GNU

⟨Taler⟩

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The World is Moving to Electronic Cash

"In future, cash may be so marginalised that it becomes difficult to use as a means of payment.
(...)
Many central banks are analysing central bank digital currencies (CBDC).
(...)
The arguments in favour of analysing a CBDC to be offered to the general public have been based on the idea that a CBDC is expected to increase financial inclusion and reduce the use of cash, which is considered costly, risky, to have negative environmental effects and to facilitate the black economy." – Riskbank e-Krona Project Report 2

What will the technical foundation for CBDC look like?


The Distraction: Bitcoin

- Unregulated payment system and currency:

  $\Rightarrow$ lack of regulation is a feature!
- Implemented in free software
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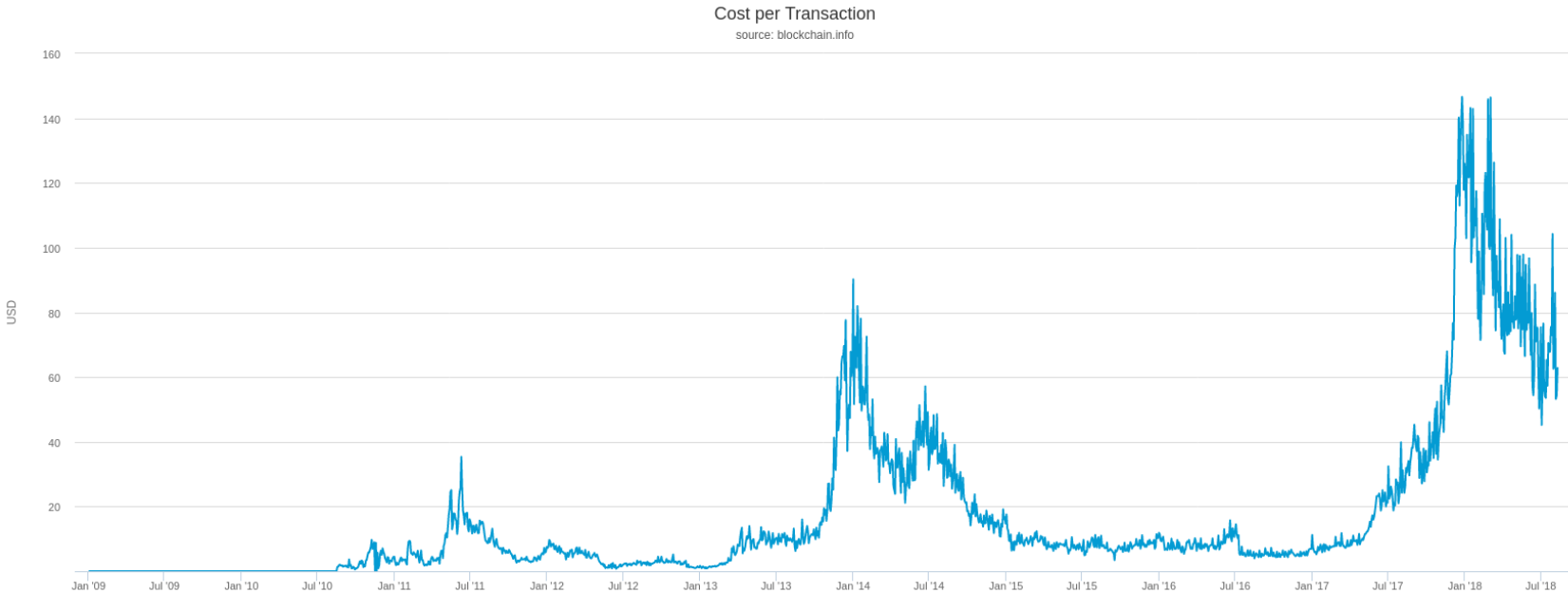
- Decentralised banking requires solving Byzantine consensus
- Creative solution: tie initial accumulation to solving consensus

  $\Rightarrow$ Proof-of-work advances ledger

  $\Rightarrow$ Very expensive banking

?



Current average transaction value: $\approx$ 1000 USD

GNU Taler: Electronic payment system designed as CBDC

Digital cash, made **socially responsible**.

⟨Taler⟩

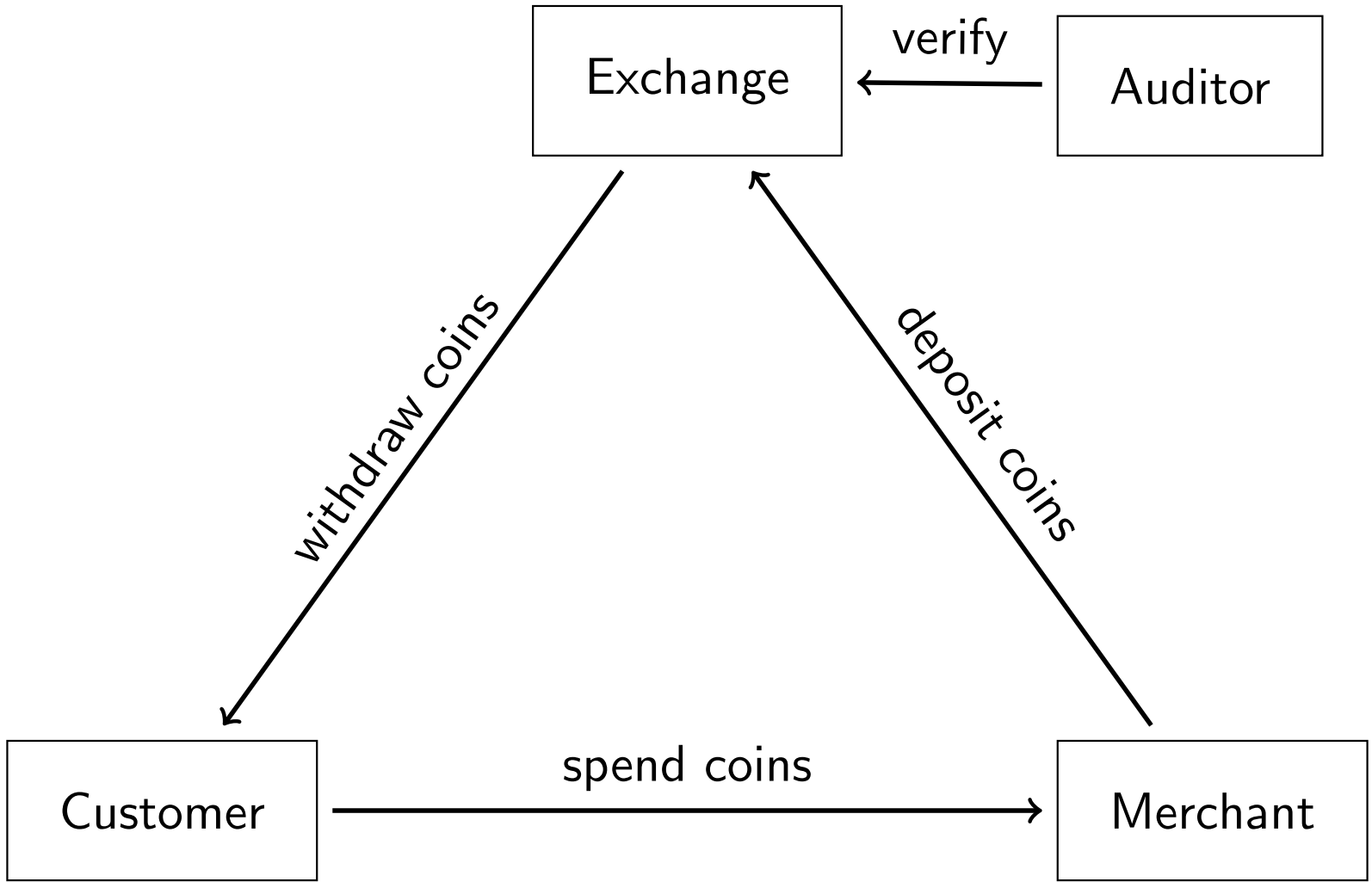
Privacy-Preserving, Practical, Taxable, Free Software, Efficient

What is Taler?

