

Interoperable Digital Proximity Tracing Protocol (IDPT)

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This is a second version of a document that describes the IDPT protocol. We are working on another document in which we make an analysis of privacy, security and implementation of this protocol.

Introduction

This document introduces the Interoperable Digital Proximity Tracing (IDPT) protocol, that can be run by applications that also run the DP3T digital proximity tracking protocol¹ to enable interoperability with the ROBERT digital proximity tracking protocol². We believe that the same mechanism can be adapted to allow interoperability between other decentralized and centralized digital proximity tracing protocols, but analysis of this is kept out of the scope of the document.

The IDPT protocol avoids the reidentification attack of positive-tested users of the centralised system that was claimed to be an inherent property of interoperability systems³, as in IDPT the system **does not publish the list of decentralised ephemeral identifier that were at risk of exposure of users of app R**. Moreover, it avoids the possibility of creation of proximity graphs for users of IDPT who were in contact with users of ROBERT.

As is well known, the current iOS and Android Exposure Notification API⁴ only supports protocols of the distributed class. Due to this lack of support for centralized approaches, the implementation of the IDPT protocol has the same known difficulties as ROBERT, which appear mainly when applications are running in the background. Additionally, since devices must transmit more BLE beacons per second, we expect that devices running IDPT will have higher power consumption compared to implementing a pure DP3T mechanism.

We believe that, in practice, the use of IDPT in countries where majority of users of DP3T-type applications should be optional, mainly in areas where the presence of R nodes is likely (for example, large cities, tourist areas, airports, etc.). Another situation in which the use of IDPT could be adequate is when a user of the app I visits a country where the majority of the population uses R application. In addition, a country could introduce a DP3T application in a first phase, and only later incorporate IDPT.

¹ <https://github.com/DP-3T/documents/blob/master/DP3T%20White%20Paper.pdf>

² https://github.com/ROBERT-proximity-tracing/documents/blob/master/ROBERT-specification-EN-v1_0.pdf

³ U. Lukas et al. "Interoperability of decentralized proximity tracing systems across regions"

⁴ <https://developer.apple.com/documentation/exposurenotification>

Assumptions and notation

We assume that in the same geographic area we have users of 3 different types of digital proximity tracking applications: R, D and I:

- Application R implements the ROBERT protocol.
- Application D implements the DP3T protocol.
- Application I implements the DP3T + IDPT protocols, that is, DP3T with the added IDPT protocol.

We assume that applications I and D interoperate, which means that if a user of the application D/I reports to the app a positive tests, devices of users of the application I/D who were exposed will be notified.

In addition, we will show that we can have interoperability between the I and R applications, meaning that **if a user of the application R/I reports to the app a positive test, devices of users of the application I/R who were exposed will be also notified.**

As we will continuously refer to devices, users, and backend servers from the three protocols, we introduce the following notation to simplify the description of the mechanism:

- For $X = R, D$ and I , "X-device" is a mobile device that runs an instance of a X-type application, "X backend server" is the backend server used by an application X, while "X-user" refers to a user of an application X.
- As prescribed by ROBERT, the R backend server generates ECC+EBID values, which will be called R-ECC+EBID. Additionally, when these fields are transmitted in a beacon, the fields "Time" and "MAC" are added.
- As prescribed by DP3T, nodes D and I generate EphID values, called D-EphID and I-EphID respectively.
- I-devices also generate EBID values called I-EBID. I-EBIDs have not attached an ECC field.
- ICDP requires the use of a relay, which we call I-relay.

The R-ECC+EBID+Time+MAC, D-EphID, I-EphID and I-EBID values are 16-byte strings, transmitted in the payload of packets type ADV_IND Bluetooth Low Energy, which we will call BLE-beacons or just beacons.

We assume that there are some metadata that distinguish the beacons emitted by different types of applications. More specifically, in the case of the app I, we assume that it is possible to distinguish beacons carrying I-EphIDs and I-EBIDs.

Backend server and relay

Protocols DP3T and ROBERT require the use of back-end servers.

The main functionalities of ROBERT backend servers are:

- Generate Ephemeral Bluetooth IDs (EBID) and Encrypted Country Codes (ECC) for each R-device. $EBID = ENC(K_s, epoch; ID)$, where K_s is a cryptographic key on the R backend server, while $ECC = MSB(AES(K_G, EBID \parallel 0^{64})) \text{ XOR } CCA$, where CCA is a country code, and K_G is a key shared among the federated backend servers. The epoch is a discretization of time in units of 15 minutes. R-devices regularly pull these values.

- Maintain an IDTable that allows the back-end server and uses a ROBERT risk score algorithm for determine the exposed users of the application R, this being one of the main differences with a protocol such as DP3T, in which the calculation of the risk score is performed in the mobile device.
- Be responsible for federation with other application servers that interoperate with application R.

