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TABLE OF CONTENTS

1 INTRODUCTION

Fox-IT was engaged with a request for an expert witness report in ongoing legal proceedings in Turkey. This request was done by a Turkish lawyer (hereafter: Principal) representing clients in custody. Principal is requesting an expert opinion on the following matter.

The Turkish government is currently actively pursuing the prosecution of members of the alleged[1] terrorist organization *fethullahçı terör örgütü/paralel devlet yapılanması (FTÖ/PDY)*. To this end, the Turkish Intelligence organization MIT (Millî İstihbarat Teşkilatı) has investigated the relation of the chat application *ByLock* to FTÖ/PDY. MIT has written a report on this investigation describing the ByLock application and MIT's findings regarding the relation of the ByLock users to the alleged FTÖ/PDY. This report (hereafter: the MIT report) was distributed to the main prosecutor's office in Ankara.

According to Principal, the report is used by Turkish prosecutors to identify a large number of people as members of the alleged FTÖ/PDY and to place people in preliminary custody based on the fact that they have used ByLock. The findings and conclusions of the MIT report are, according to Principal, not sufficiently scrutinized and incorrect. Therefore, Principal requests Fox-IT to review the report and provide its expert opinion on the soundness of the methodology, findings and conclusions.

Fox-IT has received two translated copies of MIT's report titled "ByLock Application Technical Report". The first translated report is a sworn translation from Turkish to Dutch by drs. E. Battaloglu. The second translated report is a sworn translation from Dutch to English by Jannie Johanna van Ravesteijn-Prins, released on 19 July 2017. The latter report was reviewed by Fox-IT for this expert witness report.

[1] The name *FTÖ/PDY* refers to a social movement in Turkey, also referred to as the *Hizmet* movement. The name *FTÖ/PDY* implies a terrorist organization. According to Principal, the movement is not generally recognized as a terrorist organization outside the Turkish government. This discussion is outside the area of expertise of Fox-IT. To prevent the impression of bias, this report will therefore refer to the organization as *alleged FTÖ/PDY*.

2 Issues Addressed

This section describes the issues addressed in the expert witness review described in this report. The issues are posed by Principal and formulated by Fox-IT in collaboration with Principal. The following issues are addressed in this report by Fox-IT:

1. What is Fox-IT's opinion on the investigation methodology used by MIT in the ByLock investigation?

2. How sound is MIT's identification of individuals that have used the ByLock application?
    a. Which method was used to link ByLock accounts to individuals and how reliable is this method?
    b. In what way were ByLock accounts created, and was it possible to add accounts that are linked to another individual?
    c. Which method was used to determine that a ByLock user was actually active on ByLock and how reliable is this method?

3. What is the qualification of soundness on MIT's conclusion regarding the relation between ByLock and the alleged FTÖ/PDY?
    a. How is it concluded that the ByLock application is used exclusively by the alleged FTÖ/PDY?
    b. What is Fox-IT's opinion on the stated findings and the resulting conclusion?
    c. How does the ByLock application relate to other similar chat applications available with respect to security?

4. Are there any other issues identified by Fox-IT that are relevant to the ByLock investigation?

3 APPROACH

This section described the approach used by Fox-IT to conduct the investigation required for this expert witness report. The approach can subdivided in two parts: analysis of the MIT report and analysis of source data to verify stated facts and observations from the MIT report. Both parts are described in the following subsections.

3.1 Analysis of MIT investigation and report

During this research, Fox-IT analyzed the MIT report regarding the soundness of the digital investigation process used by MIT in their investigation. Specifically, the methodology, argumentation, findings and conclusions of the MIT investigation were assessed. Since results from the ByLock investigation are submitted as evidence in legal procedures, the investigation is evaluated as a forensic investigation. Multiple relevant articles and books are written and cited on the principles of forensic evidence and forensic investigation. Fox-IT adheres to the following principles when conducting investigations which are well-described in the book *Digital Evidence and Computer Crime*[2]:

1. **Objectivity.** The interpretation and presentation of evidence should be free of bias to provide decision with clearest possible view of the facts. All possible hypotheses should be analyzed and evaluated in order to make sure that the investigator has no tunnel vision and is unbiased in his/her investigation.
2. **Evidence authenticity.** Authentication of evidence is the process to determine that the evidence is wat the proponents claim it is. This includes demonstrating that presented evidence is the same as when it was collected, but also the date and location of where the evidence was collected. A chain of custody document is important in demonstrating who handled the evidence and why.
3. **Evidence integrity.** Integrity checking is required to verify that evidence is not altered since it was collected, thus supporting evidence authentication. The verification process of digital data is usually based on calculating cryptographic hash functions. The hash functions produce a (nearly) unique fingerprint of data. This fingerprint can be used at any time to verify that data is unchanged from when the hash was calculated.
4. **Transparency/Repeatability.** It should be possible to independently examine and verify the digital forensic process in its entirety. A key element of verification is the ability to reproduce the forensic process under the same conditions with a consistent level of quality being observed each time the process is run. Sources for all hypotheses should be included.

These principles were applied as criteria to evaluate the MIT investigation and report.

3.2 Fact-checking

Fox-IT attempted to verify the facts and observations relevant to the conclusions of the MIT report. To this end, open and closed sources were researched and data from ByLock was analyzed to the extent that this was available at the time of this research. Analysis was also performed by decompilation of the ByLock Android application and static analysis of the decompiled code. Section 5 describes which ByLock application data was examined by Fox-IT.

Furthermore, online open sources were researched to verify observations described by MIT related to Google searches, Twitter and other online platforms.

Data from the ByLock servers was not available for analysis by Fox-IT. Therefore, the observations and facts stated by MIT with respect to the ByLock server data were not checked.

Various observations and facts (presented by Fox-IT and MIT) have been plotted in a timeline to create a clear overview of the various events. Since the MIT report appears to use the attempted coup on 15 July 2016 in Turkey as an important point in time, this date is mentioned on multiple occasions in this report as a reference point in time.

[2] Digital Evidence and Computer Crime, 3rd edition. 2014. Eoghan Casey.

4 FINDINGS

4.1 What is Fox-IT's opinion on the investigation methodology used by MIT in the ByLock investigation?

The ByLock application and the corresponding communicating servers were subjected to technical examination by MIT. In the MIT report, the methodology is not described explicitly. Fox-IT has attempted to deduce the investigation performed by MIT and summarized the content of each section of the MIT report as follows:

- Section 2 provides general information on the ByLock application.
- Section 3.1 describes the legal grounds for, and methods used, in obtaining data stored in the ByLock application servers.
- Section 3.2 describes an analysis performed by MIT of IP addresses and domain names related to ByLock. Through analysis of the different versions of the application and open-source investigation, MIT makes observations and draws conclusions on the application infrastructure.
- Section 3.3 describes results from an open-source research on ByLock performed by MIT. MIT compared the searches made from Turkey and worldwide for the word "ByLock" in search engines. Based on their observations, MIT draws conclusions with respect to the usage and goals of the ByLock application.
- Section 3.4 describes results from analysis of cryptographic protocols used by ByLock and reverse engineering performed by MIT.
- Section 3.5 describes results from an analysis of a ByLock server performed by MIT. It explains the ByLock infrastructure and describes observations about the supposed administrator of the ByLock server and the server itself. Conclusions are drawn based on these observations with respect to intentions of the administrator.
- Section 3.6 describes the results of the examination of database files derived from the server. MIT obtained a database file of 109GB where the ByLock application data was stored. This section elaborates on the database model and the content.
- Section 3.7 describes statistical data of the ByLock server analyzed by MIT.
- Section 4 holds the assessment and conclusion. MIT concludes that ByLock has been offered to the exclusive use of the members of the alleged terrorist organization of FTÖ/PDY.

4.1.1 Transparency and evidence authenticity

Fox-IT noticed a general lack of transparency in the MIT report. Furthermore, no information was found that allows verification of integrity of the investigated data. This section will elaborate on these two findings.

Based on the MIT report available, Fox-IT is unable to verify that the evidence has not been affected during handling of the ByLock data. Calculating cryptographic hashes of an acquired dataset is the accepted method to fingerprint forensic data for later verification of integrity. It is good practice to document the hashes and generate an audit trail, such that at a later stage, it is possible to independently verify that the meaning of the evidence has not been altered during the digital forensic process. No hashes and no audit trail have been included within the MIT report. Especially for the ByLock database data it is essential that an audit trail and hashes are available, since essential findings have been derived from that dataset.