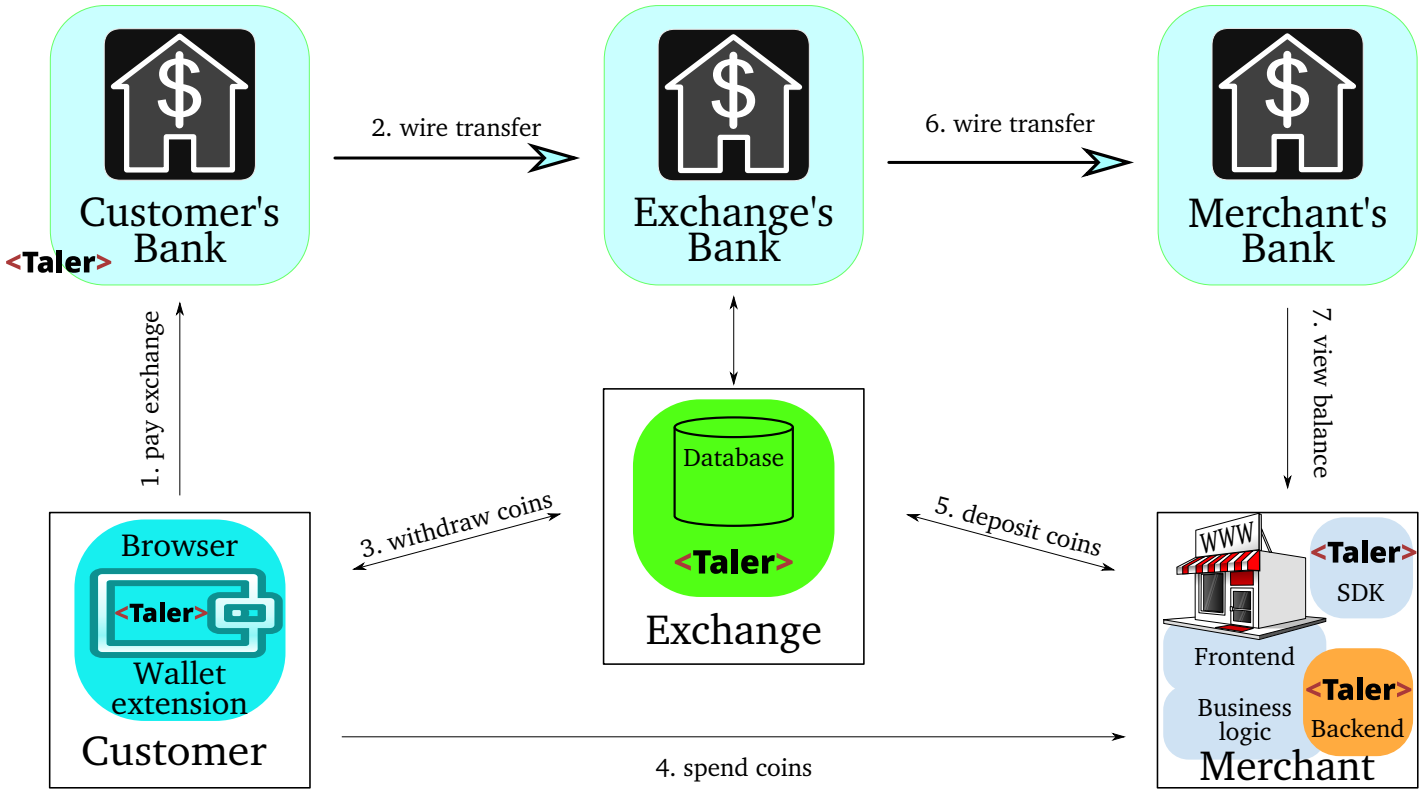
Taler is an electronic instant payment system.

- Uses electronic coins stored in **wallets** on customer's device
- Like **cash**
- Pay in **existing currencies** (i.e. EUR, USD, BTC), or use it to create new **regional currencies**

Taler Overview



Architecture of Taler



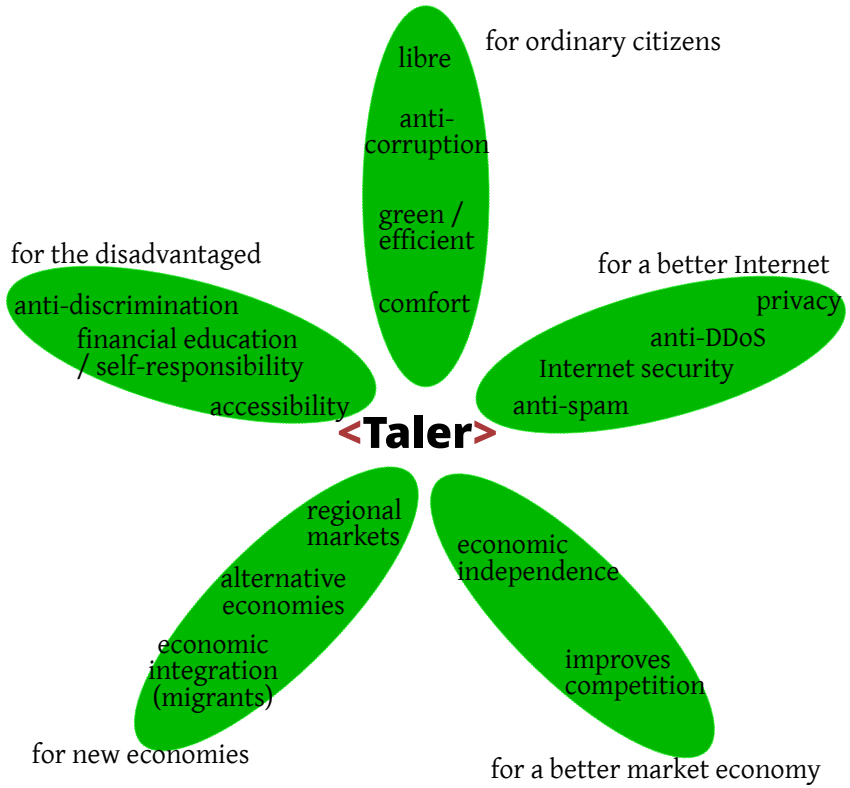
⇒ Convenient, taxable, privacy-enhancing, & resource friendly!

