Operating Systems Design
22. Authentication

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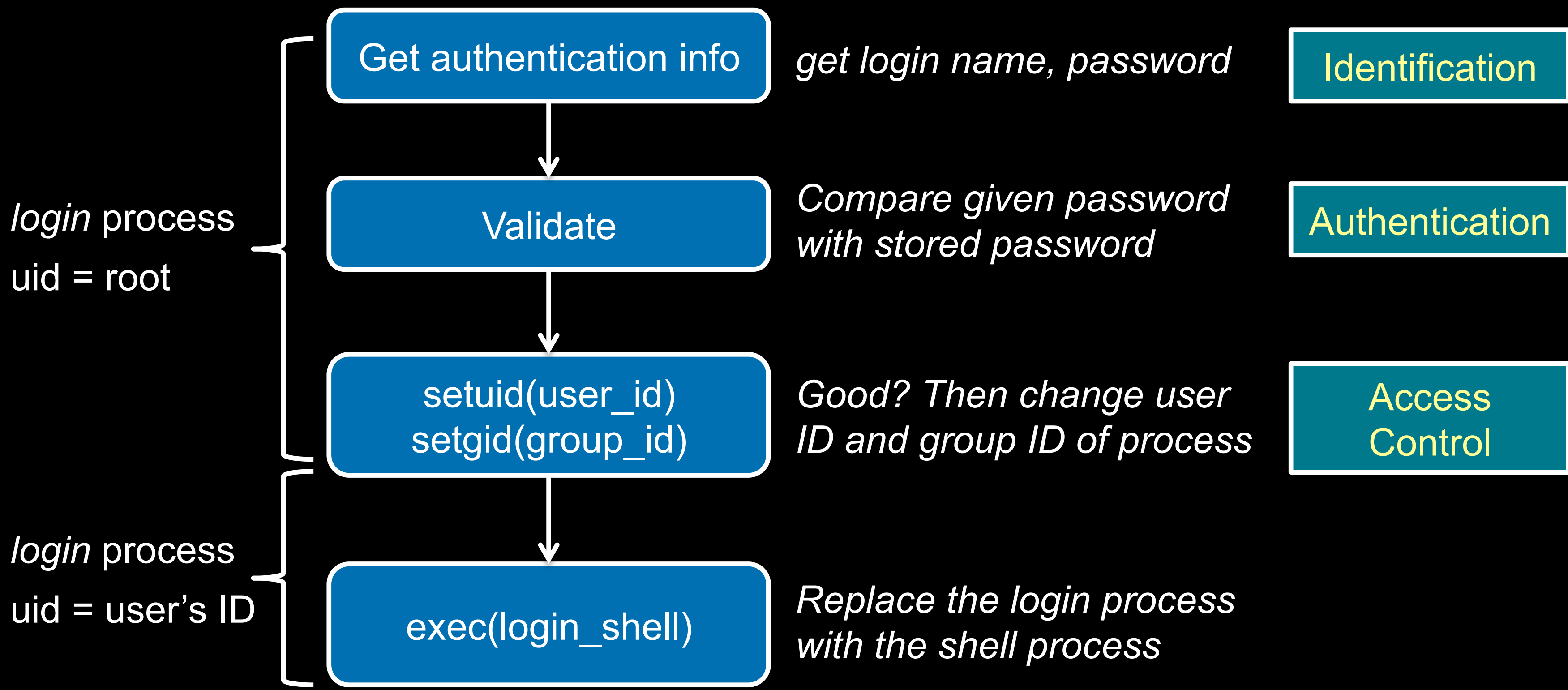
Authentication

- For a user/process:
  - Establish & verify identity
  - Then decide whether to allow access to resources
- For a file or data stream:
  - Validate that the integrity of the data; that it has not been modified by anyone other than the author
  - E.g., digital signature

Local authentication example: login



Authentication

Three factors:

- something you have *key, card*
  - can be stolen
- something you know *passwords*
  - can be guessed, shared, stolen
- something you are *biometrics*
  - costly, can be copied (sometimes)

Multi-Factor Authentication

Factors may be combined

- ATM machine: 2-factor authentication
  - ATM card *something you have*
  - PIN *something you know*