The MIT report describes multiple findings and conclusions, but the report lacks a description of the analysis steps taken leading to most of the findings. This makes it difficult for the readers to scrutinize the investigation method(s) used. Transparency is in the interest of natural justice: it should be possible to verify that the investigation was reliable and accurate. The most notable section in the MIT report where this fails is section 3.6. This section describes a crucial part of the ByLock investigation: outcomes of the investigation on the ByLock server. The section contains screenshots that contain inconsistencies in itself or are inconsistent with the surrounding text, suggesting manipulation of either the source data or the screenshot (or both). Section 4.4.1 of this report elaborates on this. If the report would have detailed the steps taken by the analyst leading to the screenshot, it may have clarified the inconsistencies. This is not the case. Fox-IT finds this a serious issue, since it raises questions regarding the integrity of the results and provides no means to examine the methods and verify results.

Furthermore, it is good forensic practice to document in what way and on which location the investigated data has been acquired and which specific techniques were used. The MIT report contains no documentation on the data acquisition. This makes it impossible to verify whether the data set is complete and that no relevant data is missing.

4.1.2 Application servers and the ByLock.net domain

The first finding that MIT presents in section 3.2 is that only IP address `46.166.160.137` had been used for `bylock.net` in the period from 1 September 2015 to 9 October 2016. MIT identified nine different IP addresses by work conducted in connection with a self-signed SSL certificate issued in the name of "David Keynes". Fox-IT performed research on the IP addresses and domain names used by ByLock in order to verify the findings.

Fox-IT has performed a search for IP addresses that hosted an SSL certificate with common name "David Keynes" using PassiveTotal[3][4]. This resulted in the following 10 IP addresses:

```
46.166.160.137
46.166.164.176
46.166.164.177
46.166.164.178
46.166.164.179
46.166.164.180
46.166.164.181
46.166.164.182
46.166.164.183
69.64.56.133
```

The first nine IP addresses are mentioned in MIT's report. The last IP address was not mentioned in the MIT report. `Bylock.net` resolved to this IP address from April 2014 to August 2014, so it is possible this was the first ByLock application server. It is unclear why this is not mentioned in the MIT report.

Fox-IT performed an open-source investigation on the domain `bylock.net` and IP address `46.166.160.137` to determine the ownership information and IP addresses referenced by this domain name. The changes in this information over time are listed in appendix 7.1. It was observed that the domain `bylock.net` resolved to `46.166.164.137` only from August 2014 to March 2016. This contradicts the statement in the MIT report, stating that `bylock.net` resolved to that IP address from 1 September 2015 to 9 October 2016. Fox-IT concludes that the `bylock.net` domain was active only until March 2016 and could not have been used in the period from April 2016 leading up to 15 July 2016. Table 1 includes a timeline on the ByLock versions.

Date	Description	Source
April 2014	`ByLock.net` domain resolving `69.64.56.133`	PassiveTotal
11 July 2014	Android ByLock 1.1.3 uploaded to downloadatoz	downloadatoz.com
13 July 2014	Android ByLock 1.1.3 uploaded to Google Play Store	web.archive.org
10 August 2014	`ByLock.net` domain resolving to `46.166.160.137`	PassiveTotal

[3] PassiveTotal from RiskIQ providec intelligence on internet data sets like passive DNS, WHOIS, SSL certificate data, web trackers, and more.

[4] https://community.riskiq.com/search/certificate/issuerCommonName/David%20Keynes

22 August 2014	iOS ByLock 1.1.3 uploaded to Apple App Store	sensortower.com
23 August 2014	Android ByLock 1.1.4 uploaded to downloadatoz	downloadatoz.com
24 August 2014	Email confirmation from balticservers that IP range 46.166.164.176/29 is ready for use	MIT report, page 14
4 September 2014	Android ByLock 1.1.6 uploaded to downloadatoz	downloadatoz.com
15 November 2014	Blog announcement re blocking of IP addresses	MIT report, page 17
24 Dec 2014	Android ByLock 1.1.7 uploaded to downloadatoz	downloadatoz.com
26 Dec 2014	Android ByLock 1.1.7 uploaded to Google Play Store	web.archive.org
March 2016	ByLock.net domain deactivated	PassiveTotal
15 July 2016	Attempted coup	Various

Table 1: Timeline of ByLock versions and domain records for bylock.net.

Next, Fox-IT examined the ByLock application for Android version 1.1.6 and 1.1.7 to determine the application server addresses used in those versions. It was observed that ByLock 1.1.6 uses the hardcoded IP address 46.166.164.177 and version 1.1.7 uses IP address 46.166.164.181. Both IP addresses are part of the IP addresses listed by the MIT report. ByLock version 1.1.6 was available as an upgrade from 4 September 2014. As a result, after 4 September 2014, upgraded or newly installed ByLock application would connect to one of these two IP addresses instead of the server at bylock.net. The two servers have been an active part of the ByLock infrastructure as either:

1. A ByLock application server or
2. A proxy server to a ByLock application server.

The MIT report does not mention anything related to investigation of these servers. This raises relevant questions:

- How were these two servers used in the ByLock infrastructure and why is investigation of these servers not included in the MIT report?
- If they were actually proxy servers, how does this relate to the statements on page 17 of the MIT report regarding the blocking of IP addresses from Turkey? MIT states that “it is clear that by blocking access of IP addresses […]. It is believed that this was another fictious measure to prevent identification of individuals using the application”. Since ByLock versions 1.1.6 and 1.1.7 do not contact 46.166.160.137, the mentioned firewall blocking on that server would not apply to those (v1.1.6 and v1.1.7) ByLock clients. This observation does not support MIT’s assessment of the developer attempting to force users through VPN connections.

4.1.3 Open-source research

There are multiple problems in the investigation and results described in section 3.3 of the MIT report. All of them are relevant for the conclusion.

Search trend incline

The first figure in section 3.3 depicts the Google Trends results for search term “ByLock” for the worldwide scope from December 17, 2013 to February 17, 2016. However, the subscription says “ByLock search statistics (Turkey)”. This raises the question: to which statistic is the text referring?

Searches from Turkey

Page 10 of the MIT report states that the searches on the term "ByLock" were made mostly from France, the United Kingdom (UK) and the United States of America (USA). Page 10 contains a figure depicting Google Trends results from a query filtered on the countries Turkey, USA, UK and France. This is misleading to the reader: if other countries would have higher scores, then it would not be shown in that graph, because it only shows the four mentioned countries.

Fox-IT attempted to reproduce the Google Trends result by searching on "ByLock" in the Google Trends web application. This query was performed on 17 Aug 2017. The query was also performed using proxy servers from different countries to account for the possibility that Google would show different results to end-users from different countries: the results are the same. The result is depicted in Figure 1. The top five countries are respectively (from high to low score): Sweden, Turkey, Azerbaijan, Cyprus and Norway. The countries France, UK and USA are actually respectively placed 20th, 14th and 15th of countries with relative most searches on ByLock during the period. This is different from MIT's observation and invalidates the conclusion in the last paragraph of section 3.3 MIT:

> *"In light of the statistics, the fact that its usage in Turkey was considerably higher (more users in Turkey than in all other countries combined) … "*

Since it is unclear what part of the searches originate from Turkey, MIT's factual statement is invalid and should be reconsidered.

