Authentication protocols

Identity attributes

- Set of attributes for setting apart individuals
  - Name
  - Numerical identifiers
    - Fixed for life
    - Variable with context
  - Address
  - Photo
  - Identity of relatives
    - Usually parents
  - ...

Authentication: Definition

- ▷ Proof that an entity has a claimed identity attribute

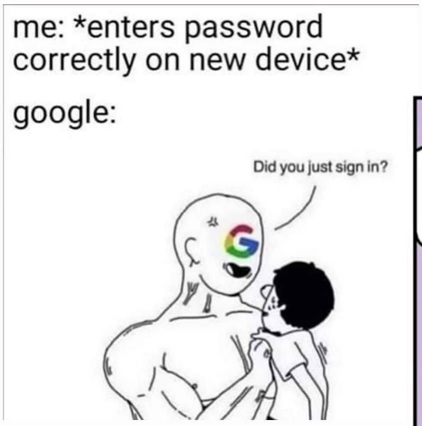
—Hi, I'm Joe
—Prove it!
—Here are my Joe's credentials
—Credentials accepted/not accepted

—Hi, I'm over 18
—Prove it!
—Here is the proof
—Proof accepted/not accepted

Authentication: proof types

- ▷ Something we know
  - A secret memorized (or written down…) by Joe
- ▷ Something we have
  - An object/token solely held by Joe
- ▷ Something we are
  - Joe's Biometry
- ▷ Multi-factor authentication
  - Join or consecutive use of different proof types

Multi-factor verification jokes



Authentication: goals

- Authenticate interactors
  - People, services, servers, hosts, networks, etc.
- Enable the enforcement of authorization policies and mechanisms
  - Authorization ⇒ authentication
- Facilitate the exploitation of other security-related protocols
  - e.g. key distribution for secure communication

Authentication: requirements

- Trustworthiness
  - How good is it in proving the identity of an entity?
  - How difficult is it to be deceived?
  - Level of Assurance (LoA) (NIST, eIDAS, ISO 29115)

    LoA 1 - Little or no confidence in the asserted identity
    LoA 2 - Some confidence in the asserted identity
    LoA 3 - High confidence in the asserted identity
    LoA 4 - Very high confidence in the asserted identity
- Secrecy
  - No disclosure of secrets used by legitimate entities

Authentication: requirements

- Robustness
  - Prevent attacks to the protocol data exchanges
  - Prevent on-line DoS attack scenarios
  - Prevent off-line dictionary attacks
- Simplicity
  - It should be as simple as possible to prevent entities from choosing dangerous shortcuts
- Deal with vulnerabilities introduced by people
  - They have a natural tendency to facilitate or to take shortcuts

Authentication: Entities and deployment model

- Entities
  - People
  - Hosts
  - Networks
  - Services / servers
- Deployment model
  - Along the time
    - Only when interaction starts
    - Continuously along the interaction
  - Directionality
    - Unidirectional
    - Bidirectional (or mutual)

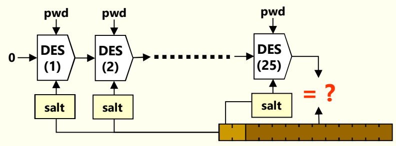
Authentication interactions: Basic approaches

- Direct approach
  - Provide credentials
  - Wait for verdict
  - Authenticator checks credentials against what it knows
- Challenge-response approach
  - Get challenge
  - Provide a response computed from the challenge and the credentials
  - Wait for verdict
  - Authenticator checks response for the challenge provided and the credentials it knows

Authentication of people: Direct approach w/ known password

- ▷ A password is matched with a stored value
  - For a claimed identity (username)
- ▷ Personal stored value:
  - Transformed by a unidirectional function
    - Key Derivation Function (KDF)
    - Preferably slow!
    - Bcrypt, scrypt, Argon2, PBKDF2
  - UNIX: DES hash + salt
  - Linux: KDF + salt
  - Windows: digest function

DES hash = $DES_{pwd}^{25}(0)$
$DES_k^n(x) = DES_k(DES_k^{n-1}(x))$
Permutation of 12 subkeys´bit pairs with salt (12 bits)



Authentication of people: Direct approach w/ known password

- ▷ Advantage
  - Simplicity!
- ▷ Problems
  - Usage of predictable passwords
    - They enable dictionary attacks
  - Different passwords for different systems
    - To prevent impersonation by malicious admins
    - But our memory has limits!
  - Exchange along insecure communication channels
    - Eavesdroppers can easily learn the password
    - e.g. Unix remote services, PAP