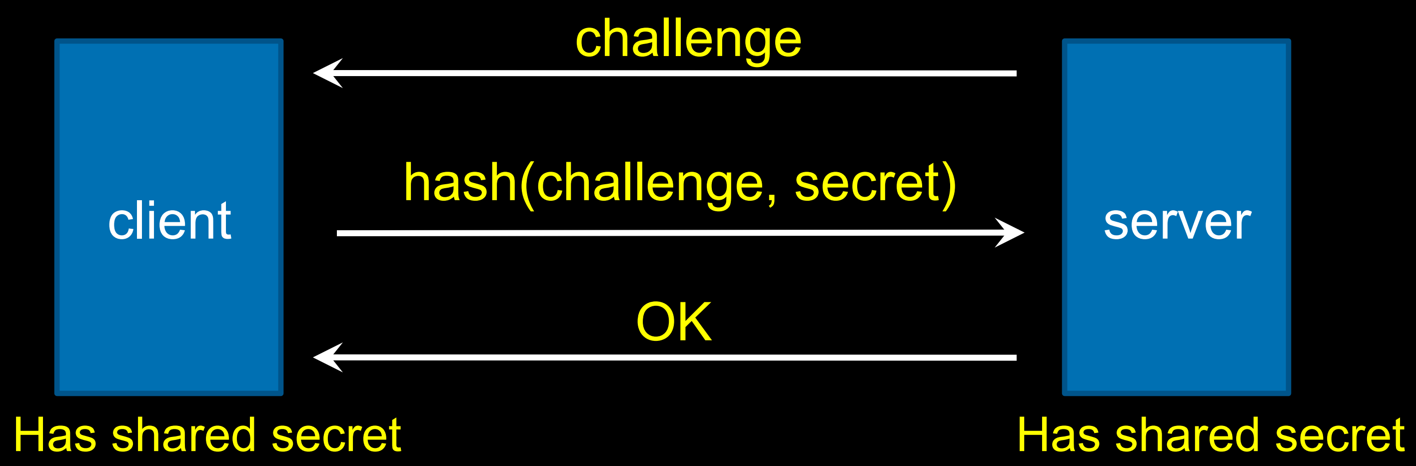
Password Authentication Protocol (PAP)

- Reusable passwords
- Server keeps a database of *username:password* mappings
- Prompt client/user for a login name & password
- To authenticate, use the login name as a key to look up the corresponding password in a database (file) to authenticate

```
if (supplied_password == retrieved_password)
      then user is authenticated
```

Authentication: CHAP

Challenge-Handshake Authentication Protocol



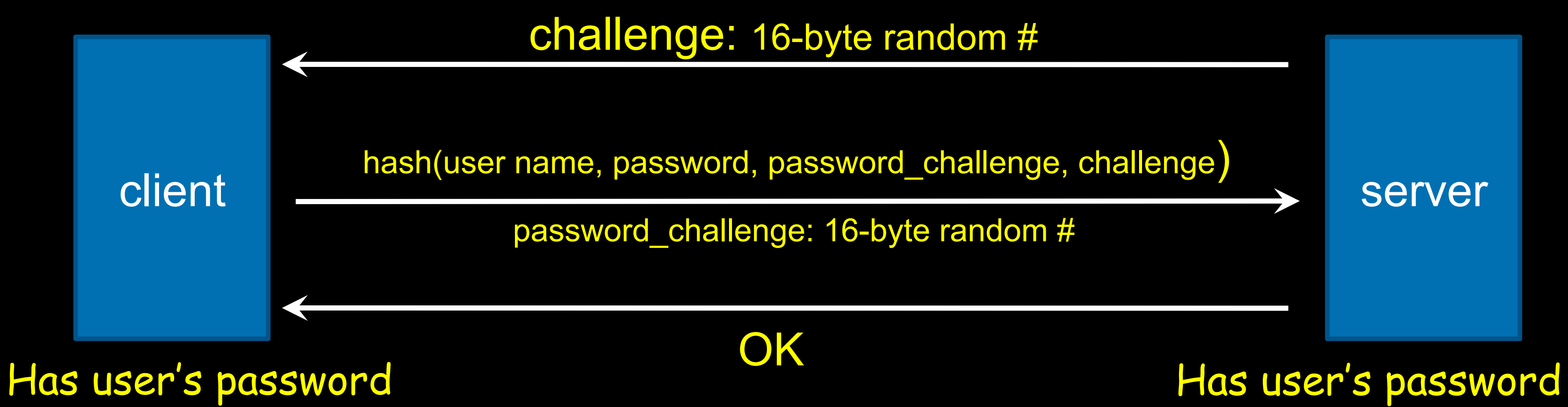
The challenge is a random bunch of bits (*nonce)*.

Client returns a hash of the nonce and the secret – demonstrates it knows the shared secret.

Server validates.