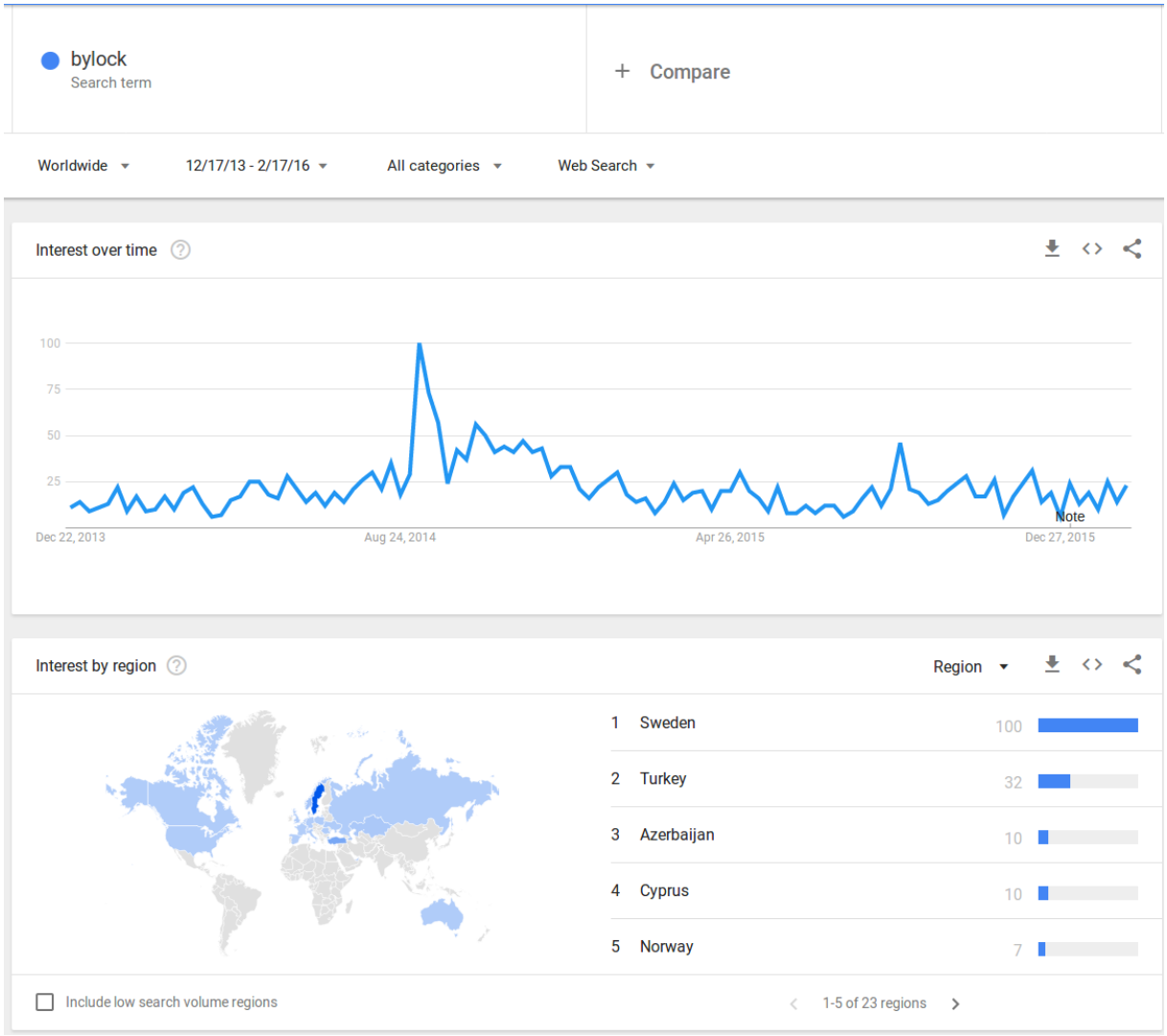


Figure 1. Google Trends results for search term "ByLock" worldwide

Twitter

On page 10 of the MIT report, the author states:

> *"It has become apparent that of the Twitter users who posted content via "ByLock" before July 15, 2016, the vast majority appear to have been posting content in support of the FETO/PDY."*

There is no explanation on how this fact was established by MIT. There is no Twitter data, statistics or other evidence in the document that supports this statement. This claim should be questioned since it is not evident and functions as one of the key findings for MIT's conclusion.

The paragraph goes further:

> *"This is seen as an indication that users who could be identified ([…]) are those who are actually affiliated with the FETO/PDY, and that they were aware of the application and widely used it before it was known to the public."*

This suggest that MIT considers the ByLock application unknown to the public before 15 July 2016. Fox-IT has attempted to verify this statement with available statistics. The Google Trends statistics suggest varying interest in ByLock from at least the end of 2013 up until the 15 July 2016, peaking between 7 September and 14 September 2014. Historical download and install statistics from Google Play store[5] indicate ByLock installations from at least April 2014 and reaching 100,000 installation on 19 January 2015[6]. Table 2 lists the statistics. These observations suggest that a public has actually known and used ByLock in the years leading up to 15 July 2016. Given the available information, it is not possible to determine whether the individuals that installed the application were members of alleged FTO/PDY or not.

Date	Total installs
22 April 2014	50+
24 April 2014	100+
4 May 2014	1,000+
20 May 2014	5,000+
1 June 2014	10,000+
24 Aug 2014	50,000+
19 Jan 2015	100,000+

Table 2. Google Play Store installation statistics on ByLock application

Limited number of platforms

On page 10 of the MIT report, the author further states:

> *"before 15 July 2016 the app appeared on a limited number of platforms apart from Twitter"*

Fox-IT has observed that before 15 July 2016, the ByLock application was hosted on multiple platforms other than Twitter. Examples of the platforms that hosted ByLock are *Google Play Store*, *Apple Store*, *apk-dl.com, apkpure.com* and *downloadatoz.com*. These platforms provide a date and time of last update for each hosted application. This date and time was well before 15 July 2016 for the ByLock application. Also, it is very likely that before 15 July 2016 a Google search on the term "ByLock" would lead to multiple platforms hosting the application. The appearance of ByLock is no different than Fox-IT would expect from an average chat application: it is hosted on the app stores and internet APK download servers and it is discussed in social media. The statement of MIT is no more true for ByLock than it is for an average chat application.

[5] http://choilieng.com/apk-on-pc/net.client.by.lock.apk

[6] After this date, the installation number has very likely risen further. The next installation number logged would be 500,000. This suggests that the final number of installations is between 100,000 and 500,000.

4.1.4 Sub-conclusions

Fox-IT has performed a thorough examination of the information relating to the ByLock investigation to the extent that the information was (made) available. Furthermore, Fox-IT has, where possible, fact-checked observation and facts stated in the MIT report. This resulted in the following conclusions regarding the ByLock investigation:

1. Fox-IT noticed a general lack of investigative transparency in the MIT report. Furthermore, no information has been found which allows verification of integrity of the investigated data. Although it is good practice to document investigation steps and the data acquisition process, the MIT report contains very little information on these matters. This makes it impossible to verify whether the investigated data set and results are valid, complete and no relevant data is missing.
2. Fox-IT examined the facts and results related to the ByLock application servers and found that the documented investigation performed by MIT is incomplete and incorrect. Investigation by Fox-IT has shown that MIT's conclusions with respect to the `bylock.net` domain were incorrect. Also, Fox-IT has identified two relevant IP addresses (`46.166.164.177` and `46.166.164.181`) belonging to the ByLock infrastructure, which apparently were not investigated.
3. The open-source investigation performed by MIT was examined and fact-checked. Fox-IT has shown that stated Google Trends observations were fundamentally different from actual Google Trends results. Furthermore, Fox-IT has shown that claims related to ByLock downloads and Twitter are not supported by evidence and in some cases contradicted by observations from open-source research performed by Fox-IT.

Overall, Fox-IT is of the opinion that, as far as the report goes, the investigation performed by MIT raises many questions which require a more thorough investigation for a definite answer. More troubling is the fact that multiple findings appear to be non-reproducible or even incorrect. Other findings could not be verified due to lack of available data (e.g. from the ByLock server investigation). There is no indication of MIT investigating the alternative scenario: that ByLock has not exclusively been offered to members of the alleged FTÖ/PDY. Investigating existing alternate scenarios is good practice in an investigation. It helps prevent tunnel vision where investigators are biased towards a predefined outcome. The conclusions above suggest that MIT was, in advance, biased towards the stated conclusion and that MIT has not shown the required objectivity and thoroughness in their investigation to counter this bias.

4.2 How sound is MIT's identification of individuals that have used the ByLock application?

4.2.1 Which method was used to link ByLock accounts to individuals and how reliable is this method?

Section 3.6 of the MIT report describes the results of the investigation into the ByLock database data. This is the only section containing a reference to identification of individuals as ByLock users.

The MIT report does not describe in what way ByLock accounts are linked to actual individuals. The only reference found in the report to identify the individual linked to an account is mentioned in section 3.6.2.11 of the MIT report. In that section, MIT describes that entries in the *Log* table of the ByLock database have been used to identify individuals. These entries contain the IP address of the ByLock user during login and registration.

