NEXT GENERATION INTERNET

GNU Taler

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Surveilance concerns

- Everybody knows about Internet surveilance.
- But is it **that** bad?
  - You can choose when and where to use the Internet
  - You can anonymously access the Web using Tor
  - You can find open access points that do not require authentication
  - IP packets do not include your precise location or name
  - ISPs typically store this meta data for days, weeks or months

This was a question posed to RAND researchers in 1971:

> *"Suppose you were an advisor to the head of the KGB, the Soviet Secret Police. Suppose you are given the assignment of designing a system for the surveillance of all citizens and visitors within the boundaries of the USSR. The system is not to be too obtrusive or obvious. What would be your decision?"*

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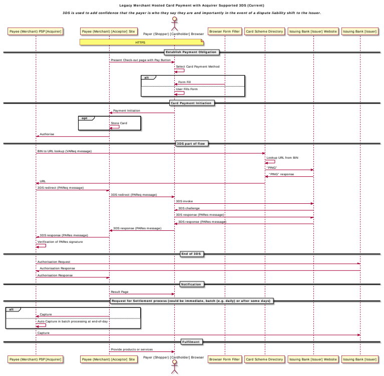
"I think one of the big things that we need to do, is we need to get a way from true-name payments on the Internet. The credit card payment system is one of the worst things that happened for the user, in terms of being able to divorce their access from their identity." –Edward Snowden, IETF 93 (2015)

Why is it worse?

- When you pay by CC, the information includes your name
- When you pay in person with CC, your location is also known
- You often have no alternative payment methods available
- You hardly ever can use someone else’s CC
- Anonymous prepaid cards are difficult to get and expensive
- Payment information is typically stored for 6-10 years!

3D secure ("verified by visa") is a nightmare:

- Complicated process
- Shifts liability to consumer
- Significant latency
- Can refuse valid requests
- Legal vendors excluded
- No privacy for buyers


Legacy Merchant Hosted Card Payment with Acquirer Supported 3DS (Current)
3DS is used to add confidence that the payer is who they say they are and importantly in the event of a dispute liability shift to the Issuer.
Payee (Merchant) PSP [Acquirer]
Payee (Merchant) [Acceptor] Site
Payer (Shopper) [Cardholder] Browser
Browser Form Filler
Card Scheme Directory
Issuing Bank [Issuer] Website
Issuing Bank [Issuer]
HTTPS
Establish Payment Obligation
Present Check-out page with Pay Button
Select Card Payment Method
alt
Form Fill
User Fills Form
Card Payment Initiation
Payment Initiation
opt
Store Card
Authorise
3DS part of flow
BIN to URL lookup (VAReq message)
Lookup URL from BIN
"PING"
"PING" response
URL
3DS redirect (PAReq message)
3DS redirect (PAReq message)
3DS invoke
3DS challenge
3DS response (PARes message)
3DS response (PARes message)
3DS response (PARes message)
3DS response (PARes message)
Verification of PARes signature
End of 3DS
Authorisation Request
Authorisation Response
Authorisation Response
Notification
Result Page
Request for Settlement process (could be immediate, batch (e.g. daily) or after some days)
alt
Capture
Auto Capture in batch processing at end-of-day
Capture
Fulfilment
Provide products or services
Payee (Merchant) PSP [Acquirer]
Payee (Merchant) [Acceptor] Site
Payer (Shopper) [Cardholder] Browser
Browser Form Filler
Card Scheme Directory
Issuing Bank [Issuer] Website
Issuing Bank [Issuer]

- Global tech companies push oligopolies
- Privacy and federated finance are at risk
- Economic sovereingity is in danger

Predicting the future

- Google and Apple will be your bank and run your payment system
- They can target advertising based on your purchase history, location and your ability to pay
- They will provide more usable, faster and broadly available payment solutions; our federated banking system will be history
- After they dominate the payment sector, they will start to charge fees befitting their oligopoly size
- Competitors and vendors not aligning with their corporate “values” will be excluded by policy and go bankrupt
- The imperium will have another major tool for its financial warfare

The Bank of International Settlements on CBDC

The Emergency Act of Canada, February 2022 https://www.youtube.com/watch?

Digital cash, made **socially responsible**.

TALER

Privacy-Preserving, Practical, Taxable, Free Software, Efficient

What is Taler?

`https://taler.net/en/features.html`

Taler is

- a Free/Libre software *payment system* infrastructure project
- ... with a surrounding software ecosystem
- ... and a company (Taler Systems S.A.) and community that wants to deploy it as widely as possible.

