Interoperable Digital Proximity Tracing Protocol (IDPT)

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This is a third version of a document that describes the IDPT 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 protocol[1] to enable interoperability with the ROBERT digital proximity tracking protocol[2]. 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 re-identification attack of positive-tested users of the centralised system that was claimed to be an inherent property of interoperability systems[3], 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 API[4] 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.

Assumptions and notation

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[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

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.
- We will use the sign “+” for string concatenation.

The R-ECC+EBID+Time+MAC, D-EphID, I-EphID values are 16-byte strings, while I-EBID is a 32 byte value. These values are transmitted in the payload of packets of Bluetooth Low Energy, which we will call BLE-beacons or just beacons. Depending on the specific protocol used, it may be required more than one packet to complete the transmission. The specific method used[5] is however kept outside the scope of the document, and for simplicity, during the description of the mechanisms we will assume that these values are transmitted using a single BLE beacon.

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 backend servers.

The main functionalities of ROBERT backend servers are:

[5] M. Cunche et al., “On using Bluetooth Low Energy for Contact Tracing”, https://hal.inria.fr/hal-02878346/document

- 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 server, while ECC = MSB(AES(K_G, EBID + 0^{64})) 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.

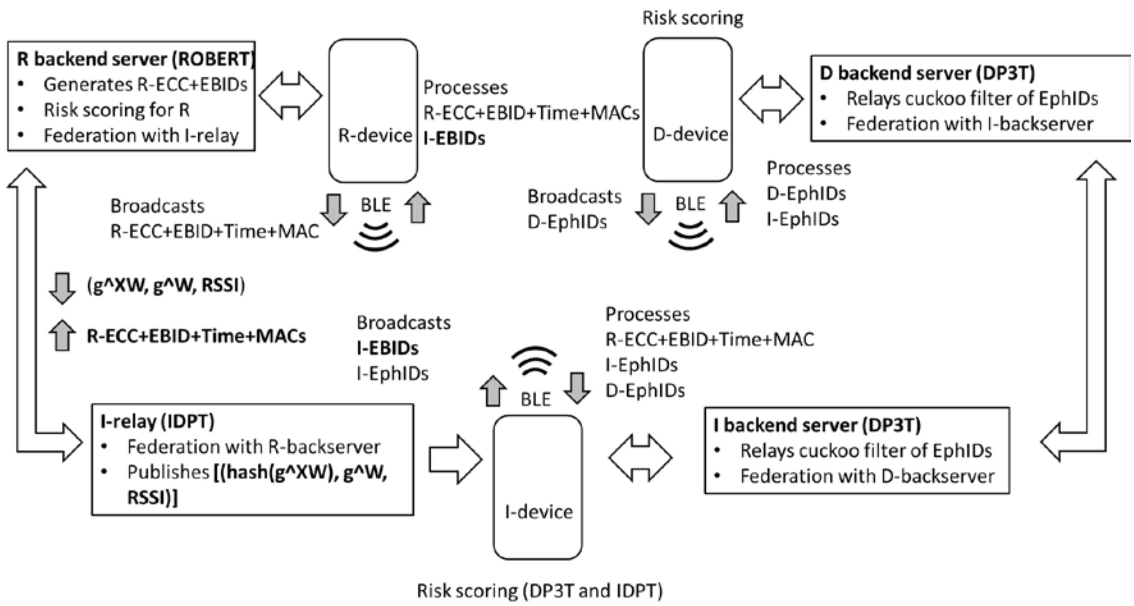

Figure 1: Functional elements

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 and the time epoch. Depending on the DP3T version used, the seed value is changed with a given periodicity (e.g. every day).