Top 15 2019 by Splashdata

1 - 123456
2 - 123456789
3 - qwerty
4 - password
5 - 1234567
6 - 12345678
7 - 12345
8 - iloveyou
9 - 111111
10 - 123123
11 - abc123
12 - qwerty123
13 - 1q2w3e4r
14 - admin
15 - qwertyuiop

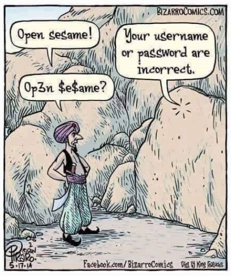
source: https://www.teampassword.com/blog/top-50-worst-passwords-of-2019
Image https://www.pinterest.com/networkboxusa/it-humor

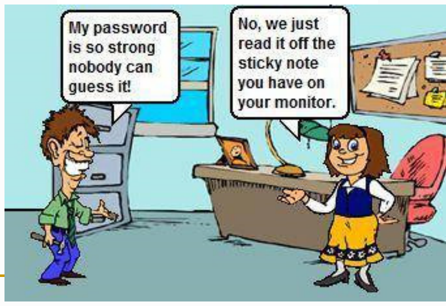
Password selection jokes

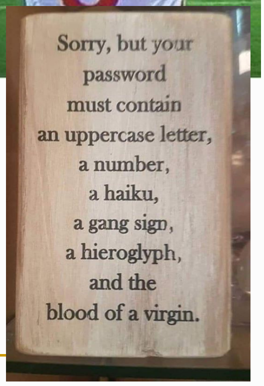
Dear IT,

the more "secure" you try to make our passwords by making them impossible to remember, the more likely I am to save them all in a big word doc named "Passwords"

Signed,
Everyone







Password bloopers

Authentication of people: Direct approach with biometrics

- People get authenticated using body measurements
  - Biometric samples or features
  - Common modalities
    - Fingerprint
    - Facial recognition
    - Palm print
    - Iris scan
    - Voice recognition
    - DNA
- Measures are compared with personal records
  - Biometric references (or template)
  - Registered in the system with a previous enrolment procedure

Biometrics: advantages

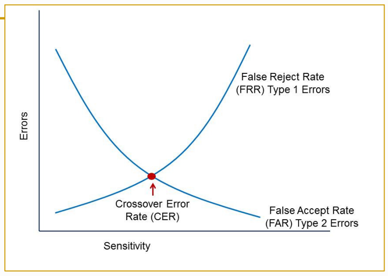
- Convenient: people do not need to use memory
  - Just be their self
- People cannot chose weak passwords
  - In fact, they don't chose anything
- Credentials cannot be transferred to others
  - One cannot delegate their own authentication
- Stealth identification
  - Interesting for security surveillance

Biometrics: problems

- ▷ Usability
  - Comfort of people, ergonomic
  - Exploitation scenario
- ▷ Biometrics are still being improved
  - In many cases they can be easily cheated
  - Liveness detection
- ▷ People cannot change their credentials
  - Upon their robbery
- ▷ It can be risky for people
  - Removal of body parts for impersonation of the victim

Image source: https://biometrics.mainguet.org/types/tongue.htm

Biometrics: problems



- ▷ Sensitivity tuning
  - Reduction of FRR (annoying)
  - Reduction of FAR (dangerous)
  - Tuning is mainly performed with the target population
    - Not with attackers!
- ▷ Not easy to deploy remotely
  - Requires trusting the remote sample acquisition system
- ▷ Can reveal personal sensitive information
  - Diseases
- ▷ Credentials cannot be (easily) copied to others
  - In case of need in exceptional circumstances

Image source: http://www.pearsonitcertification.com/articles/article.aspx?p=1718488

Authentication of people: Direct approach with OTPs

- One-time password (OTP)
  - Credential that can be used only once
- Advantage
  - OTPs can be eavesdropped
  - Eavesdroppers cannot impersonate the OTP owner
    - True for passive eavesdroppers
    - False for active attackers!

Authentication of people: Direct approach with OTPs

- Problems
  - Interactors need to know which password they should use at different occasions
    - Requires some form of synchronization
  - People may need to use extra resources to maintain or generate one-time passwords
    - Paper sheets
    - Computer programs
    - Special devices, etc.