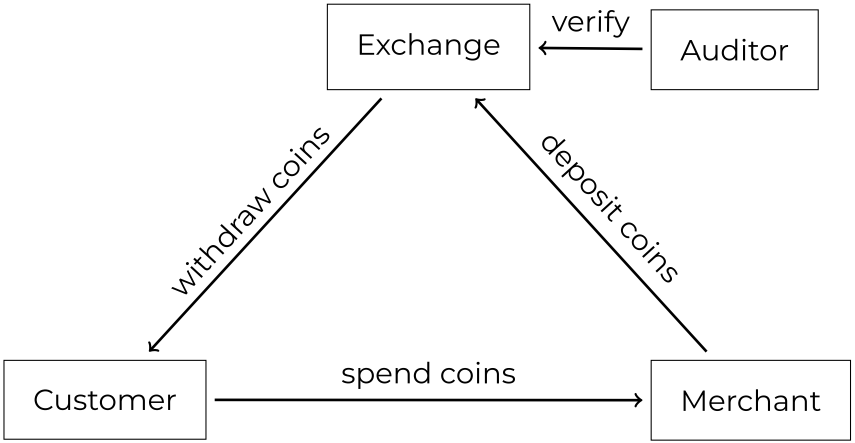
However, Taler is

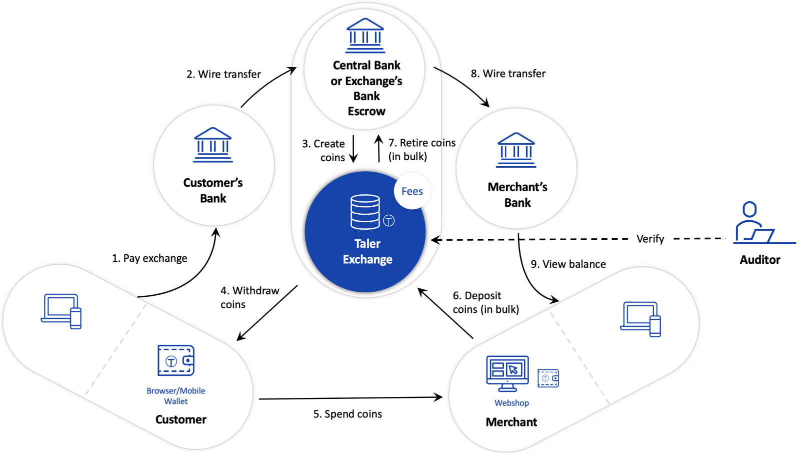
- *not* a currency
- *not* a long-term store of value
- *not* a network or instance of a system
- *not* decentralized
- *not* based on proof-of-work or proof-of-stake
- *not* a speculative asset / "get-rich-quick scheme"

GNU Taler must ...

1. ... be implemented as **free software**.
2. ... protect the **privacy of buyers**.
3. ... must enable the state to **tax income** and crack down on illegal business activities.
4. ... prevent payment fraud.
5. ... only **disclose the minimal amount of information necessary**.
6. ... be usable.
7. ... be efficient.
8. ... avoid single points of failure.
9. ... foster **competition**.

Taler overview





Central Bank
or Exchange's
Bank
Escrow
2. Wire transfer
8. Wire transfer
Customer's
Bank
3. Create
coins
7. Retire coins
(in bulk)
Merchant's
Bank
Fees
Taler
Exchange
Verify
Auditor
1. Pay exchange
9. View balance
4. Withdraw
coins
6. Deposit
coins (in bulk)
Browser/Mobile
Wallet
Customer
5. Spend coins
Webshop
Merchant

`https://demo.taler.net/`

1. Install Web extension.
2. Visit the `bank.demo.taler.net` to withdraw coins.
3. Visit the `shop.demo.taler.net` to spend coins.

Taxability

We say Taler is taxable because:

- Merchant's income is visible from deposits.
- Hash of contract is part of deposit data.
- State can trace income and enforce taxation.

Limitations:

- withdraw loophole
- *sharing* coins among family and friends

Other contemporary payment systems have similar limitations on identification, and thus these limitations should not be a legal issue.

It would be inefficient to pay EUR 100 with 1 cent coins!

- Denomination key represents value of a coin.
- Exchange may offer various denominations for coins.
- Wallet may not have exact change!
- Usability requires ability to pay given sufficient total funds.

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Key goals:

- maintain unlinkability
- maintain taxability of transactions

Giving change

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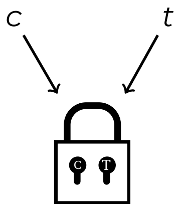
Method:

- Contract can specify to only pay *partial value* of a coin.
- Exchange allows wallet to obtain *unlinkable change* for remaining coin value.

