

Tartu Ülikool
Arvutiteaduse instituut
Computer Science Curriculum

Arkadi Statsenko
**State Registry Data Access Notifications for
Estonian eID Holders**
Bachelor's Thesis (9 ECTS)

Juhendaja:
Daniel Würsch, MSc

Tartu 2025

State Registry Data Access Notifications for Estonian eID Holders

Abstract:

Andmejälgija is a protocol developed by Information System Authority (RIA), the purpose of which is to provide a uniform interface for querying Estonian residents' data access logs. There is also an *Andmejälgija* web-view accessible from the state-portal *eesti.ee*.

The purpose of this thesis is to create a mobile application that would notify its users of updates in the access logs, letting them know that their data in some state database has been accessed. Implementation choices of different aspects of the solution are also going to be covered together with advantages and disadvantages of each. Additionally, the overview of the existing state databases will be provided, including whether they provide access logs or not.

Keywords: Data Tracker, *Andmejälgija*, personal data, state databases, data access, data access monitoring, Android, Estonian e-governance

CERCS: P170 Computer science, numerical analysis, systems, control

Teavitused riiklike andmekogude andmete juurdepääsu kohta Eesti eID omanikele

Lühikokkuvõte:

Käesoleva lõputöö eesmärk on luua rakendus, mis teavitaks kasutajaid juurdepääsulogide uuendustest, andes neile teada, et nende andmeid mõnes riigi andmebaasis on kasutatud. Rakendusel on olnud erinevad rakendusvariandid, mida käsitletakse ka koos igäühe eeliste ja puudustega. Lisaks antakse ülevaade olemasolevatest riiklikest andmebaasidest, sealhulgas sellest, kas nad pakuvad juurdepääsulogisid või mitte.

Võtmesõnad: Andmejälgija, isikuandmed, riiklikud andmekogud, andmete juurdepääs, andmete juurdepääsu jälgimine, Android, Eesti e-riik

CERCS: T170 Arvutiteadus, arvutusmeetodid, süsteemid, juhtimine (automaatjuhtimisteooria)

Contents

1. Introduction	5
2. <i>Andmejälgija</i>	6
2.1 The protocol	6
2.2 Usage	7
2.3 Adoption.....	7
3. Overview of state databases	10
3.1 Databases implementing <i>Andmejälgija</i>	10
3.1.1 Examples of good implementation	10
3.1.2 Other databases implementing <i>Andmejälgija</i>	10
3.2 Databases providing other form of data access tracking	11
3.2.1 E-File System (E-Toimik)	11
3.3 Databases not providing any kind of data access tracking	13
4. Implementation	15
4.1 Description.....	15
4.2 Discussion of implementation choice.....	15
4.2.1 X-Road service.....	15
4.2.2 Standalone approach.....	16
4.3 Development	16
4.3.1 Licensing	18
4.3.2 Authentication.....	18
4.3.3 Interacting with <i>eesti.ee</i> internal APIs.....	19
4.3.4 Keeping the session alive	20
4.3.5 WorkManager approach.....	21
4.3.6 Foreground service approach.....	22
4.3.7 Hybrid AlarmManager approach.....	22
4.3.8 Session limitations	23
4.3.9 Handling logs and notification delivery	26
4.4 Software distribution	27
4.5 User guide.....	28
4.6 Observations while using Data Access Notifier	30
4.7 Limitations	31
4.7.1 Tested devices.....	31

4.8 Battery usage	32
4.9 Bug reports	32
4.10 Contributions	33
5. Conclusion	34
6. Discussion	35
6.1 Future Development Opportunities	35
6.2 Optimal Solution	35
References	36
7. Glossary	38
7.1 Estonian Government and Technology Terms	38
7.2 Android Development Terms	38
License	40

1. Introduction

In Estonia there are a lot of state databases holding users' data, like Population Registry (*Rahvastikuregister*) and Health Portal (*Terviseportaal*). People's data in these databases is accessed by different parties for the variety of purposes. Usually those are legitimate purposes, like a doctor accessing person's health documents, or people themselves accessing their data in some information systems. However, sometimes the purpose of data access is not clear.

For the purposes of making the process more transparent, the Estonian Information System Authority (RIA) created a special service, Data Tracker (*Andmejälgija*), in 2017, through which users can check which parties have accessed their data [1].

The Data Tracker is a people-oriented service on the state portal *eesti.ee*, which aims to ensure transparency in the processing of personal data in both private and public sectors. The Data Tracker relies on the ability of each state database to store the data processing taking place within itself in the form of logs, in order to later display it to the individual, i.e. the data subject, via the service on *eesti.ee* [2].

Architecturally, it is a fully distributed system, i.e. the information displayed to the user comes directly from the database that implemented the Data Tracker service. At the user's request, *eesti.ee* makes a query to each of the Data Tracker services and displays the query response without saving it [2].

The Data Tracker should display to the individual information about data processing taking place locally in the database (activities of officials-employees or automated systems with personal data) as well as an overview of when data has been transferred to a third party (via X-Road to another government agency or private entity) [2].

The Data Tracker doesn't notify, however, when the data is accessed by someone. In order to learn about the update in the data access logs, the person has to go to the *eesti.ee* web-view and manually query access logs from specific databases.

The primary objective of this thesis is to solve this problem by creating a mobile phone application that would notify its users about the new data access logs in near-real time.

Additionally, existing state databases processing people's personal data would be examined, including whether they provide data access logs or not.

2. *Andmejälgija*

2.1 The protocol

Andmejälgija is a protocol that state databases are responsible for implementing themselves. In order for the database to offer an *Andmejälgija* service, they have to create an X-Road interface according to RIA specification[3].

X-Road is a REST-based protocol which is used for secure data exchange between Estonian information systems over the Internet.

The *Andmejälgija* X-Road interface is expected to have the following endpoints:

findUsage

A query searches the data recorder database for usage records that match the constraints given in the input. The output of the query returns all records found[3].

usagePeriod

The time period for which usage information can be requested[3].

heartbeat

Requesting the availability status of the tracker's usage information[3].

The overall architecture of the *Andmejälgija* system is illustrated in Figure 1, which shows how state databases interact with the *eesti.ee* portal through X-Road to provide data access logs to end users.

