Entity authentication and symmetric key establishment

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Outline

- 1. Cryptology: concepts and algorithms
  - symmetric algorithms for confidentiality
  - symmetric algorithms for data authentication
  - public-key cryptology
- **2. Cryptology: protocols**
  - **identification/entity authentication**
  - **key establishment**
- 3. Public-Key Infrastructure principles
- 4. Networking protocols
  - email, web, IPsec, SSL/TLS
- 5. New developments in cryptology
- 6. Cryptography best practices

Definitions (ctd)

Confidentiality
Integrity
Availability

	data	**entities**
confidentiality	encryption	anonymity
authentication	data authentication	identification

Authorisation

Non-repudiation of origin, receipt

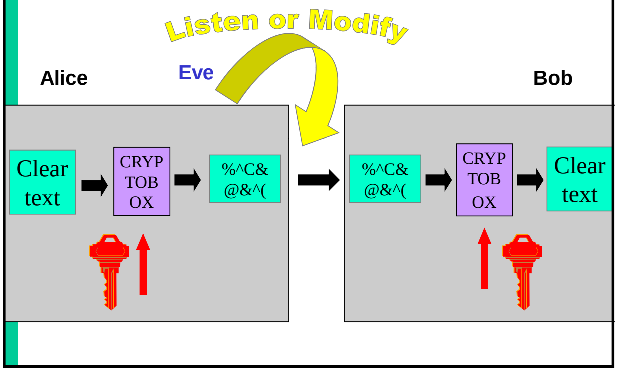
Contract signing

Notarisation and Timestamping

E-voting, e-auction,…

Don't use the word authentication without defining it

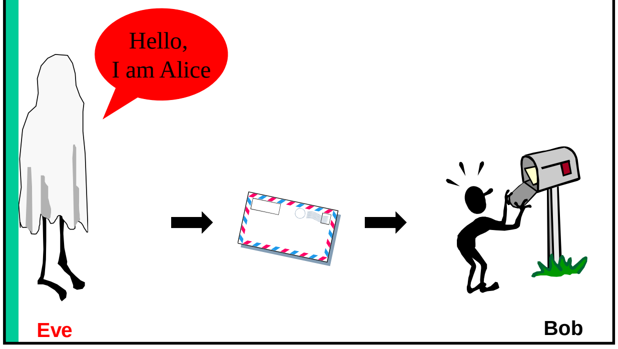
Cryptology: basic principles



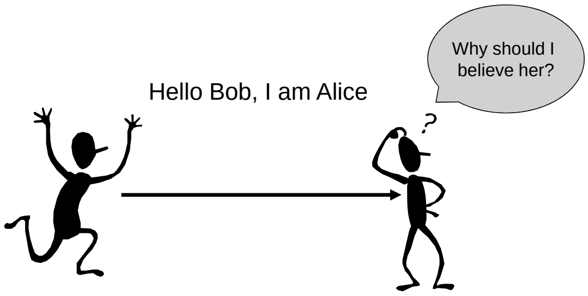
Identification

- the problem
- passwords
- challenge response with symmetric key and MAC (symmetric tokens)
- challenge response with public key (signatures, ZK)
- biometry
- symmetric key establishment and Kerberos
- public key establishment

Entity authentication



Entity authentication

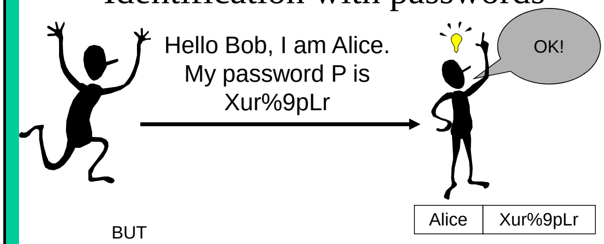


Identification is based on one or more of the following elements:

- what someone knows
  - password, PIN
- what someone has
  - magstripe card, smart card
- what someone is (biometrics)
  - fingerprint, retina, hand shape,...
- how someone does something
  - manual signature, typing pattern
- where someone is
  - dialback, location based services (GSM, secure GPS)

ert5^r$#89Oy

Identification with passwords



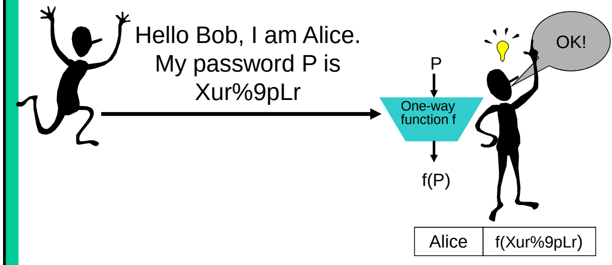
Hello Bob, I am Alice.
My password P is
Xur%9pLr