The MIT report does not describe how this IP address is linked to an individual. However, this attribution of IP address to individual is not trivial and can be prone to mismatching, since an IP address is usually not strictly assigned to one individual. There are multiple challenges with attributing an IP address to an individual:

> **Internet service provider log retention.** An IP address is a unique identifier of a device in a computer network that uses the Internet Protocol for communication. A device can be a personal computer, laptop, tablet, phone, server, etc. An IP address is issued by a Regional Internet Registry (RIR). Five RIRs manage the allocation and registration of IP addresses each for a particular region of the world. The customers of a RIR could be either an Internet Service Provider (ISP) or end-user organization. In order to link an IP address to a registrar, information from the RIR can be obtained. However, when the registrar is an ISP, the ISP holds the information about which IP address has been assigned to which customer. This information can be requested in legal proceedings.
>
> The Turkish regulation on the process and the protection of Personal Data in Telecommunication Sector published 14 July 2012 contains the regulation with respect to log retention by telecom- and infrastructure providers. The law states that both telecom- and infrastructure providers must retain communication metadata for at least 1 year[7].
>
> When identifying the subscriber using the IP address that logged on to ByLock, it is likely that MIT relied on log information from the service provider to identify individuals. IP addresses logged on the ByLock server may be NAT[8] addresses or dynamic addresses assigned to a subscriber at a certain time. In both cases, log data is necessary to attribute the IP address to an individual.
>
> It is unknown when the ByLock investigation was conducted by MIT (this information is not in the report), but the estimate is end of 2016. This leaves the question whether the communication metadata from before end 2015 was available. And if not, how the subscribers using the ByLock IP addresses were reliably identified.

[7] Telecom laws and regulations handbook. Volume 1 strategic information and regulations. ISBN-978-1-3291-6456-7

[8] Network Address Translation is a method of remapping one IP address space into another by modifying network address information in IP traffic while it is in transit across a traffic routing device. In more advanced NAT implementations featuring IP masquerading, it has become a popular and essential tool in conserving global address space allocations in face of IPv4 address exhaustion by sharing one Internet-routable IP address of a NAT gateway for an entire private network.

Shared Wi-Fi access points. One scenario where an individual accesses ByLock is by connecting their smartphone to the internet over a Wi-Fi connection. Wi-Fi access points allow multiple devices to access the same internet connection at the same time. It is not uncommon for access point in people's homes to be unsecured or an owner sharing their Wi-Fi password and thus allowing other (unknown) people to access the same internet connection. In this scenario, when an IP address found in logs on the ByLock server is investigated it will be linked to an internet subscription number. This subscription is registered on the name of the individual that owns the service contract. However, as shown above, that individual may be just one of the users using the Wi-Fi connection and not the ByLock user the investigation suggests.

VPN[9] or other anonymizing technology. Nowadays, it is not uncommon to use a VPN server to keep web browsing secure and private. Many VPN services are available on the internet for this purpose. According to the MIT report, section 3.5.5, ByLock users from Turkey were forced to use such VPN services to access the ByLock servers due to firewall blocking on the ByLock server. Consider the scenario where a ByLock user connects to ByLock through a VPN session (see Figure 2 for an illustration).

Now, the source IP address found in the Log table on the ByLock server would belong to the VPN server's pool of IP addresses. Thus hiding the IP address of the ByLock user's internet connection. To retrieve the user's home IP-address, the investigator would likely need access to information stored on the VPN server, since the VPN provider holds the information on which client IP address relates to which VPN session (and corresponding VPN IP address seen in the ByLock log). Often this information is not available on the VPN server due to protection of the user data on those servers or it will not be provided upon request. It is possible to use multiple VPN connections, which means that for each VPN server, the investigators needs to overcome the same challenge.

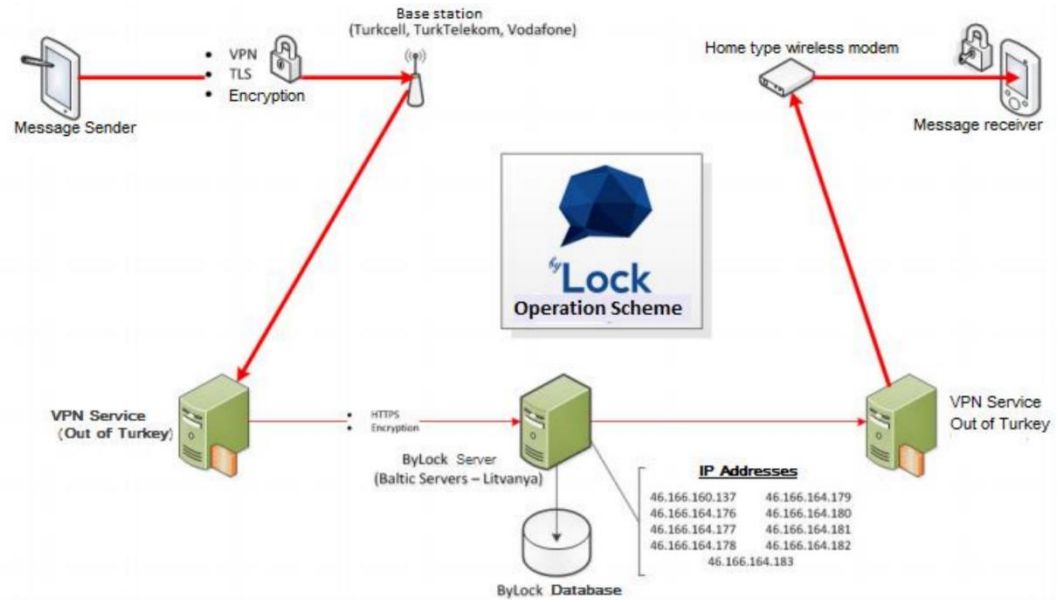


Figure 2: ByLock over VPN connection (from MIT report)

Any of the abovementioned three issues may lead to incorrect attribution or impossible attribution of an IP address to an individual. Since this is a crucial step in identifying the individuals, this method should be scrutinized. Currently, MIT does not provide any information that allows the examination of their method.

[9] Virtual Private Network. A technology used to tunnel network traffic over a secure network channel. It is also used to provide secure and anonymous access to the internet.

4.2.2 In what way were ByLock accounts created, and was it possible to add accounts that are linked to another individual?

As mentioned, Fox-IT analyzed versions 1.1.6 and 1.1.7 of the ByLock application. In both versions, a user can register by creating a username and entering a password. Figure 3 depicts the registration screen of ByLock 1.1.7. No email address, phone number or other personal identifying information is required when creating an account. Fox-IT has confirmed, by reverse engineering of the ByLock application that no other information of the phone or user is sent to ByLock servers.

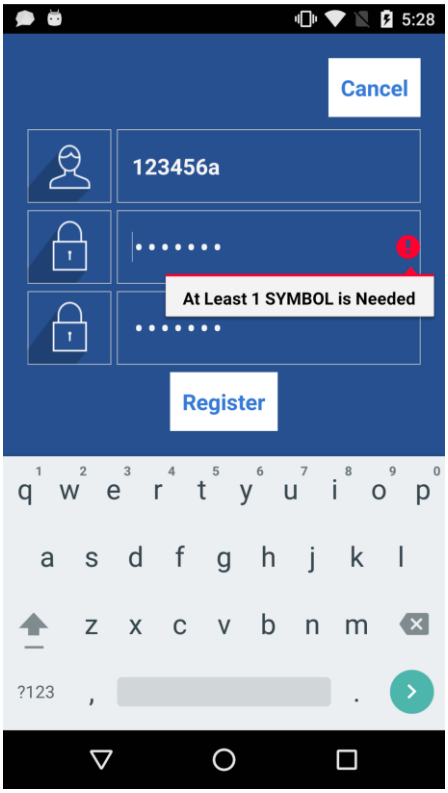


Figure 3: Screenshot of registration for a ByLock account.

The loose registration scheme allows creation of arbitrary accounts, since:

- There are no restrictions found that require a specific group membership as a condition of use;
- There is no verification of phone number or email address by the application;
- There are no format restrictions in the username chosen during registration. This allows entering arbitrary text like email address, phone number, nickname, etc.
- No invitation is required to register an account. Anyone having access to a ByLock application can register an account.

This scheme allows for creation of suggestive accounts by registering and using an account with a name or other identifier (e.g. email address or phone number) related to a real individual while that individual is unaware of the existence of that ByLock account.

4.2.3 Which method was used to determine that a ByLock user was actually active on ByLock and how reliable is this method?

Section 4.2.2 of this report describes that arbitrary ByLock user accounts may be registered by anyone having access to the ByLock application. This leads to the question how MIT has differentiated between users that have only been registered and logged on to ByLock and users that have actually used ByLock to communicate.

In the report it is not explicitly described if and how MIT determined the actual activity of the ByLock users. It is therefore unclear whether the individuals identified by the ByLock investigations have actually been communicating using ByLock.