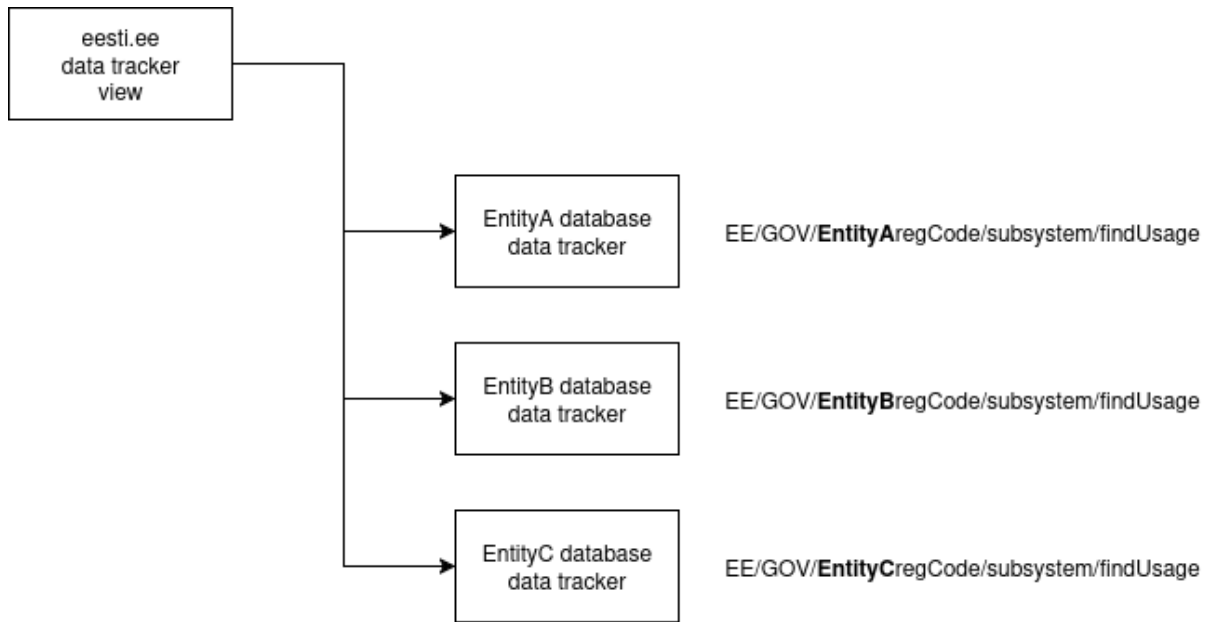


Figure 1. *Andmejälgija* (Data Tracker) system architecture showing the interaction between entities implementing data tracking and *eesti.ee* Data Tracker view. The data exchange happens via X-Road[2].

2.2 Usage

There are several ways for end-users to access their Data Tracker data. State portal *eesti.ee* provides a web-view for *Andmejälgija* where end users can access their data access logs. Recently, RIA have also published a mobile application for *eesti.ee*, that also features a view of data access logs.

Another way to access Data tracker data is through Estonian Population Registry, although, is seems to be Population Registry specific as it doesn't provide access logs from other databases

2.3 Adoption

The current adoption of *Andmejälgija* has some noticeable issues. Very often it is not at all clear why your data have been accessed, at least from the first glance. Explanation messages are vague and confusing, often being similar to “data access by personal code”, making it difficult to understand the reason behind the data access, even if it was you who accessed it.

There is even an information sheet with recommendations for services implementing the *Andmejälgija* protocol, and it states that providing poor quality explanations for data access is a bad practice[4]. The good and poor examples of data access descriptions are shown in Table 1 and Table 2.

Good practice example:

Data Processing Time	Activity	Party Receiving Personal Data
13.01.2015 10:20:27	Prescription viewed by doctor; prescription number 1018472350	Doctor Viktor Pihlakas
19.01.2018 10:58:23	Individual query for valid driver's licenses through state portal <i>eesti.ee</i>	Jaan Kask 32405023456

Table 1. Example of good data access descriptions[4]

Bad practice example:

Data Processing Time	Activity	Party Receiving Personal Data
13.01.2015 10:20:27	PERSONAL DATA BY PERSONAL CODE	INSTITUTION X
19.01.2018 10:58:23	INDIVIDUAL EXTENDED INFO QUERY BY PERSONAL CODE	FOUNDATION Y

Table 2. Example of poor data access descriptions[4]

Apparently, the advice is often ignored, as many institutions tend to follow the bad example in practice. The thesis author's Data Tracker view is flooded with entries containing poor quality descriptions like those shown in Table 3.

Date & Time	Institution	Database	Activity
02.08.2025 11:15	Health and Welfare Information Systems Centre	Population Registry	INDIVIDUAL EXTENDED INFO QUERY BY PERSONAL CODE
01.08.2025 22:37	Health and Welfare Information Systems Centre	Population Registry	INDIVIDUAL NAME RETRIEVAL BASED ON PERSONAL CODE
01.08.2025 20:23	Education and Youth Board	Population Registry	PERSONAL DATA BY PERSONAL CODE

Table 3. Extract from author's Data Tracker view demonstrating poor quality descriptions

Furthermore, currently there is no law requiring institutions to implement the *Andmejälgija* protocol, meaning that its use is essentially voluntary. This may change in the future, however, as the current coalition government formed by the Estonian Reform Party and Eesti 200 has promised to make the use of *Andmejälgija* compulsory according to their coalition agreement[5].

In the following chapter, different state databases and their implementations of *Andmejälgija* will be covered, including whether they implement the protocol at all.

3. Overview of state databases

3.1 Databases implementing *Andmejälgija*

3.1.1 Examples of good implementation

The following information systems demonstrate an exemplary implementation of the *Andmejälgija* protocol. They provide very descriptive information about data access requests, making it clear to users what specific piece of data has been accessed, and by whom.

- Digital Registry (Digiregistratuur)
- Prescription Centre (Retseptikeskus)

3.1.2 Other databases implementing *Andmejälgija*

- Residence and Work Permit Register (*Elamislubade ja töölubade register*)
- Land Register (*Kinnistusraamat*)
- Professional Qualifications Register (*Kutseregister*)
- Taxpayers Register (*Maksukohustuslaste register*)
- Police Tactical Management Database (*Politsei taktikalise juhtimise andmekogu*)
- Agricultural Animals Register (*Põllumajandusloomade register*)
- Agricultural Subsidies and Land Blocks Register (*Põllumajandustoetuste ja põllumassiivide register*)
- Population Register (*Rahvastikuregister*)
- Social Protection Information System (*Sotsiaalkaitse infosüsteem*)
- Social Services and Benefits Register (*Sotsiaalteenuste ja toetuste register*)
- Labour Inspectorate Working Life Information System (*Tööinspektsiooni tooelu infosüsteem*)
- Unemployment Insurance Database (*Töötuskindlustuse andmekogu*)
- Information System POLIS (*Infosüsteem POLIS*)

3.2 Databases providing other form of data access tracking

3.2.1 E-File System (E-Toimik)

E-File System provides its own web-view for displaying requests made about the user, independent of the standard *Andmejälgija* protocol, as shown in Figure 2.

Minu kohta tehtud päringud

Päringud, mis on tehtud karistusregistrist kahe viimase aasta jooksul minu, minu alaealise lapse või eestkostetava või minuga seotud juriidilise isiku kohta.

Aeg -

Päringud*

Kuupäev	Päringu liik	Päringu sooritaja	Eesmärk
15.04.2025	Minu kohta tehtud päringute vaatamine	Arkadi Statsenko, 50305170834 (E-toimik)	Isik enda kohta
18.03.2025	Päring kõikide karistuste kohta	Kaitseressursside Amet, 70007647 (Kaitseväekohustuslaste register)	Automaatkontroll
18.02.2025	Päring kõikide karistuste kohta	Kaitseressursside Amet, 70007647 (Kaitseväekohustuslaste register)	Automaatkontroll

Figure 2. E-File System (E-Toimik) web interface for data access tracking[6]

An interesting observation regarding E-File is that similarly to the Data Tracker, it is not guaranteed to include all information about data access.

To be more specific, I once had to request a criminal record extract from Finland for employment purposes, as I had to undergo a background check. At some point I enquired about the status of my application and they responded, mentioning that it took longer than anticipated due to them also having requested my criminal record extract from Estonia, a country of my citizenship. The response e-mail is shown in Figure 3

The inquiry to Finnish Legal Register was made on the 14th of May, 2025. Despite that there are no relevant records in the E-File system in the period from 14.05.2025 to 20.05.2025 (The day the extract was posted).



ORK Rikosterikisteri <rikosterikisteri@om.fi>

Mon, May 26, 3:20 PM



to me ▾

Hello!

Thank you for your email.

Since you also have the citizenship of Estonia, we requested a criminal record information from there as well, it caused a delay in the process. We have prepared the extract for you on 20th of May 2025. The extract and invoice have been sent separately by regular mail to ICOVER SAS.

Hopefully you/they will receive it soon.

