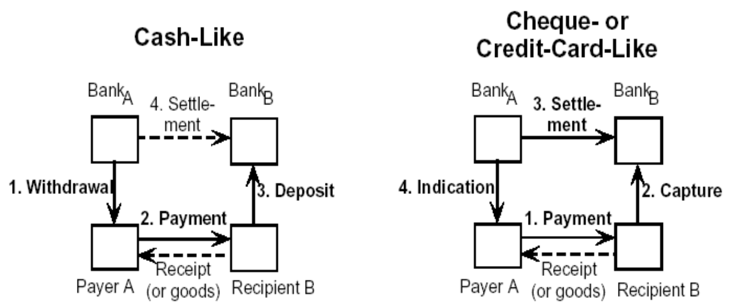
Electronic cash

Payment systems



Picture by Birgit Pfitzmann

Properties of cash

- Cash has a **value**. It can be traded for goods or services;
- It is **anonymous** (unlinkable anonymity). Previous owners of the cash are not known and in general it is not possible to keep track of by whom and where the cash is spent.
- It is **secure**. Cash currency is specifically designed to deter counterfeiting.

Requirements for e-cash

Okamoto and Ohta (1992):

- **Privacy;**
- **Security;**
- **Transferability;**
- **Divisibility;**
- Hardware Independence;
- Scalability;
- **Acceptability.**

Privacy and Security

- **Privacy ("Untraceability" or "Anonymity"):**
  The privacy of the user should be protected. The relationship between the user and his purchases must be untraceable.

- **Security:**
  The aim of security in cash payment protocols as in is to prevent any party from cheating the system

(compulsory requirements)

Transferability

Transferability:

- the transfer of "coins" (units of electronic cash) from individual to individual may be allowed in a system;
- Unlimited transferability is not without problems. It may conflict with the security requirement.

(optional requirement)

Divisibility

- A cash scheme which satisfies the divisibility requirement allows an electronic coin to be divided into smaller parts;
- E-cash as compared with the conventional cash may provide greater degree of divisibility (micropayments in the fraction of pence)

(optional requirement)

Acceptability

- The acceptability property allows an anonymous payment scheme with multiple banks to accept coins minted by other banks;

(optional requirement)

Blind Digital Signatures

- First introduced by D. Chaum, 1985;
- One of the most important mechanisms used in e-cash;
- The main aim of the blind signature is to allow a participant to **sign** a particular message **without gaining knowledge** of the message.

RSA-based blind digital signatures,I

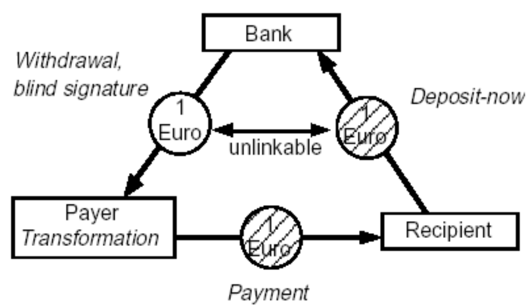
Let **(e,n)** be the bank's public key and **(d,n)** the bank's private key.

- The customer chooses a random value **k**, between 1 and n. **k** is the blinding factor. The customer blinds the message **m** by calculating: $\mathbf{t = mk^e \bmod n}$. The customer sends **t** to the bank.
- The bank signs **t** by applying **d:** $\mathbf{t^d = (mk^e)^d \bmod n}$. The bank returns the signed message $\mathbf{t^d}$ to the customer;

RSA-based blind digital signatures,II

- The customer unblinds by calculating $\mathbf{s = t^d/k \bmod n}$;
- Thus $\mathbf{s = m^d \bmod n}$. The blinding factor has been removed;
- Anyone can check that **m** has been signed by the bank, by applying the bank's public key **e**;
- At the same time the bank has not learned anything about **m.**

Basic e-cash system with blind signatures



Picture by Birgit Pfitzmann

Withdrawal

Withdrawal:

1. The payer generates a coin *coin* with an operation *gencoin*. For example the payer generates a random value *c*, which is 160 bits shorter than *n*, and sets *coin* = (*c*, *hash*(*c*)).
2. He transforms it with an operation *blind* by multiplying coin by blinding factor (modulo *n*) . We call the result *blindcoin.*

3. He sends the blinded coin to the bank together with a withdrawal order stating what amount he wants, e.g., 1 Euro, and from which account.

4. The bank subtracts the amount from the account and signs *blindcoin* with a special key depending on this amount.

5. The bank sends the resulting signature, *sigblind*, back to the payer, who tests it.

Payment with deposit

6.The payer uses an operation *unblind* on the signature and get the result *sig*. He needs stored parameters (blinding factor) from *blind* for this.

7. He sends (*coin*, *sig*) to the recipient.

8. The recipient simply forwards this to the bank to make an on-line verification against doublespending.

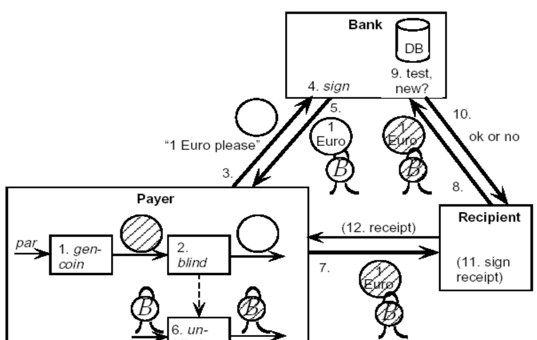
9. The bank verifies the signature and checks in a database that this coin was not deposited

before. If all is ok, it enters the coin there and adds the amount to the recipient's account.

10. The bank tells the recipient the result of the tests.

11. If it was ok, the recipient typically signs a receipt or gives the payer goods.

Withdrawal and payment



Picture by Birgit Pfitzmann

Property of the basic system

- Payer anonymity with unlinkability;
- Transferability;

but

- No recipient anonymity;
- No divisibility;
- No security in disputes.