4.2.4 Sub-Conclusions

Fox-IT has examined the methods used by MIT to identify individuals that have used ByLock. The goal of this examination was to determine the quality of the methods and then conclude on the soundness of the identification. This examination resulted in the following conclusions:

1. No identifying information (e.g. email address or phone number) is required to register as a ByLock user. As a result, it is easy to impersonate other individuals when creating a ByLock account by using a suggestive nickname.
2. The MIT report states that IP addresses from the ByLock database are used for identifying individuals using ByLock. However, the report omits the method used to attribute the IP addresses to individuals. Attribution of an IP address to individual is not trivial and prone to incorrect attributions. Fox-IT identified multiple issues that may lead to incorrect attribution or impossible attribution of a source IP address to an individual. Since attribution of a source IP address to an individual is a crucial step in identifying the individuals using ByLock, it should be possible to scrutinize this method. In the MIT report no information is provided that allows the reader to verify whether the attribution of an IP address to an individual is reliable.
3. The MIT report does not mention how MIT has differentiated between user accounts that were actively communicating and user accounts that have only registered and logged on. It is therefore unclear whether the individuals identified by the ByLock investigation have actually been communicating using ByLock.

Overall, the MIT report contains very limited information on the identification of individuals. Fox-IT has shown that ByLock user accounts are on their own difficult to attribute to an individual.

4.3 What is the qualification of soundness on MIT's conclusion regarding the relation between ByLock and the alleged FTÖ/PDY?

4.3.1 How is it concluded that the ByLock application is used exclusively by the alleged FTÖ/PDY?

Below, Fox-IT has summarized the arguments and conclusions as described in the MIT report and as interpreted by Fox-IT.

MIT concludes that the ByLock application is used exclusively by the alleged FTÖ/PDY based on the following:

1. The ByLock application is designed to communicate over the internet using a strong cryptographic system, which allows sending each message with a *crypto key*. Fox-IT assumes MIT intends to describe that the messages can be encrypted using a cryptographic key instead of sending the actual cryptographic key itself.
2.
    a. MIT states multiple observations and findings about the developer of ByLock and concludes that the developer does not have any corporate or commercial nature.
    b. MIT states multiple observations with respect to ByLock and Turkish language and users. Then MIT continues to conclude that ByLock was meant to be used by the members of the alleged FTÖ/PDY under the disguise of a global application. Some of the arguments listed are:
        - The administrator blocked IP addresses with origin Turkey.
        - Users were forced to use VPN in order to hide their identities.
        - Almost all searches on Google for the search term "bylock" were made from Turkey and significantly increased as of the date access to the application from Turkish IP addresses were blocked.
        - Publications related to ByLock have mostly been posted through fake accounts and in which the content was in favor of the alleged FTÖ/PDY.
        - Before the coup attempt on 15 July 2016, the ByLock application was not known to Turkish public or known outside of Turkey.
3. Utmost security of user id and communication was an aim of the ByLock application. Also, the reason why the application does not require personal information during sign up and does not have a verification system is to ensure anonymity.
4. The application developer used personally "developed" SSL certificates instead of verified SSL certificates. Fox-IT assumes that with the term personally developed SSL certificate, MIT means to refer to a self-signed certificate. MIT continues to conclude on that observation and on the intentions of the developer; MIT believes that a self-signed certificate was chosen to prevent the flow of information to servers other than his own.
5. In order to be able to communicate with another registered user, both parties need to mutually add each other's username/code. The application is therefore considered to have been designed to allow communication suitable to "the cell structure".
6. The application meets all organizational communication needs and are controlled and supervised by the application administrator.
7. The automatic deletion of messages from the device after a certain period without manual intervention indicates that the system is designed to prevent access to communication data and details in the event of a possible legal confiscation of the device.
8. MIT makes an inference of the users intention to hide their identity, based on the following observations:
    - Users create long passwords.
    - Users manually download the application on APK websites instead of Android Market or Apple Appstore.
    - Users did not use the real name as user ID during sign up.
    - Users used inter-organizational code names instead of real identities in their contact lists and communication.

    Furthermore, MIT states that 'almost all' of the content of the decrypted messages are of communications and activities of alleged FTÖ/PDY and matched the organization's jargon.

9. Members of the organization who were subjected to judicial control measures following the coup attempt of 15 July 2016 conducted by the alleged FTÖ/PDY have stated that ByLock had been used as an inter-organizational communication medium by the member of the alleged FTÖ/PDY.

Based on the above, the MIT concludes that ByLock has been offered to the exclusive use of the members of the alleged terrorist organization of FTÖ/PDY.

4.3.2 What is Fox-IT's opinion on the stated findings and the resulting conclusion?

Fox-IT is of opinion that the resulting conclusion is not founded by the stated findings of MIT above. In this section each of the arguments is analyzed to determine the accuracy, correctness and soundness. Finally, Fox-IT will provide an opinion on the overall conclusion.

1. Strong cryptography. MIT states that the ByLock application makes use of a strong cryptographic algorithm. Strong is a relative term and Fox-IT does not regard the ByLock cryptography stronger than other known chat applications. The use of cryptography has become common practice in communications in recent years. Chat applications for the masses like WhatsApp and Facebook use the Signal Protocol which implements sophisticated cryptographic protocols for securing communications[10,11]. The encryption used in the ByLock application is readily available using the default Java Application Programming Interface (API). ByLock used standard, publicly available Java libraries to provide encrypted communication between users of the application. Those are included in java.security and javax.crypto[12] and are well-documented[13,14]. Section 4.3.3 further elaborates on the comparison between ByLock and other applications in light of the security measures discussed.

2a. Lack of commercial nature. Assessment of commercial nature of software is outside the expertise of Fox-IT and therefore Fox-IT will not address this point.

2b. Disguise of global application. The conclusion mentioned in this paragraph is based on findings from section 3.3 and 3.5 from the MIT report. Fox-IT has shown in section 6.1 of this report that relevant findings are not backed by evidence, questionable or incorrect. The findings described in bullets 5, 6, 7 and 8 were shown to be invalid. Without those findings as arguments, the conclusion does not hold true.

3. Aim at security and anonymity. Fox-IT finds it likely that the developer had a focus on creating a secure communication application allowing anonymous use of the application. In a world where privacy is of high importance, Fox-IT is of the opinion that the ByLock application's anonymity aim does not imply an intent for use in illegal activities. There are numerous well-known free applications that have similar goals. For example, the Tor project[15] is a well-known anonymity browser that improve privacy and security on the internet. Journalists use Tor, as well as the U.S. Navy, for surveilling websites without leaving government IP addresses[16]. Section 4.3.3 further elaborates on the comparison between ByLock and other applications in light of the security measures discussed.

[10] https://fbnewsroomus.files.wordpress.com/2016/07/secret_conversations_whitepaper-1.pdf

[11] https://www.whatsapp.com/security/WhatsApp-Security-Whitepaper.pdf

[12] https://docs.oracle.com/javase/7/docs/api/javax/crypto/package-summary.html

[13] https://docs.oracle.com/javase/7/docs/technotes/guides/security/crypto/CryptoSpec.html

[14] http://docs.oracle.com/javase/8/docs/technotes/guides/security/crypto/CryptoSpec.html

[15] https://www.torproject.org/

[16] https://www.torproject.org/about/torusers.html.en

4. Self-signed certificate. It is unclear whether the MIT author is referring to SSL certificates on the ByLock servers (for HTTPS) or SSL certificates on the application. In both cases, the SSL signing party does not impact the 'flow of information' as the MIT author states it. In case of SSL certificates for HTTPS, having a certificate authority sign the certificate does not give the authority access to the data, since the private key is not shared with the authority. The reasoning on this point by MIT is very unclear and suggests a misunderstanding of public key infrastructures and SSL certificates on the part of the MIT author.

Fox-IT finds it unlikely that the self-signed certificate was implemented by the developer to prevent data flowing to servers other than its own. In general, self-signed certificates are easier to implement and are free of cost. It is possible that this was an incentive for the developer to use self-signed certificates.

5. Communication only in a way suitable to the cell structure. The term cell structure is undefined and ambiguous in this context. Fox-IT assumes here that it refers to the way the alleged FTÖ/PDY is organized. Organizational structures are outside the expertise of Fox-IT.

With respect to the registration procedure, it is relevant to nuance the requirement to meet face-to-face or by intermediary to exchange login details. The author fails to identify a third, more likely scenario to exchange ByLock details out of band: use of another communication method (e.g. phone call, WhatsApp, Facebook, Skype). Assuming two individuals are in contact by WhatsApp (the MIT author does not seem to scrutinize how two individuals meet on WhatsApp), they could exchange their ByLock details and then switch to communication by ByLock.

6. Organizational communication needs. Assessment of communication needs of organization is outside the expertise of Fox-IT and therefore Fox-IT will not address this point.