Authentication of people: OTPs and secondary channels

- OTPs are codes sent through secondary channels
  - A secondary channel is a channel that is not the one were the code is going to be used
    - SMS, email, Twitter, Firebase, QR codes, NFC, etc.
  - The secondary channel provides the synchronization
    - Just-in-time provision of OTP
- Two authentications are possible
  - Confirm a secondary channel provided by a profile owner
    - In order to trust that that channel belongs to the profile owner
  - Authenticate the owner of a profile
    - Which is bound to a secondary channel

Authentication of people: OTPs produced from a shared key

- HOTP (Hash-based One Time Password, RFC 4226)
  - OTP generated from a counter and a shared key
  - Counters are updated independently
- TOTP (Time-based One Time Password, RFC 6238)
  - OTP generated from a timestamp and a shared password
  - TOTP is HOTP with timestamps instead of counters
  - Clocks need a rough synchronization

Token-based OTP generators: RSA SecurID

- ▷ Personal authentication token
  - Or software modules for handhelds (PDAs, smartphones, etc.)
- ▷ It generates a unique number at a fixed rate
  - Usually one per minute (or 30 seconds)
  - Bound to a person (User ID)
  - Unique number computed with:
    - A 64-bit key stored in the token
    - The actual timestamp
    - A proprietary digest algorithm (SecurID hash)
    - An extra PIN (only for some tokens)

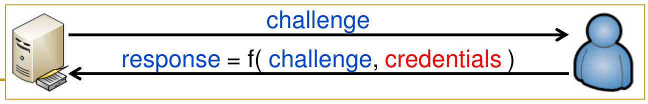
RSA SecurID

- ▷ OTP-based authentication
  - A user combines their User ID with the current token number

    OTP = User ID, Token Number
- ▷ An RSA ACE Server does the same and checks for match
  - It also knows the person's key stored in the token
  - There must be a synchronization to tackle clock drifts
    - RSA Security Time Synchronization
- ▷ Robust against dictionary attacks
  - Keys are not selected by people

Challenge-response approach: Generic description

- The authenticator provides a challenge
- The entity being authenticated transforms the challenge
  - With its authentication credentials
- The result (response) is sent to the authenticator
- The authenticator checks the response
  - Produces a similar result and checks if they match
  - Transforms the result and checks if it matches the challenge or a related value



Challenge-response approach: Generic description

- Advantage
  - Authentication credentials are not exposed
- Problems
  - People may require means to compute responses
    - Hardware or software
  - The authenticator may have to have access to shared secrets
    - How can we prevent them from using the secrets elsewhere?
  - Offline dictionary attacks
    - Against recorded challenge-response dialogs
    - Can reveal secret credentials (passwords, keys)

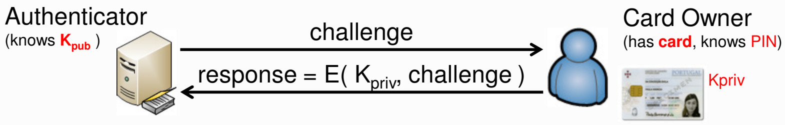
Challenge-response protocols: selection of challenges

- ▷ Challenges cannot be repeated for the same entity
  - Same challenge → same response
  - An active attacker can impersonate a user using a previously recorded protocol run
- ▷ Challenges should be nonces
  - Nonce: number used only once
  - Stateful services can use counters
  - Stateless services can use (large) random numbers
  - Time can be used, but with caution
    - Because one cannot repeat a timestamp

Authentication of people: Challenge-response with smartcards

- ▷ Authentication credentials
  - The smartcard
    - e.g. Citizen Card
  - The private key stored in the smartcard
  - The PIN to unlock the private key
- ▷ The authenticator knows
  - The corresponding public key
  - Or some personal identifier
    - Which can be related with a public key through a (verifiable) certificate

Authentication of people:
Challenge-response with smartcards



- ▷ Signature-based protocol
  - The authenticator generates a random challenge
    - Or a value not used before
  - The card owner ciphers the challenge with their private key
    - PIN-protected
  - The authenticator decrypts the result with the public key
    - If the output matches the challenge, the authentication succeeds
- ▷ Encryption-based protocol
  - Possible when private key decryption is available

Authentication of people:
Challenge-response with memorized password

- ▷ Authentication credentials
  - Passwords selected by people
- ▷ The authenticator knows
  - All the registered passwords; or
  - A transformation of each password
    - Preferable option
    - Preferably combined with some local value (salt)
    - Preferable using a tunable function (e.g. iterations)

Authentication of people:
Challenge-response with memorized password

- The authenticator generates a random challenge
- The person computes a function of the challenge and password
  - e.g. a joint digest: response = digest (challenge, password)
  - e.g. an encryption response = $E_{password}$ (challenge)
- The authenticator does the same (or the inverse)
  - If the output matches the response (or the challenge), the authentication succeeds
- Examples
  - CHAP, MS-CHAP v1/v2, S/Key

PAP & CHAP
(RFC 1334, 1992, RFC 1994, 1996)

