COVID-19 Notification App - Solution Architecture

Baseline for the "Proof of Concept"

Version: 0.6 (28/5/2020)
Status: Draft

Introduction

The ministry of VWS is currently investigating if and how a contract tracing app could be used to help with the current corona crisis. As there are significant technical, privacy, epidemiological and behaviour-science related challenges this will initially be a "Proof of Concept" (PoC) only.

This document describes the functional and technical architecture of this PoC. Note that, as part of the Dutch Covid19 response, there are also several other workstreams happening in parallel (such as for example investigating a follow up, post infection, support app).

The requirements document received from the Dutch health authority GGD are leading in the decisions in this solution architecture. The original requirements document can be found at https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/publicaties/2020/05/19/programma-van-eisen/20200519+Programma+van+Eisen+def.pdf

This document only details the proof of concept for exposure notification.

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Guiding principles

We have defined a number of guiding principles that a solution must adhere to. This means that this project has a number of key contextual requirements that drive or otherwise define the architecture or are used as a benchmark:

- The eHealth Network toolbox "Mobile applications to support contact tracing in the EU's fight against COVID-19" as published by the European commission <https://ec.europa.eu/health/sites/health/files/ehealth/docs/covid-19_apps_en.pdf>
- The key principles as published by "Veilig Tegen Corona" at http://veiligtegencorona.nl (This is an approximate translation of the key principles, see the Veilig Tegen Corona site for the original Dutch manifesto):

    1. Only one goal: keeping the virus under control
    2. Based on scientific insights and proven to be effective
    3. Proven to be reliable and built from expertise
    4. Deployment of the app is temporary, by default
    5. Not relatable to individuals
    6. Use as few details as possible
    7. No central storage of personal details
    8. Safe and resilient against abuse
    9. User friendly and accessible
    10. Government and third parties are not allowed to force or require the use of the app
- The baseline standard that applies to all government systems in the Netherlands:
    - Baseline Informatiebeveiliging Overheid 1.04 https://bio-overheid.nl/media/1400/70463-rapport-bio-versie-104_digi.pdf
    - Algemene Verordening Gegevensbescherming (AVG) https://autoriteitpersoonsgegevens.nl/sites/default/files/atoms/files/verordening_2016_-_679_definitief.pdf
    - Handreiking Mobiele App Ontwikkeling en Beheer 3.0 https://www.noraonline.nl/images/noraonline/a/a5/Handreiking_Mobiele_App_3.0.pdf
    - Web Content Accessibility Guidelines 2.1 https://www.w3.org/TR/WCAG21/
    - NCSC beveiligingsrichtlijnen voor webapplicaties https://www.ncsc.nl/documenten/publicaties/2019/mei/01/ict-beveiligingsrichtlijnen-voor-webapplicaties

- NCSC beveiligingsrichtlijnen voor mobiele apps
  https://www.ncsc.nl/documenten/publicaties/2019/mei/01/ict-beveiligingsrichtlijnen-voor-mobiele-apps

Key characteristics

Decentralised approach

Like most EU countries - the Netherlands believes that a decentralised approach (i.e. no central tracking) best meets the privacy and security expectations of society.

This Proof of Concept therefore focuses on this approach; at the expense of a Central approach.

Bluetooth Low Energy (BLE)

There are several ways in which contact/encounters between people may be registered on a smartphone; from a simple manual diary to GPS to bluetooth and so on.

The EU Toolbox recommends the use of Low Energy Bluetooth (BLE). Although this project keeps open other options - our first 'Proof of Concept' version will be BLE based.

It is well documented that BLE measurements are inaccurate. For this reason there are several parallel activities (both in this project, by other countries and in collaboration with the other member states) to validate and verify this in field tests and to establish the level of accuracy that we can achieve and whether that is sufficient.

It is also known that for BLE on mobile apps on Android and iOS to work reliably in the background, there is a need for either a) relatively low level access (which is not routinely granted by the vendors) or b) it is required to use the Google/Apple Exposure Notification framework.

Google/Apple Exposure Notification framework (GAEN)

Given the timeline (and the desire for cross border interoperability within the EU eHealth network) this "Proof of Concept' - a GAEN based approach is currently given priority.