Alice	Xur%9pLr

BUT

- •Eve can guess the password
- •Eve can listen to the channel and learn Alice's password
- •Bob needs to know Alice's secret
- •Bob needs to store Alice's secret in a secure way

Improved identification with passwords



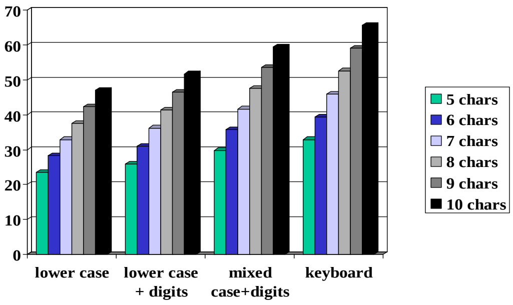
Hello Bob, I am Alice.
My password P is
Xur%9pLr

Alice	f(Xur%9pLr)

Bob stores f(P) rather than Alice's secret P

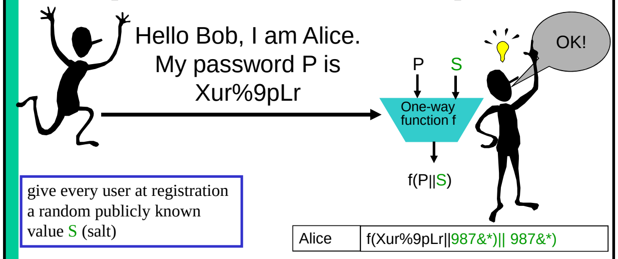
- it is difficult to deduce P from f(P)

Password entropy: effective key length



Problem: passwords from dictionaries

Improved+ identification with passwords



Hello Bob, I am Alice.
My password P is
Xur%9pLr

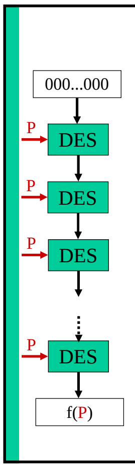
give every user at registration a random publicly known value S (salt)

Alice	f(Xur%9pLr||987&*)|| 987&*)

Bob stores f(P,S) || S rather than Alice's secret P

it is harder to attack the passwords of all users simultaneously

Example: UNIX

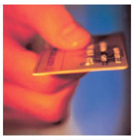


- Function f() = DES applied 25 times to the all zero plaintext with as key the password P (8 7-bit characters)
- Salt: 12-bit modification to DES
- etc/passwd public
- PC: 10-20 million passwords/second
- But time-memory tradeoff…
  - Precomputation per salt 25 . 2^{56}
  - Storage per salt: 2 Terabyte
  - Find one key in time 25.2^{38}

Improving password security

- Apply the function f "x" times to the password (iteratively)
  - if x = 100 million, testing a password guess takes a few seconds
  - need to increase x with time (Moore's law)
- Disadvantage: one cannot use the same hashed password file on a faster server and on an embedded device with an 8-bit microprocessor
  - need to use different values of x depending on the computational power of the machine

Problem: human memory is limited



- Solution: store key K on magstripe, USB key, hard disk
- Stops guessing attacks

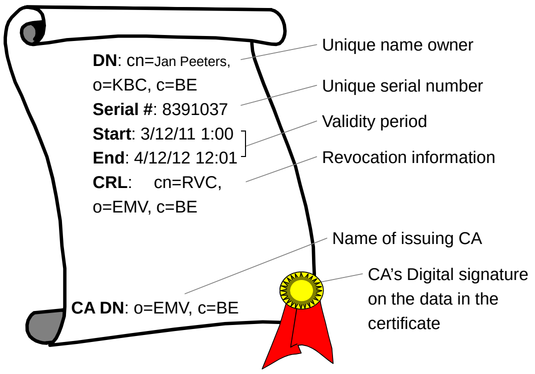
But this does not solve the other problems related to passwords

And now you identify the card, not the user….