Usability of Taler

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

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

Social Impact of Taler



Use Case: Journalism

Today:

- Corporate structure
- Advertising primary revenue
- Tracking readers critical for business success
- Journalism and marketing hard to distinguish

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With GNU Taler:

- One-click micropayments per article
- Hosting requires no expertise
- Reader-funded reporting separated from marketing
- Readers can remain anonymous

Use Cases: Refugee Camps

Today:

- Non-bankable
- Direct distribution of goods to population
- Limited economic activity in camps
- High level of economic dependence

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- Non-bankable
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- Limited economic activity in camps
- High level of economic dependence

With GNU Taler:

- Local currency issued as basic income backed by aid
- Taxation possible based on economic status
- Local governance enabled by local taxes
- Increased economic independence and political participation

Use Case: Anti-Spam

Today, p≡p provides authenticated encryption for e-mail:

- Free software
- Easy to use opportunistic encryption
- Available for Outlook, Android, Enigmail
- Spies & spam filters can no longer inspect content

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With GNU Taler:

- Peer-to-peer payments via e-mail
- If unsolicited sender, hide messages from user & automatically request payment from sender
- Sender can attach payment to be moved to inbox
- Receiver may grant refund to sender

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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- Hash of contract is part of deposit data.
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Limitations:

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

How does it work?

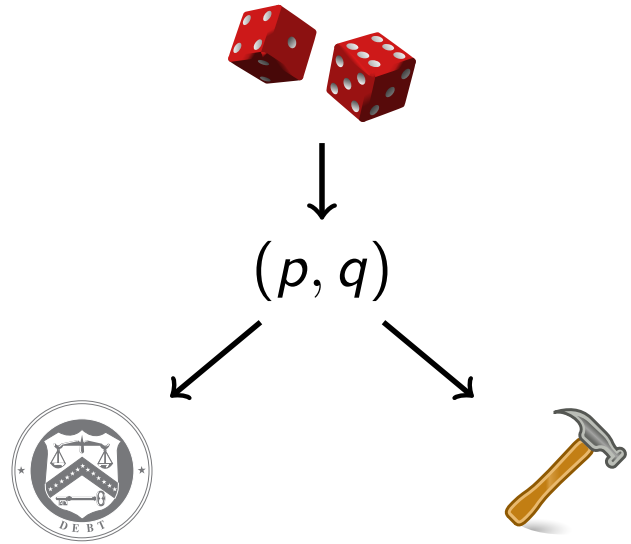
We use a few ancient constructions:

- 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.

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).

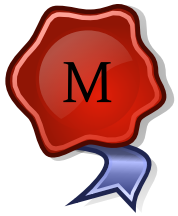


Merchant: Create a signing key (EdDSA)

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

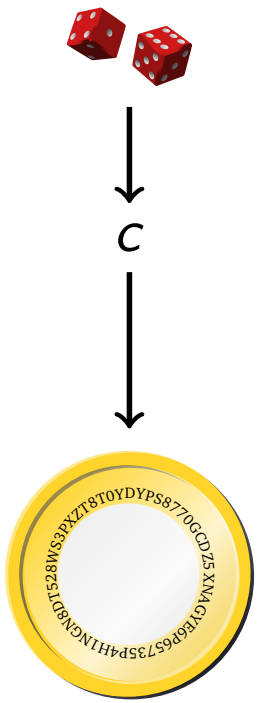
m

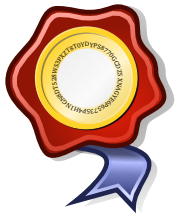
M

Capability: $m \Rightarrow$ 

Customer: Create a planchet (EdDSA)

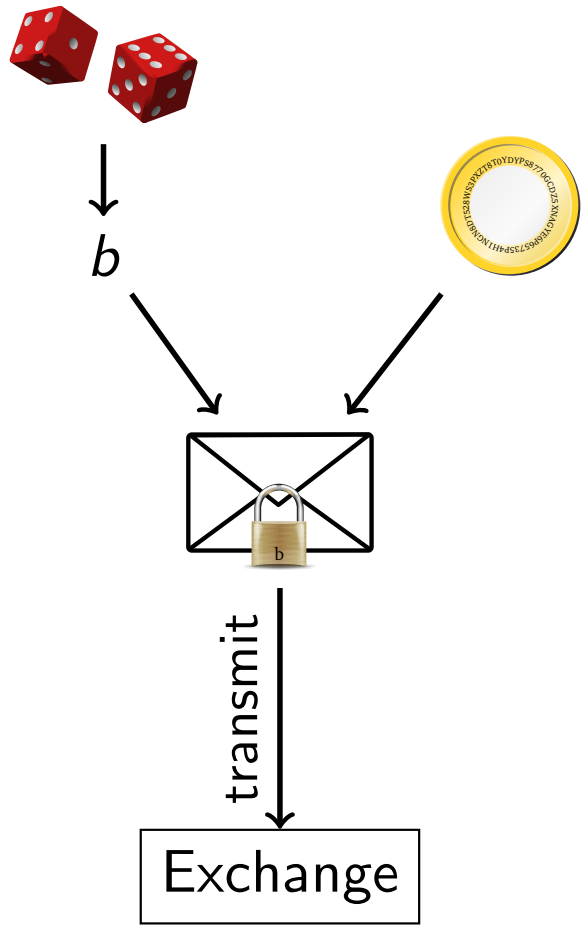
- Pick random c mod o private key
- $C = cG$ public key



Capability: $c \Rightarrow$ 

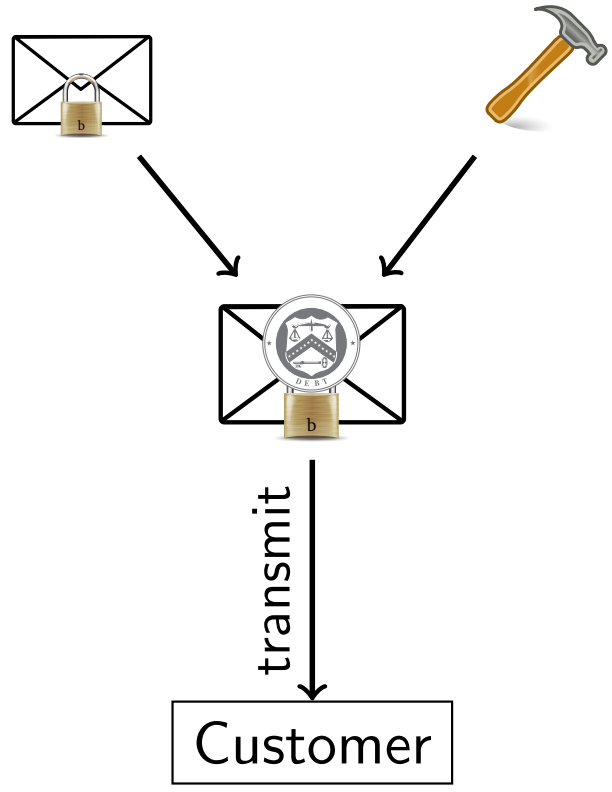
Customer: Blind planchet (RSA)

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



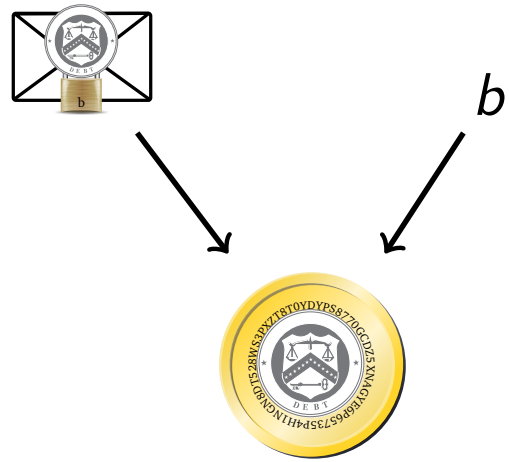
Exchange: Blind sign (RSA)

