GNU Taler Exchange Manual

Release 0.6.0pre1

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CONTENTS

CHAPTER

ONE

INTRODUCTION

This manual is an early draft that still needs significant editing work to become readable.

1.1 About GNU Taler

GNU Taler is an open protocol for an electronic payment system with a free software reference implementation. GNU Taler offers secure, fast and easy payment processing using well understood cryptographic techniques. GNU Taler allows customers to remain anonymous, while ensuring that merchants can be held accountable by governments. Hence, GNU Taler is compatible with anti-money-laundering (AML) and know-your-customer (KYC) regulation, as well as data protection regulation (such as GDPR).

GNU Taler is not yet production-ready, after following this manual you will have a backend that can process payments in "KUDOS", but not regular currencies. This is not so much because of limitations in the backend, but because we are not aware of a Taler exchange operator offering regular currencies today.

1.2 About this manual

This tutorial targets system administrators who want to install and operate a GNU Taler exchange.

1.3 Organizational prerequisites

Operating a GNU Taler exchange means that you are operating a payment service provider, which means that you will most likely need a bank license and/or follow applicable financial regulation.

GNU Taler payment service providers generally need to ensure high availability and have *really* good backups (synchronous replication, asynchronous remote replication, off-site backup, 24/7 monitoring, etc.).[1] This manual will not cover these aspects of operating a payment service provider.

We will assume that you can operate a (high-availability, high-assurance) Postgres database. Furthermore, we expect some moderate familiarity with the compilation and installation of free software packages. You need to understand the cryptographic concepts of private and public keys and must be able to protect private keys stored in files on disk. An exchange uses an *offline* master key as well as *online* keys. You are advised to secure your private master key and any copies on encrypted, always-offline computers. Again, we assume that you are familiar with good best practices in operational security, including securing key material.[2]

[1] Naturally, you could operate a Taler exchange for a toy currency without any real value on low-cost setups like a Raspberry Pi, but we urge you to limit the use of such setups to research and education as with GNU Taler data loss instantly results in financial losses.

[2] The current implementation does not make provisions for secret splitting. Still, the use of a hardware security module (HSM) for protecting private keys is adviseable, so please contact the developers for HSM integration support.

1.4 Architecture overview

Taler is a pure payment system, not a new crypto-currency. As such, it operates in a traditional banking context. In particular, this means that in order to receive funds via Taler, the merchant must have a regular bank account, and payments can be executed in ordinary currencies such as USD or EUR. Similarly, the Taler exchange must interact with a bank. The bank of the exchange holds the exchange's funds in an escrow account.

When customers wire money to the escrow account, the bank notifies the exchange about the incoming wire transfers. The exchange then creates a *reserve* based on the subject of the wire transfer. The wallet which knows the secret key matching the wire transfer subject can then withdraw coins from the reserve, thereby draining it. The liability of the exchange against the reserve is thereby converted into a liability against digital coins issued by the exchange. When the customer later spends the coins at a merchant, and the merchant *deposits* the coins at the exchange, the exchange first *aggregates* the amount from multiple deposits from the same merchant and then instructs its bank to make a wire transfer to the merchant, thereby fulfilling its obligation and eliminating the liability. The exchange charges *fees* for some or all of its operations to cover costs and possibly make a profit.

Auditors are third parties, for example financial regulators, that verify that the exchange operates correctly. The same software is also used to calculate the exchange's profits, risk and liabilities by the accountants of the exchange.

The Taler software stack for an exchange consists of the following components:

- HTTP frontend The HTTP frontend interacts with Taler wallets and merchant backends. It is used to withdraw coins, deposit coins, refresh coins, issue refunds, map wire transfers to Taler transactions, inquire about the exchange's bank account details, signing keys and fee structure. The binary is the `taler-exchange-httpd`.
- Aggregator The aggregator combines multiple deposits made by the same merchant and (eventually) triggers wire transfers for the aggregate amount. The merchant can control how quickly wire transfers are made. The exchange may be charge a fee per wire transfer to discourage excessively frequent transfers. The binary is the `taler-exchange-aggregator`.
- Auditor The auditor verifies that the transactions performed by the exchange were done properly. It checks the various signatures, totals up the amounts and alerts the operator to any inconsistencies. It also computes the expected bank balance, revenue and risk exposure of the exchange operator. The main binary is the `taler-auditor`.
- Wire plugin A wire plugin enables the HTTP frontend to talk to the bank. Its role is to allow the exchange to validate bank addresses (i.e. IBAN numbers), for the aggregator to execute wire transfers and for the auditor to query bank transaction histories. Wire plugins are *plugins* as there can be many different implementations to deal with different banking standards. Wire plugins are automatically located and used by the exchange, aggregator and auditor.
- DBMS Postgres The exchange requires a DBMS to stores the transaction history for the Taler exchange and aggregator, and a (typically separate) DBMS for the Taler auditor. For now, the GNU Taler reference implemenation only supports Postgres, but the code could be easily extended to support another DBMS.