The main functionalities of DP3T backend servers and I backend servers are:

- Forward a compacted representation of the EphIDs of the users who reported a positive test to the devices of other users of the application. Using this information, mobile devices can verify if they have received these EphIDs, which means that they were in proximity of a user who tested positive. Risk score is evaluated in the devices -this is a main feature of DP3T- using parameters such as the intensity of the received Bluetooth signal or the duration of the contact to quantify the risk of exposure to users.
- Achieve interoperability of DP3T applications.

IDPT requires additionally the use of a relay node, that we call I-relay. Its main functionalities are:

- Allow the exchange with the R backend server of ephemeral identifiers of devices of R-users and I-users applications who tested positive.
- Post lists of values that allow I-devices check whether they were in exposure contact with a device of a user of the application R who reported a positive test.

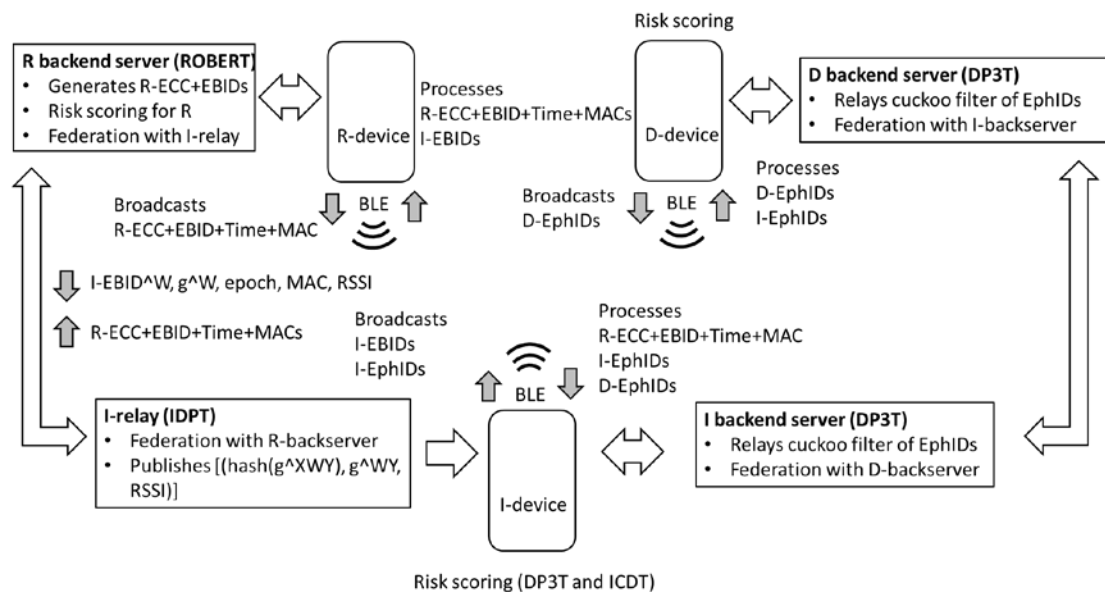


Figure 1: Functional elements

Ephemeral IDs generation

The R backend server is responsible of generating the R-ECC-EBIDs. In DP3T, however, the devices are the ones responsible of generating the EphIDs, using a hash of a secret seed, which is changed every time epoch.

Also, and this is a key feature of IDPT, **I apps generate another kind of ephemeral bluetooth ID that we will call I-EBID**. I-EBIDs are calculated as in a 16 byte Diffie-

Hellman exchange: each I-device generates a sequence of secret numbers $\{X_n\}$ and computes a sequence $\{I\text{-EBID}_n\} = g^X X_n$. These X_n values are stored in the I-device for several days (for example, 21 days) and are kept secret.

The format of the 3 types of payloads transmitted in the BLE beacons by the apps R, I and D is shown in the figure:

Payload of beacons for apps R (ROBERT)

ECC	EBID	Time	MAC
8 b	64 b	16 b	40 b

Payload of beacons for apps I (IDPT)

EBID = g^X
128 b

Payload of beacons for apps D and I (DP3T)

EphID
128 b

Figure 2: 16 byte payloads of ADV_IND BLE packets

Note that ROBERT includes some fields in the beacon payloads (Time and MAC) that prevents against identity attacks and mitigates against replay attacks.

Federation and backend server interconnection

The federation between applications that use ROBERT is based on the use of the field ECC, that encrypts a country code. This country codes identifies whether the data (R-ECC+EBID+Time+MAC, time) must be processed locally or forwarded to another ROBERT backend. For achieving interoperability with IDPT, the R backend server must be able to identify the data to be forwarded to the I-relay by another means, as I-EBIDs are transmitted without an encrypted country code.