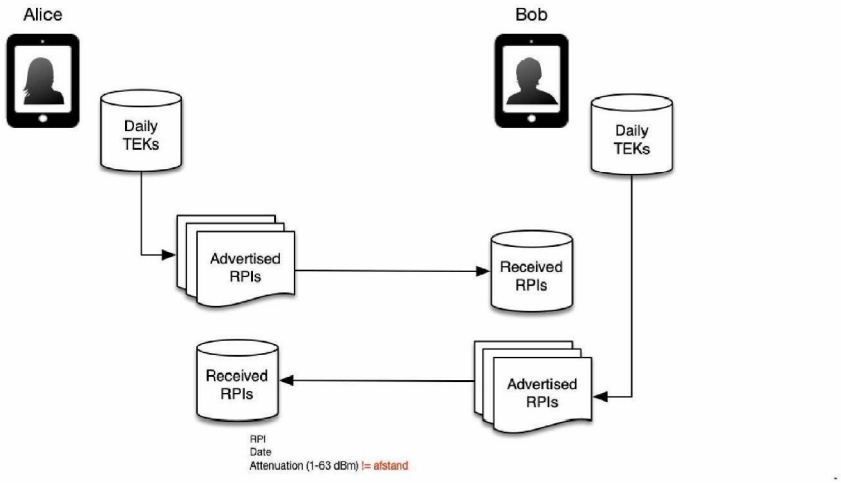
However it should be noted that alternatives are kept open. We have identified several privacy/security- and practicality issues that will have to be addressed by Google and Apple, or suboptimal workarounds need to be implemented. Based on testing and the international conversations we are having around this subject, we will continuously evaluate if the GAEN path is still the right one.

Baseline Approach

This chapter describes the core flow that we are following, which is partially dictated by the choice of protocol.

Recording encounters

As described in the GAEN document set - the users' mobile phones are able to record ephemeral IDs of other phones they meet. These are generated from a daily seed key (Temporary Exposure Key, TEK). Details about this can be found in the GAEN documentation, but it boils down to the following:

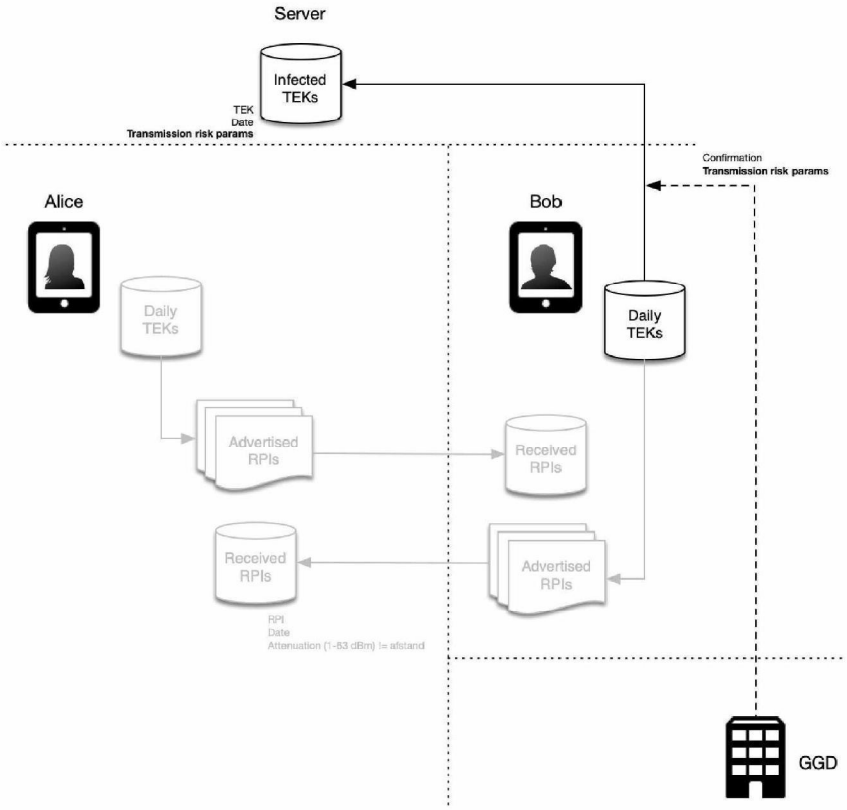


From the daily keys a set of Rolling Proximity Identifiers (RPI) is generated that are exchanged between phones over Bluetooth Low Energy and get recorded on the recipient's device. The device records the 'attenuation' of the encounter. This is a representation of how near the devices were, but is not an exact representation of distance. It can later be used to calculate the probability that this encounter was risky.