- Protocols used in PPP (Point-to-Point Protocol)
  - Unidirectional authentication
    - Authenticator is not authenticated
- PPP developed in 1992
  - Mostly used for dial-up connections
- PPP protocols are used by PPTP VPNs
  - e.g. vpn.ua.pt

PAP & CHAP (RFC 1334, 1992, RFC 1994, 1996)

- ▷ PAP (PPP Authentication Protocol)
  - Simple UID/password presentation
  - Insecure cleartext password transmission
- ▷ CHAP (CHallenge-response Authentication Protocol)

  Aut → U: authID, challenge
  U → Aut: authID, MD5(authID, pwd, challenge), identity
  Aut → U: authID, OK/not OK

  - The authenticator may require a reauthentication anytime

MS-CHAP (Microsoft CHAP) (RFC 2433, 1998, RFC 2759, 2000)

▷ Version 1

A → U: authID, **C**
U → A: **R1**, **R2**
A →U: OK/not OK

R1 = DES_{LMPH}(C)
R2 = DES_{NTPH}(C)

LMPH = DEShash(pwd')
NTPH = MD4(pwd)

pwd' = capitalized(pwd)

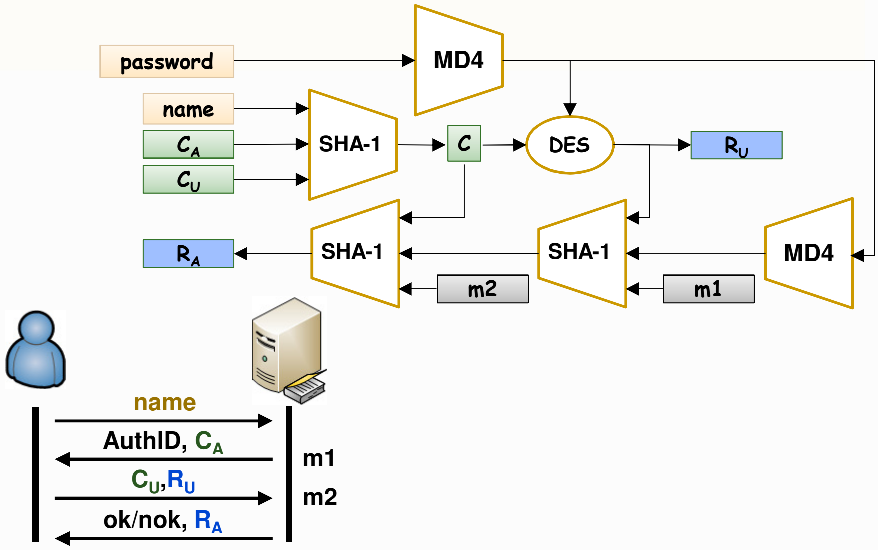
▷ Version 2

A → U: authID, $\mathbf{C_A}$ ← m1
U → A: $\mathbf{C_U}$, **R1** ← m2
A → U: OK/not OK, **R2**

R1 = DES_{PH} (C)
C = SHA(C_U, C_A, username)
PH = MD4(password)
R2 = SHA(SHA(MD4(PH), R1, m1), C, m2)

- Mutual authentication
- Passwords can be updated

MS-CHAP v2

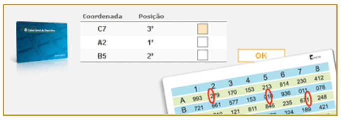


Authentication of people: Generation of OTPs with challenges

- OTPs can be produced from a challenge received
  - The fundamental protocol is password-based
    - But passwords are OTPs
  - OTPs are produced from a challenge
  - One can use several algorithms to handle OTPs

Authentication of people: OTPs selected from shared data

- ▷ Advantage:
  - Shared data can be random
  - No long-term short secrets to protect
- ▷ OTPs build from printed data
  - Example: online bank codes