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

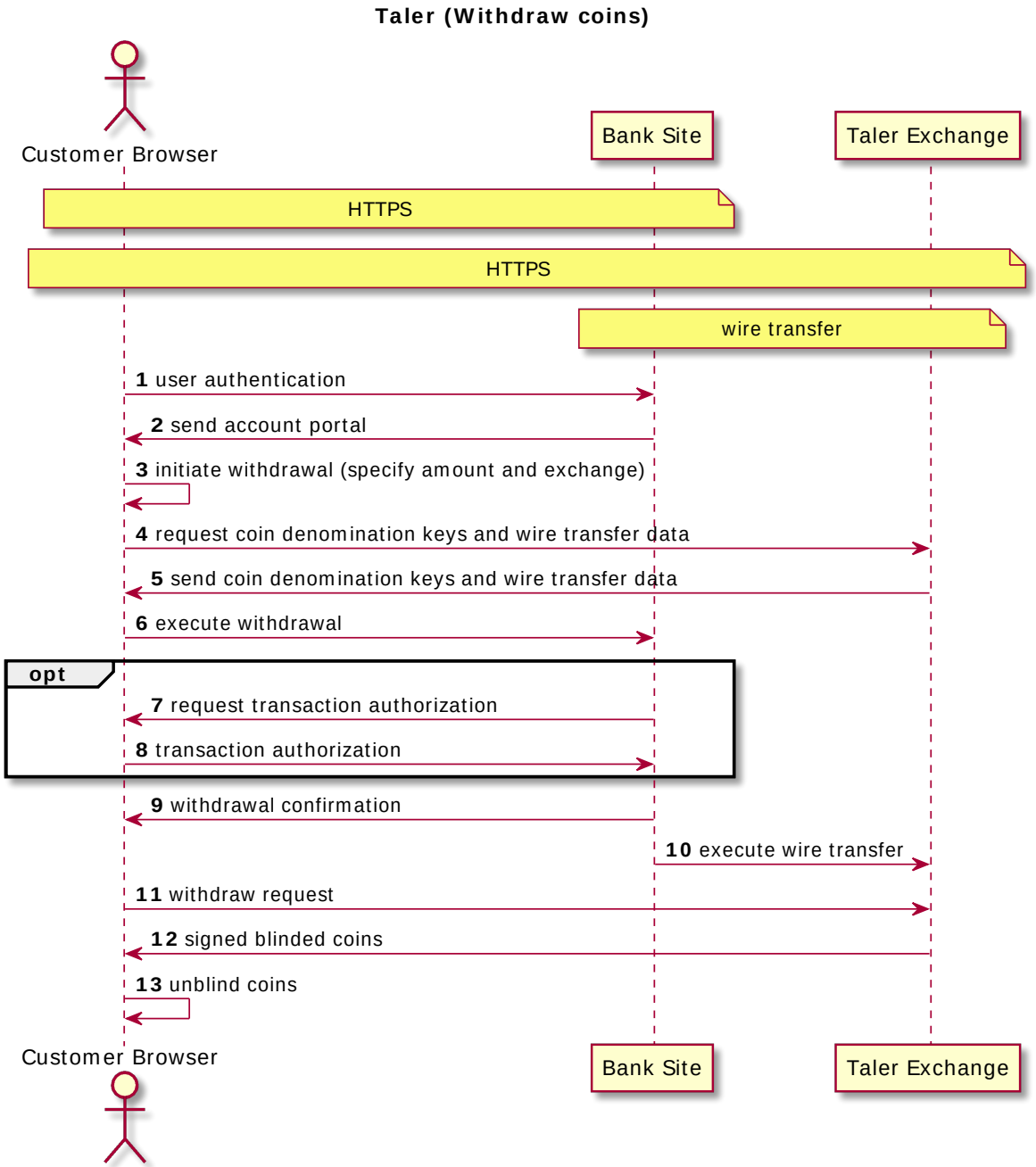


Customer: Unblind coin (RSA)

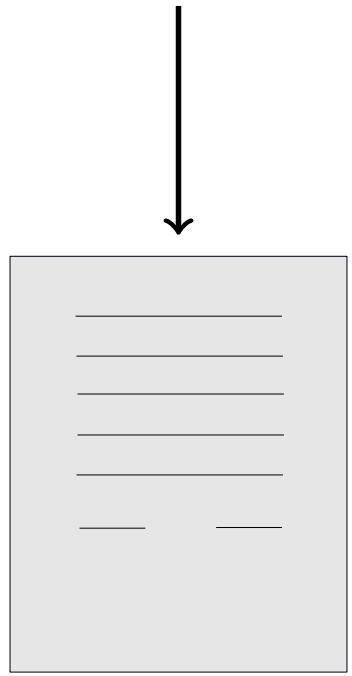
1. Receive s'.
2. Compute $s := s'b^{-1} \mod n$



Withdrawing coins on the Web



Customer: Build shopping cart



transmit

Merchant

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

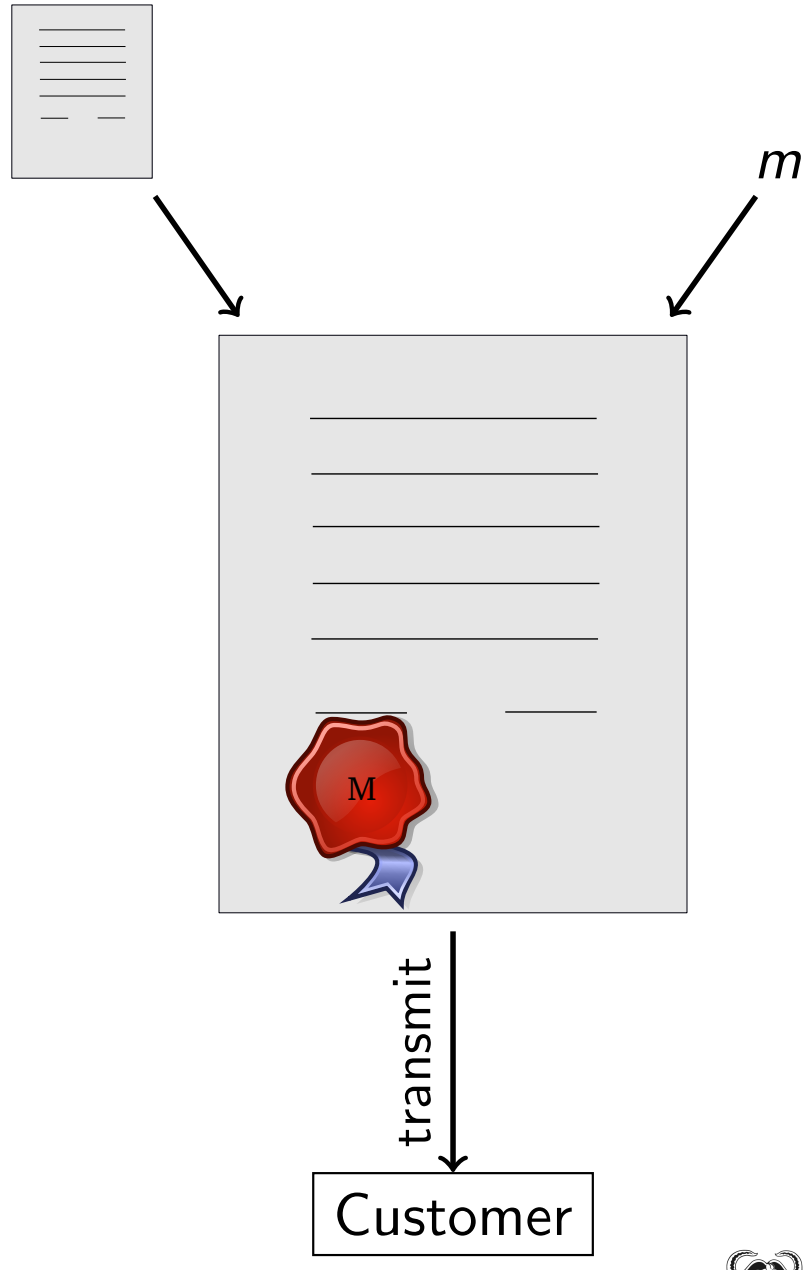
```
HTTP/1.1 402 Payment Required
Content-Type: text/html; charset=UTF-8
X-Taler-Contract-Url: https://shop/generate-contract/42

<!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":0,"value":1},
  "max_fee":{"currency":"EUR","fraction":100000,"value":0},
  "auditors":[{"auditor_pub":"42V6TH91Q83FB846DK1GW3JQ5E8DS273W4..."}],
  "exchanges":[{"master_pub":"1T5FA8VQHMMKBHDMYPRZA2ZFK2S63AKF0Y...",
                "url":"https://exchange/"}],
  "fulfillment_url": "https://shop/article/42?tid=249&time=14714744",
  "merchant":{"address":"Mailbox␣4242","jurisdiction":"Jersey",
                "name":"Shop␣Inc."},
  "merchant_pub":"Y1ZAR5346J3ZTEXJCHQY9NJN78EZ2HSKZK8M0MYTNRJG5N...",
  "products":[{
    "description":"Essay:␣The␣GNU␣Project",
    "price":{"currency":"EUR","fraction":0,"value":1},
    "product_id":42,"quantity":1}],
  "pay_deadline":"/Date(1480119270)/",
  "refund_deadline":"/Date(1471522470)/",
  "timestamp":"/Date(1471479270)/",
  "transaction_id":24996019406626 9
}
```