Best regards,



Palveluasiantuntija / Servicespecialist / Service Specialist
Oikeusrekisterikeskus / Rättsregistercentralen / Legal Register Centre
PL / PB / P.O. Box 157, 13101 Hämeenlinna / Tavastehus
www.oikeusrekisterikeskus.fi



Figure 3. An e-mail from Finnish Legal Registry confirming the request for criminal record extract made to Estonian authorities

Date	Query Type	Query Performer	Purpose
20.05.2025	Query for all convictions (incl. archive data)	Arkadi Statsenko (E-File)	Person about themselves
18.05.2025	Query for all convictions	Defence Resources Agency, 70007647 (Conscripts Register)	Automatic control
15.05.2025	Query for all convictions (incl. archive data)	Arkadi Statsenko (E-File)	Person about themselves
15.05.2025	Query for all convictions (incl. archive data)	Arkadi Statsenko (E-File)	Person about themselves
15.05.2025	Query for all convictions (incl. archive data)	Arkadi Statsenko (E-File)	Person about themselves

Table 4. E-File System query result showing the absence of cross-border data sharing records between 14.05.2025 and 20.05.2025

As shown in Table 4, there is no record of Estonian authorities providing criminal record information to the Finnish Legal Registry during the period from May 14th to May 20th, 2025, despite confirmation from Finland that such a request was made. This demonstrates a significant gap in data access logging, highlighting limitations in the current tracking systems.

3.3 Databases not providing any kind of data access tracking

- Schengen Information System National Register (*Schengeni infosüsteemi riiklik register*)
- Border Control Database (*Piirikontrolli andmekogu - PIKO*)
- Vehicle Registration Database (*Liiklusregister*)
- Court Information System (*Kohtute infosüsteem - KIS*)
- Employment register (*Töötamise register (TÖR)*)

These are only a few examples. There are a lot more databases that don't provide any kind of data access tracking. It is in fact much easier to count those databases that do provide some kind of data tracking than those that don't. A more complete view of what state databases exist is available from the State Information System Management System (*Riigi Infosüsteemi*

Haldussüsteem, RIHA)¹. At the time of writing (9.08.2025) the search returns information about 1386 databases in total, including 1100 about those in use. It is worth noting, however, that not all of these databases process personal data, and it is not possible to filter them immediately by this criterion. Whether a specific database processes personal data can be determined from the data composition (*andmekoosseis*) information provided as part of each database's description on the RIHA portal.

¹ <https://www.riha.ee/Infosüsteemid>

4. Implementation

4.1 Description

The main objective of this thesis has been to develop a solution that would notify users of data access events logged in the *Andmejälgija* (Data Tracker) system. The resulting solution provides near real-time notifications when government institutions or other authorized entities access an eID holder's personal data.

4.2 Discussion of implementation choice

There are several possible approaches for developing such a solution. In this section different implementation options will be discussed, as well as their advantages and disadvantages.

4.2.1 X-Road service

Andmejälgija specifications require entities responsible for the state databases to implement an X-Road interface themselves, as described in 2.1, so one option would be to create an X-Road service that would query *Andmejälgija* data over X-Road directly from those entities. The main advantage of this approach would be the freedom in how to notify users of changes to the access logs. As a server-based solution, the service could support various communication channels for delivering notifications to users, including instant messenger bots or e-mail notifications, for example. However, the list of requirements to operate such a service is daunting.

- In order to join X-Road, a legal entity is needed.
- Permission has to be requested from every X-Road service you want to query data from. Specifically, considering that each information system is responsible for implementing the *Andmejälgija* protocol themselves, the permission would be required from each entity responsible for the information systems from which the access logs would be requested.
- As part of X-Road network, one needs to operate a Security Server. For testing, it can be self-hosted on any hardware, but for production, a Hardware Security Module (HSM) is needed, in order to be compliant with eIDAS requirements. Obtaining or renting such hardware involves substantial financial investment. For example, a Thales Luna PCIe HSM A700 suitable for eIDAS qualified digital signing costs €8,990 (€10,877.90 incl. VAT) [7]. Alternatively, renting a production ready Security server from Telia costs 210€ per month [8]

- Finally, considering that this approach would include creating a service that would store and transmit user's data, it would be required to follow strict regulatory requirements including the General Data Protection Regulation (GDPR). Staying compliant requires a continuous effort, and in case of failure to do so, there are harsh fines.

Satisfying these criteria is difficult and expensive. Additionally, even with successful implementation, people would have to consent and entrust me with their data in order to be able to use the solution, which is not in the spirit of creating a solution for monitoring personal data access, as another data controller would be introduced.

4.2.2 Standalone approach

This approach uses the *eesti.ee* session for accessing *Andmejälgija* data. Once the user is logged in to the *eesti.ee* state portal, certain internal API endpoints become available. Namely the GET endpoint `https://www.eesti.ee/andmejalgiija/api/v1/usages` can be used to query *Andmejälgija* data. The endpoint requires a parameter `dataSystemCodes` with which specific databases can be specified. For example, the GET request `/usages?dataSystemCodes=digiregistratuur&dataSystemCodes=rahvastikuregister` would request access logs from *Digiregistratuur* and *Rahvastikuregister*.

The main advantage of this approach is the absence of all disadvantages of the X-Road approach: there are no legal requirements and the solution could be an open-source project, available for anybody to compile and use. There arises a problem, however. What about the notification part? Are users expected to set everything up on their hardware, including relevant communication channels? That would narrow down the project's user base to technical people knowing how to self-host, and having a server.

Consequently, creating a mobile application was determined to be the most optimal approach. A mobile application would keep the *eesti.ee* session alive and poll the *Andmejälgija* API. This approach combines ease of setup and use while keeping the solution standalone, without requiring a central server.

4.3 Development

First, the feasibility and reliability of the standalone approach had to be determined, especially as the approach would include a reverse-engineering of the user-facing service. The main challenge was to keep the session alive for as long as possible.

The *eesti.ee* session is established using one of the strong authentication methods via the *TARA* (Trusted Authentication and Authorization) service. Once the user is authenticated using ID-card, Mobile-ID, Smart-ID, or eID solution of another EU country, a JSON Web Token (JWT) token is issued, valid for 30 minutes. The session management is then handled by *GovSSO* (Government Single Sign-On), which maintains the master server-side session token and imposes certain limitations as discussed in 4.3.8.

Once the user is authenticated, certain internal API endpoints become available, including those for refreshing the JWT token and getting *Andmejälgija* access logs. The JWT refresh endpoint returns `Set-Cookie` headers that include an updated `JWTOKEN` on success, with an updated expiration date (30 minutes from the moment of extension).

To test whether the session could be kept alive indefinitely, the Tab Reloader extension for Firefox by James Fray [9] was used. Using this browser extension, the browser was configured to automatically reload the tab with the JWT token refresh endpoint. After the 8-hour experiment, the approach was deemed successful.

The next step was the development of the **Data Access Notifier** Android application. The reason why Android was chosen over iOS is that Android development is significantly more accessible for developers who do not own an Apple computer. Unlike iOS, Android development can be performed on nearly any modern computer with reasonably common operating system installed, including Linux.

The application was developed using the Kotlin programming language due to it being the new standard for developing Android applications [10], as well as its more expressive syntax and promise of faster development speed.

The application is compatible with all Android versions starting from Android 8.1, meaning that it works on approximately 96.4% of Android devices according to the Android Studio API version distribution chart shown in Figure 4.