Proximity Discovery

- R-devices broadcast R-ECC + EBIDs plus two fields “Time” and “MAC” on the payload of Bluetooth Low Energy (BLE) ADV packets (BLE beacons), which have a payload of 16 bytes.
- D-devices and I-devices transmit D-EphID and I-EphID on BLE beacons.
- I-devices also broadcast I-EBID on BLE beacons.

Ephemeral IDs processing

- R-devices store R-ECC+EBID+Time+MAC and I-EBIDs.
- D-devices store D-EphIDs and I-EphIDs
- I-devices store I-EphIDs, D-EphIDs and R- ECC+EBID+Time+MACs.

This internal storage adds the reception epoch and possible additional information, such as the RSSI of the BLE signal.

Exposure Status notifications

For all three types of applications, when a user has a test COVID+, she receives an authentication token and voluntarily decides if she will use this token to report the application. If the user decides to report the test COVID+ to the application, the following procedures are followed:

User of app D reports a test COVID+

Application D reacts as prescribed by the DP3T protocol, and since we assume interoperability between applications D and I, devices of exposed users of applications I and D are notified. The I-devices and D-devices applies a DP3T Risk Scoring algorithm to decide whether users should be notified. Unfortunately, R-devices applications do not receive notifications, since R and D do not interact.

User of app I reports a test COVID+

The application I reacts as prescribed by the DP3T protocol, which means that devices of users of both I and D apps are notified as we are assuming interoperability between the two applications. Again, devices apply a Risk Scoring algorithm to decide whether users should be notified.

In addition, the I-device transfers the received R-ECC+EBID+Time+MAC -which have been stored for several days (for example, 21 days)- to the I-relay. I-devices do not transfer received I-EBIDS to the I-relay, as received I-EBIDs are not even stored by I-devices. This is not necessary since the other I-users are notified using the distributed mechanisms.

The I-relay de-encrypts the field ECC from the received R-ECC+EBIDs and forwards the information to the R backend server⁵. The R backend server runs a Risk Scoring algorithm which decides which users of apps R who were in contact with an I-user who tested positive are notified.

In other words, if an I-user has a test COVID+, exposed devices of applications I, D, and R are notified.

Obviously, the I-relay cannot de-encrypt the EBID field since these EBIDs were generated by R backend server using a secret key K_S .

User of app R reports a test COVID+

The application R reacts as prescribed by the ROBERT protocol: it transfers the received R-ECC+EBID+Time+MAC and I-EBIDs (i.e. the *LocalProximityList*) to the R backend server. This LocalProximityList must include now a field that allows the identification of I-EBIDs for a given I application.

In order to anonymize the transfer of I-EBIDs, and avoid the possibility of creation of proximity graphs in the R-backend and in the I-relay, the R-devices chose a random

⁵ In this document we do not address the case of multiple R applications in the same geographical area

number W^6 , and in the LocalProximityList transfer the pairs $(I\text{-EBID}^W, g^W) = (g^{XW}, g^W)$. Note that RSSI values or other additional info could be also included here.

The R backend server will separate these pairs (g^{XW}, g^W) from the R-ECC+EBID+Time+MACs. The R-ECC+EBID+Time+MACs are processed locally by the R backend server, which runs a risk scoring algorithm that decides which R-users should be notified. It transfers the list $[(g^{XW}, g^W)]$ to the I-relay.

The I-relay receives the list $[(g^{XW}, g^W)]$, and generates one secret numbers Y per received pair⁷. For each pair (g^{XW}, g^W) , it computes $(g^{XW})^Y$ and $(g^W)^Y$. These values will be equal to g^{XWY} and g^{WY} for some secret value X of an I-user who was in contact with the R-user who reported a positive test.

The I-relay publishes a list of values $[(\text{hash}(g^{XWY}), g^{WY})]$, with may be associated with other additional information such as RSSI of the received beacon at the R-device.

I-devices periodically pull this list, e.g. twice daily. They compute $\text{hash}((g^{WY})^{X_n}) = \text{hash}(g^{X_n WY})$ for the values stored in the sequence $\{X_n\}$ that were generated by the device and all the values $\{g^{WY}\}$. Then, they check if there is an intersection of the calculated values and some of the hashes in the list. They also determine the time epoch of the exposition. The number of computations would be $21 \cdot 4 \cdot 24 \cdot \text{length}([(\text{hash}(g^{XWY}), g^{WY})])$ ⁸.

Once the device determines the intersections, the application can run a risk scoring algorithm that decides whether the I-user is notified. This algorithm is discussed in the next section.