7. Prevent access in case of legal confiscation. Fox-IT is of the opinion that insufficient knowledge of the developers intention is available to agree or disagree with the MIT report on this argument. Following, Fox-IT is of the opinion that MIT is jumping to conclusions on the intent of the developer based on the observations stated in the report, unless more information is available to MIT corroborating their conclusion. Automatic deletion of messages is also used in popular social media applications like SnapChat[17]. Section 4.3.3 further elaborates on the comparison between ByLock and other applications in light of the security measures discussed.

8. Identity hiding. Fox-IT is of opinion that users do not explicitly hide their identity by:

- Creating long passwords
  The minimum requirement of choosing a password in ByLock is six characters plus at least one symbol. MIT states that the decrypted passwords included passwords of 38 characters long and half of them were at least 9 characters long. The usage of a strong password is important for security reasons and not considered as a manner of hiding your identity. The stronger your password, the harder it is to crack the password by hackers (brute-force attack[18]). According to the new guidelines of the National Institute of Standards and Technology published in June 2017[19], a minimum of 8 characters is advised and applications should allow a maximum length of at least 64 characters.
- Manually download the application from APK websites

[17] https://www.snapchat.com/

[18] https://en.wikipedia.org/wiki/Brute-force_attack

[19] http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-63b.pdf

In order to launch an application from Google Play Store, the application should meet a number of requirements[20][21]. This is in order for Google to give some guarantee to the users that an application is as expected. Some developers choose to make their application available on other APK websites for ease of use. However, the intention of the developer cannot be verified.

- Use another name as user ID during sign up
  Most of the chat applications, like WhatsApp and SnapChat, do not require the use of the user's real name. In fact, it is not uncommon to use another name as user identification. This applies to the general usage of chat applications, social media platforms and overall internet services.

9. ByLock used during coup attempt. Fox-IT is unable to verify the statement that ByLock was used by the alleged FTÖ/PDY. However, in any case, this argument is invalid due to the base-rate fallacy in statistics[22]. The statement indicates the following misconception:

All members of a terrorist organization use ByLock, therefore all ByLock users are members of the terrorist organization.

This reasoning is a common mistake. A very basic and intuitive analogy to this reasoning is:

All fish swim, therefore everything that swims is a fish.

Which is obviously incorrect. One could still be of the impression that the statement does approximate reality (nearly everything that swims is a fish). Then consider the related example below:

1 in 10,000 people is an online criminal
1 in 1000 people use Tor
All criminals use the Tor network for communications

How many of TOR users are criminal?

The answer is only 1 in 10. So, even though all criminals use Tor, only 1 in 10 of the TOR users is criminal.[23]

Assuming that, indeed, all alleged FTÖ/PDY members used ByLock (which is unlikely), there will be a significant number of ByLock users that are not a member of alleged FTÖ/PDY. The exact number is determined by the base-rate of the actual FTÖ/PDY members.

Based on the analysis described above, Fox-IT is of opinion that the findings presented by MIT do not support the conclusion that ByLock had been used[24] as an inter-organizational communication medium by the members of the alleged FTÖ/PDY.

4.3.3 How does the ByLock application relate to other similar chat applications available with respect to security?

In this section, Fox-IT will elaborate on the comparison between the ByLock application and other known communication applications. The authors of the MIT report suggest that the security features of ByLock (MIT report section 4 point 1, 3 and 7) are arguments to the conclusion that ByLock was offered to the exclusive use by alleged FTÖ/PDY. The goal of this investigation is to put the security features of ByLock into context of other chat applications and determine to what extent the security features distinguish ByLock from the other chat applications.

[20] https://developer.android.com/distribute/best-practices/launch/launch-checklist.html

[21] http://r-stylelab.com/company/blog/mobile-technologies/how-to-meet-google-play-requirements

[22] https://en.wikipedia.org/wiki/Base_rate_fallacy

[23] This can be calculated using Bayes theory: P(criminal | Tor) = P(Tor | criminal) * P (criminal) / P(Tor)

[24] The MIT report states 'offered to the exclusive use', which Fox-IT has interpreted as used

Encryption

As mentioned in paragraph 4.3.1, the use of encryption has become common practice in communications in recent years. According to the investigation performed by Fox-IT, the encryption used in the ByLock application was created using standard, publicly available Java libraries available using the default Java Application Programming Interface (API).

However, other chat applications have more sophisticated encryption techniques implemented. The Electronic Frontier Foundation (EFF) launched on 6 November 2014 a score card with an overview of encryption features per application[25], see Figure 4. This score card was last updated on 4 May 2016. From this Figure, it can be seen that WhatsApp is one of the most secure chat applications. Also, according to recent sources[26,27], of chat applications investigated, WhatsApp is the best secured chat application and has 1,3 billion users[28] as of July 2017. This implies, that encryption, and therefore secure messaging, is of great importance to the general user.

Figure 4 lists the security features used by EFF to score chat applications on security. Of these features, only two features were confirmed by Fox-IT to be implemented in the ByLock application:

1. Encrypted in transit;
2. Encrypted so the provider can't read it

[25] https://www.eff.org/node/82654

[26] http://www.techworld.com/security/best-secure-mobile-messaging-apps-3629914/

[27] http://www.techradar.com/news/top-10-best-secure-messaging-apps-of-2017

[28] https://www.statista.com/statistics/260819/number-of-monthly-active-whatsapp-users/

Figure 4: Secure Messaging Scorecard of the EFF.

Self-destruction

Other than ByLock, a well-known and popular messaging application with a self-destructing message feature is Snapchat. Snapchat was released in 2011 and has 173 million users[29]. Also, the popular chat application Viber with 800 million users added a self-destruction feature[30].

[29] https://www.statista.com/statistics/545967/snapchat-app-dau/

[30] https://www.theverge.com/2017/3/10/14879986/viber-secret-chats-self-destructing-encryption

Other chat application with a similar feature where content and messages created by the user will automatically delete themselves after a period of time are:

- Telegram[31]
- Bleep[32]
- Wickr[33]
- Confide[34]
- SpeakOn[35]

This survey has shown that multiple Android applications, totaling millions of users, implemented this security feature. Therefore, ByLock does not appear exceptionally secure.

4.3.4 Sub-Conclusions

Fox-IT has examined the MIT report to determine the quality of reasoning in the conclusion. In the conclusion, MIT puts substantial weight on ByLock's security measures and alleged goals of the developer. Therefore, Fox-IT has compared ByLock to other chat applications to put the security features of ByLock into context of the available chat applications.

From this comparison, Fox-IT concludes that the security measures implemented in ByLock are not exceptional and actually on par with widely used chat applications. The use of self-destruct messages and well-known cryptographic protocols for hashing passwords and securing data in transit has been implemented in other communication applications used by millions of users. Therefore, the features mentioned in the conclusion of the MIT report in point 1, 3 and 7 are in no way an indication that ByLock is aimed at a specific user group (alleged FTÖ/PDY) or with a specific purpose other than to communicate in a secure manner.

The conclusions of the MIT report were thoroughly examined and assessed by Fox-IT. It was shown that the argumentation is seriously flawed and that seven out of nine stated arguments (findings) are invalid or questionable. This follows from the Fox-IT findings described in section 4.1. The remaining arguments are in itself not sufficient to support MIT's conclusion. As a result, the conclusion of the MIT report, "ByLock has been offered to the exclusive use of the members of the terrorist organization of FTÖ/PDY", is not sound.

4.4 Are there any other issues identified by Fox-IT that are relevant to the ByLock investigation?

4.4.1 Notable inconsistencies

Figure 5 in Section 3.6.2.4 (screenshot of SQL output) and Figure 15 in section 3.6.2.15 (another screenshot) of the MIT report are remarkable. The screenshots suggest output of an SQL query, showing the rows and a total number of rows returned. The total number of rows does not match the actual number of depicted rows. Also, there is a subtle spacing difference in the rows. This suggest manipulation of the screenshot or output. Figure 5 highlights the inconsistency.