Taking a test

At some point a person carrying the app on their phone may get tested at a test centre (e.g. referred by a GP, on request of the GGD, etc -- see the PVE document).

It is expected that at this point the TEKs of that person are captured and sent to a central server:



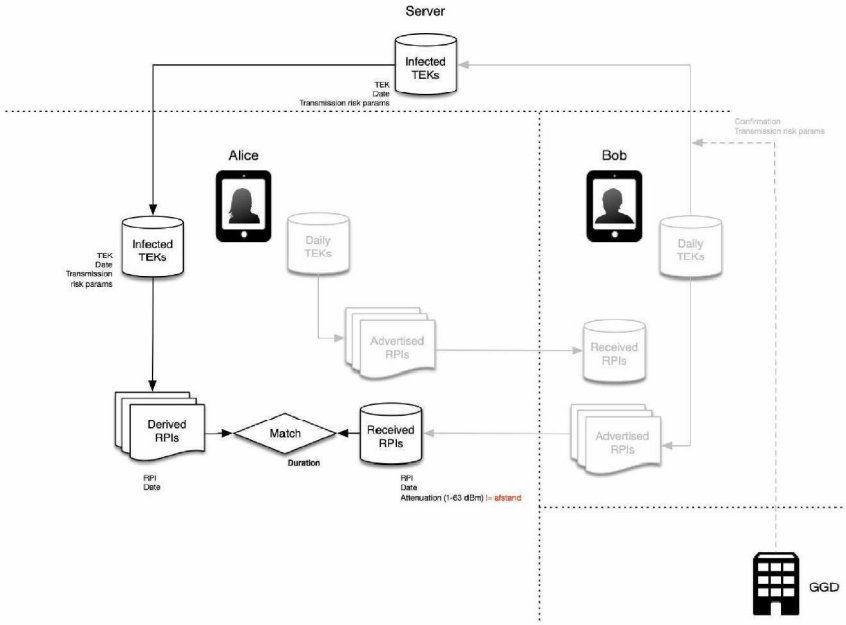
This upload should be validated / authorised by a health authority, so that people cannot upload their keys without a validated positive test result. (As per the requirements, we will not support self-assessment at this point). The keys are not shared (i.e. uploaded to the central server) until after the infected person has been informed of the test result and has provided consent to share the keys.

The GAEN protocol has the ability to enhance the keys with a 'transmission risk parameter' which allows to provide 8 levels of 'infectiousness'. (Whether this parameter will be used and how, should be determined by GGD/RIVM and is, for now, out of scope of the architecture.)

The infected keys are, at regular intervals, batched, signed and pushed out to a CDN. Once the batches are available on the CDN, the keys are no longer needed in the central database so they can be removed.

Checking for exposures

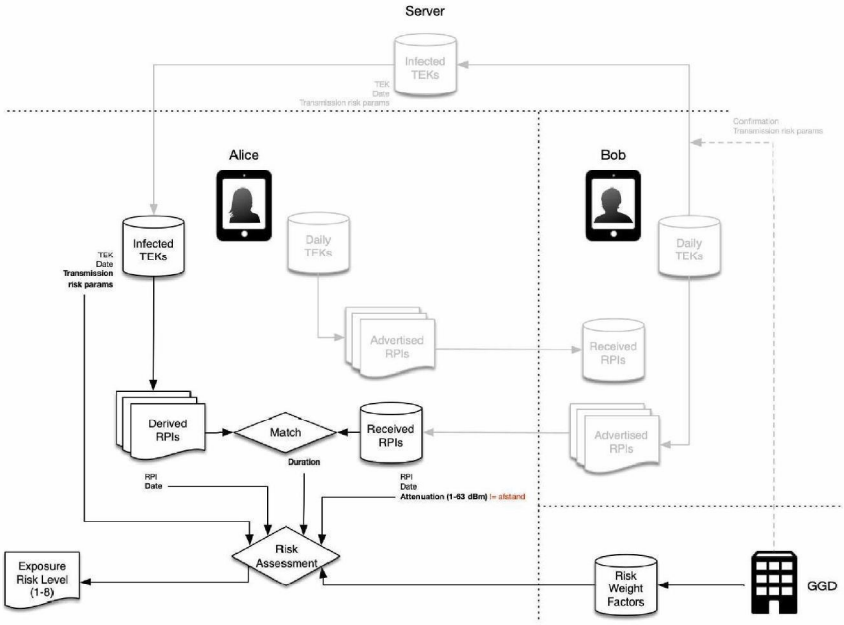
Once the keys are available on the CDN, clients can download the sets of infected keys and use these to verify if they have encountered an infected person.