CHAPTER

TWO

INSTALLATION

Please install the following packages before proceeding with the exchange compilation.

- GNU autoconf >= 2.69
- GNU automake >= 1.14
- GNU libtool >= 2.4
- GNU autopoint >= 0.19
- GNU libltdl >= 2.4
- GNU libunistring >= 0.9.3
- libcurl >= 7.26 (or libgnurl >= 7.26)
- GNU libmicrohttpd >= 0.9.59
- GNU libgcrypt >= 1.6
- libjansson >= 2.7
- Postgres >= 9.6, including libpq
- libgnunetutil (from Git)
- GNU Taler exchange (from Git)

Except for the last two, these are available in most GNU/Linux distributions and should just be installed using the respective package manager.

The following instructions will show how to install libgnunetutil and the GNU Taler exchange.

Before you install libgnunetutil, you must download and install the dependencies mentioned above, otherwise the build may succeed but fail to export some of the tooling required by Taler.

To download and install libgnunetutil, proceed as follows:

```
$ git clone https://git.gnunet.org/gnunet/
$ cd gnunet/
$ ./bootstrap
$ ./configure [--prefix=GNUNETPFX]
$ # Each dependency can be fetched from non standard locations via
$ # the '--with-<LIBNAME>' option. See './configure --help'.
$ make
# make install
```

If you did not specify a prefix, GNUnet will install to `/usr/local`, which requires you to run the last step as `root`.

To download and install the GNU Taler exchange, proceeds as follows:

```
$ git clone git://git.taler.net/exchange
$ cd exchange
$ ./bootstrap
$ ./configure [--prefix=EXCHANGEPFX] \
              [--with-gnunet=GNUNETPFX]
$ # Each dependency can be fetched from non standard locations via
$ # the '--with-<LIBNAME>' option. See './configure --help'.
$ make
# make install
```

If you did not specify a prefix, the exchange will install to `/usr/local`, which requires you to run the last step as `root`. Note that you have to specify `--with-gnunet=/usr/local` if you installed GNUnet to `/usr/local` in the previous step.

CHAPTER

THREE

CONFIGURATION

This chapter provides an overview of the exchange configuration. Or at least eventually will do so, for now it is a somewhat wild description of some of the options.

3.1 Configuration format

configuration In Taler realm, any component obeys to the same pattern to get configuration values. According to this pattern, once the component has been installed, the installation deploys default values in ${prefix}/share/taler/config.d/, in .conf files. In order to override these defaults, the user can write a custom .conf file and either pass it to the component at execution time, or name it taler.conf and place it under $HOME/.config/.

A config file is a text file containing sections, and each section contains its values. The right format follows:

```
[section1]
value1 = string
value2 = 23

[section2]
value21 = string
value22 = /path22
```

Throughout any configuration file, it is possible to use `$`-prefixed variables, like `$VAR`, especially when they represent filesystem paths. It is also possible to provide defaults values for those variables that are unset, by using the following syntax: `${VAR:-default}`. However, there are two ways a user can set `$`-prefixable variables:

by defining them under a `[paths]` section, see example below,

```
[paths]
TALER_DEPLOYMENT_SHARED = ${HOME}/shared-data
..
[section-x]
path-x = ${TALER_DEPLOYMENT_SHARED}/x
```

or by setting them in the environment:

```
$ export VAR=/x
```

The configuration loader will give precedence to variables set under `[path]`, though.

The utility `taler-config`, which gets installed along with the exchange, serves to get and set configuration values without directly editing the .conf. The option `-f` is particularly useful to resolve pathnames, when they use several levels of `$`-expanded variables. See `taler-config --help`.

Note that, in this stage of development, the file `$HOME/.config/taler.conf` can contain sections for *all* the component. For example, both an exchange and a bank can read values from it.

