GNU Taler: Ein neues elektronisches Bezahlsystem

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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)

Motivation

Modern economies need currency ...

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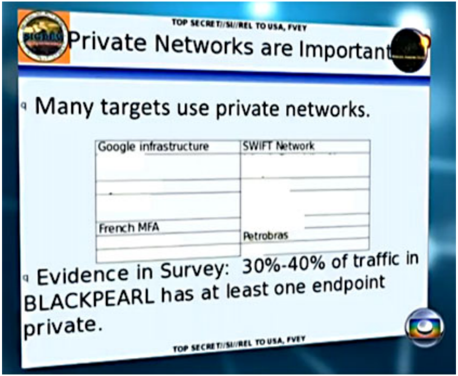
Modern economies need payments online.

SWIFT?



SWIFT/Mastercard/Visa are too transparent.

Bitcoin

- Unregulated payment system and currency:

  $\Rightarrow$ lack of regulation is a feature!
- Decentralised peer-to-peer system

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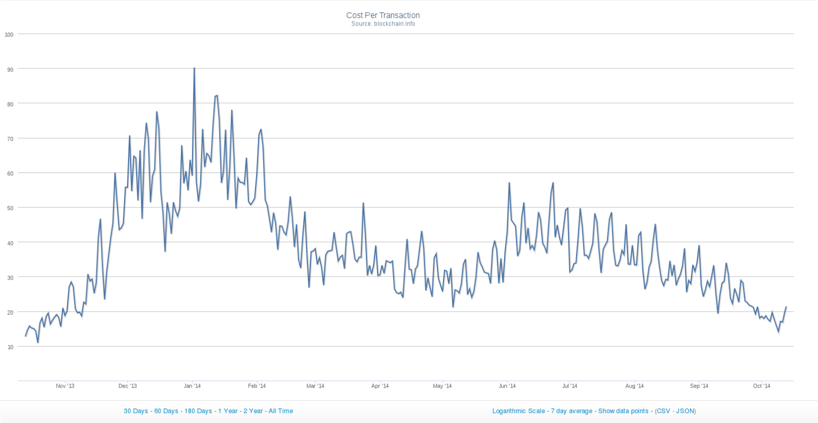
- Decentralised banking requires solving Byzantine consensus
- Creative solution: tie initial accumulation to solving consensus

Bitcoin

- Unregulated payment system and currency:
  $\Rightarrow$ lack of regulation is a feature!
- Decentralised peer-to-peer system
- Decentralised banking requires solving Byzantine consensus
- Creative solution: tie initial accumulation to solving consensus
  $\Rightarrow$ Proof-of-work advances ledger
  $\Rightarrow$ Very expensive banking

?



Current average transaction value: $\approx$ 1000 USD

?

Cryptography is rather primitive:

All Bitcoin transactions are public and linkable!

$\Rightarrow$ no privacy guarantees

$\Rightarrow$ enhanced with "laundering" services

ZeroCoin, CryptoNote (Monero) and ZeroCash (ZCoin) offer anonymity.

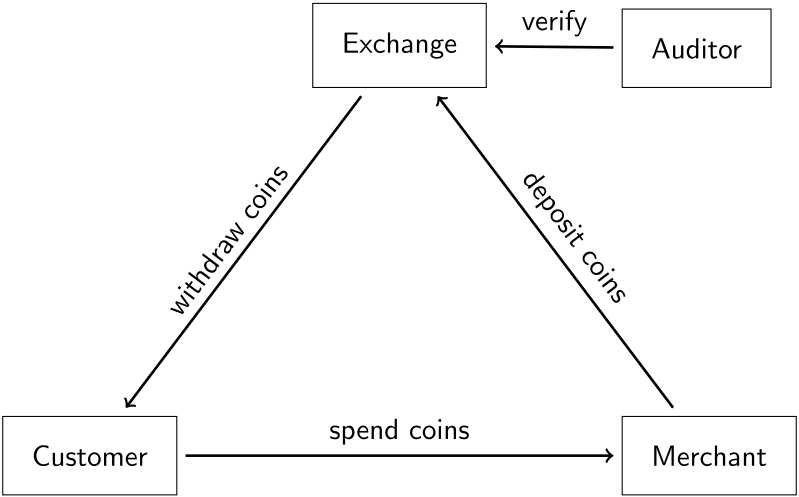
Is society ready for an anarchistic economy?