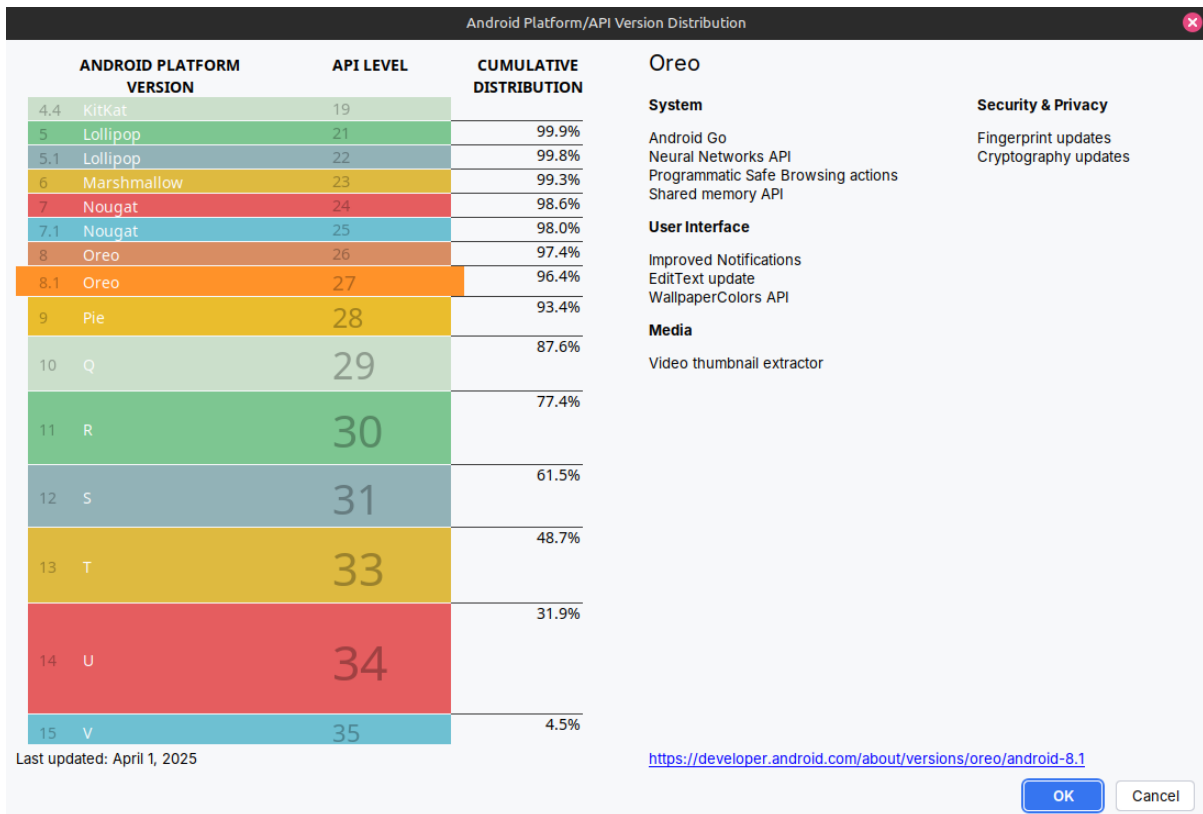


Figure 4. Android Studio API Level Distribution for Android 8.1+ compatibility

Currently, the application support is limited to Android 8.1 and higher. While support for iOS and other platforms is not planned due to limited development time and resources, anybody who deems this solution useful is encouraged to port it to platforms other than Android.

4.3.1 Licensing

The **Data Access Notifier** application is released as open-source software under the MIT License. This simple and permissive license allows users to freely use, modify, and distribute the software for both commercial and non-commercial purposes.

The choice of MIT License aligns with the project’s goal of providing a transparent and accessible solution for personal data monitoring, enabling the broader community to contribute to and benefit from the development efforts without strict licensing barriers.

4.3.2 Authentication

To gain access to *eesti.ee* internal APIs, the user needs to be authenticated via the State Authentication Service (*TARA*). The initial plan was to reverse engineer the authentication flow and authenticate the user by sending raw HTTP requests and handling responses. This

approach, however, would be fragile and require substantial engineering effort to develop and maintain due to the flow being fairly complex and prone to unannounced changes to *TARA*.

Instead, it was decided to use Android WebView for authentication as a more reliable and convenient approach for both the user and the developer. By leveraging WebView, the **Data Access Notifier** application can present the official *TARA* login page directly to the user, allowing them to authenticate using their preferred method (ID-card, Mobile-ID, Smart-ID, or eID of another EU country). This approach significantly reduces the risk of breaking changes due to updates on the *eesti.ee* or *TARA* platforms. Once the user is authenticated, the application can access the necessary session cookies and JWT token to interact with the internal APIs.

4.3.3 Interacting with *eesti.ee* internal APIs

For interacting with *eesti.ee* internal APIs, the OkHttp library by Square, Inc.[11] was used. The following API endpoints were utilized:

- **GET** `https://www.eesti.ee/timur/jwt/extend-jwt-session`

An endpoint for extending JWT session.

- **GET** `https://www.eesti.ee/andmejalgija/api/v1/usages`

An endpoint for querying Data Tracker access logs.

Query parameters:

- `dataSystemCodes`: The name of the information system the access logs are queried from.

Response body format (JSON):

```

{
  "findUsageResponses": [
    {
      "logTime": "2025-08-03T22:40:47",
      "receiver": "Tervise ja Heaolu Infosüsteemide Keskus",
      "infoSystemCode": "rahvastikuregister",
      "action": "ISIKU NIME VÄLJASTAMINE ISIKUKOODI PÕHJAL"
    },
    // more objects to follow
  ]
}

```

Listing 1. API response format for Andmejälgija usage data

Response fields:

- `logTime`: Timestamp of the data access event in ISO 8601 format
- `receiver`: Entity that accessed the data
- `infoSystemCode`: The information system where the data has been accessed.
- `action`: Description of the action performed (in Estonian)

Both endpoints require a valid JWT token to succeed. `WebView's CookieManager` serves as a single source of truth in this application, where all cookies are loaded from for making requests and written to upon receiving responses.

4.3.4 Keeping the session alive

The API requests are authenticated using a JWT token cookie, the lifetime of which is 30 minutes. This means that the **Data Access Notifier** application must either run a continuous foreground service or be awakened periodically to request an updated JWT token and send requests to *Andmejälgija*.

On Android, there are several ways to accomplish this, although it is worth mentioning that Android is very restrictive regarding background tasks and battery usage. Several approaches were tried and the experience with them in the context of developing this application will be described.

4.3.5 WorkManager approach

According to the Android documentation, WorkManager is the recommended solution for persistent work [12]. Work is persistent when it remains scheduled through application restarts and system reboots. This seemed to describe the use case very well, so this was the first approach that was tried.

Work is defined in WorkManager using a WorkRequest. There are several WorkRequest types available, including `PeriodicWorkRequest` and `OneTimeWorkRequest`.

Using `PeriodicWorkRequest`, it is possible to schedule periodic tasks. The important limitation here is that it is not possible to schedule a task to execute more frequently than every 15 minutes. While this may sound appropriate for the use case of having to renew the session at least every 30 minutes, in practice, the situation is different.

During development, a critical difference between session handling in web browsers versus HTTP client libraries was discovered. While the browser-based testing with Tab Reloader successfully maintained the session by refreshing the JWT token every 15 minutes, the same approach using OkHttp in the Android application failed to keep the session alive.

The exact cause of this discrepancy remains unclear. It appears that the *eesti.ee* session management system expects more frequent interaction or handles cookie management differently when requests originate from HTTP client libraries compared to full web browsers. Indeed, with shorter intervals of 5 minutes, the session remains alive. This behavioral difference rendered the `PeriodicWorkRequest` approach with 15-minute intervals unsuitable for maintaining persistent sessions in the application context.

While `OneTimeWorkRequest` is designed for one-time tasks, it is possible to chain them by having each one-time work create another one-time work at the end of its lifespan. This approach allows setting custom intervals shorter than 15 minutes, circumventing the limitation imposed by `PeriodicWorkRequest`.