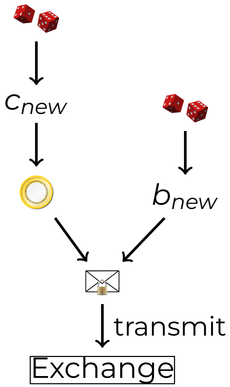
1. Create private keys $c, t \mod o$
2. Define $C := cG$
3. Define $T := tG$
4. Compute DH:
   $cT = c(tG) = t(cG) = tC$



Given partially spent private coin key c_{old}:

1. Pick random $c_{new} \mod o$ private key
2. Compute $C_{new} := c_{new}G$ public key
3. Pick random b_{new}
4. Compute $f_{new} := FDH(C_{new}), m < n$.
5. Transmit $f'_{new} := f_{new}b^{e}_{new} \mod n$

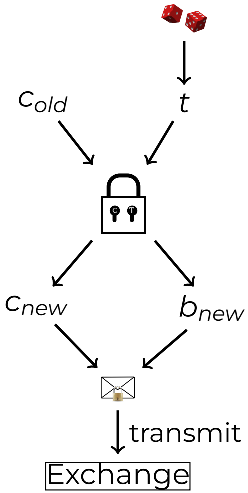
... and sign request for change with c_{old}.



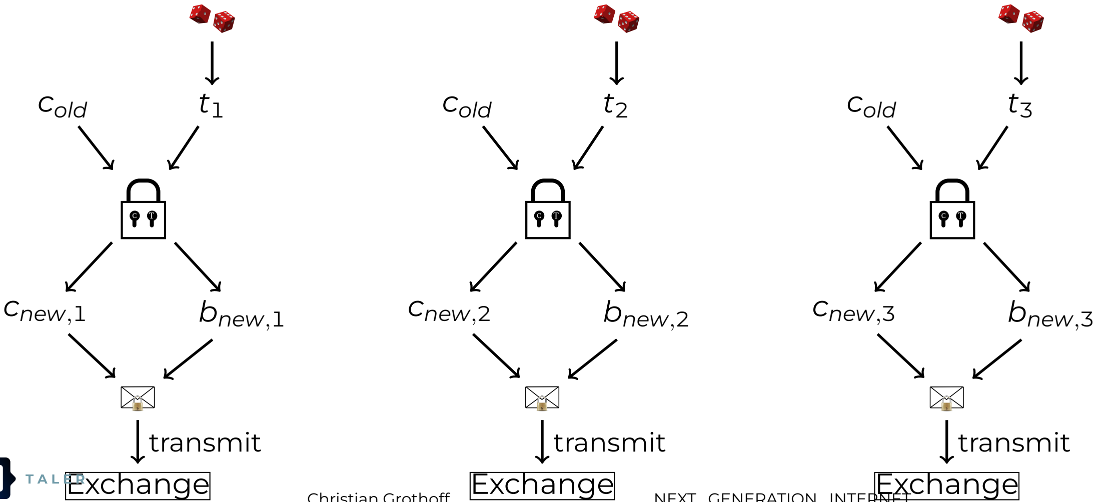
Customer: Transfer key setup (ECDH)

Given partially spent private coin key c_{old}:

1. Let $C_{old} := c_{old}G$ (as before)
2. Create random private transfer key $t \mod o$
3. Compute public transfer key $T := tG$
4. Compute $X := c_{old}(tG) = t(c_{old}G) = tC_{old}$
5. Derive c_{new} and b_{new} from X using HKDF
6. Compute $C_{new} := c_{new}G$
7. Compute $f_{new} := FDH(C_{new})$
8. Transmit $f'_{new} := f_{new}b^e_{new}$



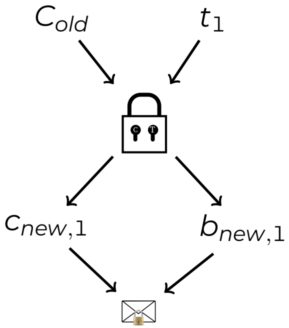
Cut-and-Choose

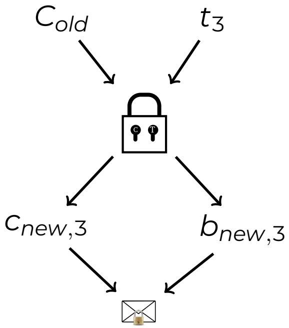


Exchange: Choose!

Exchange sends back random $\gamma \in \{1, 2, 3\}$ to the customer.