This match takes place entirely on the user's phone. By deriving the set of RPIs from the infected TEK that a user received, it can compare these to the RPIs it has recorded. If there is a match, it can use its previous recordings to determine the approximate duration of the encounter.

Risk assessment

Once the device has determined that it has seen the phone of an infected user, the next step is to calculate the risk that the phone's owner could be infected. This assessment is performed on the phone.



The following parameters are available to the calculation:

1. The 'attenuation' (an approximation of how near the phones were)
2. The date on which the encounter happened (e.g. if it was longer ago, the risk might be lower)
3. The duration of the encounter
4. The transmission risk parameter, if provided by GGD

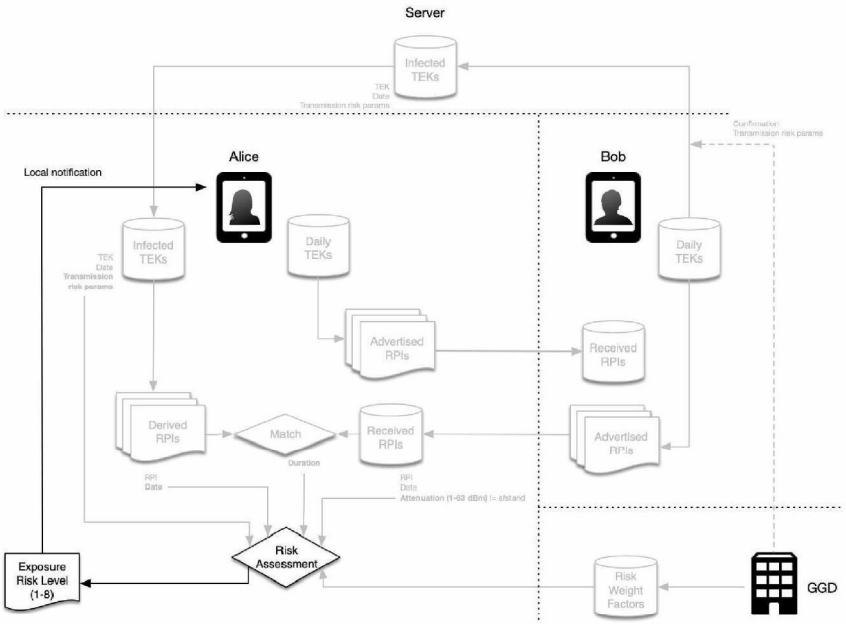
The GAEN protocol breaks each parameter up into 8 buckets. By assigning values to these buckets, GGD can influence the calculation of the risk. Since these values are not defined by technology but should be provided by experts who can assess the risk, the architecture prescribes that the input values for this calculation can be retrieved from a server, so that they can be adjusted over time.

For an understanding of how these buckets and parameters work, we have made available a test sheet that can be copied and used to get an understanding of the calculation: https://docs.google.com/spreadsheets/d/18RVkBjahiVxd3lLgOS7weKEoc8KxxTufZVQ2exWOgR4/edit?usp=sharing

Note: a prior version of the GAEN protocol allowed these experts to not only assign scores to the buckets, but also to provided weights that could be used to make, for example, duration more important than attenuation. These weights have been removed in the mid-May 2020 version of the GAEN protocol.

Notification of exposure

The final step in the flow is to notify the user of an exposure if the risk calculation exceeds a certain threshold.