While `OneTimeWorkRequest` may appear to be a suitable solution, WorkManager itself proved to be rather unreliable for the use case after testing. The limitation of WorkManager is that tasks scheduled by it are managed by the system and may be deferred if deemed necessary by the Android system. For example, tasks may not execute if the phone has low battery level, or even in other scenarios depending on the aggressiveness of the Android variant regarding the restrictions imposed on application behavior.

4.3.6 Foreground service approach

A foreground service is one of the most reliable types of tasks an application can schedule. In contrast to background services, foreground services are considered to be of higher priority by the system and thus are not candidates for termination when the system is low on memory or the phone has low battery level.

However, an important limitation has been introduced in recent Android versions. More specifically, starting from Android 15, the system places restrictions on how long certain foreground services are allowed to run while the application is in the background. Currently, this restriction only applies to `dataSync` and `mediaProcessing` foreground service types. The foreground services of those types are allowed to run for a total of 6 hours in a 24-hour period [13].

The most appropriate foreground service type for the use case is `dataSync`, meaning that it falls under the 6-hour per day restriction. While it should be possible to choose an arbitrary foreground service type regardless of the actual task type, doing so is not the cleanest approach, especially considering the existence of better alternatives. Furthermore, doing so may also impact the application's acceptance into the Google Play Store.

4.3.7 Hybrid AlarmManager approach

After evaluating the limitations of `WorkManager` and the restrictions on foreground services, a hybrid approach combining `AlarmManager` with a `dataSync` foreground service was ultimately adopted. `AlarmManager` is a system service that allows scheduling operations to be executed at specific times, even if the application is not running. By using `AlarmManager` to trigger the application at regular intervals (e.g., every 5 minutes), it is ensured that the session renewal and data polling tasks are reliably executed.

When the alarm fires, the application starts a short-lived `dataSync` foreground service to perform the necessary network operations: refreshing the JWT token and querying the *Andmejälgija* API. This approach leverages the reliability of foreground services for critical tasks while minimizing battery usage by only running the service when needed. `AlarmManager` itself is not subject to aggressive background restrictions and can wake the application even in Doze mode, making it suitable for periodic tasks.

This solution proved to be robust and reliable across different Android versions and device manufacturers. Both `AlarmManager` and foreground services are extremely reliable even under

low battery conditions, ensuring that the session remains alive and notifications are delivered promptly to the user.

4.3.8 Session limitations

During the development and testing process, an important server-side limitation that affects the overall feasibility of the session-based approach was discovered. Despite the successful implementation of session renewal mechanisms, the *GovSSO* session management system imposes a hard limit of 12 hours on session duration. After this period, the session expires permanently and cannot be renewed.

The problem was discovered when it became apparent that JWT extension fails regularly with response code 500 (Internal Server Error) from the server and no further information. Following a number of retries, the server would send code 400 (Bad Request). At some point a pattern was identified, and it was discovered that the session extension starts failing after exactly 12 hours. The *GovSSO* GitHub repository [14] was investigated and the answer was found in the configuration file.

In the file `/src/main/resources/application.yml`, the following configuration parameter is defined [15]:

```
session-max-duration-hours: 12
```

Listing 2. GovSSO session configuration parameter [15]

The function responsible for checking the `notBefore` date of the JWT token is shown below [16]:

```

private boolean isNbfValid(JWT idToken) throws ParseException {
    Date idTokenDate = idToken.getJWTClaimsSet().getNotBeforeTime();
    Date currentDate = new Date();
    long diffInMillis = Math.abs(currentDate.getTime() -
                                idTokenDate.getTime());
    long diffInSeconds = TimeUnit.SECONDS.convert(diffInMillis,
                                                TimeUnit.MILLISECONDS);
    long maxDurationInSeconds = TimeUnit.SECONDS.convert(
        ssoConfigurationProperties.getSessionMaxDurationHours(),
        TimeUnit.HOURS);

    return diffInSeconds <= maxDurationInSeconds;
}

```

Listing 3. GovSSO JWT token validation function

Initially, it was hypothesized that this limitation was related to the JWT token issued to the client, with the server rejecting it once it reaches the age of 12 hours. This would have been an easy fix, as there is another way to extend the session that would issue a “fresh” JWT token each time. As can be derived from the name *GovSSO*, this authentication service supports single-sign-on, meaning that if you are signed into one state e-service, you can log into another by clicking a “Continue session” button, as demonstrated in Figure 5. The same can be achieved for the same state portal where the system was initiated, if you go to the right URL. Automating this type of flow is relatively simple to implement.



RIIGI AUTENTIMISTEENUS

SISEMINISTEERIUM Logging in to Self-service portal for population register

To log in to **Self-service portal for population register** it is sufficient to continue your session because you are logged in to another service. Data that will be transmitted to service:

First name	Personal code
ARKADI	██████████
Surname	Date of birth
STATSENKO	██████████

[Continue session](#) [Re-authenticate](#)

Figure 5. GovSSO single sign-on interface with session continuation option [17]

However, after experimenting with this method, it was discovered that the 12-hour limitation applies to a different token than initially expected. The time validation is not performed on the client-side JWT token that the application receives, but rather on a server-side master JWT token that is created during the initial *TARA* authentication process (ID-card, Mobile-ID, Smart-ID, etc.) and managed by *GovSSO*.

When a user logs into additional services using the single-sign-on functionality, these secondary sessions are all linked to the same original server-side JWT token managed by *GovSSO*. This architecture means that regardless of which session extension method is used, the 12-hour limit cannot be circumvented because all sessions share the same underlying authentication token that expires after 12 hours.

This limitation has significant implications for the notification system's reliability. Users who expect continuous monitoring must re-authenticate manually at least once every 12 hours to maintain the service functionality. However, this constraint is substantially mitigated by the API's design, which ensures that no data access events are permanently lost, though it does introduce periodic interruptions in real-time monitoring.

Specifically, the API returns comprehensive historical access logs, ensuring that once a user re-authenticates after a session expiry, they will receive all notifications for events that occurred during the period when they were logged out. This behavior is crucial for maintaining data

completeness and ensuring that no critical access events are missed due to authentication gaps. The technical implementation of this log handling is detailed in 4.3.9.

Additionally, in order to enhance user awareness of session expiry, the application implements a proactive notification mechanism, as shown in Figure 6, informing the user that they have been logged out and prompting them to re-authenticate to continue monitoring.

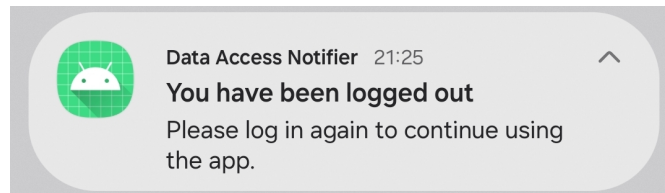


Figure 6. Notification informing the user about session expiry.

4.3.9 Handling logs and notification delivery

In this section the following aspects of access log handling will be tackled: their storage, deduplication and filtering.

First of all, user inquiries about themselves are also considered data access and therefore produce access logs. This includes *Andmejälgija* data queries. However, making frequent queries to the *Andmejälgija* API produces numerous logs.

This makes it important to distinguish logs made by the user themselves from the logs made by third-parties. Thankfully, the `receiver` field contains the user’s Estonian personal code in case the query is made by them. In fact, filtering by whether the receiver field contains user’s personal code is exactly how the access log filtering is implemented on *eesti.ee* itself when the user ticks the “Exclude queries I have made/initiated” checkbox. Here is the *eesti.ee* code extract that demonstrates this approach [18]:

```
this.accountService.getUserInfo().subscribe((o) => {
  this.filteredData.data = this.filteredData.data.filter(
    (d) => !d.receiver.toUpperCase()
      .includes(o.personalCode.replace(/^EE/, ""))
  );
})
```

Listing 4. Estonian state portal JavaScript code for filtering self-access events

The same approach was used to implement access log filtering in the **Data Access Notifier** application. The user's personal code that is needed for filtering is extracted from the JWT token, along with the user's first name which is used to greet the user.