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 32 byte Diffie-Hellman exchange: each I-device generates a sequence of secret numbers $\{X_n\}$ and computes a sequence $\{\text{I-EBID}_n\}$ = $g^\wedge X_n$. Note that if we use an Elliptic Curve Diffie-Hellman (ECDH)[6], a product is used instead of an exponentiation. We will, however, keep the exponentiation notation through the document. These X_n values are stored in the I-device for several days (for example, 14 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:

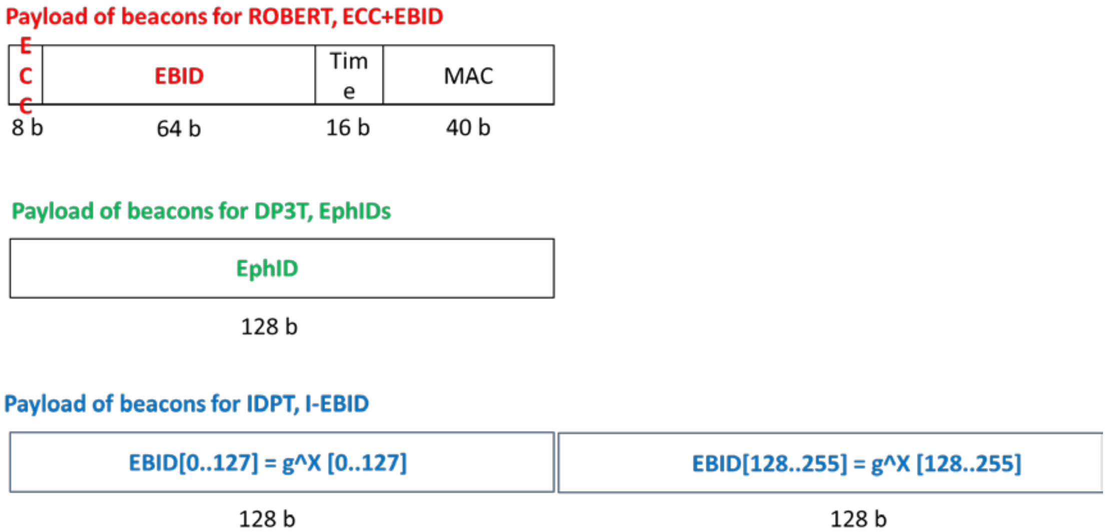

Figure 2: Payload formats. Note that depending on the method used for transmitting the I-EBIDS the format could be different.

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.

[6] For instance, based on the Curve25519, see D. J. Bernstein, “A state-of-the-art Diffie-Hellman function”, https://cr.yp.to/ecdh.html.

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, 14 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.

A suitable mechanism should be used to avoid the identification of the specific I-user that transfers the R-EBIDs to the I-relay.

The I-relay de-encrypts the field ECC from the received R-ECC+EBIDs and forwards the information to the R backend server. 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 (i.e. the *LocalProximityList*) to the R backend server.

Additionally, it also transfers information derived from the received I-EBIDs. The R-devices chose a random 32-byte number W per received g^X, and in the LocalProximityList transfer the tuples (H(I-EBID^W), g^W, RSSI)=(H(g^XW), g^W, RSSI)[7]. Where RSSI indicates the strength of the signal for the received beacon carrying the I-EBID. Note that other additional info could be also included here.

The use of this Diffie-Hellman exchange means that we can anonymize the transfer of I-EBIDs, and avoid the possibility of creation of proximity graphs in the R-backserver and in the I-relay.

The R backend server will differentiate these tuples (H(g^XW), g^W, RSSI) 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. The R-backend server transfers the list [(H(g^XW), g^W, RSSI)] to the I-relay.

The I-relay receives the list [(H(g^XW), g^W, RSSI)]. These values will be equal to g^XW and g^W 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 [(H(g^XW), g^W, RSSI)], wich may be associated with other additional information of the received beacon at the R-device.

I-devices periodically pull this list, e.g. twice daily. They compute $H((g^W)^X_n) = H(g^X_nW)$ for the values stored in the sequence $\{X_n\}$ that were generated by the device and all the values {g^W}. 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 use of the shared secret g^XW, in fact a hash of this value, avoids the possibility of re-identify R-users that has a COVID+ test, as the only device that can recognize this contact is the I-device that generated g^X.

The number of computations would be 14*4*24*length([(H(g^XW), g^W, RSSI)])[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

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[7] H is a cryptographic hash function.