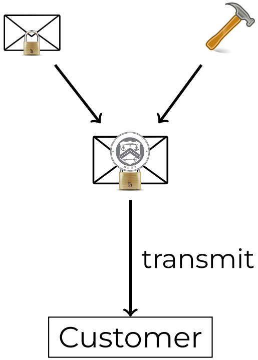
1. If $\gamma = 1$, send t_2, t_3 to exchange
2. If $\gamma = 2$, send t_1, t_3 to exchange
3. If $\gamma = 3$, send t_1, t_2 to exchange


C_{old}
t_1
$c_{new,1}$
$b_{new,1}$

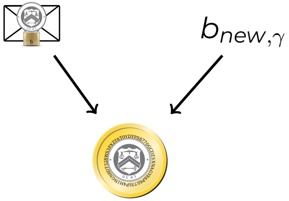

C_{old}
t_3
$c_{new,3}$
$b_{new,3}$

Exchange: Blind sign change (RSA)

1. Take $f'_{new,\gamma}$.
2. Compute
   $s' := f'^{d}_{new,\gamma} \mod n$.
3. Return signature s'.



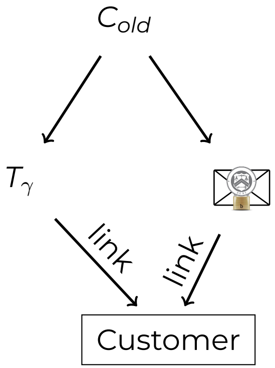
1. Receive s'.
2. Compute $s := s' b_{new,\gamma}^{-1} \mod n$.



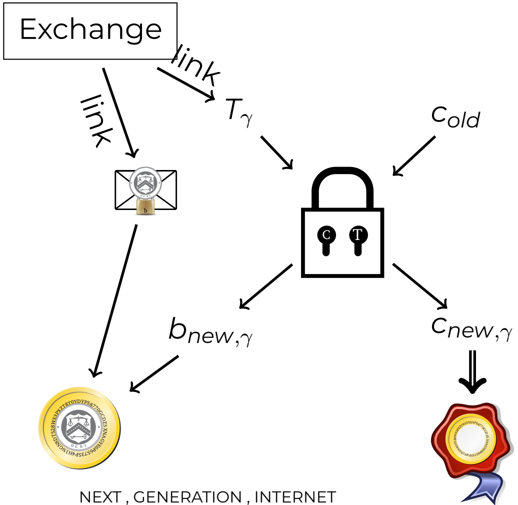
Given C_{old}

return T_γ and

$s := s' b_{new,\gamma}^{-1} \mod n.$



1. Have c_{old}.
2. Obtain T_γ, s from exchange
3. Compute $X_\gamma = c_{old} T_\gamma$
4. Derive $c_{new,\gamma}$ and $b_{new,\gamma}$ from X_γ
5. Unblind $s := s' b_{new,\gamma}^{-1} \mod n$



Refresh protocol summary

- Customer asks exchange to convert old coin to new coin
- Protocol ensures new coins can be recovered from old coin

$\Rightarrow$ New coins are owned by the same entity!

Thus, the refresh protocol allows:

- To give unlinkable change.
- To give refunds to an anonymous customer.
- To expire old keys and migrate coins to new ones.
- To handle protocol aborts.

Transactions via refresh are equivalent to *sharing* a wallet.

An *oracle* is a party in a game that the adversary can call upon to indirectly access information that is otherwise hidden from it.
For example, **IND-CPA** can be formalized like this:

- Setup: Generate random key k, select $b \in \{0, 1\}$ for $i \in \{1, \ldots, q\}$.
- Oracle: Given M_0 and M_1 (of same length), return $C := \texttt{enc}(k, M_b)$.

The adversary wins, if it can guess b with probability greater than $\frac{1}{2} + \epsilon(\kappa)$ where $\epsilon(\kappa)$ is a negligible function in the security parameter κ.

Problem:

Verification of minimum age requirements in e-commerce.

Common solutions:

1. ID Verification
2. Restricted Accounts
3. Attribute-based

Age restriction in E-commerce

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Common solutions:

	Privacy
1. ID Verification	bad
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3. Attribute-based	good

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Principle of Subsidiarity is violated

Principle of Subsidiarity

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For age-restriction, the lowest level of authority is:

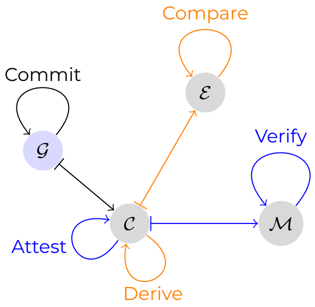
Parents, guardians and caretakers

1. Tie age restriction to the **ability to pay** (not to ID’s)
2. maintain **anonymity of buyers**
3. maintain **unlinkability of transactions**
4. align with **principle of subsidiartiy**
5. be **practical and efficient**

Age restriction

Assumptions and scenario

- Assumption: Checking accounts are under control of eligible adults/guardians.
- *Guardians* **commit** to an maximum age
- *Minors* **attest** their adequate age
- *Merchants* **verify** the attestations
- Minors **derive** age commitments from existing ones
- *Exchanges* **compare** the derived age commitments