For deduplication of access logs, the `Set` data structure was utilized. Each access log entry is represented as a data class, and a `Set` of these entries is maintained to ensure that duplicate logs are not stored or processed multiple times. This approach leverages the fact that `Sets` in Kotlin do not allow duplicate elements.

To persist the access logs across application restarts and device reboots, Proto Data Store was used, which is Android's recommended solution for storing typed objects or lists in a transactional and type-safe manner. Proto Data Store uses Protocol Buffers [19] for serialization, offering efficient storage and schema evolution capabilities.

Whenever new logs are fetched from the API, they are first filtered to exclude self-access events. The newly fetched logs are then merged with the existing logs stored in Proto Data Store, and the combined set is deduplicated using Kotlin's `Set` data structure. To determine which logs are new and should trigger notifications, the application computes the set difference between the combined deduplicated logs and the previously stored logs. Only the new items resulting from this difference are used to notify the user. This approach ensures that notifications are sent only for genuinely new access events, while avoiding redundant alerts for logs that have already been seen.

4.4 Software distribution

The **Data Access Notifier** application is distributed as an open-source project hosted on GitHub [20]. Users can download the `APK` file directly from the GitHub Releases page [21]. To keep the application up to date, users can utilize third-party applications such as Obtainium [22], which enables automatic updates for applications distributed outside of traditional application stores.

While the application is not currently available from application stores like Google Play Store, this possibility is not excluded in the future. Any updates regarding the application distribution would be posted on GitHub README.

4.5 User guide

After installation and opening for the first time, the **Data Access Notifier** application will prompt the user for necessary permissions, which are the ability to schedule alarms (for AlarmManager to work) as well as to post notifications.

Once the necessary permissions are given, the Log In screen appears. When the Log In button is pressed, an Android WebView is opened, redirecting the user to the *TARA* Log In screen. There the user is free to choose their preferred state authentication option.

The setup process is now complete. As soon as authentication is successfully completed, the user will start receiving notifications whenever new data access logs are returned from the server. There is also a view inside of the application showing all data access logs saved. The setup process is illustrated in Figure 7, with the relevant settings page for permitting the application to schedule alarms being opened automatically.

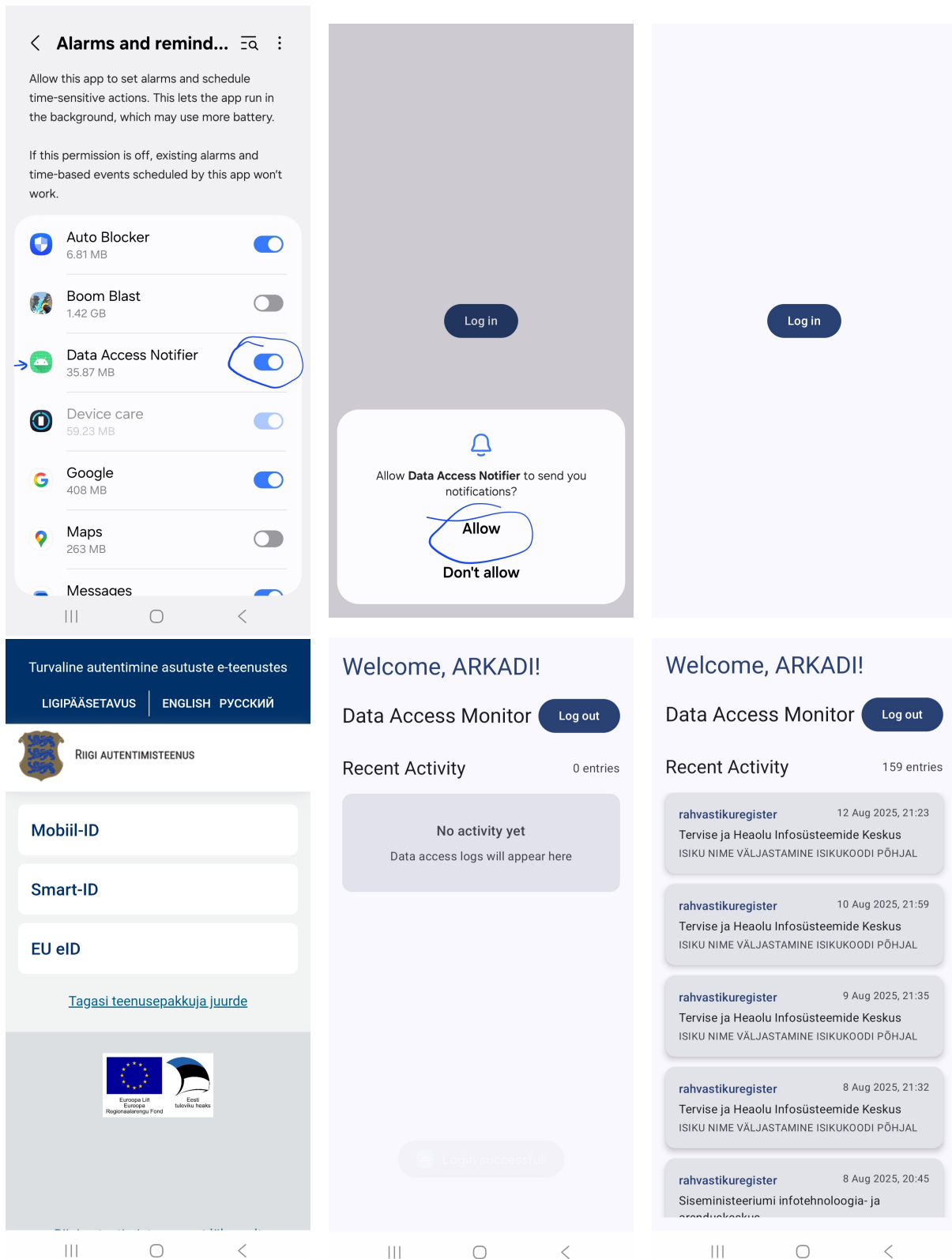


Figure 7. Authentication to Data Access Notifier

Once authenticated, users will start receiving real-time alerts when their data is accessed, as shown in Figure 8.

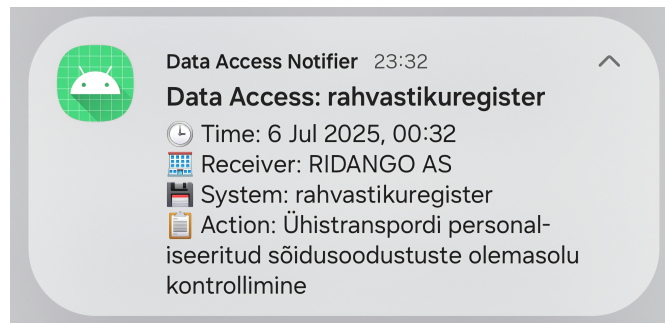


Figure 8. Data access notification

4.6 Observations while using Data Access Notifier

While using the **Data Access Notifier** application over several weeks, several interesting observations were made about the behavior of the *Andmejälgija* API and the reliability of real-time access logging.

One notable discovery was related to delayed log entries. Notifications were occasionally received for access events dated several months in the past - specifically, events from May 2025 would sometimes appear in August 2025. Initially, this was suspected to be a deduplication issue within the application, but after examining the stored notification history, it became clear that these were genuinely new log entries that had not been seen previously by the application.

