the data that was sensitive to him, he saved it in a text file placed, as mentioned above, on a system disk partition invisible from the MS Windows user (the save operation would not have been possible (for an intermediate user) if newer Tails distributions such as version 5.2 had been used. This fact may explain why cases considered under current test orders are able to contain older development versions of the system in evidence). In fact, the file in question contained the address of a TOR network site, which, due to a syntax characterized by high character entropy, as mentioned earlier (e.g.: https://zqktlwi4fecvo6ri.onion/wiki/index.php/Main_Page), is cumbersome to remember. The address in question led to a personalized user page on a site specializing in the trafficking of illegal substances. Including the substances involved in the study order. The transparency policy of the said

Fig. 10. View of the reader with the Linux Tails carrier

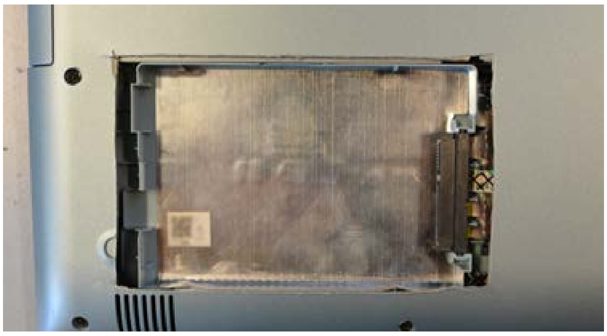


Fig. 11. View of modifications to the computer case pictured above

site allowed individual users to write public feedback. Thus, it was established that based on complaints from recipients (related to the breaking of contact and failure to deliver the purchased goods), the personalized site in question was blocked immediately after the date of activities related to securing the equipment submitted for testing. In addition, the author would like to point out that while the presence of the disclosed address in the area accessible to the MS Windows user can be tried to explain even by processes of digital geology, e.g. related to the „cache" of Internet browsers, the appearance of the file in the described area of the storage medium, indicates intentional behavior, and this with the use of non-specific professional tools.

Summarizing the above analysis, the author would like to point out that the Linux Tails tool version 5.2 is a system that minimizes the emergence of geological digital evidence (Altheide, 2014, 18), i.e. that which is related to the autonomous operation of the computer system and arises automatically and unintentionally. At the same time, the amount of artifacts of the nature of digital archaeology (Altheide, 2014, 18), that is, those created intentionally as a result of the user's actions of the datasets depends in this case on the user's self-awareness and the nature and level of complexity of the operations performed. With regard to criminal applications, a key user concern is the tediousness of performing sometimes habitually simple operations, and thus the temptation to abandon certain security principles. Such behavior provides a field for the use of the computer forensic scientist's most valuable skills, which, in addition to special knowledge, are the ability to think analytically and correlate facts, without which even increasingly sophisticated forensics software will still be useless.

My special appreciation for the exchange of scientific ideas go to: Rafał Czech, Marcin Napiórkowski and Krzysztof Turowski.

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