Authentication: MS-CHAP

Microsoft's Challenge-Handshake Authentication Protocol



The same as CHAP – we're just hashing more things in the response

PAP: Reusable passwords

One problem: what if the password file isn't sufficiently protected and an intruder gets hold of it, he gets all the passwords!

Even if a trusted admin sees your password, this might also be your password on other systems.

Enhancement:

Store a hash of the password in a file

- given a file, you don't get the passwords
- have to resort to a dictionary or brute-force attack

- Unix approach
  - Password encrypted with 3DES hashes;
    then MD5 hashes; now SHA512 hashes
  - Salt used to guard against dictionary attacks

PAP: Reusable passwords

Passwords can be stolen by observing a user's session in person or over a network:

- snoop on telnet, ftp, rlogin, rsh sessions
- Trojan horse
- social engineering
- brute-force or dictionary attacks

One-time passwords

Use a different password each time

- generate a list of passwords

or:

- use an authentication card

S/key authentication

- One-time password scheme
- Produces a limited number of authentication sessions
- relies on one-way functions

S/key authentication

Authenticate Alice for 100 logins

- pick random number, R
- using a one-way function, f(x):

$$x_1 = f(R)$$
$$x_2 = f(x_1) = f(f(R))$$
$$x_3 = f(x_2) = f(f(f(R)))$$
$$\dots \quad \dots$$
$$x_{100} = f(x_{99}) = f(\dots f(f(f(R)))\dots)$$

- then compute:

$$x_{101} = f(x_{100}) = f(\dots f(f(f(R)))\dots)$$

S/key authentication

Authenticate Alice for 100 logins

store $\mathbf{x_{101}}$ in a password file or database record associated with Alice

alice: x_{101}

S/key authentication

Alice presents the *last* number on her list:

Alice to host: { “alice”, x_{100} }

Host computes $f(x_{100})$ and compares it with the value in the database

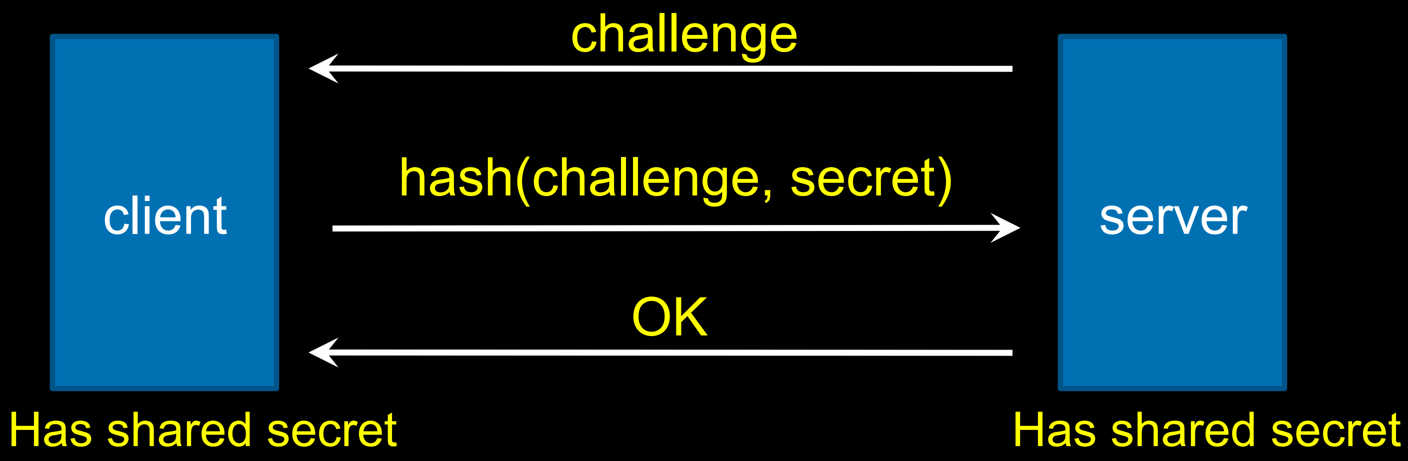
```
if  (x_100 provided by alice) = passwd("alice")
    replace x_101 in db with x_100 provided by alice
    return success
else
    fail
```

next time: Alice presents x_{99}

if someone sees x_{100} there is no way to generate x_{99}.