Searching for functions with the following signatures

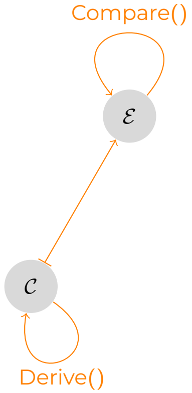
$$\begin{array}{lrl}
\text{Commit}: & (a,\omega) \mapsto (Q,P) & \mathbb{N}_M \times \Omega \to \mathbb{O} \times \mathbb{P}, \\
\text{Attest}: & (m,Q,P) \mapsto T & \mathbb{N}_M \times \mathbb{O} \times \mathbb{P} \to \mathbb{T} \cup \{\bot\}, \\
\text{Verify}: & (m,Q,T) \mapsto b & \mathbb{N}_M \times \mathbb{O} \times \mathbb{T} \to \mathbb{Z}_2, \\
\text{Derive}: & (Q,P,\omega) \mapsto (Q',P',\beta) & \mathbb{O} \times \mathbb{P} \times \Omega \to \mathbb{O} \times \mathbb{P} \times \mathbb{B}, \\
\text{Compare}: & (Q,Q',\beta) \mapsto b & \mathbb{O} \times \mathbb{O} \times \mathbb{B} \to \mathbb{Z}_2,
\end{array}$$

with $\Omega, \mathbb{P}, \mathbb{O}, \mathbb{T}, \mathbb{B}$ sufficiently large sets.

Basic and security requirements are defined later.

Mnemonics:
$\mathbb{O}$ = *c$\mathbb{O}$mmitments*, Q = *Q-mitment* (commitment), $\mathbb{P}$ = *$\mathbb{P}$roofs*, P = *Proof*,
$\mathbb{T}$ = *a$\mathbb{T}$testations*, T = *aTtestation*, $\mathbb{B}$ = *$\mathbb{B}$lindings*, β = *βlinding*.

$$\begin{tikzcd}
\mathcal{G} \arrow[loop above, "\text{Commit}"] \arrow[dr, mapsto] & & \mathcal{E} \arrow[loop above, "\text{Compare}"] & \\
& \mathcal{C} \arrow[loop left, "\text{Attest}"] \arrow[loop below, "\text{Derive}"] \arrow[ur, mapsto] \arrow[rr, mapsto] & & \mathcal{M} \arrow[loop above, "\text{Verify}"]
\end{tikzcd}$$

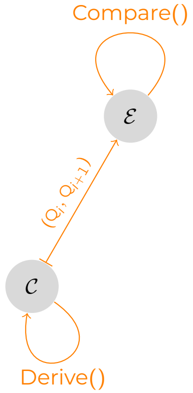


Simple use of Derive() and Compare() is problematic.

- Calling Derive() iteratively generates sequence $(Q_0, Q_1, \ldots)$ of commitments.
- Exchange calls Compare($Q_i, Q_{i+1}, .$)

$\Longrightarrow$ **Exchange identifies sequence**

$\Longrightarrow$ **Unlinkability broken**



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Achieving unlinkability

Define cut&choose protocol DeriveCompare$_\kappa$, using Derive() and Compare().

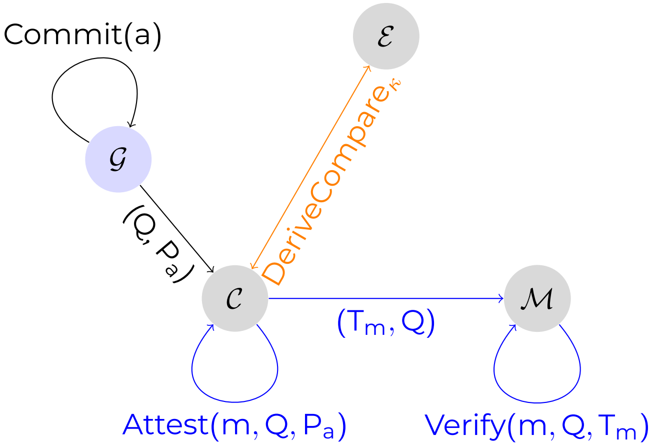
Sketch:

1. $\mathcal{C}$ derives commitments $(Q_1, \dots, Q_\kappa)$ from Q_0 by calling Derive() with blindings $(\beta_1, \dots, \beta_\kappa)$
2. $\mathcal{C}$ calculates $h_0 := H\left(H(Q_1, \beta_1) || \dots || H(Q_\kappa, \beta_\kappa)\right)$
3. $\mathcal{C}$ sends Q_0 and h_0 to $\mathcal{E}$
4. $\mathcal{E}$ chooses $\gamma \in \{1, \dots, \kappa\}$ randomly
5. $\mathcal{C}$ reveals $h_\gamma := H(Q_\gamma, \beta_\gamma)$ and all (Q_i, β_i), except (Q_γ, β_γ)
6. $\mathcal{E}$ compares h_0 and $H\left(H(Q_1, \beta_1)||...||h_\gamma||...||H(Q_\kappa, \beta_\kappa)\right)$ and evaluates Compare(Q_0, Q_i, β_i).