As a conclusion, we see that if an R-user has a test COVID+, exposed devices of applications R, and I are notified. Again, D-devices are not notified as R and D do not interoperate.

Risk Scoring for IDPT

The algorithm that evaluates the risk scoring from exposures with R-users who have reported a positive test would be different from the one used for DP3T. The main difference comes from the fact that in general the device cannot determine the R-ECC+EBID+Time+MACs of the users who reported a positive test. The only information it has is the set of received $\text{hash}(R\text{-ECC+EBIDs})$ and signal strengths during the time interval during which the X_n that indicated an exposure were transmitted.

As we mentioned before, one possibility is to modify the operation of R-devices in such a way the LocalProximityList includes RSSI values of received beacons, meaning that the Risk scoring algorithm would be essentially the same as in DP3T.

⁶ It can also chose a different W per g^X .

⁷ If the values W are chosen to be different per g^X , a unique value Y would suffice.

⁸ If this computations becomes too big, several techniques can be used. For instance, the R-device could also include $\text{hash}_n(g^X)$ for a small number n (e.g. $n=8$), meaning that for a given tuple $(\text{hash}(g^{XWY}), g^{WY}, \text{hash}_n(g^X))$, the I-device only need to perform the checks with values its secret values X' for which $\text{hash}_n(g^X) = \text{hash}_n(g^{X'})$. A small value of n would ensure no reidentification of values g^X .

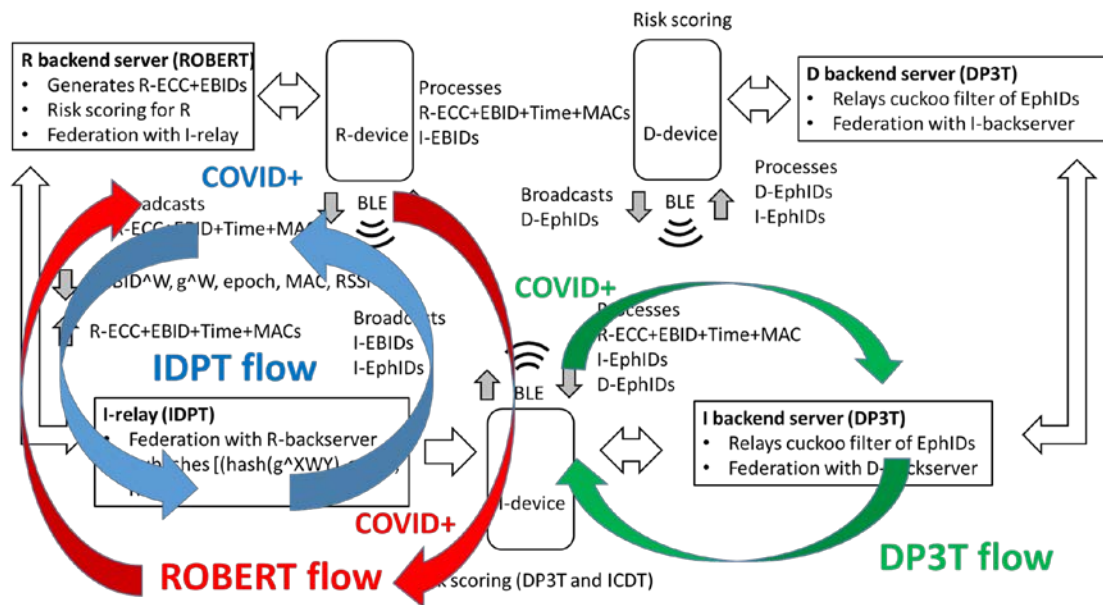


Figure 3: Flows of information

What should be modified?

- The system D does not need any change with regards to the standard decentralized approach.
- The R apps should be modified in order to recognize the beacons with I-EBIDs generated by I devices. The *LocalProximityList* uploaded to the R backend server in case the user reports a positive test should be modified to indicate the two different types of EBIDs (ECC+EBID+Time+MACs and I-EBIDs) to the R backend server. They should generate the pairs (I-EBID^W, g^W).
- The R backend server must be able to recognise the pairs (I-EBID^W, g^W) and transfer these values to the I-relay,
- In the I-devices, we must generate two types of content for the BLE beacons (i.e. I-EphIDs and I-EBIDs).
- The I app must have a faster beacon rate, that could lead to higher power consumption.
- The IDPT implementation will be not supported by the current Exposure Notification API of Google and Apple. This means that it will suffer from the same implementation difficulties of other centralized protocols as ROBERT.
- The BLE beacons must have some metadata that makes it possible for another application that receives the beacons to differentiate the 4 types of content: ECC+EBID+Time+MACs, D-EphID, I-EphID, I-EBID.
- We need to add an I-relay

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