Attribute-based Authorisation

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Outline

Motivation & support for the work

- **Original motivation:** develop privacy-friendly alternative for OV-chipkaart (in public transport)
  - using electronic attributes instead of identities
  - card says only e.g. "I'm a valid 2nd class year pass"
  - involves non-trivial cryptographic protection (see later)
- Research project supported by:
  - NLnet Foundation (`nlnet.nl`)
  - Open Ticketing / TLS (`openticketing.nl`)
- **Later, broader motivation**: develop attribute infrastructure for e-Identity card
  - citizens can obtain attributes from attribute-providers (age ≥ 18, age ≥ 65, student, address, bank account, ip-address)
  - and use them for online transactions

Who are you? Identities and attributes

- If you wish to buy a bottle of whiskey, you have to show that you are over 18 — fair enough
- In practice (offline) you wave an identity card in front of the shopkeeper
- But what if the shopkeeper would make a photocopy, or read your identity document electronically?
  - online this becomes even more problematic
- The transaction only requires the attribute "over 18"
  - and not your identity (whatever that is)
  - any additional information, besides "over 18", can be abused (identity fraud, profiling)
  - attribute-usage fits in data minimalisation requirements

Identities & attributes I

- Difficult question: *What is your identity?*
  - is it your social security number (BSN, in Dutch)?
  - who knows his/her number by heart?
  - does it make you feel: this is me?
- Possible way out:

Your identity is the collection of attributes that hold for you

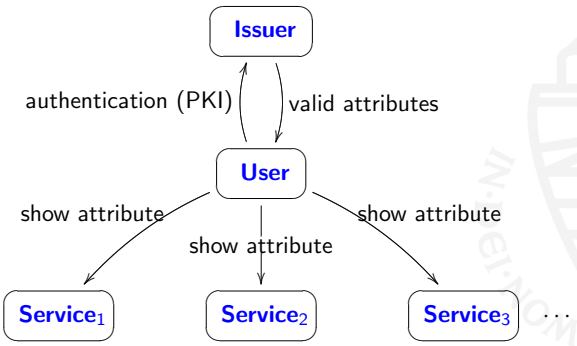
Identities & attributes II

- Some attributes are identifying
  - like your social, security number or bank account, or OV-chipcard number
  - they are different for different people
- Other attributes are non-identifying (anonymous)
  - like your gender, whether you're over 18, your home-town
  - whether you have a valid ticket to travel by bus
  - whether you are a nurse or a doctor
- Sometimes your identity is understood as a (small) set of identifying attributes, like on your passport
- When going digital, attributes are often replaced by identities, like in public transport
  - why do I have to tell who I am when I get on the bus
  - more unnecessary surveillance / profiling / fraud risk

Attribute-based authentication & authorisation

- Many transactions can be performed on the basis of non-identifying attributes
  - a cheaper hair-cut for a student, or cheaper public transport for senior citizens
  - participation in local referendum for locals
  - buying games online (over 16, or over 18)
  - viewer restrictions for missed TV-program website
- Attribute-based extends role-based access control
  - the captain of the ship can turn the ship's wheel
  - very relevant in the medical sector (access to files)
  - or in the military, or in any other organisation with different authorisations for different hierarchies/roles
- Typical transactions involve a combination of attributes
  - address, possibly with bank account, for pizza delivery
  - age + bank account for online gambling / XXX / ...
  - "doctor" status + medical registration number for write-access to medical record

Attribute issuance-usage model



One may also have multiple issuers (government, banks, isp's, ...)

Requirements for attribute-bases systems

- Non-transferability: my little nephew should not be able to get my "over 18" attribute (and go to XXX sites)
  - realised via binding to my private key
- Issuer-unlinkability: the issuers should not be able to track where I use which attribute
  - typically realised via blind signature
- Multi-show unlinkability: service providers should not be able to connect usage (at different providers)
  - realised via zero-knowledge proofs, or via "self-blindable" credentials
- Revocation: rogue attributes (via stolen/lost cards) should be blockable.
  - most difficult, partly in conflict with previous requirements

Three main systems

- U-Prove
  - developed by Stefan Brands (Credentica), bought by Microsoft
  - specification available, under the Open Specification Promise
  - open source reference toolkits in C# and Java
  - multiple attributes in single (traceable) token, selective disclosure
- Idemix ("Identity Mixer")
  - developed by Camenisch & Lysyanskaya, IBM Research Zürich
  - specs & sources also openly available
  - most properties, including revocation (by users, not by issuers)
  - most complicated (even "over-engineered")
- Self-blindable certificates
  - developed by Verheul (Radboud Univ. & PWC) and others
  - only one attribute per token
  - uses bilinear pairings on elliptic curves
  - open implementation available