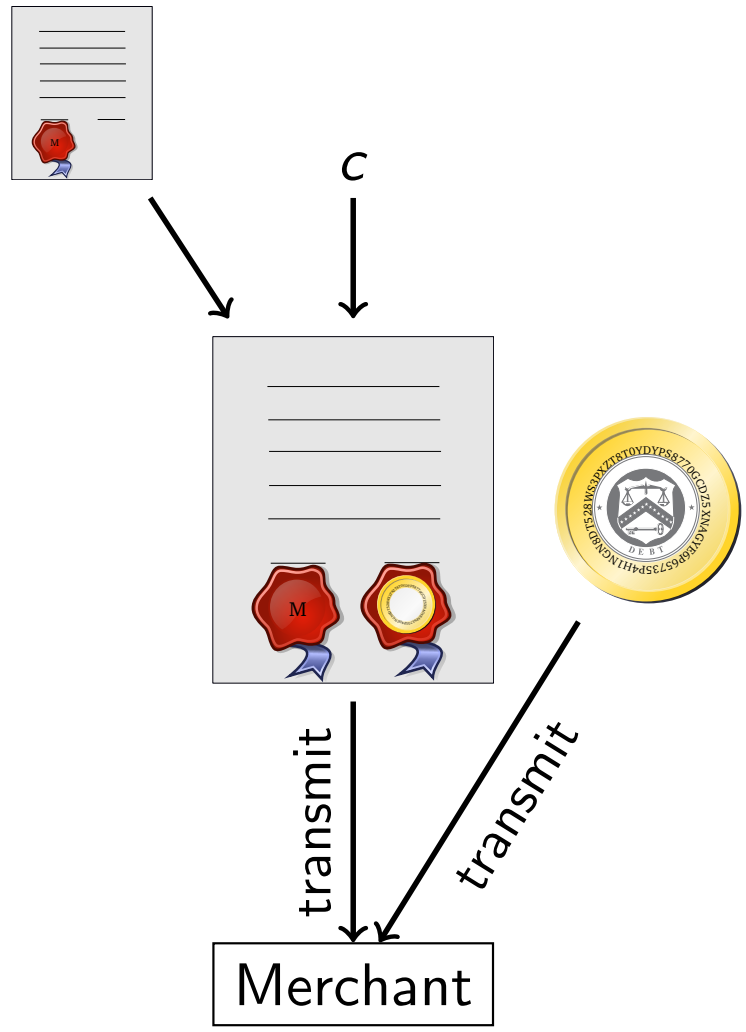
Merchant: Propose contract (EdDSA)

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



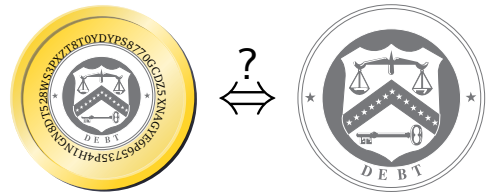
Customer: Spend coin (EdDSA)