Authentication: CHAP

Challenge-Handshake Authentication Protocol



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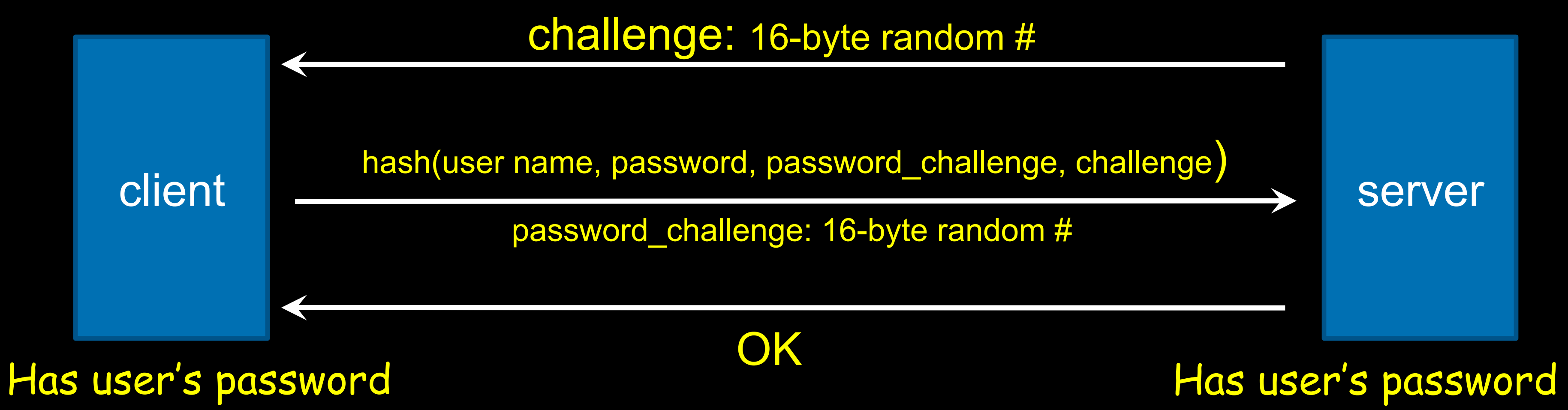

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SecurID card

Username:

paul

Password:

$\underbrace{1234}_{\text{PIN}}\underbrace{032848}_{\text{passcode from card}}$

Something you know

Something you have

1. Enter PIN
2. Press ◊
3. Card computes password
4. Read password & enter

Password:

354982

SecurID card

- from RSA; SASL mechanism: RFC 2808
- two-factor authentication based on:
  - shared secret key (seed)
    - stored on authentication card
  - shared personal ID – PIN
    - known by user

SecurID (SASL) authentication: server side

- Look up user's PIN and seed associated with the token
- Get the time of day
  - DB stores relative accuracy of clock in that SecurID card
  - historic pattern of drift
  - adds or subtracts offset to determine what the clock chip on the SecurID card believes is its current time
- passcode is a cryptographic hash of seed, PIN, and time
  - server computes *f*(seed, PIN, time)
- Server compares results with data sent by client

SecurID

- An intruder (sniffing the network) does not have the information to generate the password for future logins
  - Needs the seed number (from the card), the algorithm (inside the card & server)
- An intruder who steals the card cannot log in
  - Needs a PIN (the benefit of 2-factor authentication)
- An intruder who sees your PIN cannot log in
  - Needs the card (the benefit of 2-factor authentication)

- But…
  - Vulnerable to man-in-the-middle attacks
    - Attacker acts as application server
    - User does not have a chance to authenticate server

Combined authentication and key exchange

Kerberos

- Authentication service developed by MIT
  - project Athena 1983-1988
- Trusted third party
- Symmetric cryptography
- Passwords not sent in clear text
  - assumes only the network can be compromised

Kerberos

Users and services authenticate themselves to each other

To access a service:

- user presents a ticket issued by the Kerberos authentication server
- service examines the ticket to verify the identity of the user

Kerberos is a trusted third party

- Knows all (users and services) passwords
- Responsible for deciding whether someone can access a service
    - *Authorization*

Kerberos

- user *Alice* wants to communicate with a service *Bob*
- both Alice and Bob have keys

- Step 1:
  - Alice authenticates with Kerberos server
    - Gets session key and ***sealed envelope***
- Step 2:
  - Alice gives Bob a session key (securely)
  - Convinces Bob that she also got the session key from Kerberos

Authenticate, get permission

Alice

"I want to talk to Bob" →

Kerberos Authentication Server (AS)

if Alice is allowed to talk to Bob,
generate session key, S

← {"Bob's server", S}$_A$

Alice decrypts this:

- gets ID of "Bob's server"
- gets session key
- *knows message came from AS*

TICKET

sealed envelope

← {"Alice", S}$_B$

eh? (Alice can't read this!)