[8] If this computations becomes too big, several techniques can be used. For instance, the I-device could only check values X_n for which there were any reception of R-ECC+EBIDs during the corresponding time epoch.

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. However, as we mentioned before, the list [(H(g^XW), g^W, RSSI)] includes RSSI values received by the R-device, meaning that the Risk scoring algorithm would be essentially the same as in DP3T, using the RSSI received by the R-device, instead of the locally measured RSSI for the beacon carrying an I-Ephid or D-Ephid.

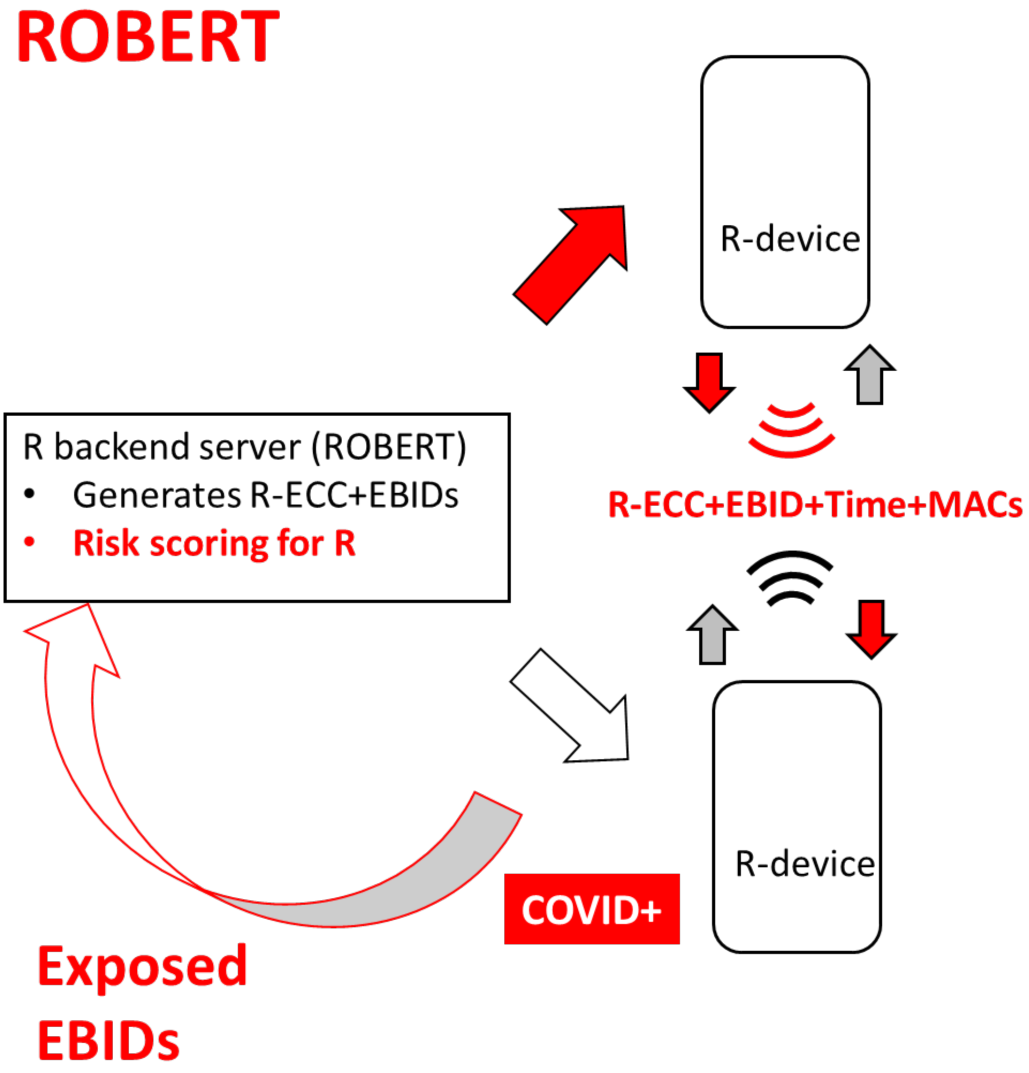
What should be modified?