Improvement: Static Data Authentication

- Replace K by a signature of a third party CA (Certification Authority) on Alice's name: $\text{Sig}SK_{CA}$ (Alice) = special certificate
- Advantage: can be verified using a public string PK_{CA}
- Advantage: can only be generated by CA
- Disadvantage: signature = 40..128 bytes
- Disadvantage: can still be copied/intercepted

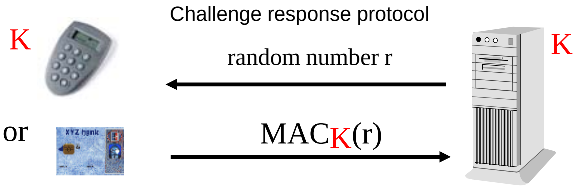
"Certificate" for static data authentication



DN: cn=Jan Peeters, o=KBC, c=BE
Serial #: 8391037
Start: 3/12/11 1:00
End: 4/12/12 12:01
CRL: cn=RVC, o=EMV, c=BE

CA DN: o=EMV, c=BE

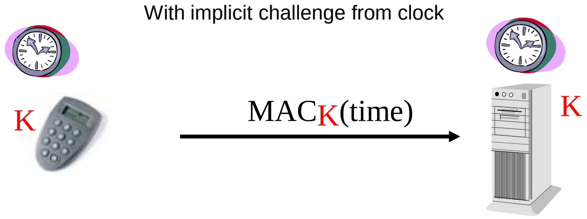
Entity authentication with symmetric token



- Eavesdropping no longer effective
- Bob still needs secret key K

Entity authentication with symmetric token

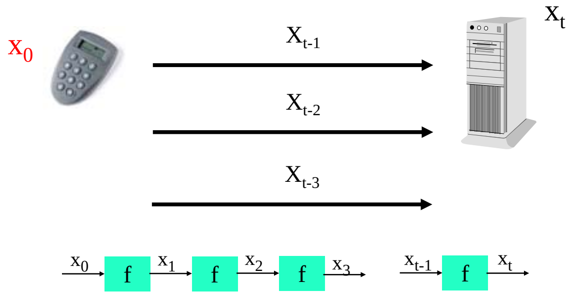
With implicit challenge from clock



- Eavesdropping no longer effective
- Bob still needs secret key K
- resynchronization mechanism needed

Lamport’s one-time passwords

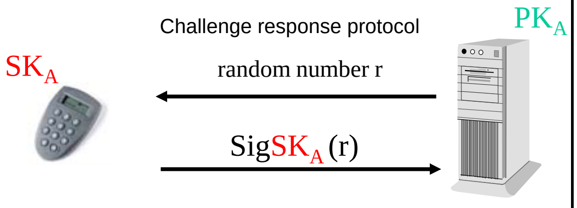
iterated one-way function



- Disadvantage: only works with one Bob

Entity authentication with public key token

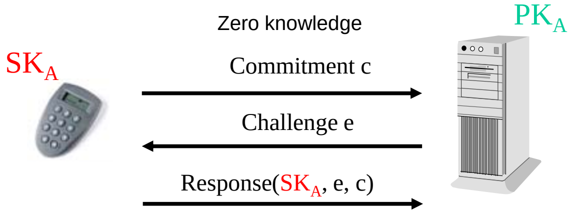
Challenge response protocol



- Eavesdropping no longer effective
- Bob no longer needs a secret – only PK_A

Entity authentication with ZK

Zero knowledge



- Mathematical proof that Bob only learns that he is talking to Alice (1 bit of information)
- Bob cannot use this information to convince a third party that he is/was talking to Alice

Overview Identification Protocols

	Guess	Eavesdrop channel	Impersonation by Bob	Secret info for Bob	Security
Password	-	-	-	-	1
Magstripe (SK)	+	-	-	-	2
Magstripe (PK)	+	-	-	+	3
Dynamic password	+	+	-	-	4
Smart card (SK)	+	+	-	-	4
Smart Card (PK)	+	+	+	+	5
Smart Card (PK) + ZK	+	+	++	+	6

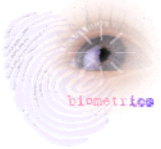
Mutual authentication

- Many applications need entity authentication in two directions
- !! This is not complete the same as 2 parallel unilateral protocols for entity authentication

2 stage authentication

- Local: user to device
- Device to rest of the world

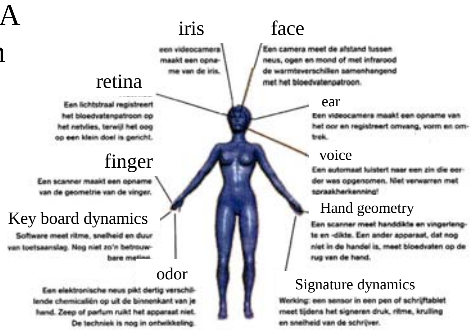
Biometry



- Based on our unique features
- Identification or verification
  - Is this Alice?
  - Check against watchlist
  - Has this person ever registered in the system?