GNU Taler

Digital cash, made **socially responsible**.

Taxable, Anonymous, Libre, Practical, Resource Friendly

Architecture of GNU Taler



Usability of Taler

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

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

Value proposition: Customer

- Convenient: pay with one click
- Guaranteed: never fear being rejected by false-positives in the fraud detection
- Secure: like cash, except no worries about counterfeit
- Privacy-preserving: payment requires no personal information
- Stable: no currency fluctuations, pay in traditional currencies
- Free software: no hidden "gadgets", third parties can verify

Value proposition: Merchant

- Fast: transactions at Web-speed
- Secure: signed contracts, no legitimate customer rejected by fraud decection
- Free software: competitive pricing and support
- Low fees: efficient protocol + no fraud = low costs
- Flexible: any currency, any amount
- Ethical: no fluctuation risk, no pyramid scheme, not suitable for illegal business
- Legal: complies with Regulation (EU) 2016/679 (GDPR)[1]

[1] Requires privacy by design and data minimization for all data processing in Europe after 25.5.2018.

Value proposition: Government

- Free software = commons: no monopoly, preserve independence
- Efficiency: high transaction costs hurt the economy
- Security: signed contracts, no counterfeit
- Audited: no bad banks
- Privacy: protection against foreign espionage
- Taxabiliy: reduces black markets

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.

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- State can trace income and enforce taxation.

Limitations:

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

Merchant Integration: Wallet Detection

```
<script src="taler-wallet-lib.js"></script>
<script>
  taler.onPresent(() => {
    alert("Taler␣wallet␣is␣installed");
  });
  taler.onAbsent(() => {
    alert("Taler␣wallet␣is␣not␣installed");
  });
</script>
```

Merchant Integration: Payment Request

```
HTTP/1.1 402 Payment Required
Content-Type: text/html; charset=UTF-8
X-Taler-Contract-Url: https://shop/generate-contract/42

<!DOCTYPE html>
<html>
  <!-- fallback for browsers without the Taler extension -->
  You do not seem to have Taler installed, here are other
  payment options ...
</html>
```

Merchant Integration: Contract

```
{
  "H_wire":"YTH0C4QBCQ10VDNTJN0DCTTV2Z6JHT5NF43F0RQHZ8JYB5NG4W4G...",
  "amount":{"currency":"EUR","fraction":1,"value":0},
  "auditors":[{"auditor_pub":"42V6TH91Q83FB846DK1GW3JQ5E8DS273W4..."}],
  "exchanges":[{"master_pub":"1T5FA8VQHMMKBHDMYPRZA2ZFK2S63AKF0Y...",
              "url":"https://exchange/"}],
  "expiry":"/Date(1480119270)/",
  "fulfillment_url": "https://shop/article/42?tid=249&time=14714744",
  "max_fee":{"currency":"EUR","fraction":01,"value":0},
    "merchant":{"address":"Mailbox␣4242","jurisdiction":"Jersey",
              "name":"Shop␣Inc."},
  "merchant_pub":"Y1ZAR5346J3ZTEXJCHQY9NJN78EZ2HSKZK8M0MYTNRJG5N...",
  "products":[{
    "description":"Essay:␣The␣GNU␣Project",
    "price":{"currency":"EUR","fraction":1,"value":0},
    "product_id":42,"quantity":1}],
  "refund_deadline":"/Date(1471522470)/",
  "timestamp":"/Date(1471479270)/",
  "transaction_id":249960194066269
}
```

Information for system integrators

https://api.taler.net/

How does it work?

We use a few ancient constructions:

- Cryptographic hash function (1989)
- Blind signature (1983)
- Schnorr signature (1989)
- Diffie-Hellman key exchange (1976)
- Cut-and-choose zero-knowledge proof (1985)

But of course we use modern instantiations.