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

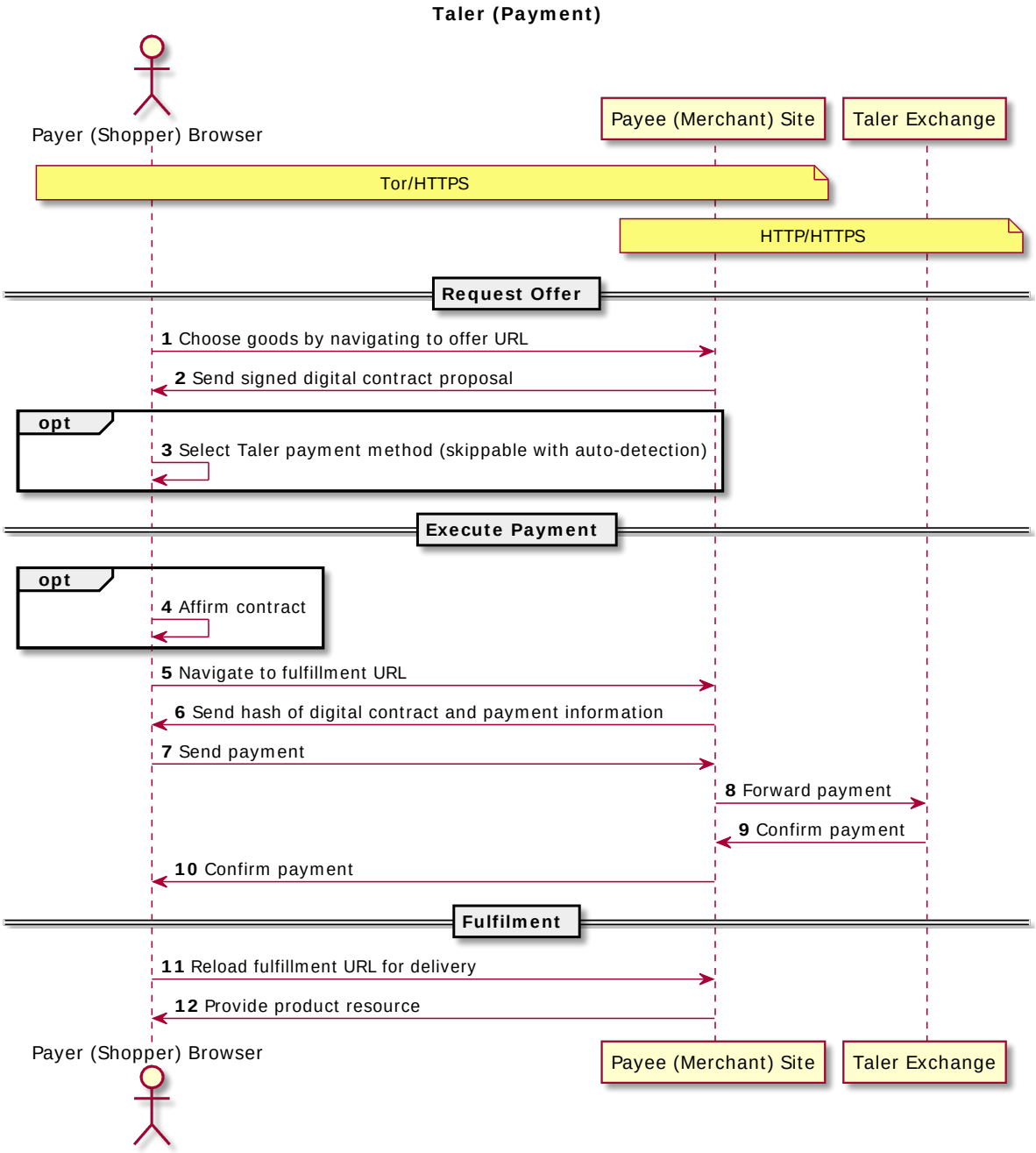


Merchant and Exchange: Verify coin (RSA)

$$s^e \stackrel{?}{\equiv} FDH(C) \mod n$$



Payment processing with Taler



Giving change

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

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

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Key goals:

- maintain unlinkability
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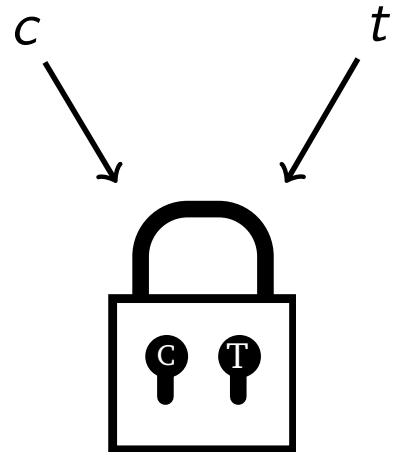
Method:

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

Diffie-Hellman (ECDH)

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

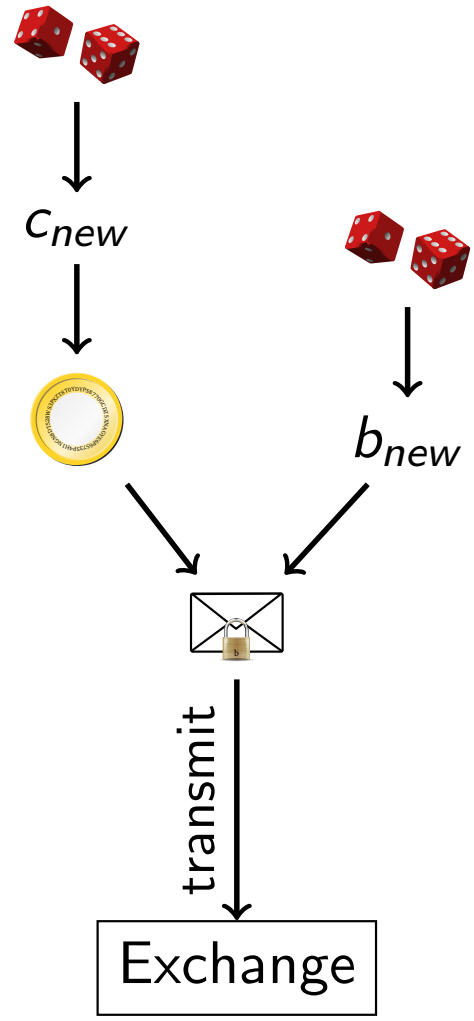


Strawman solution

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 $f_{new} := FDH(C_{new})$, $m < n$.
5. Transmit $f'_{new} := f_{new} b^e_{new}$ mod n

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



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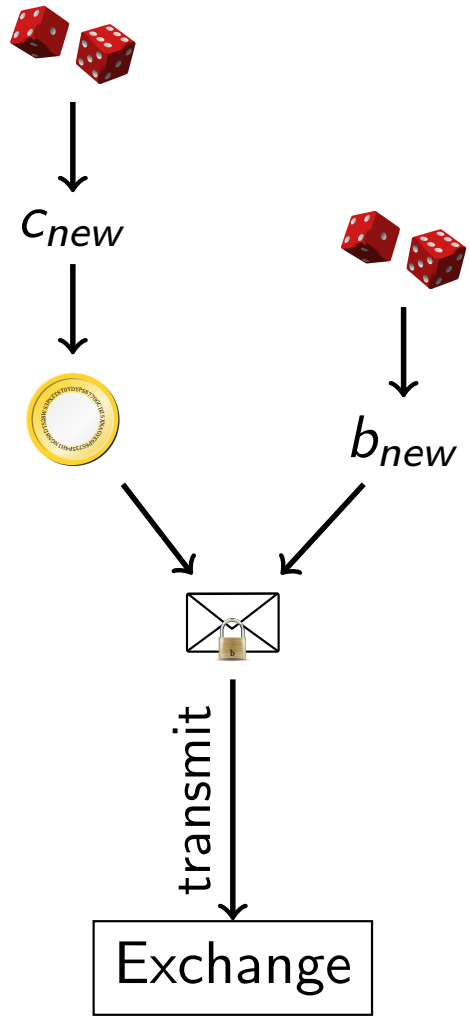
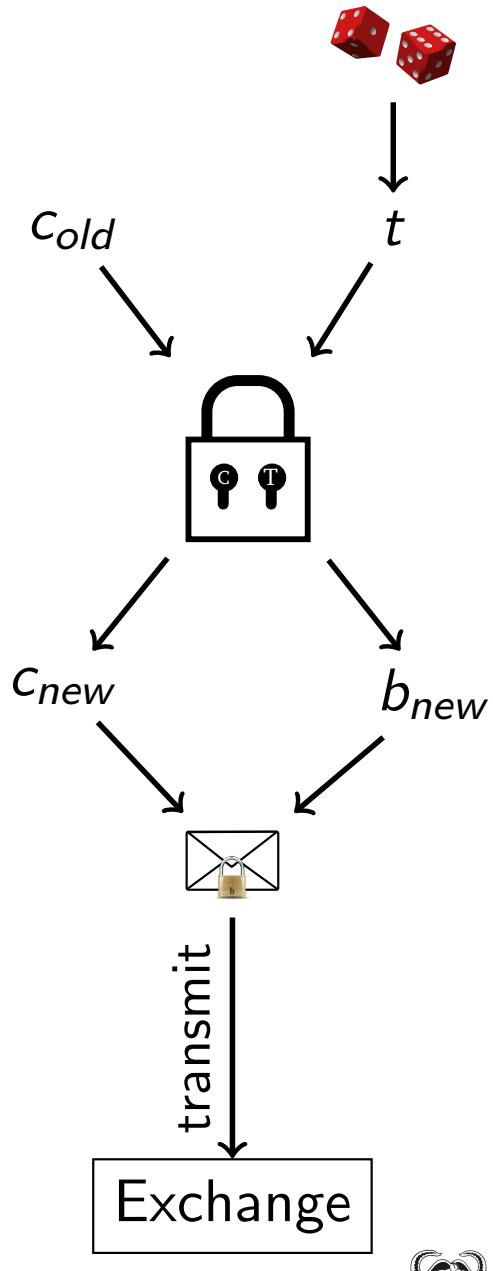


Problem: Owner of c_{new} may differ from owner of c_{old}!