The repository `git://taler.net/deployment` contains examples of configuration file used in our demos. See under `deployment/config`.

> **Note**
>
> Expectably, some components will not work just by using default values, as their work is often interdependent. For example, a merchant needs to know an exchange URL, or a database name.

3.2 Using taler-config

The tool `taler-config` can be used to extract or manipulate configuration values; however, the configuration use the well-known INI file format and can also be edited by hand.

Run

```
$ taler-config -s $SECTION
```

to list all of the configuration values in section `$SECTION`.

Run

```
$ taler-config -s $section -o $option
```

to extract the respective configuration value for option `$option` in section `$section`.

Finally, to change a setting, run

```
$ taler-config -s $section -o $option -V $value
```

to set the respective configuration value to `$value`. Note that you have to manually restart the Taler backend after you change the configuration to make the new configuration go into effect.

Some default options will use $-variables, such as `$DATADIR` within their value. To expand the `$DATADIR` or other $-variables in the configuration, pass the `-f` option to `taler-config`. For example, compare:

```
$ taler-config -s ACCOUNT-bank \
               -o WIRE_RESPONSE
$ taler-config -f -s ACCOUNT-bank \
               -o WIRE_RESPONSE
```

While the configuration file is typically located at `$HOME/.config/taler.conf`, an alternative location can be specified to `taler-merchant-httpd` and `taler-config` using the `-c` option.

3.3 Keying

The exchange works with three types of keys:

- master key
- sign keys
- denomination keys (see section Coins)
- MASTER_PRIV_FILE: Path to the exchange's master private file.

- MASTER_PUBLIC_KEY: Must specify the exchange's master public key.

3.4 Serving

The exchange can serve HTTP over both TCP and UNIX domain socket.

The following values are to be configured in the section [exchange]:

- serve: must be set to tcp to serve HTTP over TCP, or unix to serve HTTP over a UNIX domain socket
- port: Set to the TCP port to listen on if serve Is tcp.
- unixpath: set to the UNIX domain socket path to listen on if serve Is unix
- unixpath_mode: number giving the mode with the access permission MASK for the unixpath (i.e. 660 = rw-rw—-).

3.5 Currency

The exchange supports only one currency. This data is set under the respective option currency in section [taler].

3.6 Bank account

To configure a bank account in Taler, we need to furnish four pieces of information:

- The `payto://` URL of the bank account, which uniquely idenfies the account. Examples for such URLs include `payto://sepa/CH9300762011623852957` for a bank account in the single European payment area (SEPA) or `payto://x-taler-bank/localhost:8080/2` for the 2nd bank account a the Taler bank demonstrator running at `localhost` on port 8080. The first part of the URL following `payto://` ("sepa" or "x-taler-bank") is called the wire method.
- A matching wire plugin that implements a protocol to interact with the banking system. For example, the EBICS plugin can be used for SEPA transfers, or the "taler-bank" plugin can interact with the Taler bank demonstrator. A wire plugin only supports one particular wire method. Thus, you must make sure to pick a plugin that supports the wire method used in the URL.
- A file containing the signed JSON-encoded bank account details for the /wire API. This is necessary as Taler supports offline signing for bank accounts for additional security.
- Finally, the plugin needs to be provided resources for authentication to the respective banking service. The format in which the authentication information must be provided depends on the wire plugin.

You can configure multiple accounts for an exchange by creating sections starting with "account-" for the section name. You can ENABLE for each account whether it should be used, and for what (incoming or outgoing wire transfers):

```
[account-1]
URL = "payto://sepa/CH9300762011623852957"
WIRE_RESPONSE = ${TALER_CONFIG_HOME}/account-1.json

# Currently, only the 'taler_bank' plugin is implemented.
PLUGIN = <plugin_name_here>

# Use for exchange-aggregator (outgoing transfers)
ENABLE_DEBIT = YES
```

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```
# Use for exchange-wirewatch (and listed in /wire)
ENABLE_CREDIT = YES

# Authentication options for the chosen plugin go here.
# (Next sections have examples of authentication mechanisms)
```

The command line tool taler-exchange-wire is used to create the `account-1.json` file. For example, the utility may be invoked as follows to create all of the WIRE_RESPONSE files (in the locations specified by the configuration):

```
$ taler-exchange-wire
```

The generated file will be echoed by the exchange when serving /wire[3] requests.

3.6.1 Wire plugin "taler_bank"

x-taler-bank taler_bank plugin The `taler_bank` plugin implements the wire method "x-taler-bank".

The format of the `payto://` URL is `payto://x-taler-bank/HOSTNAME[:PORT]`.

For basic authentication, the `taler_bank` plugin only supports simple password-based authentication. For this, the configuration must contain the "USERNAME" and "PASSWORD" of the respective account at the bank.