Global setup: Pick an Elliptic curve

Need:

G generator in ECC curve, a point

n size of ECC group, $o := |G|$, o prime

Now we can, for example, compute:

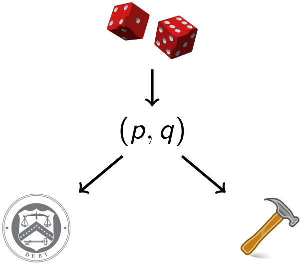
$$\begin{aligned} A &= G + G \\ &= 2G \\ B &= A + G \\ &= 3G \\ C &= cG \texttt{ for } c \in \mathbb{Z} \end{aligned}$$

Note:

$$G = (o + 1)G$$

Exchange setup: Create a denomination key (RSA)

1. Pick random primes p, q.
2. Compute $n := pq$,
   $\phi(n) = (p-1)(q-1)$
3. Pick small $e < \phi(n)$ such that
   $d := e^{-1} \mod \phi(n)$ exists.
4. Publish public key (e, n).



Merchant: Create a signing key (EdDSA)

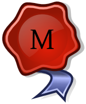
- pick random $m \mod o$ as private key
- $M = mG$ public key

$\downarrow$

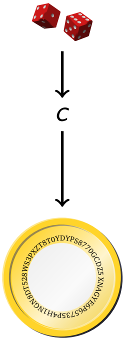
m

$\downarrow$

M

Capability: $m \Rightarrow$ 

Customer: Create a planchet (EdDSA)

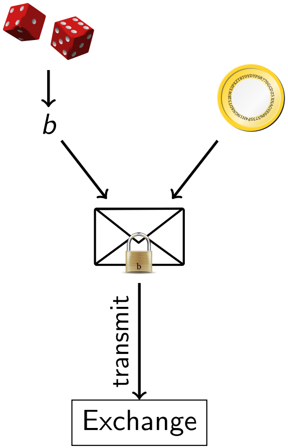


- Pick random $c \mod o$ private key
- $C = cG$ public key

Capability: $c \Rightarrow$ 

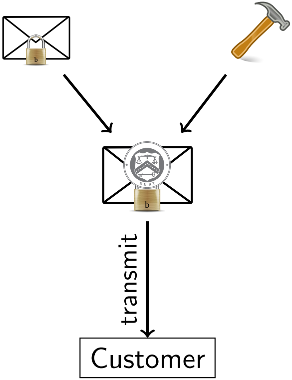
Customer: Blind planchet (RSA)

1. Obtain public key (e, n)
2. Compute $m := FDH(C)$, $m < n$.
3. Pick blinding factor $b \in \mathbb{Z}_n$
4. Transmit $m' := mb^e \mod n$



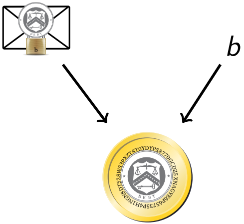
Exchange: Blind sign (RSA)

1. Receive m'.
2. Compute $s' := m'^d \mod n$.
3. Send signature s'.

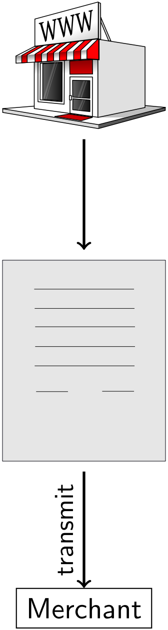


Customer: Unblind coin (RSA)

1. Receive s'.
2. Compute $s := s'b^{-1} \mod n$.

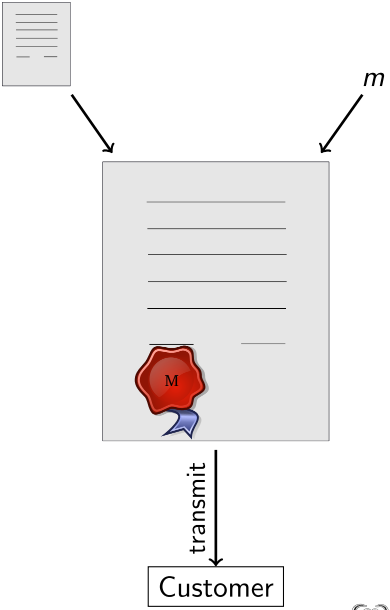


Customer: Build shopping cart



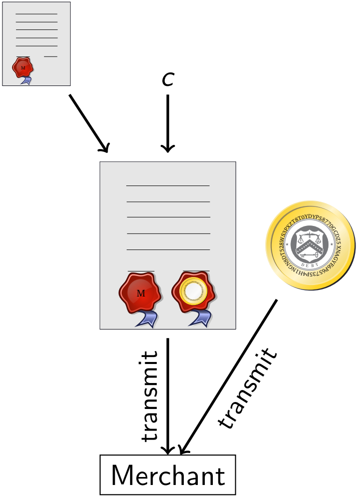
Merchant: Propose contract (EdDSA)