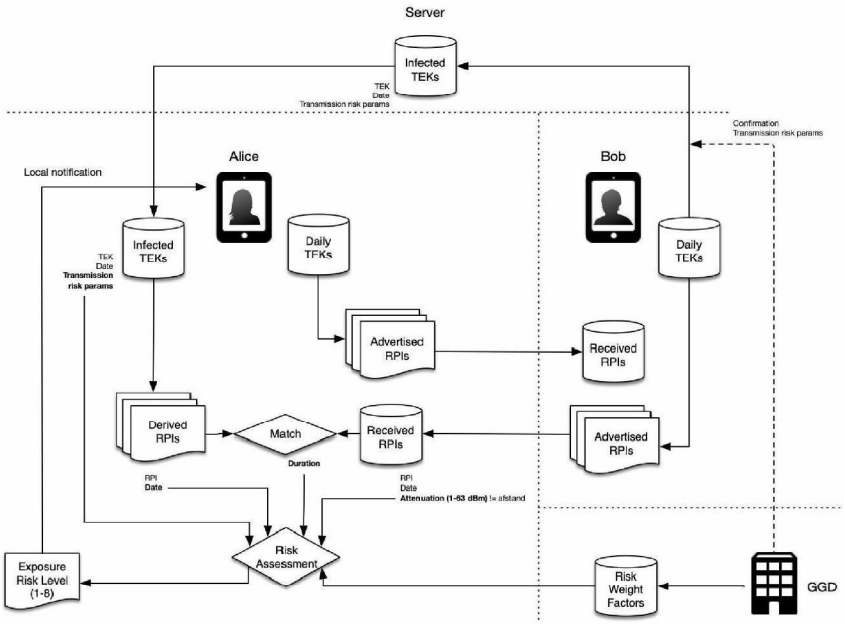


Note: the diagram indicates a calculated risk level of 1-8, but after the weights were removed from the latest version of the GAEN protocol, this level is now a number between 0 and 4096 (or 255; parts of the GAEN documentation mention a cap at 255)

If the level exceeds a threshold to be defined by experts, the app can provide the user with a notification. This happens entirely locally on the user's device. The notification is NOT sent by a server.

Summary

The following diagram provides an overview of all the above steps, in a single picture:



Key elements to be built

- A mobile app. Key here is penetration, broad participation (supporting old android phones and small MB/Bundles & prepaid are important)
- A distribution service that distributes the "public" keys. Optimised for best effort, bulk distribution of essentially static files that change a few times per day.
- A submission service which sees very little traffic (just those getting tested that day) but which should be optimised for 'not losing data' and authorizing the upload..
- A portal for health staff that pushes through the infected keys; and, as it is in key primary workflows of the health authorities, should be very stable and 'always up'. It is also the system that is closest to (what little) data that is sensitive; so it will require authentication of an appropriate level. Integration with the workflows of the health authorities should be kept to a minimum so that health and personal information that is not needed for solid exposure notification, is confined to the health system and can not be stored inside the app ecosystem / backends.

System Landscape

Based on the flows in the previous chapter and the elements that need to be built, we can provide a system landscape that illustrates how each component relates to the other components:

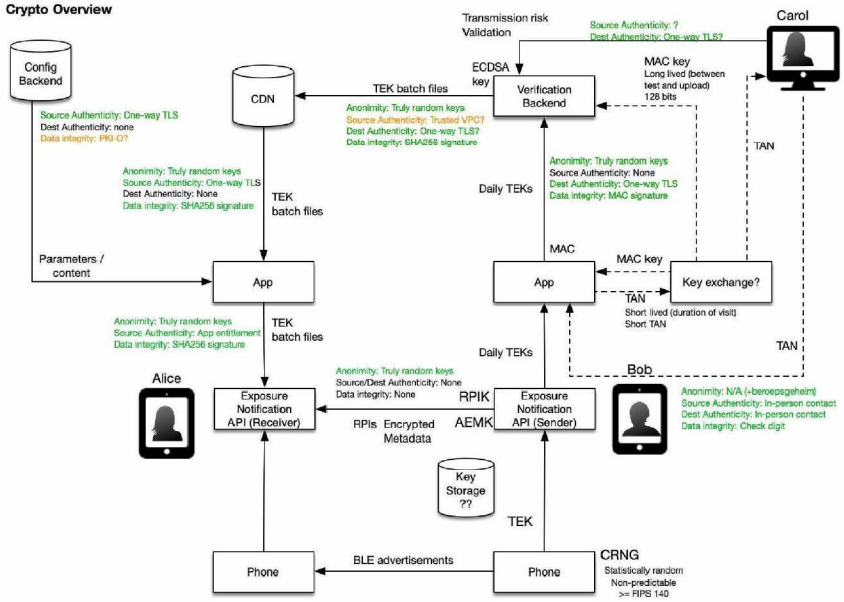
TODO more detailed description of system landscape