Some unique features

DNA
skin
…


iris
een videocamera maakt een opname van de iris.
face
Een camera meet de afstand tussen neus, ogen en mond of met infrarood de warmteverschillen samenhangend met het bloedvatenpatroon.
retina
Een lichtstraal registreert het bloedvatenpatroon op het netvlies, terwijl het oog op een klein doel is gericht.
ear
Een videocamera maakt een opname van het oor en registreert omvang, vorm en omtrek.
finger
Een scanner maakt een opname van de geometrie van de vinger.
voice
Een automaat luistert naar een zin die eerder was opgenomen. Niet verwarren met spraakherkenning!
Key board dynamics
Software meet ritme, snelheid en duur van toetsaanslag. Nog niet zo'n betrouwbare meting.
Hand geometry
Een scanner meet handdikte en vingerlengte en -dikte. Een ander apparaat, dat nog niet in de handel is, meet bloedvaten op de rug van de hand.
odor
Een elektronische neus pikt dertig verschillende chemicaliën op uit de binnenkant van je hand. Zeep of parfum ruikt het apparaat niet. De techniek is nog in ontwikkeling.
Signature dynamics
Werking: een sensor in een pen of schrijftablet meet tijdens het signeren druk, ritme, krulling en snelheid van de schrijver.

Biometric procedures

- Registration
- Template extraction
- Measurement
- Processing
- Template matching
- Link with applications

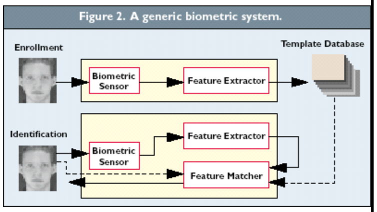
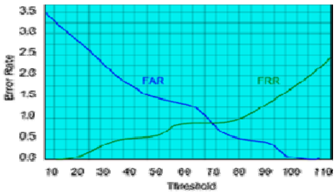


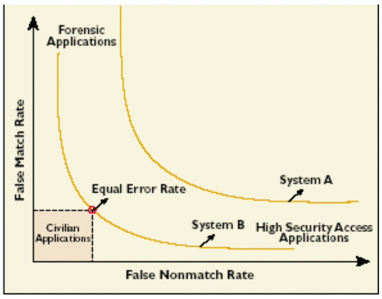
Figure 2. A generic biometric system.

Robustness/performance

- Performance evaluation
  - False Acceptance Ratio or False Match Rate
  - False Rejection Ratio or False Non-Match Rate
- Application dependent

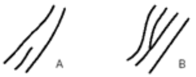


Robustness/performance (2)



Fingerprint

- Used for PC/laptop access
- Widely available
- Reliable and inexpensive
- Simple interface

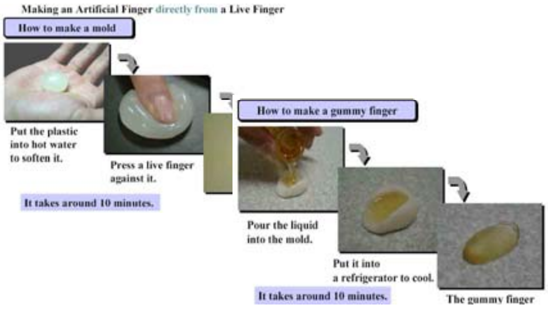


minutiae

Fingerprint (2)

- Small sensor
- Small template (100 bytes)
- Commercially available
  - Optical/thermical/capacitive
  - Liveness detection
- Problems for some ethnic groups and some professions
- Connotation with crime

Fingerprint (3): gummy fingers


Making an Artificial Finger directly from a Live Finger
How to make a mold
Put the plastic into hot water to soften it.
Press a live finger against it.
It takes around 10 minutes.
How to make a gummy finger
Pour the liquid into the mold.
Put it into a refrigerator to cool.
It takes around 10 minutes.
The gummy finger

Hand geometry

- Flexible performance tuning
- Mostly 3D geometry
- Example: 1996 Olympics

Voice recognition

- Speech processing technology well developed
- Can be used at a distance
- Can use microphone of our gsm
- But tools to spoof exist as well
- Typical applications: complement PIN for mobile or domotica

Iris Scan

- No contact and fast
- Conventional CCD camera
- 200 parameters
- Template: 512 bytes
- All etnic groups
- Reveals health status

Retina scan

- Stable and unique pattern of blood vessels
- Invasive
- High security

Manual signature

- Measure distance, speed, accelerations, pressure
- Familiar
- Easy to use
- Template needs continuous update
- Technology not fully mature

Facial recognition

- User friendly
- No cooperation needed
- Reliability limited
- Robustness issues
  - Lighting conditions
  - Glasses/hair/beard/...