1. Complete proposal D.
2. Send D, $EdDSA_m(D)$



Customer: Spend coin (EdDSA)

1. Receive proposal D, $EdDSA_m(D)$.
2. Send s, C, $EdDSA_c(D)$



Merchant and Exchange: Verify coin (RSA)

$$s^e \stackrel{?}{\equiv} m \mod n$$

Giving change

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

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Method:

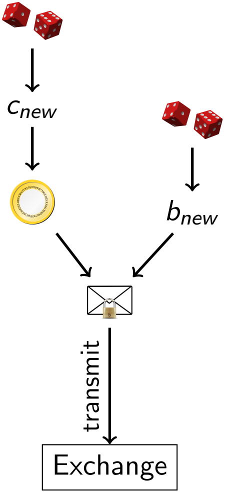
- Contract can specify to only pay *partial value* of a coin.
- Exchange allows wallet to obtain *unlinkable change* for remaining coin value.

Strawman solution

Given partially spent private coin key c_{old}:

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

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



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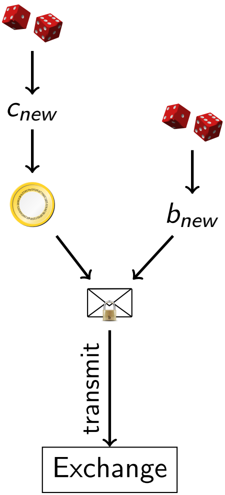
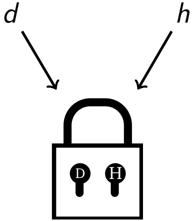


Problem: Owner of c_{new} may differ from owner of c_{old}!

Diffie-Hellman (ECDH)

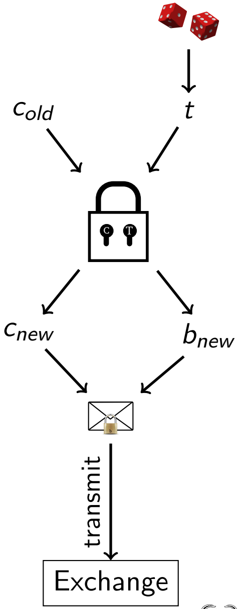
1. Create private keys $d, h \mod o$
2. Define $D = dG$
3. Define $H = hG$
4. Compute $DH := d(hG) = h(dG)$



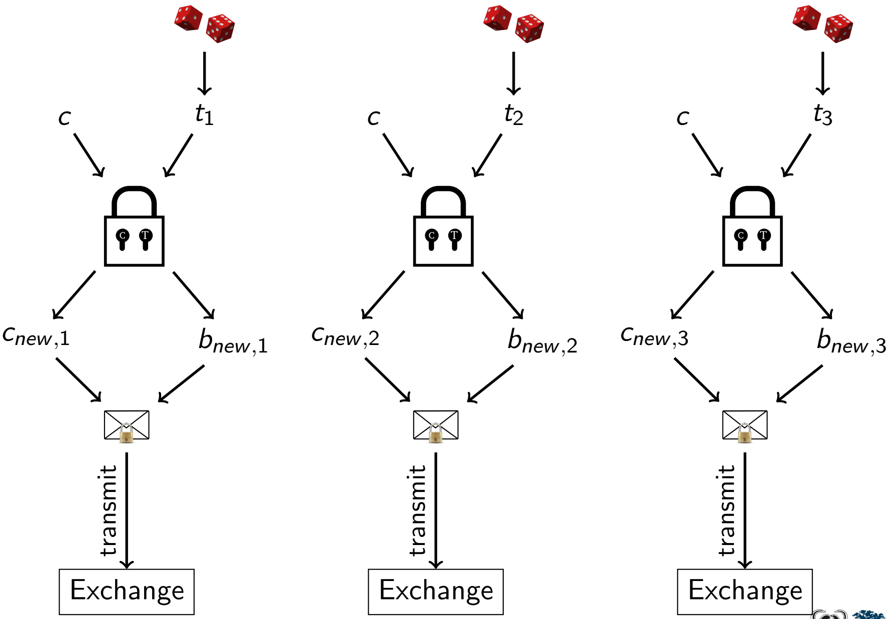
Customer: Transfer key setup (ECDH)