- ▷ Selection of an OTP from a printed / saved list

```
TPW list generated 2020-12-01 14:10 on ubuntu

000 jZOs ZoWc  056 Q%8x reaG  112 Pwvj ZZKE  168 b%qB ZxJ=  224 MABc m8dj
001 e6+w ZTpi  057 bUZv 67yK  113 dct6 M3m3  169 WL7T szrM  225 UXzZ BgJa
002 Z5/n bWH2  058 wKps yVeW  114 gY=X X3R%  170 MFL: /3aH  226 6+w2 v2Mj
003 FOCV E=/4  059 ufUT j2Ag  115 tF6u E8mh  171 fk9H 2bvb  227 7z=8 xOPO
004 yAOF YbvS  060 NExv %hmn  116 E38O HQ85  172 Ls9u 8DXn  228 4Tow uKkz
005 SBP4 NP8r  061 P4pZ JrL9  117 qdXp FYxc  173 4ZbJ RMXL  229 G4eL od:N
006 K=Ze O7sp  062 K2ys +Wvb  118 wwcC =85E  174 zPnj 2rA8  230 54f= P5xH
007 9Bqp 9E97  063 yBP= rE39  119 sIdC mqDi  175 5Kek oaI+  231 2mwJ uAJV
008 mHmP BjMX  064 Yayh Y=uM  120 3bcx 4cSB  176 Z:Q6 dsCn  232 9kB: :xap
009 3KLK w2ck  065 t6FW er=a  121 dE:9 97vL  177 :afX buOx  233 eR3O mben
010 %MXc 3x7:  066 J+y: DpVR  122 BWMz 65GX  178 ZTFQ IJHS  234 D+rQ WPwO
011 jRTZ Ftsu  067 wERC JF5Q  123 XaYP XUFN  179 A3tN 9p5v  235 o2m% PmS=
012 :UtJ xzLb  068 bCuN eGIX  124 =AWj %J%p  180 MCre BFGp  236 dz3+ EZRd
013 PgVK M+vS  069 mo+D taKT  125 wODU =mwS  181 56IO Vh6B  237 3RNm xFHY
014 NT/s F8mf  070 XiSO rNDz  126 qCnE 5Kp/  182 6=im Rht4  238 rLKG N:3c
015 Hj+Z nmCK  071 UA8U qECw  127 pafc fofR  183 RM7Q 9Twe  239 d4z2 HTuc
016 =QKR rInR  072 PjGj n:oS  128 DSdk ufcM  184 eKmq avXK  240 PnPM NThB
017 hKhD UrZX  073 YXTD ZKfn  129 dFAc /zVX  185 wEtS X3P5  241 gTiF 69k4
018 tCbN wfiR  074 q4B2 uPh9  130 Ix2: XsGF  186 RgQe OnoQ  242 sy/U bpZJ
019 8R2V MNx5  075 =qV2 oMr9  131 gc2Y YSWd  187 WAF9 5Ac/  243 =v5S pXxx
020 9Wc7 Q8Vh  076 E/2P e5I=  132 GhI6 P4bP  188 u/K4 MyTy  244 PLKS roct
021 g2Pg qIuF  077 TaFC /cs7  133 b=aP UeSQ  189 3FOC /9nd  245 ACj4 4s:A
022 9uxI P:Dy  078 ILZ6 Tvpi  134 wIiT AgSS  190 vh+y RMe2  246 GmvO Cp2N
023 qtUo GAX3  079 bD2x GRet  135 tDoH 7qXH  191 oHnH y5KG  247 /mcs Gair
024 ZXFQ 8HAV  080 W%Ig c:T=  136 VgNd Evz6  192 CT6a HrAc  248 yozd vKTf
025 E8/N 7kxE  081 eRwK nzx8  137 =Gsw EHWg  193 %Xm/ =pbj  249 z:BY BW5L
026 guVQ LjhB  082 xfeT z9ta  138 9QOX RtQT  194 f4gE NHOB  250 tsBj jsvd
027 Y%8n :y6f  083 a3ob rjvf  139 KfMj VE6k  195 %38V 3ZEH  251 %ZNR vDBY
028 rDmL X9pH  084 q89w pFka  140 YYm+ hmaY  196 =Tho ORDr  252 qAOt tbe7
029 awpG M6Rt  085 7/no X/m3  141 gGub j:hz  197 PpjO AwgM  253 c3F4 Q4oD
030 Jt:w DGUX  086 5iWg L=Am  142 4iBd IpBy  198 %mdT opDB  254 hwQw BQoO
031 aFh2 uPSP  087 cMxK 6tjU  143 dsRp NTN/  199 rtM2 OGN+  255 fxeC Q%mB
032 mz4E GIVc  088 guQR h+Kd  144 Mk6X S/qJ  200 LHQo rOVN  256 o5zt +xMm
033 xh7V CYgj  089 VIw/ AaFq  145 Otm3 %Nff  201 IfsK JGkk  257 OTkn Co4p
034 ZjBZ xW:j  090 bDcc mMUb  146 YR28 OxTH  202 d5zO tWbb  258 ceb+ s=2%
035 RwHa wcV:  091 KuOk nf/G  147 8aKW 99u7  203 dMOJ d:/I  259 moQh RoOK
036 XRrS NPGR  092 PSY3 expc  148 onxi /gBe  204 L3WG AH8K  260 SMuY 9ArI
037 B6VS EKT/  093 TiRy 5ZQj  149 ozwu O2br  205 EzB6 =Uc9  261 AGDP pYdT
038 %J6/ 6HR7  094 /HQz jeUC  150 NVR7 tsgm  206 46f9 g9BX  262 i%7h RcnF
039 eYQa fwAg  095 RZd2 /3kF  151 EWer s9/f  207 Va2M LR=S  263 dn8j 955y
040 uWT4 3TQA  096 XjtZ AEep  152 bxC5 /+Sv  208 :+mD drVx  264 tjYf uP22
041 4Pop W68U  097 kZBy t8WW  153 zfGv Xz8q  209 ayGk e8oF  265 Q%WZ BcR=
042 Myi3 j9k9  098 b:Kx PUi6  154 Zsp2 UaNN  210 9hv6 Vu3:  266 XC%Q GpOG
043 QH58 kQhy  099 z3w7 B8Qa  155 9POg ih8e  211 kv8n kn+o  267 /:KI Ik3w
044 zYCi y5NZ  100 4wdV :=ak  156 bhy4 UkfN  212 qL8a cDz=  268 2ei5 dY43
045 s=Dz a2F2  101 BITZ JP9Q  157 UFv% T:Wx  213 LTWv 96a9  269 :ABM 3mN2
046 7AFp RCtz  102 4WPg HNko  158 XsED ywx+  214 ywp+ Xq2P  270 7yoU fB6w
047 ao8H 5PHh  103 g6mJ T3YK  159 mTuL ZsrQ  215 ST2: qzCf  271 uA:4 Q+bJ
048 /vgM /h%c  104 wsiw x3/U  160 nHGY aIb+  216 CnOh WT6P  272 =aJb w97Z
049 TznT mhbL  105 UTNP 6vjE  161 :Cin i7:4  217 IFJh x5cZ  273 5dSN evT=
050 6Tha :rnG  106 zKAu 8Qt6  162 /ECm Z6yy  218 8U5W Xu%=  274 eiM+ eWz%
051 DM9G wb37  107 tojS KwqB  163 PbA7 3rja  219 N=8= pCIu  275 +QmX %zZo
052 NUze JzMn  108 66n8 jhKk  164 O:I7 :2qO  220 CPuy =y3K  276 Qs4k i5HP
053 Rff% 7:BN  109 Pt9u +/p+  165 j=vu O:dt  221 O5vF XaoK  277 +2KS +rvR
054 mJqq hmK=  110 Aped PQbv  166 9KAR Fazs  222 umBy =t5d  278 pU47 XSUO
055 FI/d nFk=  111 PF+k FdfZ  167 x%a= 22fP  223 iC2I =2eJ  279 xP6i 3TcQ
```