Comparison

Feature	Uniqueness	Permanent	Performance	Acceptability	Spoofing
Facial	Low	Average	Low	High	Low
Fingerprint	High	High	High	Average	High
Hand geometry	Average	Average	Average	Average	Average
Iris	High	High	High	Low	High
Retina	High	Average	High	Low	High
Signature	Low	Low	Low	High	Low
Voice	Low	Low	Low	High	Low

Biometry: pros and cons

- Real person
- User friendly
- Cannot be forwarded
- Little effort for user
- Secure implementation: derive key in a secure way from the biometric

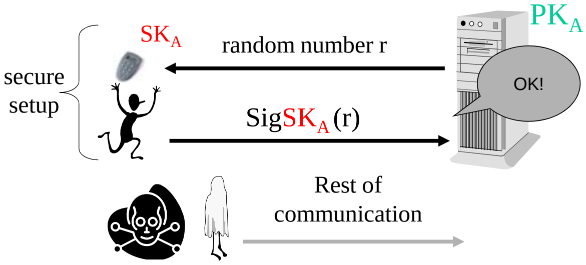
- Privacy (medical)
- Intrusive?
- Cannot be replaced
- Risk for physical attacks
- Hygiene
- Does not work everyone, e.g., people with disabilities
- Reliability
- No cryptographic key

Location-based authentication

- Dial-back: can be defeated using fake dial tone
- IP addresses and MAC addresses can be spoofed
- Mobile/wireless communications: operator knows access point, but how to convince others?
- Trusted GPS?

Limitations of entity authentication

- Establish who someone is
- Establish that this person is active
- But what about keeping authenticity alive?



SK_A

random number r

PK_A

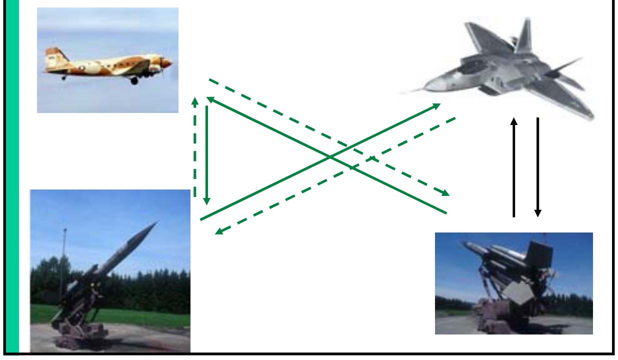
OK!

secure setup

SigSK_A (r)

Rest of communication

The maffia fraud
– or the grandmaster chess problem



Solution

- Authenticated key agreement

- Run a mutual entity authentication protocol
- Establish a key
- Encrypt and authenticate all information exchanged using this key

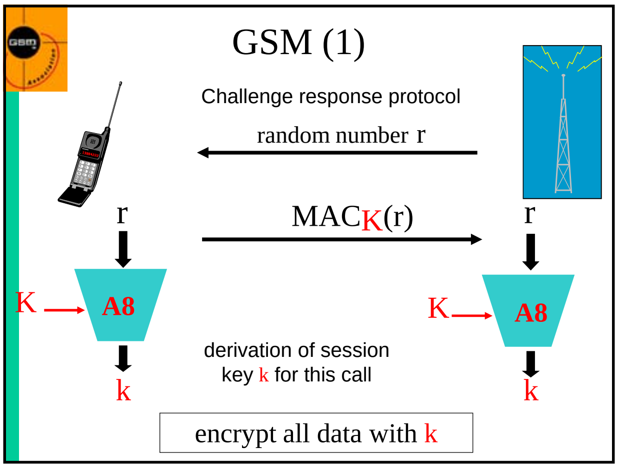
Key establishment

- The problem
- How to establish secret keys using secret keys?
- How to establish secret keys using public keys?
  - Diffie-Hellman and STS
- How to distribute public keys? (PKI)