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 $T := tG$
4. Compute $X := c_{old}(tG) = t(c_{old} G) = tC_{old}$
5. Derive c_{new} and b_{new} from X
6. Compute $C_{new} := c_{new} G$
7. Compute $m_{new} := FDH(C_{new})$
8. Transmit $m'_{new} := m_{new} b^e_{new}$



Cut-and-Choose



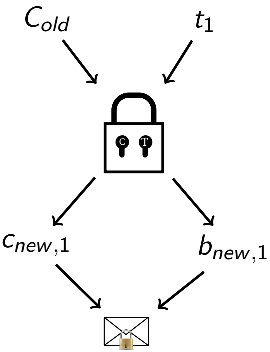
Exchange: Choose!

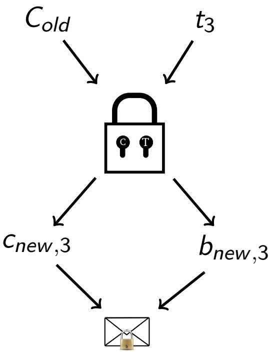
Exchange sends back random $\gamma \in \{1, 2, 3\}$ to the customer.

Customer: Reveal

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

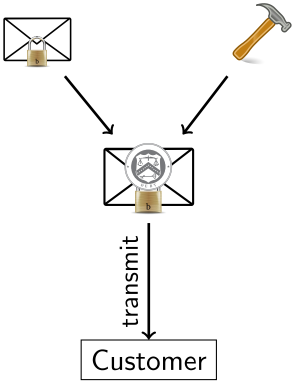
Exchange: Verify ($\gamma = 2$)





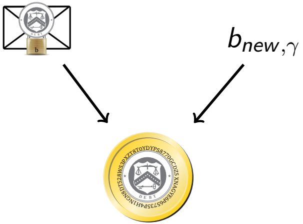
Exchange: Blind sign change (RSA)

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



Customer: Unblind change (RSA)

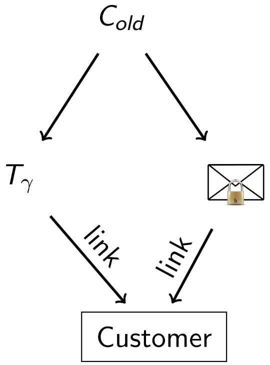
1. Receive s'.
2. Compute $s := s' b_{new,\gamma}^{-1} \mod n$.



Exchange: Allow linking change

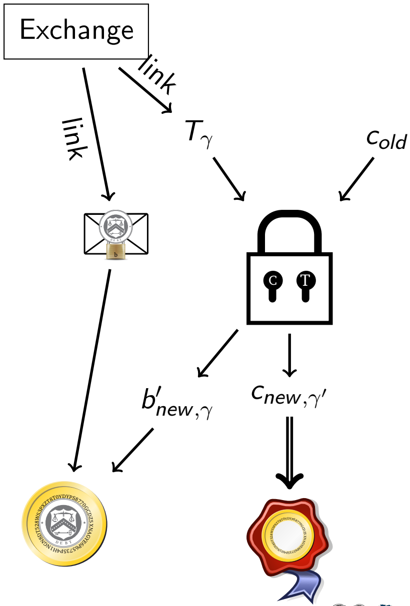
Given C_{old}

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



Customer: Link (threat!)

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.

Transactions via refresh are equivalent to sharing a wallet.

Current technical developments

- Tutorial for merchants
- Tutorial for Web shop integration
- Improving wallet (error handling, features, browser support)
- Ongoing work on exchange auditing

Business considerations

- Exchange needs to be a legal (!) business to operate.
- Exchange operator income is from *transaction fees*.
- Created Taler Systems S.A. in Luxemburgh.
- Now trying to find partners and financing for startup.

Payment solutions - Pricing

Provider	**Pricing**
Alipay	2,0% - 3,0%
Allied Wallet	1,95% + $ 0,20
Amazon Payments	2,9% + $ 0,30
Avangate	4,9% + $ 2,50
Billpro	2,1% + 3,5% fee
BitGold Inc.	1% fee on every purchase
Checkout.com	2,95% - 3,95% + £0,15
Coinify (Bitcoin)	0%
eComCharge	3,5% + €0,35
GoCardless	1% up to a maximum of £2
LaterPay (Cookie)	15%
Western Union	Variable — From 5% up
Taler Systems S.A. (planned)	0.5%

Conclusion

What can we do?