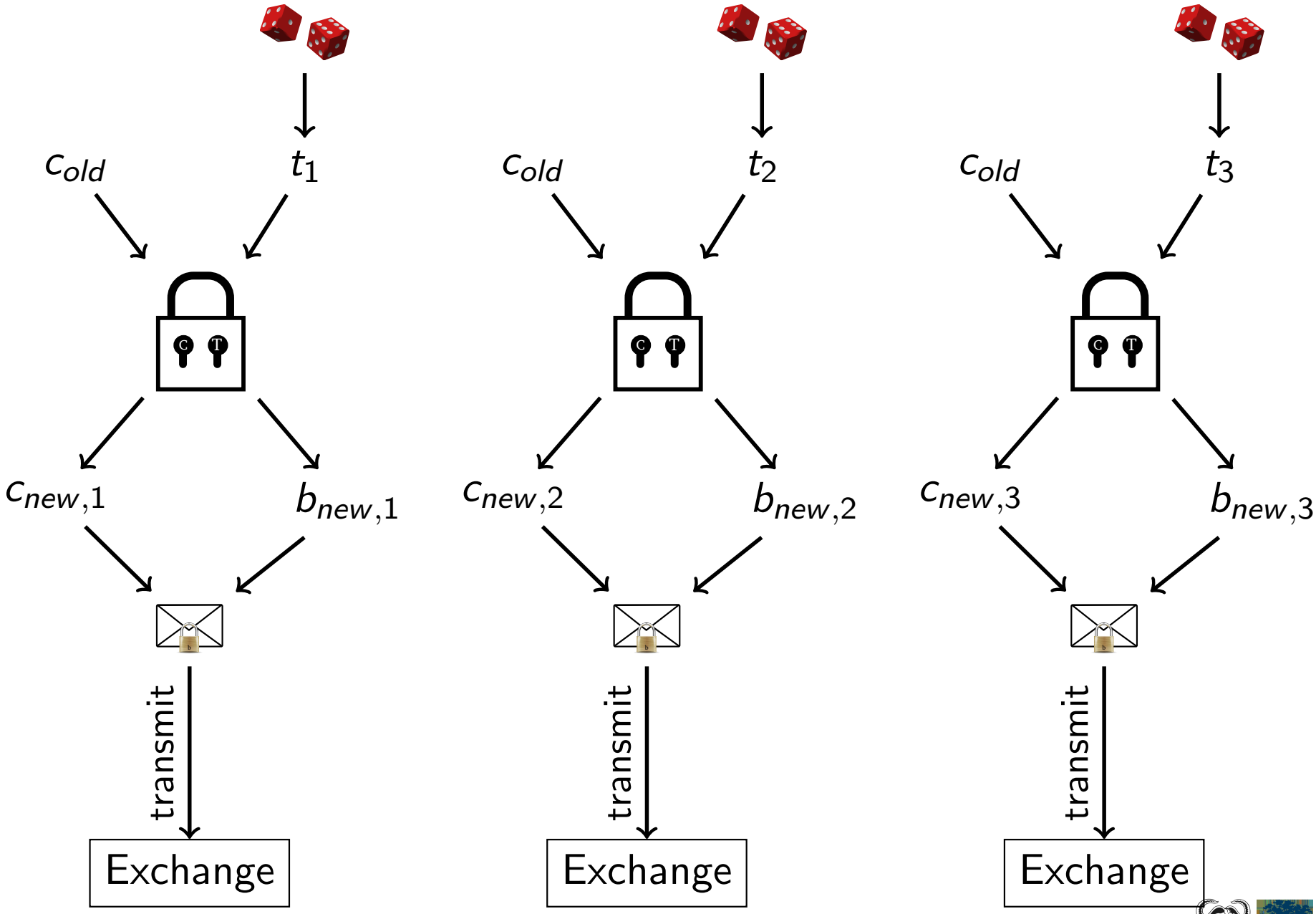
Customer: Transfer key setup (ECDH)

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 $T := tG$
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 $f_{new} := FDH(C_{new})$
8. Transmit $f'_{new} := f_{new} b_{new}^e$



Cut-and-Choose



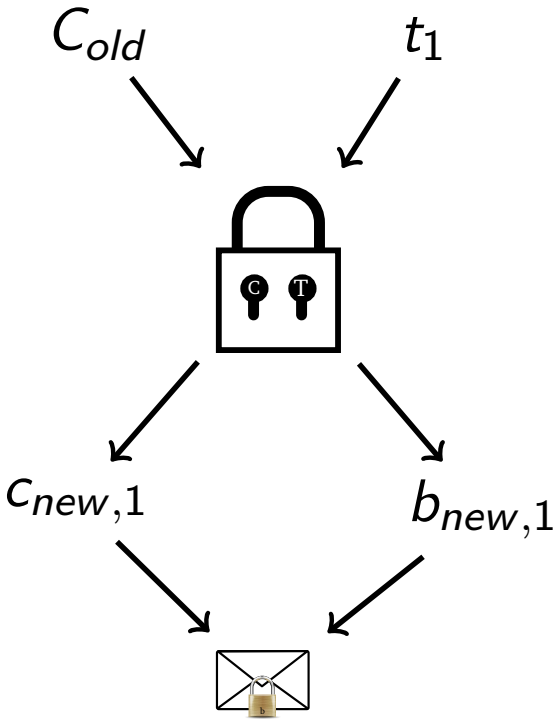
Exchange: Choose!

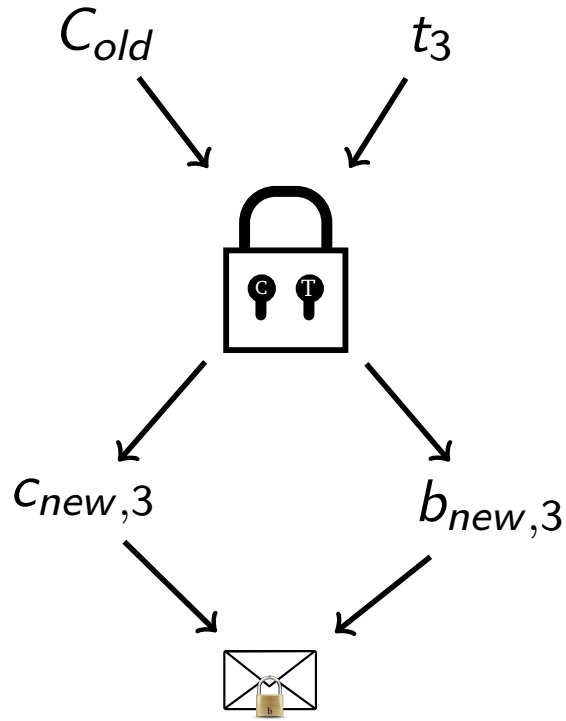
Exchange sends back random $\gamma \in \{1, 2, 3\}$ to the customer.