Key establishment: the problem

- Cryptology makes it easier to secure information, by replacing the security of information by the security of keys
- The main problem is how to establish these keys
  - 95% of the difficulty
  - integrate with application
  - if possible transparent to end users

GSM (1)

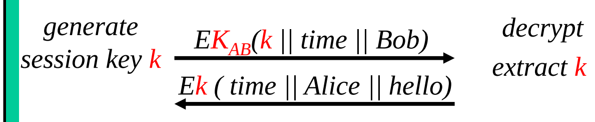

Challenge response protocol
random number r
MAC$_K$(r)
r
r
K
A8
k
K
A8
k
derivation of session key k for this call
encrypt all data with k

GSM (2)

- SIM card with long term secret key K (128 bits)
- secret algorithms
  - A3: MAC algorithm
  - A8: key derivation algorithm
  - A5.1/A5.2: encryption algorithm
- anonimity: IMSI (International Mobile Subscriber Identity) replaced by TIMSI (temporary IMSI)
  - the next TIMSI is sent (encrypted) during the call set-up

Point-to point symmetric key distribution

- Before: Alice and Bob share long term secret K_{AB}



generate session key k

$E K_{AB}(k \,||\, time \,||\, Bob)$

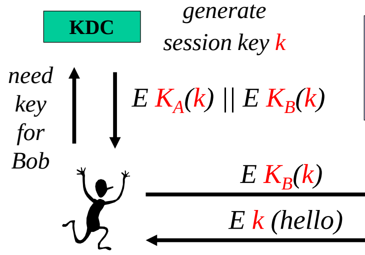
$E k\,(time \,||\, Alice \,||\, hello)$

decrypt extract k

- After: Alice and Bob share a short term key k
  - which they can use to protect a specific interaction
  - which can be thrown away at the end of the session
- Alice and Bob have also authenticated each other

Symmetric key distribution with 3rd party

- Before (KDC=Key Distribution Center)
  - Alice shares a long term secret with KDC: K_A
  - Bob shares long term secret with KDC: K_B



KDC

generate session key k

need key for Bob

$E\, K_A(k) \,||\, E\, K_B(k)$

$E\, K_B(k)$

$E\, k\, (hello)$

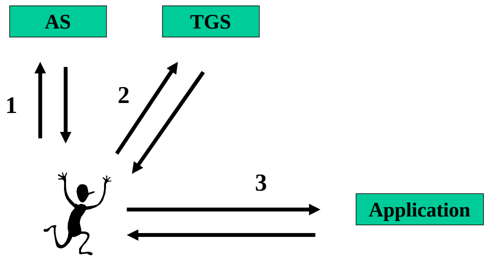
!! never use this protocol in practice – it is just a toy example

Symmetric key distribution with 3rd party(2)

- After: Alice and Bob share a short term key k
- Need to trust third party!
- Single point of failure in system

Kerberos/Single Sign On (SSO)

- Alice uses her password only once per day



AS

TGS

1

2

3

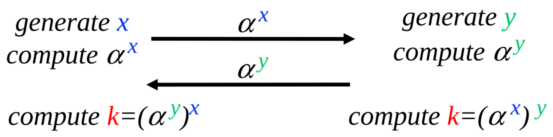
Application

Kerberos/Single Sign On (2)

- Step 1: Alice gets a "day key" K_A from AS (Authentication Server)
  - based on a Alice's password (long term secret)
  - K_A is stored on Alice's machine and deleted in the evening
- Step 2: Alice uses K_A to get application keys k_i from TGS (Ticket Granting Server)
- Step 3: Alice can talk securely to applications (printer, file server) using application keys k_i

A public-key distribution protocol: Diffie-Hellman

- Before: Alice and Bob have never met and share no secrets; they know a public system parameter α



generate x
compute α^x

α^x

α^y

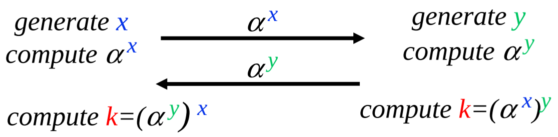
generate y
compute α^y

compute $k=(\alpha^y)^x$

compute $k=(\alpha^x)^y$

- After: Alice and Bob share a short term key k
  - Eve cannot compute k : in several mathematical structures it is hard to derive x from α^x (this is known as the discrete logarithm problem)

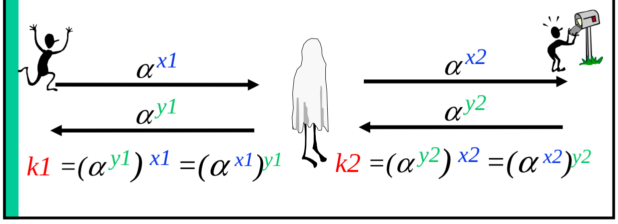
Diffie-Hellman (continued)



- BUT: How does Alice know that she shares this secret key ***k*** with Bob?
- Answer: Alice has no idea at all about who the other person is! The same holds for Bob.