S/Key (RFC 2289, 1998)

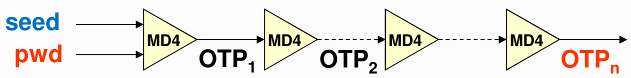
- ▷ Authentication credentials
  - A password (pwd)
- ▷ The authenticator knows
  - The last used one-time password (OTP)
  - The last used OTP index
    - Defines an order among consecutive OTPs
  - An seed value for the each person's OTPs
    - The seed is similar to a UNIX salt

S/Key setup

- ▷ The authenticator defines a random seed
- ▷ The person generates an initial OTP as:

  $OTP_n = h^n$ (seed, pwd), where h = MD4

  - Some S/Key versions also use MD5 or SHA-1
- ▷ The authenticator stores seed, n and OTP_n as authentication credentials



S/Key authentication protocol

- ▷ Authenticator sends seed & index of the person
  - They act as a challenge
- ▷ The person generates index-1 OTPs in a row
  - And selects the last one as result
  - result = $OPT_{index-1}$
- ▷ The authenticator computes h (result) and compares the result with the stored OPT_{index}
  - If they match, the authentication succeeds
  - Upon success, stores the recently used index & OTP
    - index-1 and $OPT_{index-1}$

S/Key

- Advantages
  - Users passwords are unknown to authenticators
  - OTPs can be used as ordinary passwords
- Disadvantages
  - People need an application to compute OTPs
  - Passwords can be derived using dictionary attacks
    - From data stored in authenticators
    - From captured protocol runs

HOTP (HMAC-based one-time password, RFC 4226)