Security & Privacy

Overview

The details surrounding the security and privacy implementation of the Proof of Concept is laid out in the document 'Corona Cryptografie Raamwerk', which is currently being prepared. While the details and rationale surrounding the choices can be found in that document, for this solution architecture we have outlined the key principles from the preliminary version in the following diagram.

NOTE: Some items, such as the orange items, dotted items and items with question marks are currently under consideration or to be investigated, so this is not a complete picture yet. It will be updated alongside progress in the Cryptografie Raamwerk.



Each part of the diagram tries to address a number of key aspects:

- Anonymity: how is the anonymity / privacy of the user protected
- Source authenticity: how can we ensure that data comes from a known / trusted source

- Destination authenticity: how can we ensure that data gets sent to a known / trusted source
- Data integrity: how can we ensure that the data has not been tampered with.

Blinding

To ensure that an eavesdropper in or on the network can not derive any contamination or exposure conclusions from the traffic he can see, we take the following measures:

1) The upload should use TLS to protect the contents of a request
2) Apps should randomly execute 'decoy' requests that can't be distinguished (from the outside) from a real request, so that the fact that a request is made, does not reveal anything about the user. Since TLS will protect the URL of the request, we can use explicit decoy names such as '/decoys' instead of /upload', so that such requests can be dropped early in the infrastructure and don't reach the actual application.
3) The request signatures and payload for POST/PUT requests such as the upload of keys, should be exactly equal so that an eavesdropper is not able to derive from the length or signature of a request that a user is uploading fake keys. (If necessary the payload should be padded)
4) Requests should not use headers that can be used to infer information about a user. E.g. a language accept header that downloads only a specific language file. It is better to download all languages and make the decision client side.

TODO: Establish the frequency of decoy calls to provide sufficient blinding.

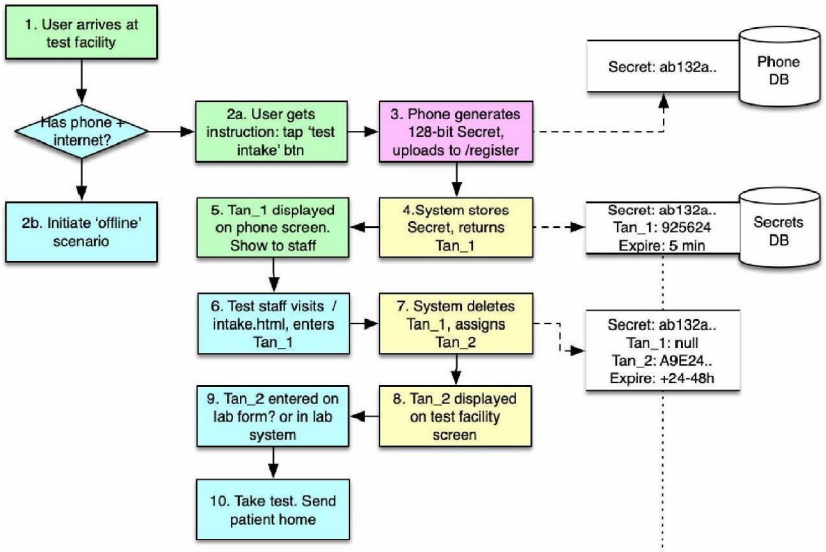
Lab result validation flow

To ensure that only keys are uploaded that belong to positive test results, the following process can be followed. (TODO: This is currently being validated to see if this can be matched with the logistical processes surrounding the test / this is seen from a security / privacy perspective, which is why it is in this chapter, and will be moved do an appropriate chapter once it has been validated)