With DeriveCompare$_\kappa$

- $\mathcal{E}$ learns nothing about Q_γ,
- trusts outcome with $\frac{\kappa-1}{\kappa}$ certainty,
- i.e. $\mathcal{C}$ has $\frac{1}{\kappa}$ chance to cheat.

Note: Still need Derive and Compare to be defined.



Candidate functions

$$(\text{Commit}, \text{Attest}, \text{Verify}, \text{Derive}, \text{Compare})$$

must first meet *basic* requirements:

- Existence of attestations
- Efficacy of attestations
- Derivability of commitments and attestations

Existence of attestations

$$\underset{\substack{a \in \mathbb{N}_M \\ \omega \in \Omega}}{\forall} : \mathrm{Commit}(a, \omega) =: (Q, P) \implies \mathrm{Attest}(m, Q, P) = \begin{cases} T \in \mathbb{T}, \text{ if } m \leq a \\ \perp \text{ otherwise} \end{cases}$$

Efficacy of attestations

$$\mathrm{Verify}(m, Q, T) = \begin{cases} 1, \text{if } \underset{P \in \mathbb{P}}{\exists} : \mathrm{Attest}(m, Q, P) = T \\ 0 \text{ otherwise} \end{cases}$$

$$\forall_{n \leq a} : \mathrm{Verify}\big(n, Q, \mathrm{Attest}(n, Q, P)\big) = 1.$$

etc.

Candidate functions must also meet *security* requirements. Those are defined via security games:

- ▶ Game: Age disclosure by commitment or attestation
- $\leftrightarrow$ Requirement: Non-disclosure of age
- ▶ Game: Forging attestation
- $\leftrightarrow$ Requirement: Unforgeability of minimum age
- ▶ Game: Distinguishing derived commitments and attestations
- $\leftrightarrow$ Requirement: Unlinkability of commitments and attestations

Meeting the security requirements means that adversaries can win those games only with negligible advantage.
Adversaries are arbitrary polynomial-time algorithms, acting on all relevant input.

Security requirements

Simplified example

Game $G_{\mathcal{A}}^{\mathsf{FA}}(\lambda)$—Forging an attest:

1. $(\mathsf{a}, \omega) \overset{\$}{\leftarrow} \mathbb{N}_{\mathsf{M}-1} \times \Omega$
2. $(\mathsf{Q}, \mathsf{P}) \leftarrow \mathsf{Commit}(\mathsf{a}, \omega)$
3. $(\mathsf{m}, \mathsf{T}) \leftarrow \mathcal{A}(\mathsf{a}, \mathsf{Q}, \mathsf{P})$
4. Return 0 if $\mathsf{m} \leq \mathsf{a}$
5. Return $\mathsf{Verify}(\mathsf{m}, \mathsf{Q}, \mathsf{T})$

Requirement: Unforgeability of minimum age

$$\underset{\mathcal{A} \in \mathfrak{A}(\mathbb{N}_{\mathsf{M}} \times \mathbb{O} \times \mathbb{P} \to \mathbb{N}_{\mathsf{M}} \times \mathbb{T})}{\forall} : \Pr\left[G_{\mathcal{A}}^{\mathsf{FA}}(\lambda) = 1\right] \leq \epsilon(\lambda)$$

To Commit to age (group) a $\in \{1, \ldots, M\}$

1. Guardian generates ECDSA-keypairs, one per age (group):

$$\langle (q_1, p_1), \ldots, (q_M, p_M) \rangle$$

2. Guardian then **drops** all private keys p_i for $i > a$:

$$\Big\langle (q_1, p_1), \ldots, (q_a, p_a), (q_{a+1}, \bot), \ldots, (q_M, \bot) \Big\rangle$$

   - $\vec{Q} := (q_1, \ldots, q_M)$ is the *Commitment*,
   - $\vec{P}_a := (p_1, \ldots, p_a, \bot, \ldots, \bot)$ is the *Proof*

3. Guardian gives child $\langle \vec{Q}, \vec{P}_a \rangle$

Child has

- ordered public-keys $\vec{Q} = (q_1, \dots, q_M)$,
- (some) private-keys $\vec{P} = (p_1, \dots, p_a, \perp, \dots, \perp)$.