Smart card implementations of attributes

Main focus of the work at Nijmegen (esp. Vullers & Mostowski)

- Self-blindable certificates
  - implemented on a Java smart card, with ECC
  - transaction (showing) times: 500-1000ms
  - too slow for public transport (requires 300ms); next, faster generation of cards is needed
- U-Prove
  - low-level implementation on MULTOS smart card
  - with low-level access to the cryptographic co-processor
  - times: 500-1000ms, depending of number of shown attributes
  - major improvement over Microsoft's device-binding approach
- Idemix
  - MULTOS implementation under development
  - (partial & slow IBM-implementation on Java card exists)

U-Prove & Idemix

- Both involve tokens with multiple attributes $a_1, \ldots, a_k$, encoded as multi-exponent $g_1^{a_1} \cdots g_k^{a_k}$
- Such tokens are blindly signed by the issuer
  - using Schnorr-style signature scheme in U-Prove
  - via Camenisch-Lysyanskaya signature for Idemix
- Proving proceeds in both cases via zero knowledge proof
- In Idemix tokens are self-blindable (aka. randomisable: owner can transform them so that they look different in each showing proof
- In U-Prove, tokens are not self-blindable and can be used to trace the owner
  - tokens thus work as pseudonyms
  - show-unlinkability still possible by using multiple tokens, or by using them only once
  - revocation of tokens thus possible via blacklisting

Basic protocol: Schnorr's proof of knowledge

Assumptions

- User has attribute a, encoded as $h = g^a$ (in some cyclic group)
- Verifier must be convinced of knowledge of a in h, without revealing a

Protocol

User | Verifier

[choose random w] $\xrightarrow{h = g^a,\ t = g^w}$

$\xleftarrow{c}$ [choose random "challenge" c]

[compute $r = c \cdot a + w$] $\xrightarrow{r}$ [check if $t = \frac{g^r}{h^c}$]

Relevant computation: $g^r = g^{c \cdot a + w} = \left(g^a\right)^c \cdot g^w = h^c \cdot t$

Basic protocol: Schnorr's signature

Assumptions

- Issuer has private key x, with associated public key $h = g^x$
- User wants signature on hash $\mathcal{H}(m)$ of message m

Protocol

Issuer | User

$\xleftarrow{m}$

[choose random w and compute: $t = g^w, c = \mathcal{H}(m \| t)$, $r = c \cdot x + w$] $\xrightarrow{\text{signature } (c, r)}$

[check if $c = \mathcal{H}\left(m \,\|\, \frac{g^r}{h^c}\right)$]

More on U-Prove and Idemix

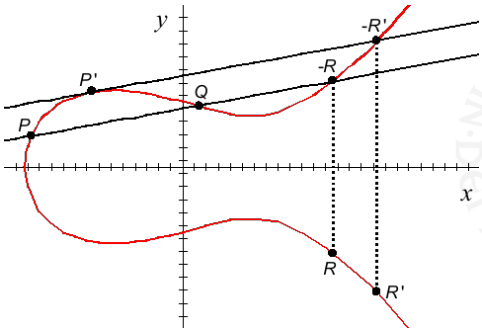
- These two protocols only describe basic building blocks
- The real U-Prove protocols are more complicated than this
- For more info:
  - Stefan Brands, *Rethinking Public Key Infrastructures and Digital Certificates: Building in Privacy*, MIT, 2000. Freely available via `credentica.com`
  - `microsoft.com/u-prove`
- For information about Idemix, see:
  - `zurich.ibm.com/security/idemix`

Self-blinding via Elliptic Curve Cryptography (ECC)

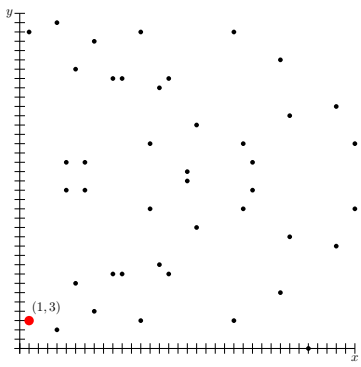
- Koblitz and Miller proposed the use of elliptic curves for cryptography in the mid 1980's
- Nowadays this technology is widely accepted
- Provides the functionality of RSA and more
  - Smaller keys
  - Pairings
- Standard public key cryptography for embedded platforms
  - used now e.g. in e-passport chip

The operations, over the real numbers

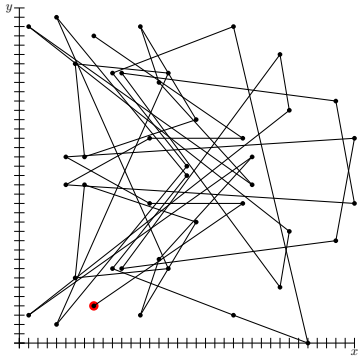
- Point addition: $P + Q = R$
- Point doubling: $2P' = R'$



Example curve: $y^2 = x^3 + 2x + 6$ over finite field $\mathbb{F}_{37}$



Repeated addition: $n \cdot P$ goes everywhere



Given $Q = n \cdot P$, finding n involves basically trying all options.