This behavior suggests that there may be delays in the centralized logging infrastructure of *Andmejälgija*, where some access events are not immediately recorded or made available through the API.

The application demonstrated substantial reliability in maintaining the authentication session during the 12-hour window. The hybrid AlarmManager approach (described in 4.3.7) successfully maintained connectivity even during extended periods of device inactivity or network fluctuations.

From a user experience perspective, the notifications provided valuable insights into data access patterns that would otherwise remain unnoticed. This transparency feature proved particularly useful for understanding which organizations access personal data and how frequently such access occurs.

4.7 Limitations

The most significant limitation of the **Data Access Notifier** application is the 12-hour session expiry imposed by the *GovSSO* authentication system. As discussed in 4.3.8, this server-side restriction cannot be circumvented through known technical means, requiring users to manually re-authenticate.

While the application successfully preserves all access log data during authentication gaps - ensuring no events are permanently lost - the periodic interruptions in real-time monitoring represent a substantial usability constraint.

Additionally, the application's scope is currently limited to Android devices running version 8.1 and higher. While this covers approximately 96.4% of the Android ecosystem, users of iOS or other mobile platforms cannot benefit from this solution without platform-specific implementations.

The reliance on reverse-engineered internal APIs also introduces inherent fragility. Changes to *eesti.ee*'s internal API structure or authentication mechanisms could potentially break the application's functionality without notice, requiring an update to the application to fix the issue.

Additionally, the session-based approach requires the device to maintain active network connectivity and remain operational to perform periodic authentication renewals and API polling. Extended periods of device inactivity, airplane mode, or network unavailability will result in session expiry and temporary loss of monitoring capabilities.

The application also doesn't currently support the access logging implemented in *E-File*.

Finally, the *Andmejälgija* protocol itself is not regulated by the law yet, so information systems are not required to implement it, and even if they do, not all data access events are guaranteed to be timely distributed or logged at all.

4.7.1 Tested devices

The **Data Access Notifier** application has been tested on the following devices:

- Xiaomi Poco X3 Pro running CrDroid without Google Services
- Xiaomi Redmi 7A running Lineage OS without Google Services
- Samsung Galaxy S25 with stock OS (Google Services included)

4.8 Battery usage

Data Access Notifier application maintains relatively low power consumption despite its continuous background operation. The hybrid AlarmManager approach with short-lived foreground services appears to be efficient in terms of battery impact.

While the battery utilization hasn't been actively monitored, some screenshots have been taken on Samsung Galaxy S25 at different times during the active use period, as shown in Figure 9.

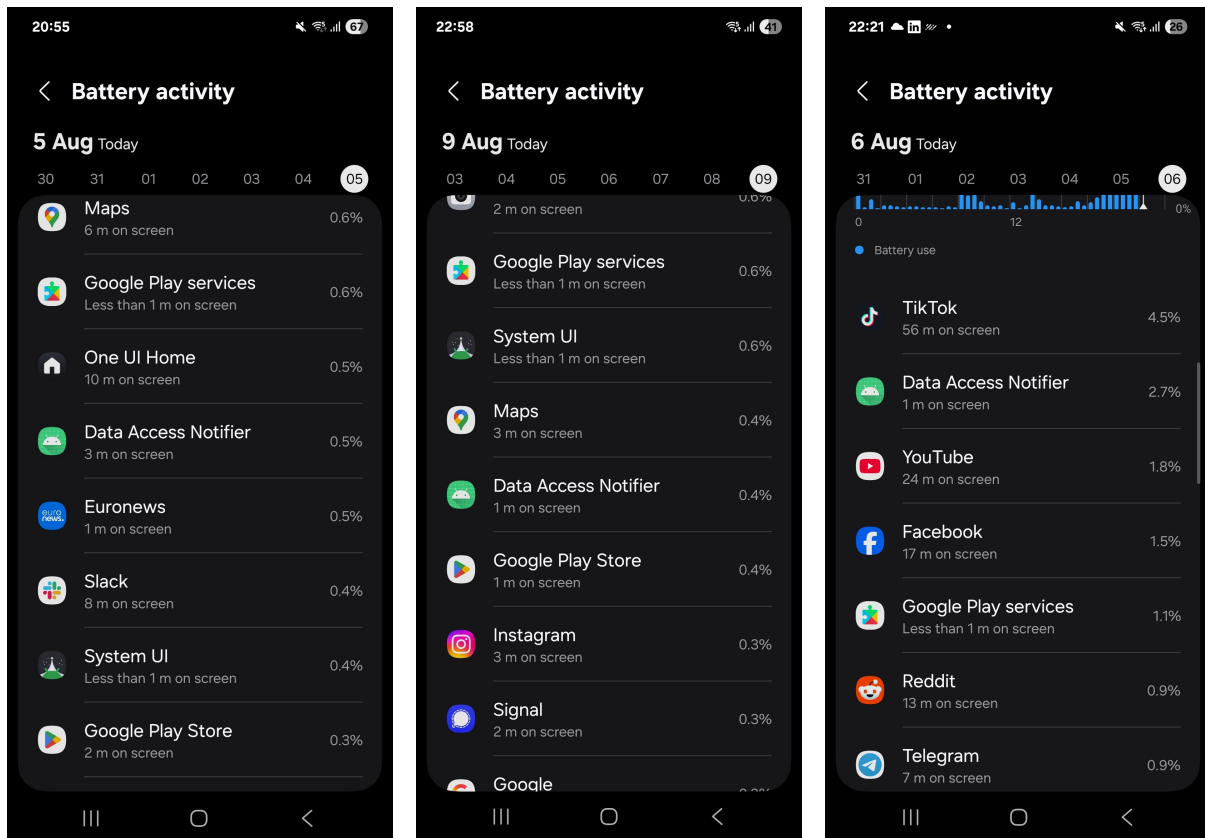


Figure 9. Battery usage statistics for Data Access Notifier on Samsung Galaxy S25

4.9 Bug reports

Users are encouraged to report any bugs, issues, or unexpected behavior through the GitHub Issues page of the project repository [20]. When submitting bug reports, users should include:

- Device model and Android version
- Detailed description of the issue
- Steps to reproduce the problem
- Any relevant error messages or screenshots

- Application version number

This feedback mechanism helps improve the application's stability and reliability across different Android devices and configurations.

4.10 Contributions

The **Data Access Notifier** project welcomes contributions from the community. Contributions are to be submitted as pull requests to the GitHub repository. Contributors can also contact the original author directly at arkadistatsenko@gmail.com for questions, suggestions, or collaboration opportunities.

5. Conclusion

The prime objective of this thesis, which is to create a mobile phone app, Data Access Notifier, has been achieved. Even though it has known limitations, it still provides valuable functionality in terms of providing notifications about data access that could have been missed otherwise, especially considering that, as observed in section 4.6, sometimes old logs are delivered with delay of several months.

6. Discussion

While an initial solution has been successfully implemented, there remains considerable scope for further development and enhancement.

6.1 Future Development Opportunities

Several potential approaches could address the current 12-hour session limitation by exploring alternative authentication flows and API endpoints. One avenue for investigation would involve reverse-engineering the official *eesti.ee* Android application to analyze its authentication mechanisms, for example by decompiling its APK and studying the resulting source code. The application is known to support biometric authentication with PIN code fallback functionality. Through proper reverse engineering and reimplementation of these authentication flows, it may be theoretically possible to automate PIN code resubmission and maintain indefinite session validity.

However, such an approach would constitute a substantial undertaking that could warrant a separate research project. Additionally, this method would likely introduce significantly greater implementation complexity compared to the current solution, potentially making it more fragile and maintenance-intensive.