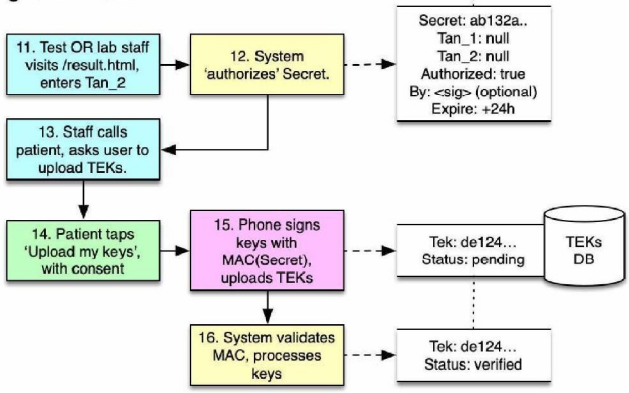
The flow is designed to:

- Minimize the effort for users and professionals
- Maximize privacy
- Move the exchange of codes to a place in the process where there's less chance of error (less stress)
- Be applicable with 'low tech' (adding conveniences such as a QR are 'on top' of the basic low tech flow and not a requirement).
- The low tech nature also allows to use channels such as a phone call to exchange tans.

Moment 1: Taking the test



Moment 2: Getting test result

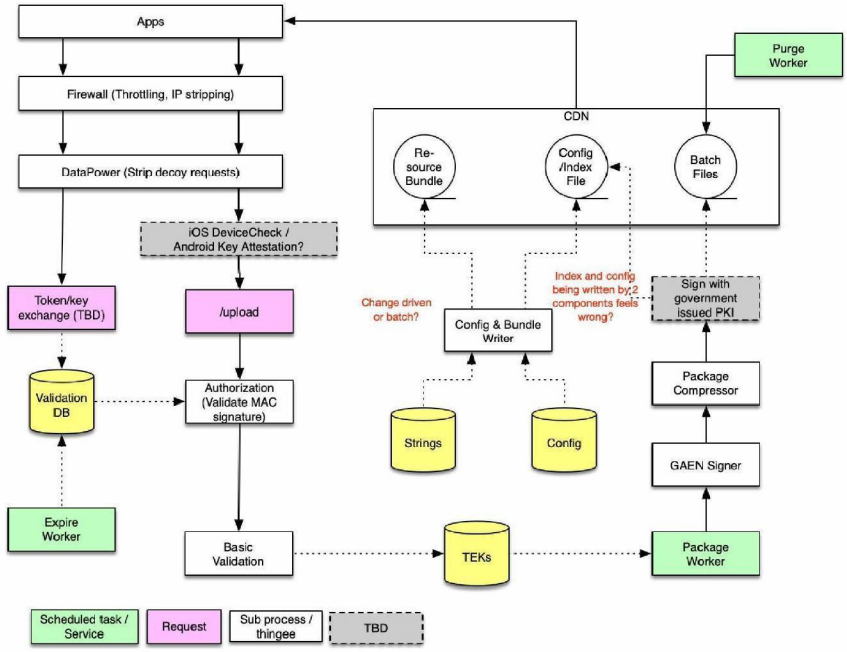


TODO: Add offline scenario.

Backend Considerations

Backend overview

The following diagram illustrates the required backend components to be able to satisfy the requirements:



Infrastructure

Defining the details of the infrastructure is outside the scope of this solution architecture, but from an architectural perspective the following requirements for the infrastructure apply:

- Server parts of the solution should be hosted in a government datacenter that is monitored by a SOC (Security Operations Center).

- The infrastructure should be able to scale to meet the volumes that can be derived from the adoption requirements as set in the Programma van Eisen.

- The infrastructure will have a guaranteed uptime of 99.x%

App/Device Verification

The Google Reference Implementation of a backend for exposure notification suggests the use of DeviceCheck (iOS) and Safetynet Attestation (Android) to validate if a request comes from a genuine android device and/or from the official app:

- https://github.com/google/exposure-notifications-server/blob/master/docs/server_functional_requirements.md

The documentation for DeviceCheck and Safetynet Attestation can be found here:

- https://developer.apple.com/documentation/devicecheck
- https://developer.android.com/training/safetynet/attestation

TODO: These checks are controversial. First, it relies on a server API at Apple and Google, which can be down and could be a privacy risk.