- 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 tuples (H(I-EBID^W), g^W, RSSI).
- The R backend server must be able to recognise the tuples (H(I-EBID^W), g^W, RSSI) 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 is 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

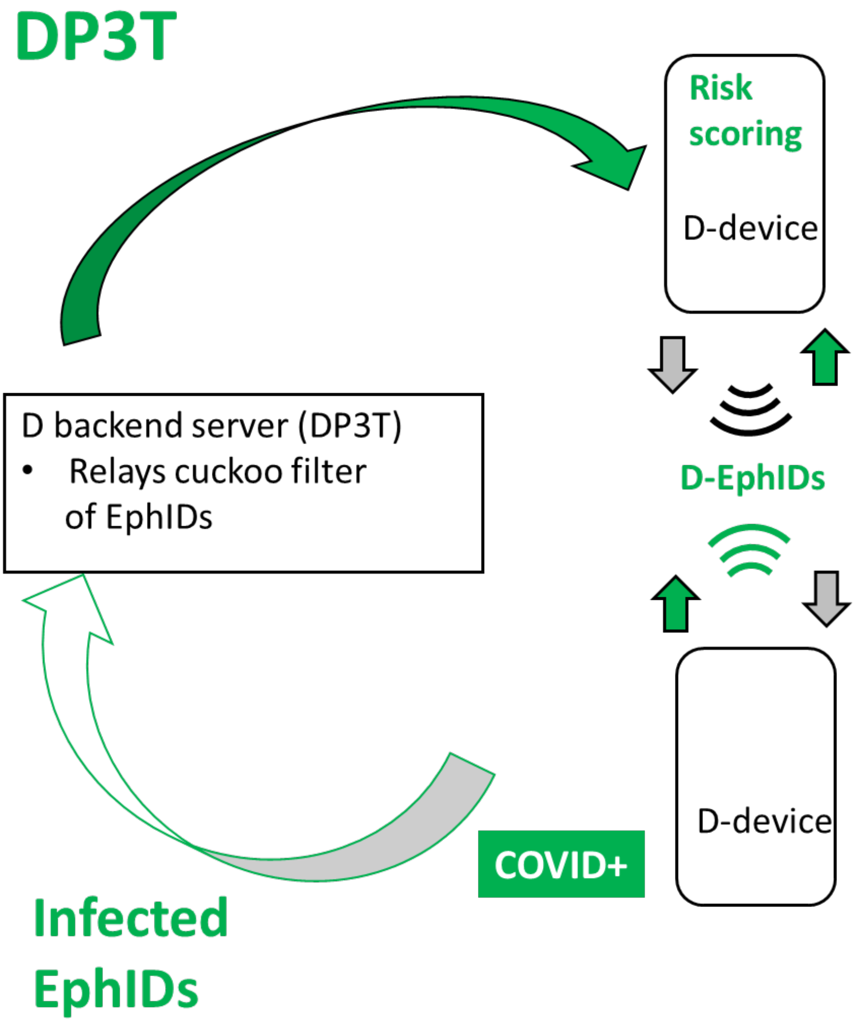
Appendix: Flows of information for different digital proximity tracing protocols

In order to understand better the differences between different proposals of digital proximity tracing protocols, it is interesting to study the flows of information.