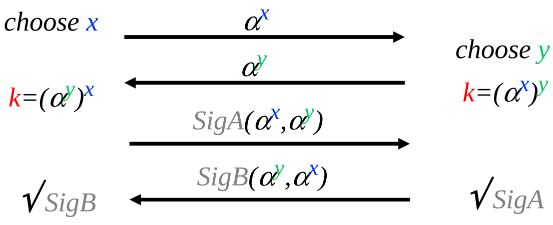
Meet-in-the middle attack

- Eve shares a key *k1* with Alice and a key *k2* with Bob
- Requires *active* attack

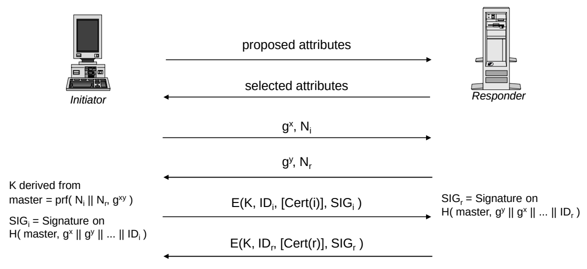

α^{x1}
α^{y1}
α^{x2}
α^{y2}
$k1=(\alpha^{y1})^{x1}=(\alpha^{x1})^{y1}$
$k2=(\alpha^{y2})^{x2}=(\alpha^{x2})^{y2}$

Station to Station protocol (STS)

- The problem can be fixed by adding digital signatures
- This protocol plays a very important role on the Internet (under different names)



IKE - Main Mode with Digital Signatures



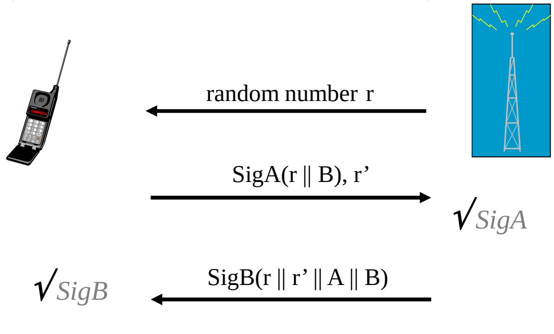
K derived from master = prf(N_i || N_r, g^{xy})

SIG_i = Signature on H(master, g^x || g^y || ... || ID_i)

SIG_r = Signature on H(master, g^y || g^x || ... || ID_r)

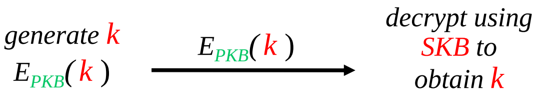
H is equal to prf or the hash function tied to the signature algorithm (all inputs are concatenated)

Key establishment in future mobile systems



[+] slightly more efficient (ECC)

Key transport using RSA



- How does Bob know that ***k*** is a fresh key?
- How does Bob know that this key ***k*** is coming from Alice?
- How does Alice know that Bob has received the key ***k*** and that Bob is present (entity authentication)?

Key transport using RSA (2)

generate k

$E_{PKB}(k)$ $\xrightarrow{E_{PKB}(k \| t_A)}$ *decrypt using SKB to obtain* k

- Freshness is solved with a timestamp t_A

Key transport using RSA (3)

generate k

$\xrightarrow{Sig_{SKA}(E_{PKB}(k \| t_A))}$ *decrypt using SKB and verify using PKA*

- Alice authenticates by signing the message
- There are still attacks (signature stripping…)

Key transport using RSA (4): X.509

generate k

$\xrightarrow{Sig_{SKA}(B \| t_A \| E_{PKB}(A \| k)) \| t_A \| E_{PKB}(A \| k)}$ *decrypt using SKB and verify using PKA*

Mutual: B can return a similar message including part of the first message

Problem (compared to D-H/STS): lack of **forward secrecy**

If the long term key *SKB* of Bob leaks, all past session keys can be recovered!