To Attest a minimum age $m \leq a$:

Sign a message with ECDSA using private key p_m

Merchant gets

- ordered public-keys $\vec{Q} = (q_1, \dots, q_M)$
- Signature σ

To Verify a minimum age m:

Verify the ECDSA-Signature σ with public key q_m.

Instantiation with ECDSA

Definitions of Derive and Compare

Child has $\vec{Q} = (q_1, \dots, q_M)$ and $\vec{P} = (p_1, \dots, p_a, \perp, \dots, \perp)$.

To Derive new $\vec{Q}'$ and $\vec{P}'$: Choose random $\beta \in \mathbb{Z}_g$ and calculate

$$\begin{aligned} \vec{Q}' &:= (\beta * q_1, \dots, \beta * q_M), \\ \vec{P}' &:= (\beta p_1, \dots, \beta p_a, \perp, \dots, \perp) \end{aligned}$$

Note: $(\beta p_i) * G = \beta * (p_i * G) = \beta * q_i$
$\beta * q_i$ is scalar multiplication on the elliptic curve.

Exchange gets $\vec{Q} = (q_1, \dots, q_M)$, $\vec{Q}' = (q'_1, \dots, q'_M)$ and β

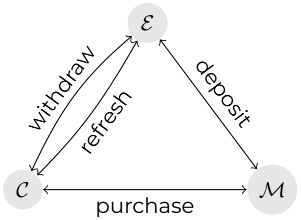
To Compare, calculate: $(\beta * q_1, \dots, \beta * q_M) \overset{?}{=} (q'_1, \dots, q'_M)$

Functions (Commit, Attest, Verify, Derive, Compare)
as defined in the instantiation with ECDSA

- meet the basic requirements,
- also meet all security requirements.
  Proofs by security reduction, details are in the paper.

Integration with GNU Taler

Key operations in the original system



- Coins are public-/private key-pairs (C_p, c_s).
- Exchange blindly signs FDH(C_p) with denomination key d_p
- Verification:

$$1 \overset{?}{\equiv} \text{SigCheck}\left(\text{FDH}(C_p), D_p, \sigma_p\right)$$

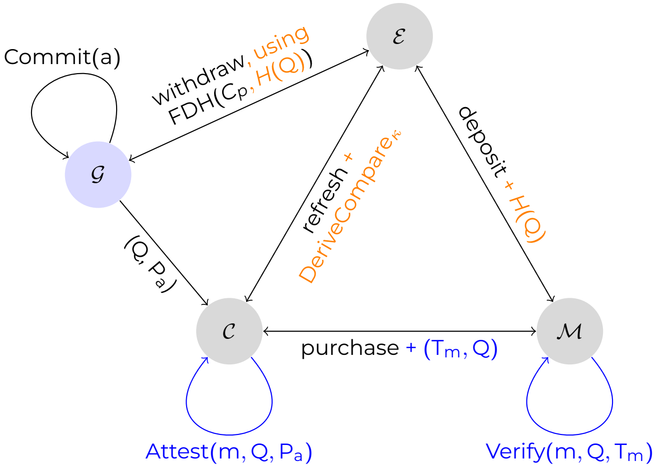
(D_p = public key of denomination and σ_p = signature)

To bind an age commitment Q to a coin C_p, instead of signing $\text{FDH}(C_p)$, $\mathcal{E}$ now blindly signs

$$\text{FDH}(C_p, H(\text{Q}))$$

Verfication of a coin now requires $H(\text{Q})$, too:

$$1 \stackrel{?}{=} \text{SigCheck}\big(\text{FDH}(C_p, H(\text{Q})), D_p, \sigma_p\big)$$



Commit(a)
withdraw, using FDH(C_p, $H(Q)$)
$\mathcal{E}$
$\mathcal{G}$
(Q, P_a)
refresh + DeriveCompare$_\kappa$
deposit + H(Q)
$\mathcal{C}$
purchase + (T_m, Q)
$\mathcal{M}$
Attest(m, Q, P_a)
Verify(m, Q, T_m)

Paper also formally defines another signature scheme: Edx25519.

- Scheme already in use in GNUnet,
- based on EdDSA (Bernstein et al.),
- generates compatible signatures and
- allows for key derivation from both, private and public keys, independently.

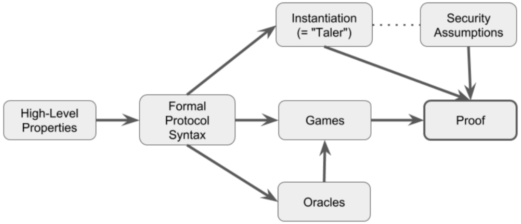
Current implementation of age restriction in GNU Taler uses Edx25519.