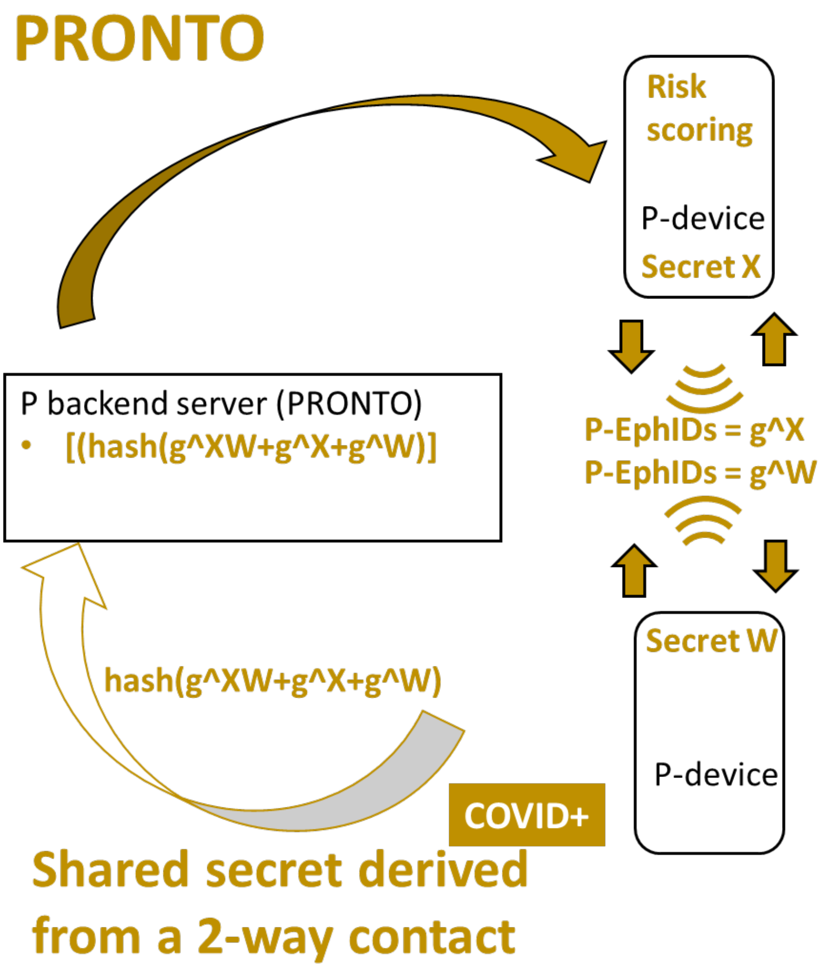
Flow for ROBERT



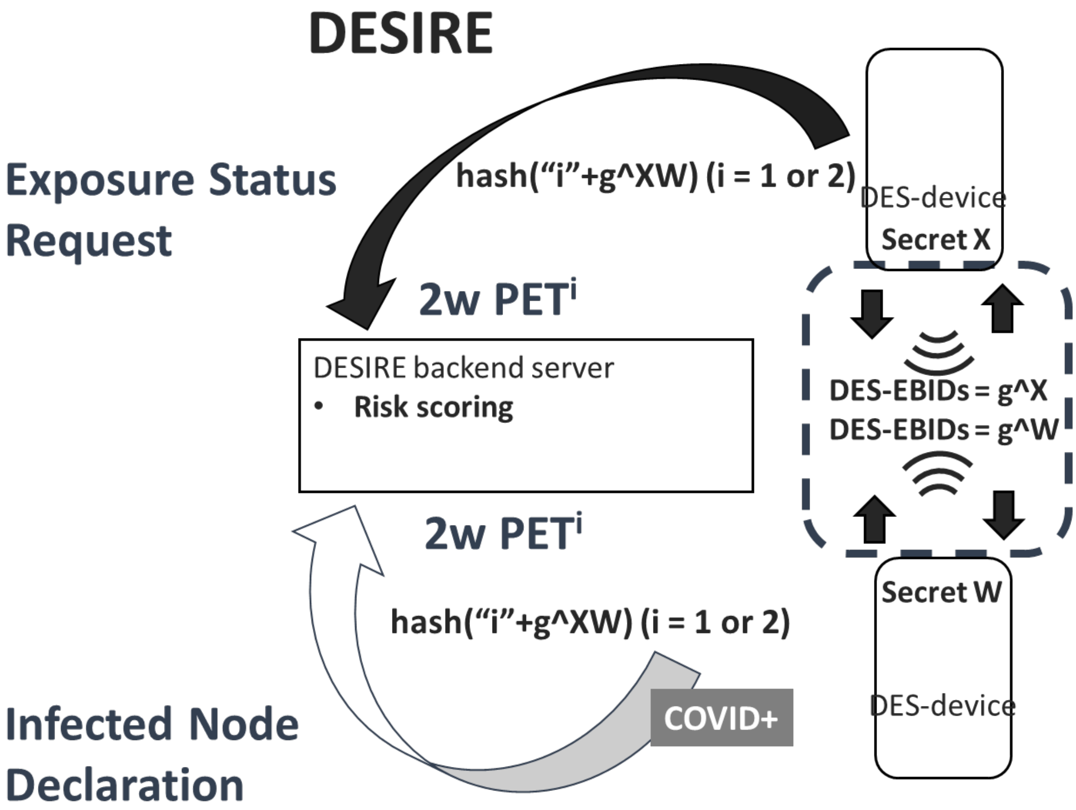
Flow for DP3T