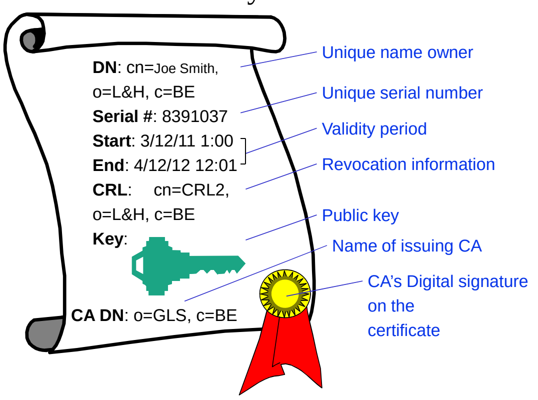
Distribution of public keys

- How do you know whose public key you have?
- Where do you get public keys?
- How do you trust public keys?
- What should you do if your private key is compromised?

reduce protection of public key of many users to knowledge of a single public key of a Certification Authority (CA)

digital certificates &
Public Key Infrastructure (PKI)

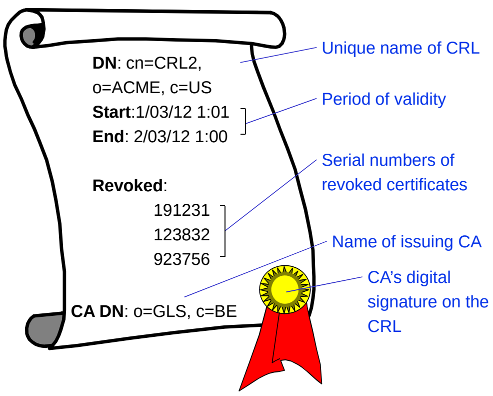
Public Key Certificates



DN: cn=Joe Smith, o=L&H, c=BE
Serial #: 8391037
Start: 3/12/11 1:00
End: 4/12/12 12:01
CRL: cn=CRL2, o=L&H, c=BE
Key:
CA DN: o=GLS, c=BE

Unique name owner
Unique serial number
Validity period
Revocation information
Public key
Name of issuing CA
CA's Digital signature on the certificate

Certificate Revocation List



DN: cn=CRL2, o=ACME, c=US
Start:1/03/12 1:01
End: 2/03/12 1:00
Revoked:
191231
123832
923756
CA DN: o=GLS, c=BE

Unique name of CRL
Period of validity
Serial numbers of revoked certificates
Name of issuing CA
CA's digital signature on the CRL

Essential PKI Components

- Certification Authority
- Revocation system
- Certificate repository ("directory")
- Key backup and recovery system
- Support for non-repudiation
- Automatic key update
- Management of key histories
- Cross-certification
- PKI-ready application software

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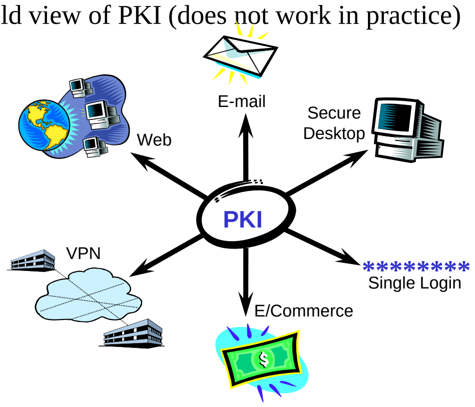
PKI-ready application software: old view of PKI (does not work in practice)



PKI

E-mail

Secure Desktop

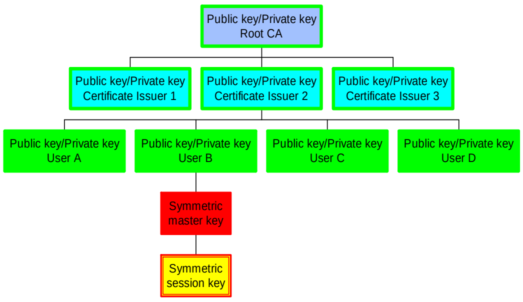
Single Login

E/Commerce

VPN

Web

Example of a key hierarchy



Public key/Private key Root CA

Public key/Private key Certificate Issuer 1

Public key/Private key Certificate Issuer 2

Public key/Private key Certificate Issuer 3

Public key/Private key User A

Public key/Private key User B

Public key/Private key User C

Public key/Private key User D

Symmetric master key

Symmetric session key