- Numeric OTP computed from shared key K and synchronized counter C
  - Hash key and counter
    - And increase counter
  - From hash, get a (floating) portion of 31 contiguous bits
    - Dynamic Binary Code (DBC)
  - Compute a *d*-long decimal number
    - $d \geq 6$
- Issues
  - Counter synchronization upon a failure
    - If the authenticator keeps it after a failure, exhaustive search attacks are viable
    - If the authenticator always increments it, DoS attacks are possible
  - Acceptance windows
    - Mitigates minor desynchronizations, but decreases security

TOPT (Time-based one-time password, RFC 6238)

▷ HOTP with a counter derived from time

▷ $C_T = \left\lfloor \frac{T - T_0}{T_x} \right\rfloor$

- T – initial time
- T_0 – initial time
- T_x – time interval (default: 30 seconds)

▷ $\text{TOTP}(K) = \text{HOTP}(\,K, C_T)$

Authentication of people: Challenge-response with shared key

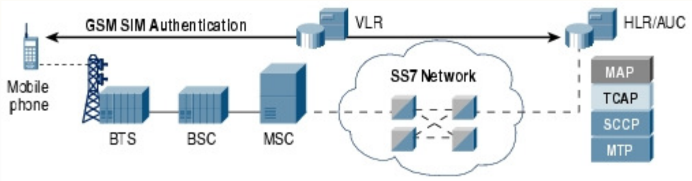
▷ Uses a shared key instead of a password

- Robust against dictionary attacks
- Requires some token to store the key

▷ Example:

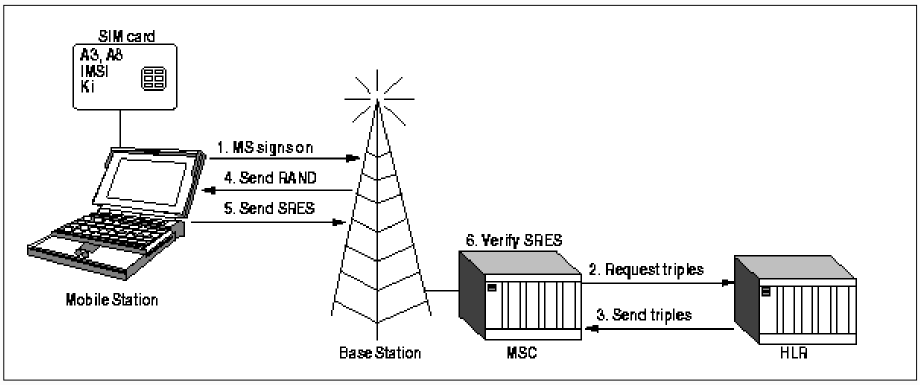
- GSM

GSM: authentication architecture



- Based on a secret key shared between the HLR and the station
  - 128 Ki, stored in the station's SIM card
  - Can only be used after entering a PIN
- Algorithms (initially not public):
  - A3 for authentication
  - A8 for generating a session key
  - A5 for encrypting the communication
- A3 and A8 implemented by SIM card
  - Can be freely selected by the operator

GSM: mobile station authentication



GSM: mobile station authentication

- MSC fetches trio from HLR
  - RAND, SRES, Kc
  - In fact more than one are requested
- HLR generates RAND and corresponding trio using subscriber's Ki
  - RAND, random value (128 bits)
  - SRES = A3 (Ki, RAND) (32 bits)
  - Kc = A8 (Ki, RAND) (64 bits)
- Usually operators use COMP128 for A3/A8
  - Recommended by the GSM Consortium
  - [SRES, Kc] = COMP128 (Ki, RAND)

Host authentication

- By name or address
  - DNS name, IP address, MAC address, other
  - Extremely weak, no cryptographic proofs
    - Nevertheless, used by many services
    - e.g. NFS, TCP *wrappers*
- With cryptographic keys
  - Keys shared among peers
    - With an history of usual interaction
  - Per-host asymmetric key pair
    - Pre-shared public keys with usual peers
    - Certified public keys with any peer