The Android Developer blog states:

"*In other words, not all users who fail attestation are necessarily abusers, and not all abusers will necessarily fail attestation. By blocking users solely on their attestation results, you might be missing abusive users that don't fail attestations. Furthermore, you might also be blocking legitimate, loyal customers who fail attestations for reasons other than abuse*"[1]

The safetynet attestation documentation further states about attestation failure: *"Most likely, the device launched with an Android version less than 7.0 and it does not support hardware attestation. In this case, Android has a software implementation of attestation which produces the same sort of attestation certificate, but signed with a key hardcoded in Android source code. Because this signing key is not a secret, the attestation could have been created by an attacker pretending to provide secure hardware*[2]*".*

[1] https://android-developers.googleblog.com/2017/11/10-things-you-might-be-doing-wrong-when.html
[2] https://developer.android.com/training/articles/security-key-attestation

This leads us to believe that when applying these checks, we could be rejecting keys from legitimate users, while not preventing any attack. TODO: Get more information and clarity around this check.

App Considerations

Native vs hybrid development

Mobile apps will be implemented as native applications, with Swift as the language used for iOS development and Kotlin for Android development.

(Note: The Google example application for the GAEN protocol was written in Java, but a rationale for this wasn't provided. Therefore we are following the general consensus that Kotlin is the language of choice for all new app developments.)

We have carefully considered whether to do native development or use a cross platform technology, and the following arguments were leading:

- There are no requirements or constraints that dictate the use of cross platform tools.
- The GAEN protocol implementations are native APIs
- The available development team has sufficient capability in native app development.
- It is expected that, should we need help from Google or Apple to resolve issues while implementing their protocol, they can do so more efficiently if we use the development stack provided by the vendors.

Lifecycle Management

Apps run on the user's device and updates require a review process that is not entirely under our control. To mitigate these factors that are outside our control, apps should implement a form of lifecycle management. This includes the following features:

- Configuration values or content that are expected to change should be retrieved from a server.
- Apps should offer a 'forced upgrade' (i.e. if a new version is available that fixes a critical bug, it should be possible to force the user to upgrade). It is recommended that this forced upgrade can distinguish between the base operation (recording encounters) and other users, so that while we wait for the user to upgrade, they can still record their exposures.

GAEN protocol considerations

Challenges to be addressed

There is a challenge in getting the complete set of keys uploaded on the day of the test result. Google and Apple will hold the current TEK key until roughly midnight, so the last key can't be uploaded until then. Releasing the keys requires user consent, but this consent is not a problem since it is valid for 24 hours, so as long as we deliver the last key within 24 hours, that is covered. But the potential risk of this 'key embargo' is delay: the key is relevant to people who have met a person on the day of that person's test result, but they won't be notified until the next day. Since someone who was at risk won't be infectious right away, there is still time to advise this person to take measures. Still, a delay is a delay, so one of our proposals contains a suggestion to make the key release immediate.

From a technical perspective, the apps will have to implement a delayed key upload that is scheduled in the background, so that the key, once it becomes available, gets added to the pool of keys. Since background operations are always a risk (the user might have turned off their phone), this is something to take into account.

Proposed enhancements to the GAEN protocol

There are some additional considerations that are not easy to work around, which is why we have created the following change requests for enhancements to the GAEN protocol:

- GACT-TIME - A proposal to remove the 'time' (and optionally the 'date') characteristics from the protocol, so that RPIs can not be linked to a specific time of the day, to adhere to the 'Use as few details as possible' guideline.
- GACT-PKI - A proposal to add a PKI based validation chain to TEK batch files, so that on a transparent CDN, a client can securely verify whether batches of TEKs originate from an official government source.
- GACT-VF - A proposal to add a 'validated feedback' loop, which allows a user to 'prove' that he has received a notification. This is important to securely implement requirements such as requirement F12 (the ability to get tested based on a notification).

Proposals that have been drafted, but later decided that we do not need them:

- GACT-VF-EW - A proposal that builds on top of the above mentioned GACT-VF and adds an 'early warning' system by implementing a secondary contact tracing protocol.

Although it will not be used in the Proof of Concept app, we have published it for other parties to consider.