Elliptic Curve Cryptosystem

- Point multiplication (repeated addition): $k \cdot P = Q$
- *Easy* to compute (double and add)
- EC discrete log problem: Given P and $Q = k \cdot P$, determine k
- This problem is believed to be *hard*

- Point multiplication is a one way function which can be used to build public key cryptosystems
- The public key is Q; and the private key is k
- Allows for key agreement (Diffie-Hellman), signatures (DSA), encryption (ElGamal), and more ...

Pairings

- A bilinear pairing is a map $e\colon G_1 \times G_2 \longrightarrow G_T$ which is bilinear, that is, linear in both components:

$$e(P + P',\ Q) \ = \ e(P,\ Q) \cdot e(P',\ Q)$$
and
$$e(P,\ Q + Q') \ = \ e(P,\ Q) \cdot e(P,\ Q')$$

- As a result, $e(n \cdot P,\ m \cdot Q) = e(P,\ Q)^{n\,m}$

Self-blindable certificates

Pairing-based Signatures

- Signature $S = s \cdot P$ over a point P is multiplication by a private key s
- Check $e(S, Q) \stackrel{?}{=} e(P, s \cdot Q)$ to verify a signature S over P: both sides are equal to $e(P, Q)^s$.

This certificate is stable under self-blinding

- card generates random blinding number b
- forms new pair

$$P_b = b \cdot P \qquad \text{with signature}$$
$$S_b = b \cdot S = b \cdot s \cdot P = s \cdot b \cdot P = s \cdot P_b$$

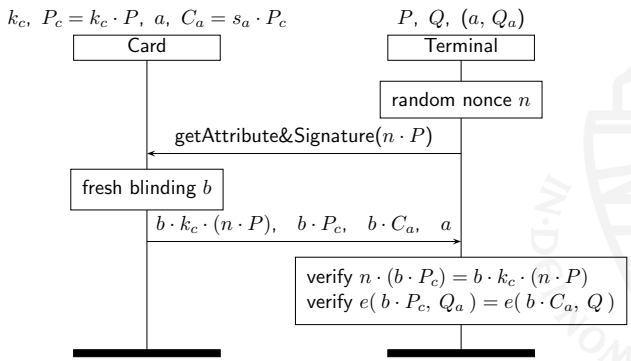
- Verification of blinded P and S: $e(b \cdot P, s \cdot Q) = e(b \cdot S, Q)$

Set up for attribute proving

- Public fixed point Q and a finite set of attributes
- A secret key s_a and public key $Q_a = s_a \cdot Q$ for each attribute a
- The associated pairs $(a,\ Q_a)$ are publicly know, and stored in all terminals together with the fixed point Q

- Card c generates a key pair k_c and $P_c = k_c \cdot P$
- Private key k_c is stored in a protected manner, in the card
- Card c receives an attribute together with a certificate $C_a = s_a \cdot P_c$ linking its public key P_c to the attribute a
- (alternative "Boneh-Boyen" certificates exist)

Protocol for Attribute-proving



This runs in a Java smart card in 500-1000 msec.

USA: NSTIC

- NSTIC = *National Strategy for Trusted Identities in Cyberspace*
  - released by the White House in April 2011
  - discussed by Cyber Security Czar Howard Schmidt in his blog

    "We have an opportunity to design privacy directly into the fabric of the Identity Ecosystem."
- NSTIC refers to privacy-enhancing technologies for implementing credentials
  - U-Prove & Idemix are not mentioned explicitly
  - but probably intended implicitly
- Issuer- and multi-show unlinkability explicitly required (and also partial information, like "over 18")

NSTIC, continued

- Discussion by Francisco Corella on pomcor.com

  "Government-issued credentials will only be acceptable if they incorporate all available privacy protections. That makes the use of privacy-enhancing technologies essential to the success of NSTIC."
- Talking about Nijmegen's U-Prove implementation:

  "A non-Microsoft implementation of U-Prove on a MULTOS smart card, where all the cryptographic computations are carried out by the card with impressive performance (close to 0.3 seconds in some cases), can be found in . . . "
- Good intentions, but the current status/progress of NSTIC is unclear.