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

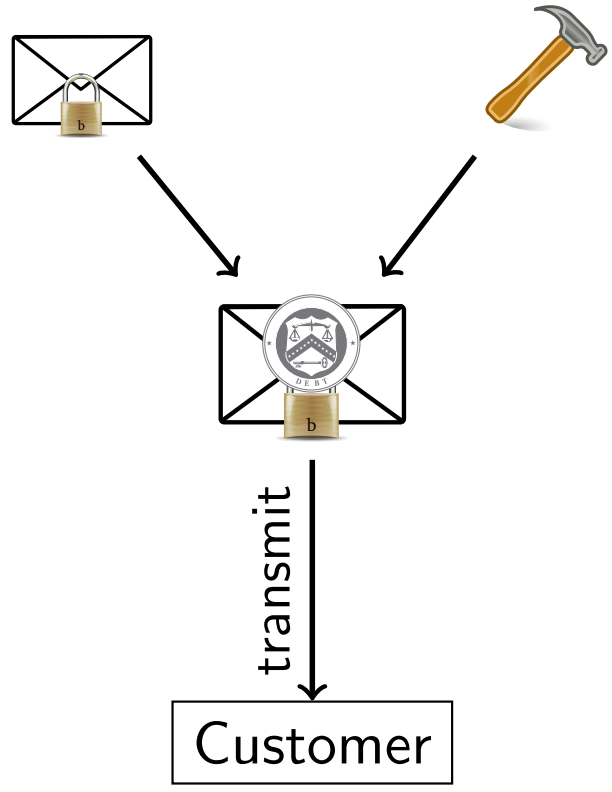
Exchange: Verify ($\gamma = 2$)





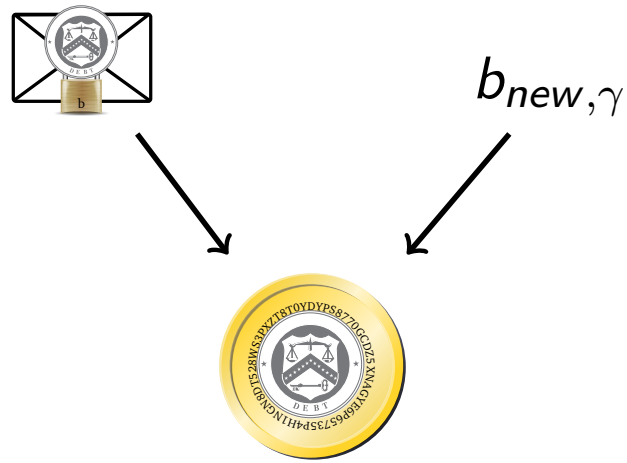
Exchange: Blind sign change (RSA)

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



Customer: Unblind change (RSA)

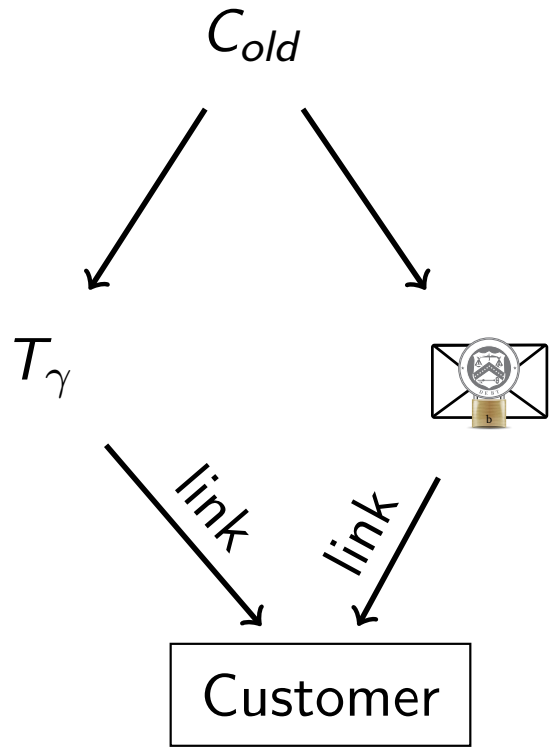
1. Receive s'.
2. Compute $s := s' b_{new,\gamma}^{-1} \mod n$.



Exchange: Allow linking change

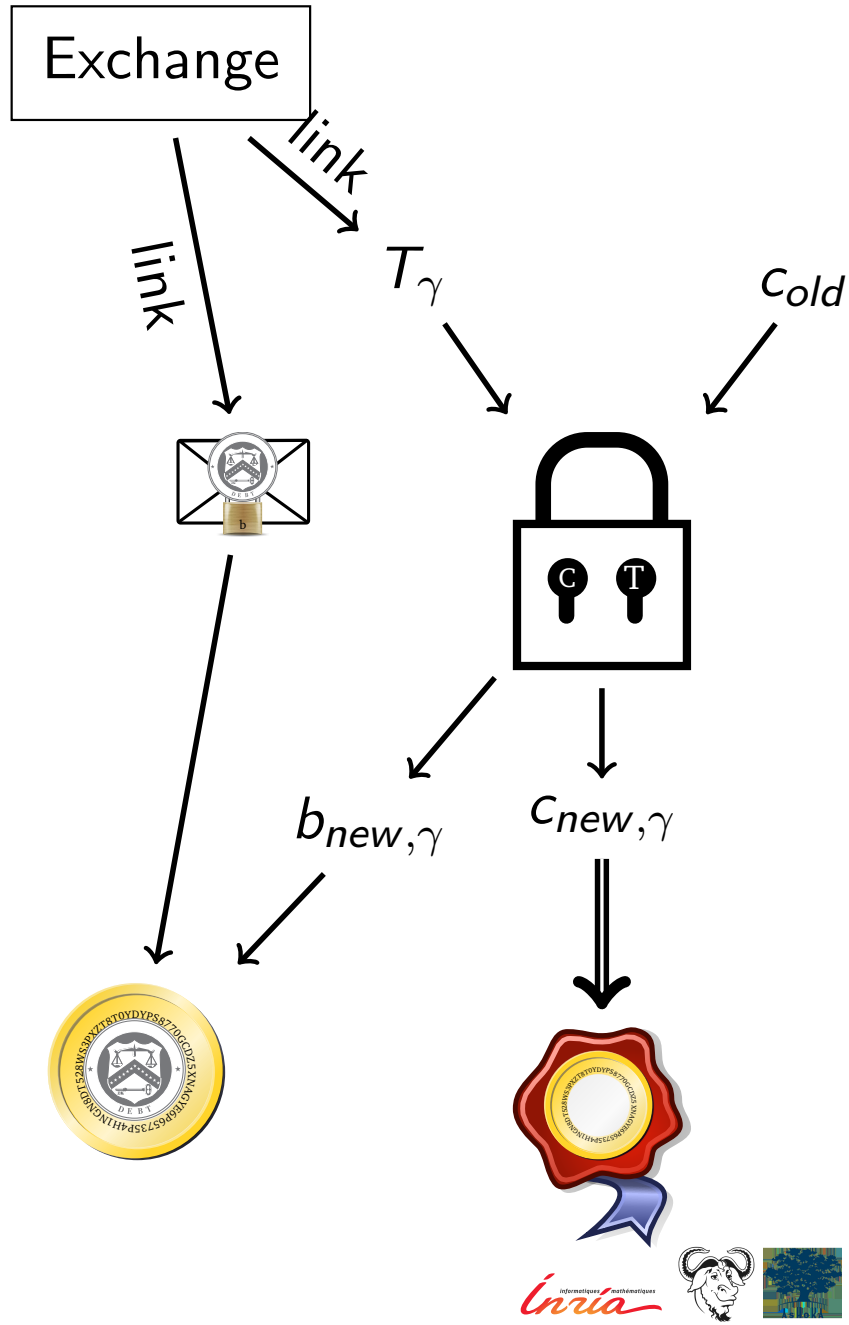
Given C_{old}

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.
- To handle protocol aborts.

Transactions via refresh are equivalent to sharing a wallet.


Competitor comparison

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

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, and
- Enjoy the "benefits" of cash

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.