Discussion

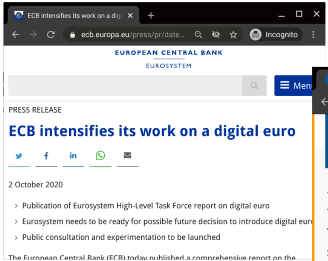
- Approach can be used with any token-based payment scheme
- Subsidiarity requires bank accounts being owned by adults
- Scheme can be adapted to case where minors have bank accounts
  - Assumption: banks provide minimum age information during bank transactions.
  - Child and Exchange execute a variant of the cut&choose protocol.

GNU Taler:

- Gives change, can provide refunds
- Integrates nicely with HTTP, handles network failures
- Has high performance
- Is Free Software
- Includes formal security proofs



Many initiatives are currently at the level of requirements discussion:


ECB intensifies its work on a digi
ecb.europa.eu/press/pr/date...
Incognito

EUROPEAN CENTRAL BANK
EUROSYSTEM

Men

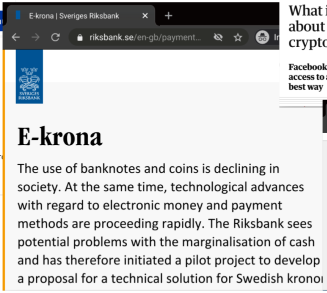
PRESS RELEASE

ECB intensifies its work on a digital euro

2 October 2020

- Publication of Eurosystem High-Level Task Force report on digital euro
- Eurosystem needs to be ready for possible future decision to introduce digital eur
- Public consultation and experimentation to be launched

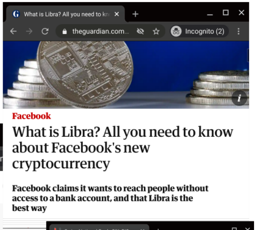
The European Central Bank (ECB) today published a comprehensive report on the


E-krona | Sveriges Riksbank
riksbank.se/en-gb/payment...

SVERIGES RIKSBANK

E-krona

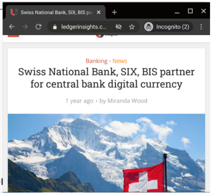
The use of banknotes and coins is declining in society. At the same time, technological advances with regard to electronic money and payment methods are proceeding rapidly. The Riksbank sees potential problems with the marginalisation of cash and has therefore initiated a pilot project to develop a proposal for a technical solution for Swedish kronoı


What is Libra? All you need to kn
theguardian.com...
Incognito (2)

Facebook

What is Libra? All you need to know about Facebook's new cryptocurrency

Facebook claims it wants to reach people without access to a bank account, and that Libra is the best way


Swiss National Bank, SIX, BIS pa
ledgerinsights.c...
Incognito (2)

Banking · News

Swiss National Bank, SIX, BIS partner for central bank digital currency

1 year ago • by Miranda Wood

1. Central bank issues digital coins equivalent to issuing cash
2. Architecture with consumer accounts at commercial banks
3. Withdrawal limits and denomination expiration
4. Income transparency and possibility to set fees
5. Revocation protocols and loss limitations
6. Privacy by cryptographic design not organizational compliance

Political support needed, talk to your representatives!

Ongoing work

- Post-quantum blind signatures
- Integration into more physical machines
- Integration with KYC/AML providers
- Deployment for regional currency in Basel
- Integration with Swiss Postfinance EBICS API
- Wallet backup and recovery with Anastasis
- Internationalization ⇒ `https://weblate.taler.net/`

`https://bugs.taler.net/` tracks open issues.

- Address remaining scalability challenges (multiple topics)
- Porting to more platforms (Web shops, iOS, embedded, ...)
- Integration with e-commerce frameworks (Prestashop, OpenCart, ...)
- Currency conversion
- SAP integration
- Design and usability for illiterate and innumerate users
- Federated exchange (wads)
- ...

Help needed, talk to us (e.g. at `https://ich.taler.net/`)

- Be paid to read advertising, starting with spam
- Give welfare without intermediaries taking huge cuts
- Forster regional trade via regional currencies
- Eliminate corruption by making all income visible
- Stop the mining by making crypto-currencies useless for anything but crime

Jeffrey Burdges, Florian Dold, Christian Grothoff, and Marcello Stanisci.
Enabling secure web payments with GNU Taler.
In Claude Carlet, M. Anwar Hasan, and Vishal Saraswat, editors, *6th International Conference on Security, Privacy and Applied Cryptographic Engineering*, number 10076 in LNCS, pages 251–270. Springer, Dec 2016.

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How to issue a central bank digital currency.
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