Germany: *Neue Personalausweis (nPA)*

- RFID smart card issued to German citizens since nov. 2010
  - non-trivial protocols developed by BSI (a.o. Dennis Kügler)
- Acces to card involves terminal authentication (part of "EAC")
  - only authorised parties can read (part of the data)
  - eg. webshops need to get certificates to access the card
- Card is protected by 6-digit PIN, with fallback via number on card & separate PUK
- Also pseudonym generation is included, providing linkability ("restricted identification") for returning customers
  - authentication of cards happens via private key . . .
  - that is same in batches of 100.000s of cards

Neue Personalausweis

- Authenticity & integrity of data in chip not guaranteed via signature, like in "passive authentication", to prevent third party usage, but implicitly via chip-authentication
  - Thus, once the authenticity of the chip is established
  - the reader trusts the provided data
  - these unsigned data are less valuable
- Signing keys are not included, but can be added by the card owner, following own choice of certificate provider
  - hence it is more difficult to force citizens to sign everything, and make themselves traceable via their certificates
- Attacks have been reported, mainly focusing on the interface
  - notably entering the PIN via the computer (key logging!)

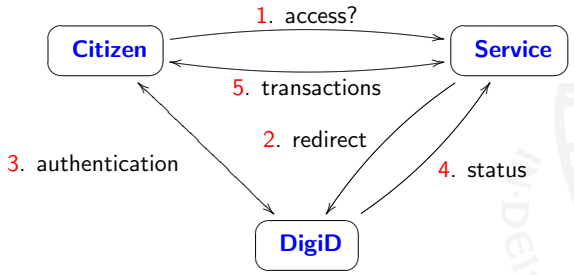
Modern smart card reader with PIN pad

- This one is available for the German e-Identity card
- Interfaces for both contact and contactless cards
- Certified by BSI; cost: 30-100 €

The Netherlands: eNIK and DigiD

- Tender for citizen smart card organised in 2007, but aborted after legal battle
  - smart card would only do authentication & signing
  - only within the government domain
- Currently, these plans are re-emerging
- No great need so far, since NL has a centralised authentication service
  - called **DigiD**, for Digital Identity
  - operational since 2005; widely used, only for public sector
  - works with two levels of authentication (password/SMS-OTP)

DigiD essentials



In step 4 the status message says: "social security number *i* with certainty level *j*". Afterwards DigiD has no role in the transactions in step 5.

DigiD: main points

- DigiD is a central authentication server
  - a bit like **Kerberos**
  - DigiD is a hotspot for traffic data (not for transactions)
  - it does not provide signatures (non-repudiation)
- Three levels of authentication are foreseen
  1. username + password (traditionally weak)
  2. one-time code via SMS (can be intercepted, now GSM is broken)
  3. smart card authentication (eNIK) not present yet
- DigiD has several weaknesses:
  - no face-to-face authentication at registration
  - "services" side is sometimes vulnerable (SQL/XSS)

DigiD reflects centralistic mentality

Citizen is reduced to authenticator

- we administer all the information that we need about you
- you, as citizen, only need to authenticate (prove who you are)

How far should one push this centralistic approach?

- Suppose I wist to enter my own house; at the front door, ...
- I push a button and authenticate to DigiD ...
- which remotely opens the door for me!

Maybe a few things should be done de-centrally

eNIK 2012

- DigiD is the dominant (centralistic) paradigm, so smart cards are not well-understood — except for authentication
- Thus, the main motivation for a eNIK is to provide a third authentication level within DigiD
  - additional value of signature via smart card is not recognised
  - some even promote server-side "signatures" !!! ☹
  - i.e. after authentication you tell a server to sign on your behalf
- Chosen card functionality for 2012 like for 2007
  - only authentication & signature (30 year old technology)
  - no ambition noticeable so far to use modern attribute mechanisms
- Attitude towards attributes: put them on the server
  - vulnerable e.g. for doctor accessing local files
  - complete trust in administration required

Main points

- Attribute-based authentication/authorisation is natural and privacy-friendly (data-minimalisation), see e.g. in NSTIC
- Cryptographic basis exists for ≥ 10 years (U-Prove/Idemix)
  - open & supported by major players (Microsoft, IBM)
- ECC-based self-blindable credentials more recent (and fancy)
- Fast smart card support available (< 1 sec for showing)
  - That is, for U-Prove & self-blindable certificates
  - Idemix card implementation is ongoing work
- Demo available (but not shown here)

Questions / Remarks?