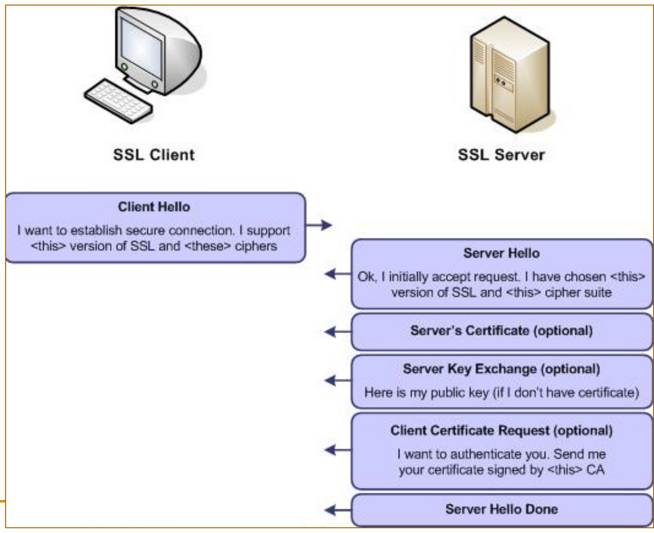
Service / server authentication

- ▷ Host authentication
  - All co-located services/servers are indirectly authenticated
- ▷ Per-service/server credentials
  - Shared keys
    - When related with the authentication of people
    - The key shared with each person can be used to authenticate the service to that person
  - Per-service/server asymmetric key pair
    - Certified or not

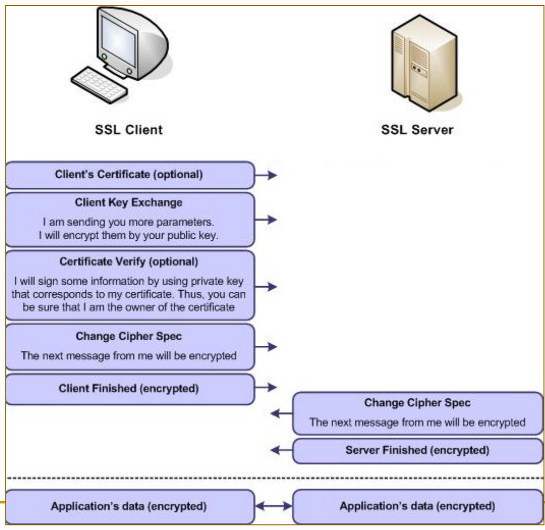
TLS (Transport Layer Security, RFC 8446)

- ▷ Secure communication protocol over TCP/IP
  - Created upon SSL V3 (Secure Sockets Layer)
  - Manages per-application secure sessions over TCP/IP
    - Initially conceived for HTTP traffic
    - Actually used for other traffic types
- ▷ There is a similar version for UDP (DTLS, RFC 6347)
- ▷ Security mechanisms
  - Communication confidentiality and integrity
    - Key distribution
  - Authentication of communication endpoints
    - Servers (or, more frequently, services)
    - Client users
    - Both with asymmetric key pairs and certified public keys

SSL/TLS interaction diagrams (1st part)



SSL/TLS interaction diagrams (2nd part)



SSH (Secure Shell, RFC 4251)

- Alternative to telnet/rlogin protocols/applications
  - Manages secure consoles over TCP/IP
  - Initially conceived to replace telnet
  - Actually used for other applications
    - Secure execution of remote commands (rsh/rexec)
    - Secure copy of contents between machines (rcp)
    - Secure FTP (sftp)
    - Creation of arbitrary secure tunnels (inbound/outbound/dynamic)
- Security mechanisms
  - Communication confidentiality and integrity
    - Key distribution
  - Authentication of communication endpoints
    - Servers / machines
    - Client users
    - Both with different techniques

SSH authentication mechanisms

- Server: with asymmetric keys pair
  - Inline public key distribution
    - Not certified!
  - Clients cache previously used public keys
    - Caching should occur in a trustworthy environment
    - Update of a server's key raises a problem to its usual clients
- Client users: configurable
  - Username + password
    - By default
  - Username + private key
    - Upload of public key in advance to the server

Single Sign-On (SSO)

- Unique, centralized authentication for a set of federated services
  - The identity of a client, upon authentication, is given to all federated services
  - The identity attributes given to each service may vary
  - The authenticator is called Identity Provider (IdP)
- Examples
  - SSO authentication @ UA
    - Performed by a central IdP (idp.ua.pt)
    - The identity attributes are securely conveyed to the service accessed by the user

Authentication metaprotocols

- Generic authentication protocols that encapsulate other authentication protocols
- Examples
  - EAP (Extensible Authentication Protocol)
    - Used in 802.1X (Wi-Fi, enterprise mode)
    - e.g. PEAP (Protected EAP) and EAP-TLS run over EAP
  - ISAKMP(Internet Security Association and Key Management Protocol)
    - Used in IPSec
    - e.g. IKE (Internet Key Exchange) runs over ISAKMP

Authentication services

- Trusted third parties (TTP) used for authentication
  - But often combined with other related functionalities
- AAA services
  - Authentication, Authorization and Accounting
  - e.g. RADIUS

Key distribution services

- Services that distribute a shared key for authenticated entities
  - That key can then be used by those entities to protect their communication and ensure source authentication
- Examples
  - 802.1X (Wi-Fi, enterprise mode)
  - Kerberos