- Suffer mass-surveillance enabled by credit card oligopolies with high fees, and
- Engage in arms race with deliberately unregulatable blockchains

OR

- Establish free software alternative balancing social goals

Do you have any questions?

References:

1. Christian Grothoff, Bart Polot and Carlo von Loesch. *The Internet is broken: Idealistic Ideas for Building a GNU Network*. **W3C/IAB Workshop on Strengthening the Internet Against Pervasive Monitoring (STRINT)**, 2014.
2. Jeffrey Burdges, Florian Dold, Christian Grothoff and Marcello Stanisci. *Enabling Secure Web Payments with GNU Taler*. **SPACE 2016**.
3. Florian Dold, Sree Harsha Totakura, Benedikt Müller, Jeffrey Burdges and Christian Grothoff. *Taler: Taxable Anonymous Libre Electronic Reserves*. Available upon request. 2016.
4. Eli Ben-Sasson, Alessandro Chiesa, Christina Garman, Matthew Green, Ian Miers, Eran Tromer and Madars Virza. *Zerocash: Decentralized Anonymous Payments from Bitcoin*. **IEEE Symposium on Security & Privacy, 2016**.
5. David Chaum, Amos Fiat and Moni Naor. *Untraceable electronic cash*. **Proceedings on Advances in Cryptology, 1990**.
6. Phillip Rogaway. *The Moral Character of Cryptographic Work*. **Asiacrypt**, 2015.

Let money facilitate trade; but ensure capital serves society.

Competitor comparison

	Cash	Bitcoin	Zerocoin	Creditcard	Taler
Online	−−−	++	++	+	+++
Offline	+++	−−	−−	+	−−
Trans. cost	+	−−−	−−−	−	++
Speed	+	−−−	−−−	o	++
Taxation	−	−−	−−−	+++	+++
Payer-anon	++	o	++	−−−	+++
Payee-anon	++	o	++	−−−	−−−
Security	−	o	o	−−	++
Conversion	+++	−−−	−−−	+++	+++
Libre	−	+++	+++	−	+++

Evolution Matrix

	ZeroCoin	CryptoNote	ZeroCash	GNU Taler
Bandwidth	45000 b	13000 b	1000 b	$\approx$ 1000 b
CPU spend	500 ms	10 ms	45s	1 ms
CPU verify	450 ms	10 ms	6 ms	2 ms
Anonymity set	ZC subset	freq. dep.	all users	customers
Change	no	yes	yes	yes
Scalability	$---$	?	?	$+++$
Trans. cost	100 USD?	20 USD?	20 USD?	0.0001 USD

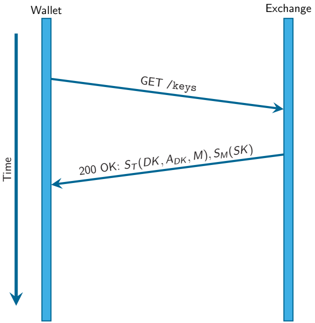
Note: Approximate figures based on current reading of the papers, not on scientific comparative experiments.

Bitcoin anonymization technology

- Coin creation and distributed ledger basically remain
- Transactions are no longer simply signed by the owner
- Instead, currency is transferred from a *pool of owners* to another *pool of owners*
- Impossible to say which specific owner initiated the transfer (there is just a zero knowledge proof it was somebody authorized)
- Impossible to say who became the new owner (just somebody now can prove that he has the right to authorize a transfer)
- Cryptography used is somewhat experimental (zk-SNARK) and expensive

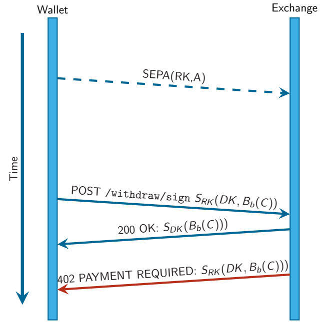
  $\Rightarrow$ Further research might enable us to find attacks (arms race)

Taler /keys



T	financial regulator key Necessarily pinned
DK	RSA public key ("denomination key")
A_{DK}	Value of coins signed by DK
M	Offline master key of exchange
SK	Online signing key of exchange

Taler /withdraw/sign

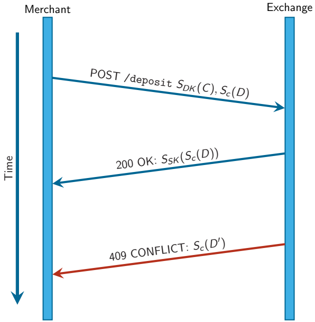


Result: $\langle c, S_{DK}(C) \rangle$.