```
[account-1]

# Bank account details here..
# ..

# Authentication options for the taler_bank plugin below:

TALER_BANK_AUTH_METHOD = basic
USERNAME = exchange
PASSWORD = super-secure
```

3.6.2 Wire plugin "ebics"

The "ebics" wire plugin is not fully implemented and today does not support actual wire transfers.

> **Note**
>
> The rationale behind having multiple bank accounts is that the exchange operator, as a security measure, may want to instruct the bank that the incoming bank account is only supposed to *receive* money.

3.6.3 Wire fee structure

wire fee fee For each wire method ("sepa" or "x-taler-wire", but not per plugin!) the exchange configuration must specify applicable wire fees. This is done in configuration sections of the format `fees-METHOD`. There are two types of fees, simple wire fees and closing fees. Wire fees apply whenever the aggregator transfers funds to a merchant. Closing fees apply whenever the exchange closes a reserve (sending back funds to the customer). The fees must be constant for a full year, which is specified as part of the name of the option.

[3] https://api.taler.net/api-exchange.html#wire-req

```
[fees-iban]
WIRE-FEE-2018 = EUR:0.01
WIRE-FEE-2019 = EUR:0.01
CLOSING-FEE-2018 = EUR:0.01
CLOSING-FEE-2019 = EUR:0.01

[fees-x-taler-bank]
WIRE-FEE-2018 = KUDOS:0.01
WIRE-FEE-2019 = KUDOS:0.01
CLOSING-FEE-2018 = KUDOS:0.01
CLOSING-FEE-2019 = KUDOS:0.01
```

3.7 Database

The option db under section [exchange] gets the DB backend's name the exchange is going to use. So far, only db = postgres is supported. After choosing the backend, it is mandatory to supply the connection string (namely, the database name). This is possible in two ways:

- via an environment variable: TALER_EXCHANGEDB_POSTGRES_CONFIG.
- via configuration option CONFIG, under section [exchangedb-BACKEND]. For example, the demo exchange is configured as follows:

```
[exchange]
...
DB = postgres
...

[exchangedb-postgres]
CONFIG = postgres:///talerdemo
```

3.8 Coins (denomination keys)

Sections specifying denomination (coin) information start with `coin_`. By convention, the name continues with "$CURRENCY_[$SUBUNIT]_$VALUE", i.e. `[coin_eur_ct_10]` for a 10 cent piece. However, only the `coin_` prefix is mandatory. Each `coin_`-section must then have the following options:

- value: How much is the coin worth, the format is CURRENCY:VALUE.FRACTION. For example, a 10 cent piece is "EUR:0.10".
- duration_withdraw: How long can a coin of this type be withdrawn? This limits the losses incurred by the exchange when a denomination key is compromised.
- duration_overlap: What is the overlap of the withdrawal timespan for this coin type?
- duration_spend: How long is a coin of the given type valid? Smaller values result in lower storage costs for the exchange.
- fee_withdraw: What does it cost to withdraw this coin? Specified using the same format as value.
- fee_deposit: What does it cost to deposit this coin? Specified using the same format as value.
- fee_refresh: What does it cost to refresh this coin? Specified using the same format as value.
- rsa_keysize: How many bits should the RSA modulus (product of the two primes) have for this type of coin.

3.9 Keys duration

Both signkeys and denom keys have a starting date. The option lookahead_provide, under section [exchange], is such that only keys whose starting date is younger than lookahead_provide will be issued by the exchange.

signkeys. The option lookahead_sign is such that, being t the time when taler-exchange-keyup is run, taler-exchange-keyup will generate n signkeys, where t + (n * signkey_duration) = t + lookahead_sign. In other words, we generate a number of keys which is sufficient to cover a period of lookahead_sign. As for the starting date, the first generated key will get a starting time of t, and the j-th key will get a starting time of x + signkey_duration, where x is the starting time of the (j-1)-th key.

denom keys. The option lookahead_sign is such that, being t the time when taler-exchange-keyup is run, taler-exchange-keyup will generate n denom keys for each denomination, where t + (n * duration_withdraw) = t + lookahead_sign. In other words, for each denomination, we generate a number of keys which is sufficient to cover a period of lookahead_sign. As for the starting date, the first generated key will get a starting time of t, and the j-th key will get a starting time of x + duration_withdraw, where x is the starting time of the (j-1)-th key.

To change these settings, edit the following values in section [exchange]:

- SIGNKEY_DURATION: How long should one signing key be used?
- LOOKAHEAD_SIGN: How much time we want to cover with our signing keys? Note that if SIGNKEY_DURATION is bigger than LOOKAHEAD_SIGN, `taler-exchange-keyup` will generate a quantity of signing keys which is sufficient to cover all the gap.

CHAPTER

FOUR

DEPLOYMENT

4.1 Keys generation

Once the configuration is properly set up, all the keys can be generated by the tool `taler-exchange-keyup`. The following command generates denomkeys and signkeys, plus the "blob" that is to be signed by the auditor.