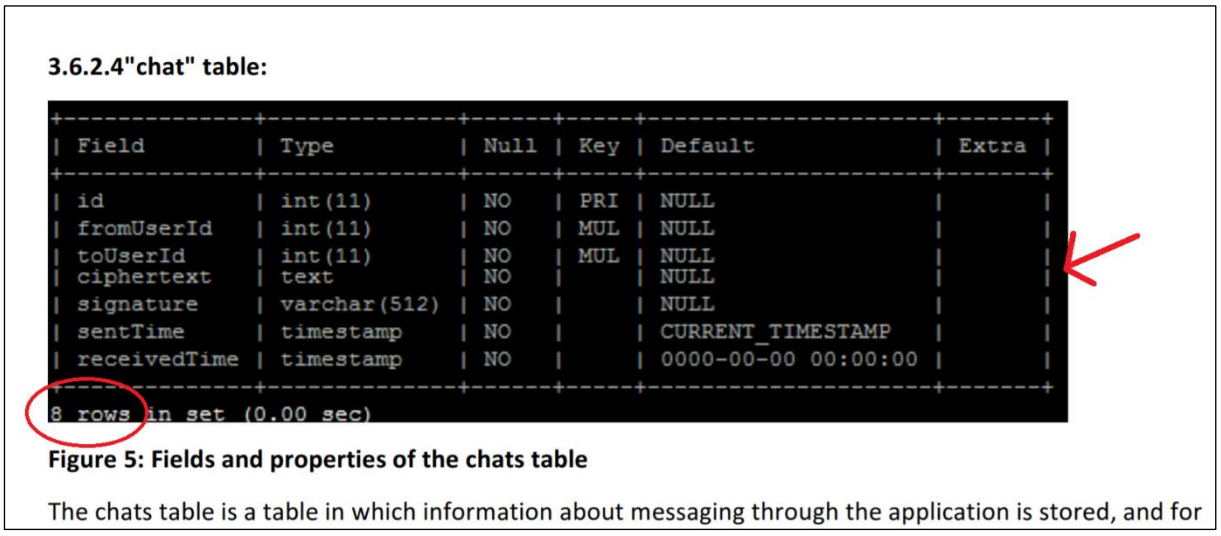
[31] https://telegram.org/

[32] https://n0where.net/chat-privately-bleep/

[33] https://www.wickr.com/

[34] https://getconfide.com/

[35] https://www.crunchbase.com/organization/speakon#/entity



3.6.2.4"chat" table:

Field	Type	Null	Key	Default	Extra
id	int(11)	NO	PRI	NULL	
fromUserId	int(11)	NO	MUL	NULL	
toUserId	int(11)	NO	MUL	NULL	
ciphertext	text	NO		NULL	
signature	varchar(512)	NO		NULL	
sentTime	timestamp	NO		CURRENT_TIMESTAMP	
receivedTime	timestamp	NO		0000-00-00 00:00:00	

8 rows in set (0.00 sec)

Figure 5: Fields and properties of the chats table

The chats table is a table in which information about messaging through the application is stored, and for

Figure 5. Inconsistency in screenshot of SQL output

Fox-IT also noted the following in section 3.6.2.15 MIT:

> *Examples of decrypted data stored in the user table are shown below: ("Username" indicates the user name / code for the information, and "plain" indicates the user password decrypted on the basis of the work done.)*

The above suggests that the column "plain" was added to the user table by MIT for analysis.

Furthermore, section 3.5.5 of the MIT report contains a listing suggesting a command line output. The listing shows:

```
root@hst-46-166-160-137:~#
iptables –N LOGGING
iptables –A INPUT –s 5.2.80.0/21 –j LOGGING

…
```

This suggests an output of the command `iptables`. However, the command itself is not visible in the listing. This is unexpected, since the command line prefix (`root@hst-46-166-160-137:~#`) is visible. This suggests that the command has been removed from this listing. As a result, it is unknown which command was entered and the reader can't verify what the output represents.

Another inconsistency is found in figure 11 (section 3.6.2.11) of the MIT report: the depicted query is `select * from log2 limit 50;`, while the title reads *"log" table*. This suggests that analysts have added or modified a table and named it `log2`. It is not clear if other information from the table was added, removed or modified.

The abovementioned inconsistencies are problematic, since it indicates manipulation of the database results or screenshots without an explanation. As a result, it is not clear which of the information in the report is from the original data and which information is modified by MIT and also to which end. This raises questions as to what more information was altered before presentation, why it was altered and what exactly was left out or changed. When presenting information as evidence, transparency is crucial in differentiating between original data (the actual evidence) and data added or modified by the analyst.

4.4.2 Reporting style and readability

Overall, Fox-IT finds the MIT report implicit, not well-structured and lacking in essential details. This is not merely a formatting issue. Writing an unreadable report that omits essential details reduces the ability for the reader to scrutinize the investigation that lead to the conclusions. When a report is used as a basis for serious legal consequences, the author should be thorough and concise in the report as to leave no questions regarding the investigation.

The following examples illustrate this problem:

- Basic document management information, such as authoring date and versioning, is missing.
- There is no description of the actual investigation question(s) that was posed. Posing the question(s) provides the reader with context information to follow the steps taken and shows that the investigators had an unbiased starting point for their investigation. The conclusions can then be merited in relation to the investigative question(s).
- In the MIT report section 4, point 2, the author describes 6 'conclusions and assessments' relating to the ByLock author and intent. These points are 1) not explained in the report (even though they are not evident) and 2) should not be first mentioned in the conclusions, since that suggests it as a fact or a finding, which was described before the conclusions.
- Point 2 in this section results in a conclusion *"… that the application was meant to be used by the members of the FETO/PDY under the disguise of a global application*". However, section 4 continues to list more arguments and then results in another, similar conclusion. It is unclear to the reader how these conclusions relate to each other and on which arguments the final conclusion is based.

Fox-IT has read and written many digital investigation reports over the last 15 years. Based on this experience, Fox-IT finds the quality of the MIT report very low, especially when weighed against the consequences of the conclusions.

5 CONCLUSIONS

This section provides the conclusions on each of the issues addressed by Fox-IT in this expert witness report. For a more elaborate documentation of the Fox-IT investigation approach and results, the reader is referred to section 4 and 4 of this report.

5.1 What is Fox-IT's opinion on the investigation methodology used by MIT in the ByLock investigation?

Multiple key findings from the MIT investigation were contradicted by open-source research conducted by Fox-IT and other findings were shown not to be supported by the evidence presented by MIT. Furthermore, the MIT investigation lacks in transparency: evidence and analysis steps were in many cases omitted from the MIT report. Multiple findings (that could be verified) were shown to be incorrect, which leaves the impression that more findings would proof to be incorrect or inaccurate if they could only be verified.

Fox-IT finds the MIT investigation lacking in objectivity, since there is no indication that MIT investigated the alternative scenario: namely that ByLock has not exclusively been offered to members of the alleged FTÖ/PDY. Investigating alternate scenarios is good practice in an investigation. It helps prevent tunnel vision in cases where investigators are biased towards a predefined outcome. Fox-IT's examination of the MIT investigation suggests that MIT was, in advance, biased towards the stated conclusion and that MIT has not shown the required objectivity and thoroughness in their investigation to counter this bias.

Fox-IT concludes that the MIT investigation as described in the MIT report does not adhere to the forensic principles as outlined in section 3.1 of this report and should therefore not be regarded as a forensic investigation. The investigation is fundamentally flawed due to the contradicted and unfounded findings, lack of objectivity and lack of transparency. As a result, the conclusions of the investigation are questionable. Fox-IT recommends to conduct a forensic investigation of ByLock in a more thorough, objective and transparent manner.

5.2 How sound is MIT's identification of individuals that have used the ByLock application?

The MIT report contains very limited information on the identification of individuals. Fox-IT has shown that ByLock user accounts are, on their own, difficult to attribute to an individual: it is easy to impersonate other individuals when registering a ByLock account and MIT is limited to an IP address from the ByLock server log to identify individuals. Attributing this IP address to actual individuals is not straightforward and error-prone; therefore, possibly leading to identification of the wrong individuals as ByLock users.

Fox-IT is unable to assess the soundness of the identification method, since the MIT report does not provide information on this method. The omission of a description of this method is troubling. Any errors in the method will not be discovered and the reader is left to assume MIT does not make mistakes. While transparency is one of the fundamental principles of forensic investigations, this critical part of the investigation is completely opaque.

5.3 What is the qualification of soundness on MIT's conclusion regarding the relation between ByLock and the alleged FTÖ/PDY?

The conclusions and findings of the MIT report were examined by Fox-IT. It was shown that the argumentation is seriously flawed and that seven out of nine stated arguments are incorrect or questionable (see conclusion 6.1). The remaining two arguments are, on their own, not sufficient to support MIT's conclusion. As a result, the conclusion of the MIT report, "ByLock has been offered to the exclusive use of the members of the terrorist organization of FTÖ/PDY", is not sound.

5.4 Are there any other issues identified by Fox-IT that are relevant to the ByLock investigation?

Fox-IT encountered inconsistencies in the MIT report that indicate manipulation of results and/or screenshots by MIT. This is very problematic since it is not clear which of the information in the report stems from original data and which information was modified by MIT (and to which end). This raises questions as to what part of the information available to MIT was altered before presentation, why it was altered and what exactly was left out or changed. When presenting information as evidence, transparency is crucial in differentiating between original data (the actual evidence) and data added or modified by the analyst.