6.2 Optimal Solution

The most effective solution would be for RIA (Information System Authority) to implement equivalent functionality directly within the *eesti.ee* platform. Such an official implementation would be relatively straightforward to develop and would provide superior reliability and future-proofing compared to any third-party solution, including the one presented in this thesis.

References

- [1] ERR. Leht: rahvastikuregistris nuhitakse ebaseaduslikult inimeste andmetes. <https://www.err.ee/590454/leht-rahvastikuregistris-nuhitakse-ebaseaduslikult-inimeste-andmetes> (10/08/2025).
- [2] Information System Authority (RIA). Andmejälgija / Data Tracker. Version 1.0.3. 15th Apr. 2025. <https://github.com/e-gov/AJ>.
- [3] Information System Authority (RIA). Andmejälgija / Data Tracker protocol specification. Version 1.4.1. 15th Apr. 2025. https://github.com/e-gov/AJ/blob/master/doc/spetsifikatsioonid/Kasutusteabe_esitamise_protokoll.md.
- [4] Information System Authority (RIA). Soovitusi Andmejälgija rakendamiseks. 2025. <https://www.ria.ee/sites/default/files/documents/2022-11/Soovitusi-Andmejalgija-rakendamiseks.pdf>.
- [5] Estonian Government. Coalition Agreement 2025-2027: Digital State. <https://valitsus.ee/valitsuse-eesmargid-ja-tegevused/valitsemise-alused/koalitsioonilepe-2025-2027/digiriik> (12/08/2025).
- [6] Statsenko A. E-File System Screenshots. Screenshots taken from the Estonian E-File System (E-Toimik) showing data access tracking interface. 2025.
- [7] QSCD.eu. Thales Luna PCIe HSM A700. Price: €8,990 (€10,877.90 incl. VAT). eIDAS qualified QSCD capable. <https://www.qscd.eu/hsms-hardware-security-modules/thales-luna-pcie-hsm-a700/> (09/08/2025).
- [8] AS T. E. X-Road security server. <https://www.telia.ee/ari/it-teenused/serverid-ja-pilv/x-tee-turvaserver/> (09/08/2025).
- [9] Fray J. Tab Reloader. <https://addons.mozilla.org/en-US/firefox/addon/tab-reloader/> (09/08/2025).
- [10] Android Developers. Kotlin-first approach for Android development. <https://developer.android.com/kotlin> (09/08/2025).
- [11] Square I. OkHttp. <https://square.github.io/okhttp/> (09/08/2025).
- [12] Android Developers. Persistent work. <https://developer.android.com/develop/background-work/background-tasks/persistent> (11/08/2025).
- [13] Android Developers. Behavior changes: apps targeting Android 15 - DataSync timeout. <https://developer.android.com/about/versions/15/behavior-changes-15#datasync-timeout> (09/08/2025).

- [14] Information System Authority (RIA). GovSSO Session. <https://github.com/e-gov/GovSSO-Session> (09/08/2025).
- [15] Information System Authority (RIA). GovSSO Session Configuration File. <https://github.com/e-gov/GovSSO-Session/blob/a95c781a8f7b05bde550acb34b8292b6c884b802/src/main/resources/application.yml#L69> (12/08/2025).
- [16] Information System Authority (RIA). GovSSO Session - HydraService.java. <https://github.com/e-gov/GovSSO-Session/blob/a95c781a8f7b05bde550acb34b8292b6c884b802/src/main/java/ee/ria/govsso/session/service/hydra/HydraService.java#L472-L480> (09/08/2025).
- [17] Statsenko A. eesti.ee Portal Screenshots. Screenshots taken from the Estonian state portal (eesti.ee) showing GovSSO session management interface. 2025.
- [18] Information System Authority (RIA). eesti.ee - Estonian State Portal. JavaScript code excerpt. <https://www.%5Chref%7Bhttps://www.eesti.ee%7D%7Beesti.ee%7D> (09/08/2025).
- [19] Google. Protocol Buffers. <https://developers.google.com/protocol-buffers> (09/08/2025).
- [20] Statsenko A. Data Access Notifier. <https://github.com/ArkadSt/DataAccessNotifier> (09/08/2025).
- [21] Statsenko A. Data Access Notifier Releases. <https://github.com/ArkadSt/DataAccessNotifier/releases> (09/08/2025).
- [22] R. I. Obtainium. <https://github.com/ImranR98/Obtainium> (09/08/2025).
- [23] Centre of Registers and Information Systems (RIK). E-File. <https://www.rik.ee/en/international/e-file> (09/08/2025).
- [24] Android Developers. WorkManager. <https://developer.android.com/reference/androidx/work/WorkManager> (09/08/2025).

7. Glossary

7.1 Estonian Government and Technology Terms

Andmejälgija Data Tracker - Protocol developed by RIA for tracking personal data access across state databases.

eesti.ee Official Estonian state portal providing access to various government e-services.

TARA Trusted Authentication and Authorization service - Estonian government service that handles initial user authentication using strong authentication methods (ID-card, Mobile-ID, Smart-ID, EU eID).

GovSSO Government Single Sign-On service - Manages session state and enables users to access multiple Estonian government e-services with a single authentication. Works in conjunction with TARA to provide seamless access across government platforms.

Digiregistratuur Digital patient registry system in Estonia.

Rahvastikuregister Estonian Population Register.

E-File (E-Toimik) An information system that provides an overview of the different phases of criminal, civil, administrative and misdemeanour proceedings, procedural acts and court adjudications to all parties involved, including citizens and their representatives [23]. Includes the data access tracker for Criminal Records Database.

RIA *Riigi Infosüsteemi Amet* (Information System Authority) - Estonian government agency responsible for information systems.

X-Road (X-tee) Estonian data exchange platform that enables secure data exchange between information systems.

eIDAS Electronic Identification, Authentication and Trust Services - EU regulation for electronic identification and trust services.

7.2 Android Development Terms

AlarmManager Android system service for scheduling operations to be executed at specific times.

WorkManager Android Jetpack library for deferrable, guaranteed background work. Uses JobScheduler for API 23+, and AlarmManager + BroadcastReceiver for API 14-22.

Automatically chooses the best execution method based on Android version and system constraints [24].

Foreground Service Android service that runs in the background but displays a persistent notification to the user, making the user aware of the ongoing operation. Despite running in the background, it is called “foreground” because it maintains user visibility through the notification.

Background Service Android service that runs without user awareness and without displaying notifications. These services are heavily restricted by the system to preserve battery life and system performance.

WebView Android component that displays web content within an application.

OkHttp HTTP client library for Android and Java applications.

Proto Data Store Android library for storing typed objects using Protocol Buffers.

Doze Mode Android power-saving feature that defers background CPU and network activity for applications.

APK Android Package - File format used to distribute and install applications on Android.

JWT JSON Web Token - Method for transmitting information between parties as a signed JSON object.

License

Non-exclusive licence to reproduce the thesis and make the thesis public

I, **Arkadi Statsenko**,

1. grant the University of Tartu a free permit (non-exclusive licence) to reproduce, for the purpose of preservation, including for adding to the digital archives of the University of Tartu until the expiry of the term of copyright, my thesis

State registry data access notifications for Estonian eID holders,

supervised by **Daniel Würsch, MSc;**

2. grant the University of Tartu a permit to make the thesis specified in point 1 available to the public via the web environment of the University of Tartu, including via the digital archives, under the Creative Commons licence CC BY NC ND 4.0, which allows, by giving appropriate credit to the author, to reproduce, distribute the work and communicate it to the public, and prohibits the creation of derivative works and any commercial use of the work until the expiry of the term of copyright;
3. am aware of the fact that the author retains the rights specified in points 1 and 2;
4. confirm that granting the non-exclusive licence does not infringe other persons' intellectual property rights or rights arising from the personal data protection legislation.

Arkadi Statsenko

12/08/2025