```
taler-exchange-keyup -o blob
```

blob contains data about denomkeys that the exchange operator needs to get signed by every auditor he wishes (or is forced to) work with.

In a normal scenario, an auditor must have some way of receiving the blob to sign (Website, manual delivery, ..). Nonetheless, the exchange admin can fake an auditor signature — for testing purposes — by running the following command

```
taler-auditor-sign -m EXCHANGE_MASTER_PUB -r BLOB -u AUDITOR_URL -o OUTPUT_FILE
```

Those arguments are all mandatory.

- `EXCHANGE_MASTER_PUB` the base32 Crockford-encoded exchange's master public key. Tipically, this value lies in the configuration option `[exchange]/master_public_key`.
- `BLOB` the blob generated in the previous step.
- `AUDITOR_URL` the URL that identifies the auditor.
- `OUTPUT_FILE` where on the disk the signed blob is to be saved.

`OUTPUT_FILE` must then be copied into the directory specified by the option `AUDITOR_BASE_DIR` under the section `[exchangedb]`. Assuming `AUDITOR_BASE_DIR = ${HOME}/.local/share/taler/auditors`, the following command will "add" the auditor identified by `AUDITOR_URL` to the exchange.

```
cp OUTPUT_FILE ${HOME}/.local/share/taler/auditors
```

If the auditor has been correctly added, the exchange's `/keys` response must contain an entry in the `auditors` array mentioning the auditor's URL.

4.2 Database upgrades

Currently, there is no way to upgrade the database between Taler versions.

The exchange database can be re-initialized using:

```
$ taler-exchange-dbinit -r
```

However, running this command will result in all data in the database being lost, which may result in significant financial liabilities as the exchange can then not detect double-spending. Hence this operation must not be performed in a production system.

CHAPTER

FIVE

DIAGNOSTICS

This chapter includes various (very unpolished) sections on specific topics that might be helpful to understand how the exchange operates, which files should be backed up. The information may also be helpful for diagnostics.

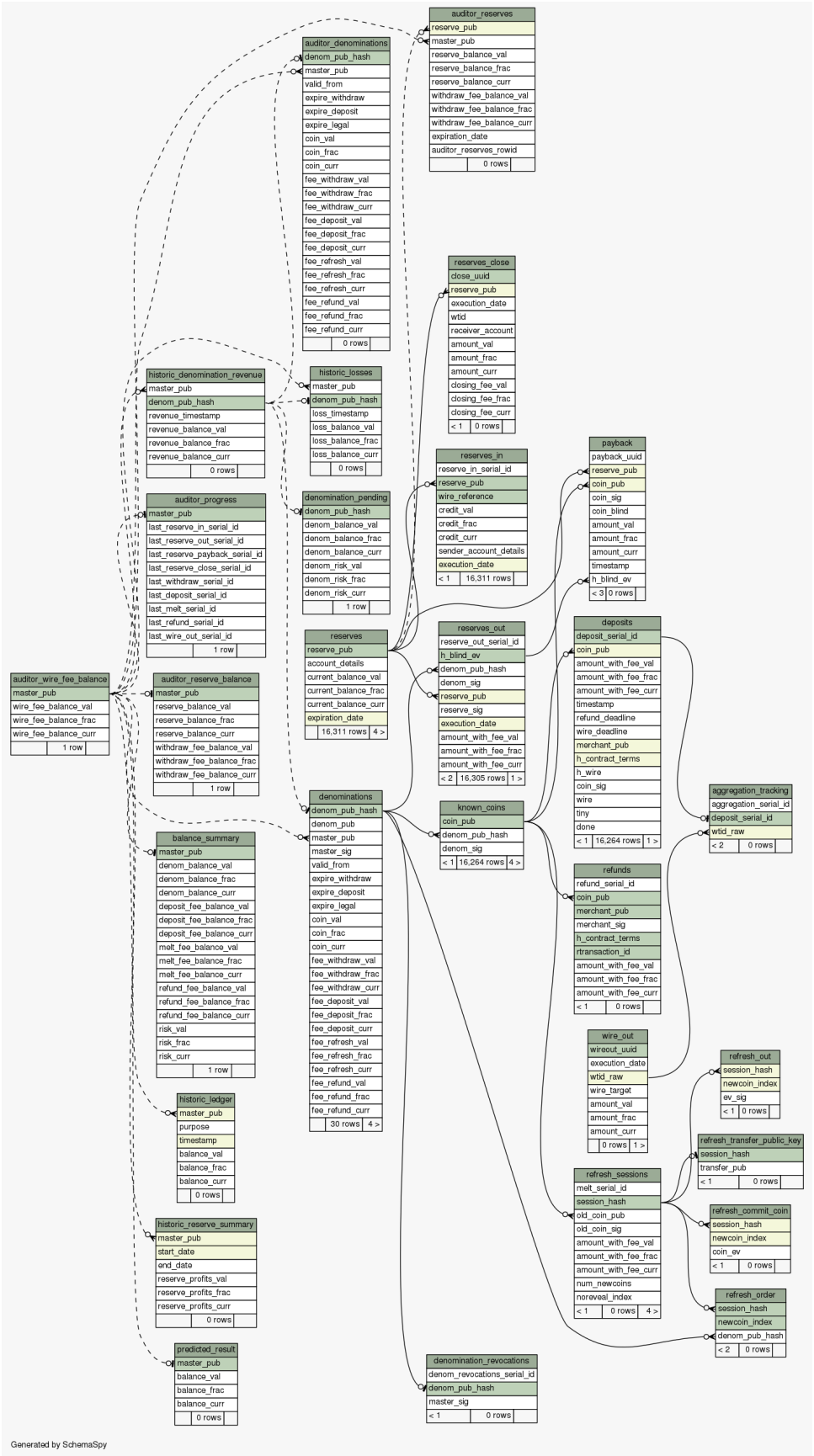
5.1 Reserve management

Incoming transactions to the exchange's provider result in the creation or update of reserves, identified by their reserve key. The command line tool taler-exchange-reservemod allows create and add money to reserves in the exchange's database.

5.2 Database Scheme

The exchange database must be initialized using taler-exchange-dbinit. This tool creates the tables required by the Taler exchange to operate. The tool also allows you to reset the Taler exchange database, which is useful for test cases but should never be used in production. Finally, taler-exchange-dbinit has a function to garbage collect a database, allowing administrators to purge records that are no longer required.

The database scheme used by the exchange look as follows:


auditor_reserves
reserve_pub
master_pub
reserve_balance_val
reserve_balance_frac
reserve_balance_curr
withdraw_fee_balance_val
withdraw_fee_balance_frac
withdraw_fee_balance_curr
expiration_date
auditor_reserves_rowid
0 rows
auditor_denominations
denom_pub_hash
master_pub
valid_from
expire_withdraw
expire_deposit
expire_legal
coin_val
coin_frac
coin_curr
fee_withdraw_val
fee_withdraw_frac
fee_withdraw_curr
fee_deposit_val
fee_deposit_frac
fee_deposit_curr
fee_refresh_val
fee_refresh_frac
fee_refresh_curr
fee_refund_val
fee_refund_frac
fee_refund_curr
0 rows
reserves_close
close_uuid
reserve_pub
execution_date
wtid
receiver_account
amount_val
amount_frac
amount_curr
closing_fee_val
closing_fee_frac
closing_fee_curr
< 1
0 rows
historic_denomination_revenue
master_pub
denom_pub_hash
revenue_timestamp
revenue_balance_val
revenue_balance_frac
revenue_balance_curr
0 rows
historic_losses
master_pub
denom_pub_hash
loss_timestamp
loss_balance_val
loss_balance_frac
loss_balance_curr
0 rows
reserves_in
reserve_in_serial_id
reserve_pub
wire_reference
credit_val
credit_frac
credit_curr
sender_account_details
execution_date
< 1
16,311 rows
payback
payback_uuid
reserve_pub
coin_pub
coin_sig
coin_blind
amount_val
amount_frac
amount_curr
timestamp
h_blind_ev
< 3
0 rows
auditor_progress
master_pub
last_reserve_in_serial_id
last_reserve_out_serial_id
last_reserve_payback_serial_id
last_reserve_close_serial_id
last_withdraw_serial_id
last_deposit_serial_id
last_melt_serial_id
last_refund_serial_id
last_wire_out_serial_id
1 row
denomination_pending
denom_pub_hash
denom_balance_val
denom_balance_frac
denom_balance_curr
denom_risk_val
denom_risk_frac
denom_risk_curr
1 row
reserves
reserve_pub
account_details
current_balance_val
current_balance_frac
current_balance_curr
expiration_date
16,311 rows
4 >
reserves_out
reserve_out_serial_id
h_blind_ev
denom_pub_hash
denom_sig
reserve_pub
reserve_sig
execution_date
amount_with_fee_val
amount_with_fee_frac
amount_with_fee_curr
< 2
16,305 rows
1 >
deposits
deposit_serial_id
coin_pub
amount_with_fee_val
amount_with_fee_frac
amount_with_fee_curr
timestamp
refund_deadline
wire_deadline
merchant_pub
h_contract_terms
h_wire
coin_sig
wire
tiny
done
< 1
16,264 rows
1 >
auditor_wire_fee_balance
master_pub
wire_fee_balance_val
wire_fee_balance_frac
wire_fee_balance_curr
1 row
auditor_reserve_balance
master_pub
reserve_balance_val
reserve_balance_frac
reserve_balance_curr
withdraw_fee_balance_val
withdraw_fee_balance_frac
withdraw_fee_balance_curr
1 row
denominations
denom_pub_hash
denom_pub
master_pub
master_sig
valid_from
expire_withdraw
expire_deposit
expire_legal
coin_val
coin_frac
coin_curr
fee_withdraw_val
fee_withdraw_frac
fee_withdraw_curr
fee_deposit_val
fee_deposit_frac
fee_deposit_curr
fee_refresh_val
fee_refresh_frac
fee_refresh_curr
fee_refund_val
fee_refund_frac
fee_refund_curr
30 rows
4 >
known_coins
coin_pub
denom_pub_hash
denom_sig
< 1
16,264 rows
4 >
aggregation_tracking
aggregation_serial_id
deposit_serial_id
wtid_raw
< 2
0 rows
refunds
refund_serial_id
coin_pub
merchant_pub
merchant_sig
h_contract_terms
rtransaction_id
amount_with_fee_val
amount_with_fee_frac
amount_with_fee_curr
< 1
0 rows
balance_summary
master_pub
denom_balance_val
denom_balance_frac
denom_balance_curr
deposit_fee_balance_val
deposit_fee_balance_frac
deposit_fee_balance_curr
melt_fee_balance_val
melt_fee_balance_frac
melt_fee_balance_curr
refund_fee_balance_val
refund_fee_balance_frac
refund_fee_balance_curr
risk_val
risk_frac
risk_curr
1 row
wire_out
wireout_uuid
execution_date
wtid_raw
wire_target
amount_val
amount_frac
amount_curr
0 rows
1 >
refresh_out
session_hash
newcoin_index
ev_sig
< 1
0 rows
historic_ledger
master_pub
purpose
timestamp
balance_val
balance_frac
balance_curr
0 rows
refresh_transfer_public_key
session_hash
transfer_pub
< 1
0 rows
refresh_sessions
melt_serial_id
session_hash
old_coin_pub
old_coin_sig
amount_with_fee_val
amount_with_fee_frac
amount_with_fee_curr
num_newcoins
noreveal_index
< 1
0 rows
4 >
refresh_commit_coin
session_hash
newcoin_index
coin_ev
< 1
0 rows
historic_reserve_summary
master_pub
start_date
end_date
reserve_profits_val
reserve_profits_frac
reserve_profits_curr
0 rows
refresh_order
session_hash
newcoin_index
denom_pub_hash
< 2
0 rows
predicted_result
master_pub
balance_val
balance_frac
balance_curr
0 rows
denomination_revocations
denom_revocations_serial_id
denom_pub_hash
master_sig
< 1
0 rows
Generated by SchemaSpy

5.3 Signing key storage

The private online signing keys of the exchange are stored in a subdirectory "signkeys/" of the "KEYDIR" which is an option in the "[exchange]" section of the configuration file. The filename is the starting time at which the signing key can be used in microseconds since the Epoch. The file format is defined by the struct TALER_EXCHANGEDB_PrivateSigningKeyInformationP:

```
struct TALER_EXCHANGEDB_PrivateSigningKeyInformationP {
   struct TALER_ExchangePrivateKeyP signkey_priv;
   struct TALER_ExchangeSigningKeyValidityPS issue;
};
```

5.4 Denomination key storage

The private denomination keys of the exchange are store in a subdirectory "denomkeys/" of the "KEYDIR" which is an option in the "[exchange]" section of the configuration file. "denomkeys/" contains further subdirectories, one per denomination. The specific name of the subdirectory under "denomkeys/" is ignored by the exchange. However, the name is important for the "taler-exchange-keyup" tool that generates the keys. The tool combines a human-readable encoding of the denomination (i.e. for EUR:1.50 the prefix would be "EUR_1_5-", or for EUR:0.01 the name would be "EUR_0_01-") with a postfix that is a truncated Crockford32 encoded hash of the various attributes of the denomination key (relative validity periods, fee structure and key size). Thus, if any attributes of a coin change, the name of the subdirectory will also change, even if the denomination remains the same.

Within this subdirectory, each file represents a particular denomination key. The filename is the starting time at which the signing key can be used in microseconds since the Epoch. The format on disk begins with a struct TALER_EXCHANGEDB_DenominationKeyInformationP giving the attributes of the denomination key and the associated signature with the exchange's long-term offline key:

```
struct TALER_EXCHANGEDB_DenominationKeyInformationP {
  struct TALER_MasterSignatureP signature;
  struct TALER_DenominationKeyValidityPS properties;
};
```

This is then followed by the variable-size RSA private key in libgcrypt's S-expression format, which can be decoded using GNUNET_CRYPTO_rsa_private_key_decode().

5.4.1 Revocations

When an exchange goes out of business or detects that the private key of a denomination key pair has been compromised, it may revoke some or all of its denomination keys. At this point, the hashes of the revoked keys must be returned as part of the `/keys` response under "payback". Wallets detect this, and then return unspent coins of the respective denomination key using the `/payback` API.

When a denomination key is revoked, a revocation file is placed into the respective subdirectory of "denomkeys/". The file has the same prefix as the file that stores the struct TALER_EXCHANGEDB_DenominationKeyInformationP information, but is followed by the ".rev" suffix. It contains a 64-byte EdDSA signature made with the master key of the exchange with purpose `TALER_SIGNATURE_MASTER_DENOMINATION_KEY_REVOKED`. If such a file is present, the exchange must check the signature and if it is valid treat the respective denomination key as revoked.

Revocation files can be generated using the `taler-exchange-keyup` command-line tool using the `-r` option. The Taler auditor will instruct operators to generate revocations if it detects a key compromise (which is possible more coins of a particular denomination were deposited than issued).

It should be noted that denomination key revocations should only happen under highly unusual (“emergency”) conditions and not under normal conditions.

5.5 Auditor signature storage

Signatures from auditors are stored in the directory specified in the exchange configuration section “exchangedb” under the option “AUDITOR_BASE_DIR”. The exchange does not care about the specific names of the files in this directory.

Each file must contain a header with the public key information of the auditor, the master public key of the exchange, and the number of signed denomination keys:

```
struct AuditorFileHeaderP {
  struct TALER_AuditorPublicKeyP apub;
  struct TALER_MasterPublicKeyP mpub;
  uint32_t dki_len;
};
```

This is then followed by dki_len signatures of the auditor of type struct TALER_AuditorSignatureP, which are then followed by another dki_len blocks of type struct TALER_DenominationKeyValidityPS. The auditor’s signatures must be signatures over the information of the corresponding denomination key validity structures embedded in a struct TALER_ExchangeKeyValidityPS structure using the TALER_SIGNATURE_AUDITOR_EXCHANGE_KEYS purpose.

APPENDIX

A

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