Furthermore, Fox-IT finds the MIT report implicit, not well-structured and lacking in essential details. Bad reporting is not merely a formatting issue. Writing an unreadable report that omits essential details reduces the ability for the reader to scrutinize the investigation that lead to the conclusions. When a report is used as a basis for serious legal consequences, the author should be thorough and concise in the report as to leave no questions regarding the investigation.

Fox-IT has read and written many digital investigation reports over the last 15 years. Based on this experience, Fox-IT finds the quality of the MIT report very low, especially when weighed against the consequences of the conclusions.

6 Documents and Data Examined

The following documents were reviewed by Fox-IT during the investigation:

1. **ByLock application technical report**. Department of Tax authorities, Department of Finance, Republic of Turkey. The original report was translated from Turkish to Dutch by sworn translator E. Battaloglu. The Dutch report was translated from Dutch to English by sworn translator for the English language, Jannie Johanna van Ravesteijn-Prins. The translated English document was delivered to Fox-IT as a physical document by Fatih Sahinler on 19 July 2017.

Fox-IT has analyzed versions of the ByLock application which were publicly available at the time of this investigation. The following versions of the ByLock Android application were found to be available and examined:

2. **ByLock for Android 1.1.6**. The application was downloaded as an APK file from *http://downloadapk.net/down_ByLock-Secure-Chat-amp-Talk.601634.html*. The file was downloaded on 20 July 2017. Fox-IT calculated hash values of the file:
    - MD5 hash[36] `b43eeb3fed4c20061e0c87f4d371508d`
    - SHA1 hash `aeb4256fa23d0d5090c5506e2d647f8d6a63f4af`
3. **ByLock for Android 1.1.7.** The application was downloaded as an APK file from *https://m.downloadatoz.com/bylock-secure-chat-talk/net.client.by.lock/bylock-secure-chat-talk,v1.1.7-download.html*. The file was downloaded on 20 July 2017. Fox-IT calculated hash values of the file:
    - MD5 hash `84fddf10a23f4f25b5212232b73cd557`
    - SHA1 hash `cac87620162e211b4fb02719a244b8127610cb7e`

The following versions are mentioned in the MIT report, but were no longer available for analysis in online public sources:

- ByLock for Android 1.1.3
- ByLock for Android 2.0 (ByLock++)

[36] A hash value is the result of a mathematical calculation, using an algorithm. The calculation only works in one direction, meaning that the hash value cannot be used to determine the original data. A hash value represents a digital fingerprint of the data and consists of a series of numbers (of a fixed length). Typically, a hash value is recorded during the creation of a forensically sound copy. The integrity of that copy can be checked (possibly by others) by calculating the hash value again, and checking it against the originally recorded hash value. Known and commonly used hash algorithms are MD5, SHA1 and SHA256.

7 APPENDIX

7.1 ByLock.net timeline

This table lists the changes in ownership information and IP addresses referenced by the bylock.net domain over time.

Date	Event	Source
14 March 2014	At this date, it was observed that ByLock.net resolved to IP address 184.168.221.39 hosted by godaddy.com	RiskIQ - PassiveTotal
18 March 2014	At this date, it was observed that ByLock.net resolved to IP address 184.168.221.39.	DomainTools
31 March 2014	At this date, it was observed that ByLock.net resolve IP address was changed from 184.168.221.39 to 69.64.56.133	DomainTools
29 April 2014 – 10 August 2014	Between these dates, it was observed that IP address 69.64.56.133 was hosted by server4you-inc.	RiskIQ – PassiveTotal
4 August 2014	At this date, it was observed that ByLock.net was last resolved to IP address 69.64.56.133	ViewDNS
10 August 2014 – 12 March 2016	Between these dates, it was observed that IP address 46.166.160.137 was hosted by uab-cherry-servers	RiskIQ – PassiveTotal
14 August 2014	At this date, it was observed that the ByLock.net hosted on IP address 69.64.56.133 and was changed to IP-address 46.166.160.137	DomainTools
19 February 2016	At this date, the last activity was observed for IP address 46.166.160.137	VirusTotal
15 March 2016	On this date, IP address 46.166.160.137 was last resolved on this date, located in Republic of Lithuania, owned by Dedicated servers	ViewDNS
20 March 2016 – 21 April 2016	Between these dates, it was observed that IP address 184.168.221.72 was hosted by godaddy.com	RiskIQ – PassiveTotal
2 April 2016	At this date, it was observed that ByLock.net resolved to IP address 46.166.160.137 was changed to IP address 184.168.221.72	DomainTools
19 April 2016	ByLock.net hosted on IP address 184.168.221.72 was last seen on this date, located in Scottsdale - United States, hosted by GoDaddy.com, LLC	ViewDNS

4 May 2016	At this date, it was observed that the IP address 184.168.221.72 was not resolvable	DomainTools
10 August 2016	On this date, the IP address 217.70.184.38 was hosted by gandi-sas	RiskIQ – PassiveTotal
11 August 2016	At this date, it was observed that ByLock.net is resolved to a new IP address: 217.70.184.38	DomainTools
12 August 2016	At this date, it was observed that ByLock.net resolved to IP address 217.70.184.38 and was changed to IP 104.27.169.137	DomainTools
13 August 2016 – 2 August 2017	Between these dates, it was observed that IP address 104.27.169.137 was hosted by Cloudflare, Inc.	RiskIQ – PassiveTotal
24 August 2016	At this date, it was observed that ByLock.net resolved to IP address 104.27.169.137 was changed to IP address 104.27.168.137	DomainTools
13 October 2016 – 2 August 2017	Between these dates, IP address 104.27.168.137 was hosted by Cloudflare, Inc.	RiskIQ – PassiveTotal
1 August 2017	ByLock.net hosted on IP address 104.27.168.137 was last seen on this date, located in San Francisco - United States, hosted by Cloudflare, Inc.	ViewDNS
1 August 2017	ByLock.net hosted on IP address 104.27.169.137 was last seen on this date, located in San Francisco - United States, owned by Cloudflare, Inc.	ViewDNS

Table 3: Bylock.net timeline

7.2 Glossary of technical terms

Android Package Kit	The package file format used by the Android operating system for distribution and installation of mobile apps and middleware.
APK	See **Android Package Kit**
Decompilation	A technique to transform executable computer code (back) to source code. Commonly used when analyzing workings of a program.
DNS	See **Domain Name System**
Domain Name System	A hierarchical decentralized naming system for computers, services, or other resources connected to the Internet or a private network. It associates various information with domain names assigned to each of the participating entities. Most prominently, it translates more readily memorized domain names to the numerical IP addresses needed for locating and identifying computer services and devices with the underlying network protocols.
HTTPS	HTTP Secure is a communications protocol for secure communication over a computer network which is widely used on the Internet. HTTPS consists of communication over Hypertext Transfer Protocol (HTTP) within a connection encrypted by Transport Layer Security, or its predecessor, Secure Sockets Layer. The main motivation for HTTPS is authentication of visited web resources and protection of the privacy and integrity of the exchanged data.
Java	A general-purpose computer programming language that is concurrent, class-based, object-oriented and specifically designed to have as few implementation dependencies as possible.
Proxy server	A server (a computer system or an application) that acts as an intermediary for requests from clients seeking resources from other servers. A client connects to the proxy server, requesting some service, such as a file, connection, web page, or other resource available from a different server. The resource requested is then fetched from the other server or retrieved from a possible cache.
SSL Certificate	A public key certificate used for a secure (SSL) connection. A public key certificate is an electronic document used to prove the ownership of a public key. The certificate includes information about the key, information about the identity of its owner (called the subject), and the digital signature of an entity that has verified the certificate's contents (called the issuer). If the signature is valid, and the software examining the certificate trusts the issuer, then it can use that key to communicate securely with the certificate's subject. In Transport Layer Security (TLS) a certificate's subject is typically a computer or other device, though TLS certificates may identify organizations or individuals in addition to their core role in identifying devices. TLS, sometimes called by its older name Secure Sockets Layer (SSL), is notable for being a part of HTTPS, a protocol for securely browsing the web.
SQL	Structured Query Language (SQL) is a domain-specific language used in programming and designed for managing data held in a relational database management system (RDBMS), or for stream processing in a relational data stream management system (RDSMS).
Virtual Private Network	A technology used to tunnel network traffic over a tunneling protocol. It is also used to provide secure and anonymous access to the internet by applying encryption techniques to secure the channel and hiding the VPN client's identity.
VPN	See **Virtual Private Network**