A	Some amount, $A \geq A_{DK}$
RK	Reserve key
DK	Denomination key
b	Blinding factor
$B_b()$	RSA-FDH blinding
C	Coin public key $C := cG$
$S_{RK}()$	EdDSA signature
$S_{DK}()$	RSA-FDH signature

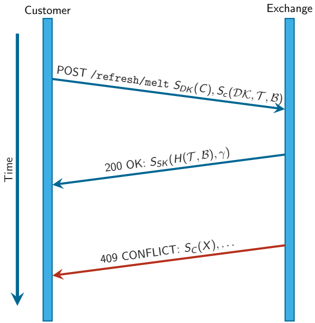
Taler `/deposit`

Merchant and exchange see only the public coin $\langle C, S_{DK}(C)\rangle$.



DK	Denomination key
$S_{DK}()$	RSA-FDH signature using DK
c	Private coin key, $C := cG$.
$S_C()$	EdDSA signature using c
D	Deposit details
SK	Exchange's signing key
$S_{SK}()$	EdDSA signature using SK
D'	Conficting deposit details $D' \neq D$

Taler /refresh/melt



κ System-wide security parameter, usually 3.

$\mathcal{DK}$ $:= [DK^{(i)}]_i$
List of denomination keys
$D + \sum_i A_{DK^{(i)}} < A_{DK}$

t_j Random scalar for $j < \kappa$

$\mathcal{T}$ $:= [T_j]_\kappa$ where $T_j = t_j G$

k_j $:= cT_j = t_j C$ is an ECDHE

$b_j^{(i)}$ $:= KDF_b(k_j, i)$

$c_j^{(i)}$ $:= KDF_c(k_j, i)$

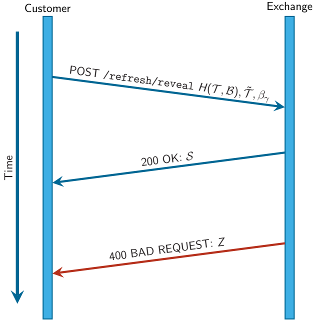
$C_j^{(i)}$ $:= c_j^{(i)} G$

$\mathcal{B}$ $:= [H(\beta_j)]_\kappa$ where

$$\beta_j := \left[B_{b_j^{(i)}}(C_j^{(i)}) \right]_i$$

γ Random value in $[0, \kappa)$

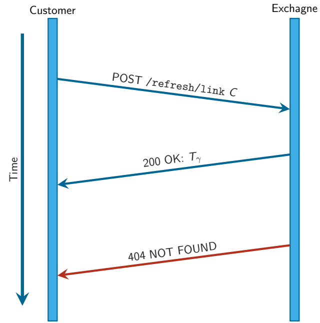
Taler /refresh/reveal



$$
\begin{aligned}
\mathcal{DK} &:= [DK^{(i)}]_i \\
t_j &\ .. \\
\tilde{\mathcal{T}} &:= [t_j | j \in \kappa, j \neq \gamma] \\
k_\gamma &:= cT_\gamma = t_\gamma C \\
b_\gamma^{(i)} &:= KDF_b(k_\gamma, i) \\
c_\gamma^{(i)} &:= KDF_c(k_\gamma, i) \\
C_\gamma^{(i)} &:= c_\gamma^{(i)} G \\
B_\gamma^{(i)} &:= B_{b_\gamma^{(i)}}(C_\gamma^{(i)}) \\
\beta_\gamma &:= \left[B_\gamma^{(i)}\right]_i \\
\mathcal{S} &:= \left[S_{DK^{(i)}}(B_\gamma^{(i)})\right]_i
\end{aligned}
$$

Z Cut-and-choose missmatch information

Taler /refresh/link



C Old coind public key

T_γ Linkage data $\mathcal{L}$ at γ