Send key

Alice

Bob

Alice encrypts a timestamp with session key

{"Alice", S}$_B$, T_S

sealed envelope

Bob decrypts envelope:

- envelope was created by Kerberos on request from Alice
- gets session key

Decrypts time stamp

- validates time window
- Prevent replay attacks

Authenticate recipient

Alice

Bob

Encrypt Alice's timestamp in return message

{"Bob's Server", T}$_S$

Alice validates timestamp

Public key authentication

Demonstrate we can encrypt or decrypt a *nonce*

A random bunch of bits

- Alice wants to authenticate herself to Bob:
- Bob: generates nonce, *S*
  – presents it to Alice
- Alice: encrypts *S* with her private key (sign it) and send to Bob

Public key authentication

- Bob:
  look up “alice” in a database of public keys
  - decrypt the message from Alice using Alice’s public key
  - If the result is *S*, then it was Alice!
- Bob is convinced.
- For mutual authentication, Alice has to present Bob with a nonce that Bob will encrypt with his private key and return

Public key authentication

- Public key authentication relies on binding identity to a public key
- One option:
  get keys from a trusted source
- Problem: requires always going to the source
  - cannot pass keys around

- Another option: *sign the public key*
  - **digital certificate**

X.509 Certificates

ISO introduced a set of authentication protocols: X.509

Structure for public key certificates:

version	serial #	algorithm, params	issuer	validity time	distinguished name	public key (alg, params, key)	signature of CA

Trusted Certification Authority issues a signed certificate

X.509 certificates

When you get a certificate

- Verify its signature:
  - hash contents of certificate data
  - Decrypt CA's signature with CA's public key

Obtain CA's public key (certificate) from trusted source

- Certification authorities are organized in a hierarchy
- A CA certificate may be signed by a CA above it
  - **certificate chaining**

Certificates prevent someone from using a phony public key to masquerade as another person

Cryptographic toolbox

- Symmetric encryption
- Public key encryption
- One-way hash functions
- Random number generators
  - Used for nonces and session keys

Examples

- Key exchange
  - Public key cryptography
- Key exchange + secure communication
  - Public key + symmetric cryptography
- Authentication
  - Nonce + encryption
- Message authentication codes
  - Hashes
- Digital signature
  - Hash + encryption
- Nonces and session keys
  - Random numbers

Code Integrity

Code Integrity: signed software

- Per-page signatures
  - Check hashes for every page upon loading (demand paging)
  - OS X & Windows 7:
    - OS X: codesign command
    - Windows 7: signwizard GUI
  - XP/Windows 7: Microsoft Authenticode
    - Hashes stored in system catalog or signed & embedded in the file
  - OS X
    - Hashes & certificate chain stored in file

Code signing: Microsoft Authenticode

- A format for signing executable code (dll, exe, cab, ocx, class files)
- Software publisher:
  - Generate a public/private key pair
  - Get a digital certificate: VeriSign class 3 Commercial Software Publisher's certificate
  - Generate a hash of the code to create a fixed-length digest
  - Encrypt the hash with your private key
  - Combine digest & certificate into a Signature Block
  - Embed Signature Block in executable
- Recipient:
  - Call *WinVerifyTrust* function to validate:
    - Validate certificate, decrypt digest, compare with hash of downloaded code

Windows 7 code integrity checks

- Implemented as a file system driver
  - Works with demand paging from executable
  - Check hashes for every page as the page is loaded
- Hashes in system catalog or embedded in file along with X.509 certificate.
- Check integrity of boot process
  - Kernel code must be signed or it won't load
  - Drivers shipped with Windows must be certified or contain a certificate from Microsoft

Dealing with application security

- Isolation & memory safety
  - Rely on operating system
    - MMU no-execute, address space layout randomiztion
  - Compiler for stack canaries
- Code auditing
  - If possible: but need access to code & skilled staff
- Access control checking at interfaces (system calls)
  - Sandboxing
- Code signing
  - E.g., Authenticode
- Runtime, load-time code verification
  - Sandboxing: Java bytecode verifier, class loader
  - Microsoft CLR

Defense from malicious software

- Access privileges
  - Don’t run as administrator
  - Warning: network services don’t run with the privileges of the user requesting them – they are extra vulnerable
  - Run code in a sandbox – per-process access controls
- Signed software
  - Validate the integrity of the software you install
    - Optionally, validate when running it
- Personal firewall
  - Intercept & explicitly allow/deny applications access to the network
  - Personal firewalls are application-aware
  - *Netfilter* hooks in the network stack

The End