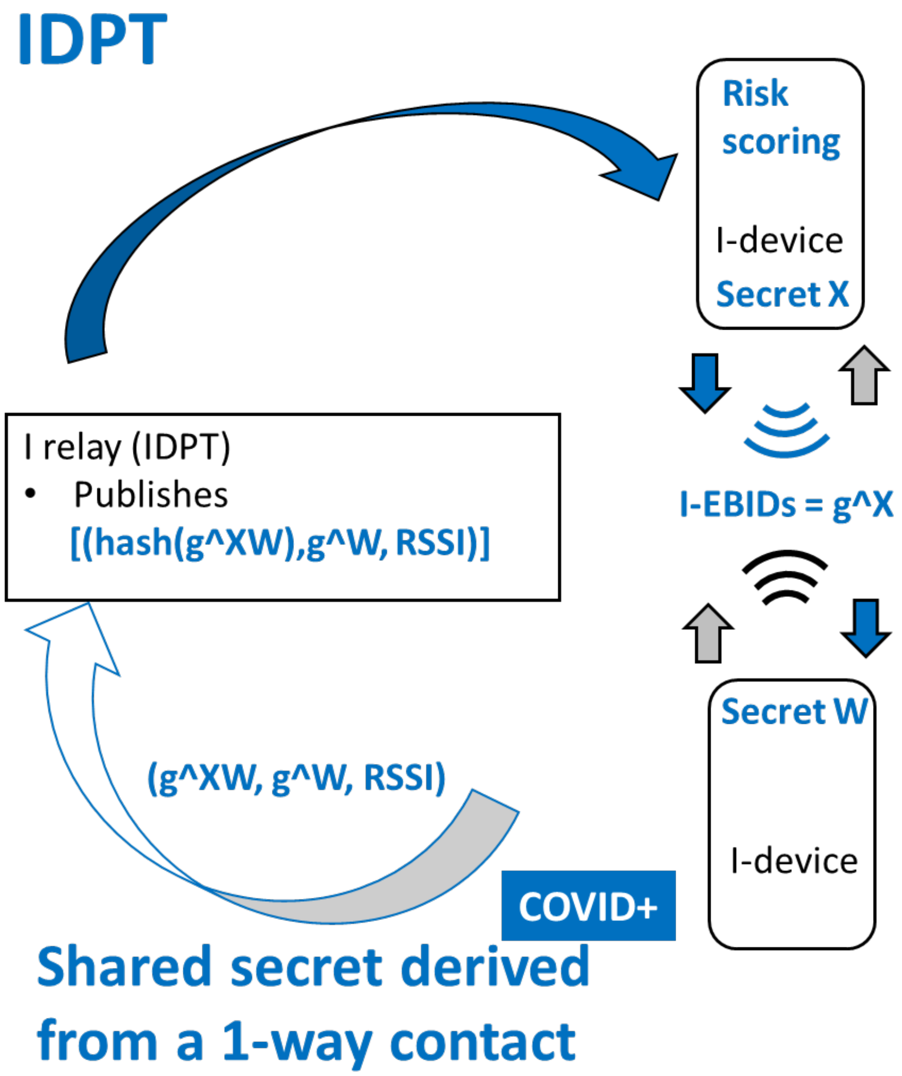
Flow for PRONTO



<u>Flow for DESIRE</u>



Flow for IDPT



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