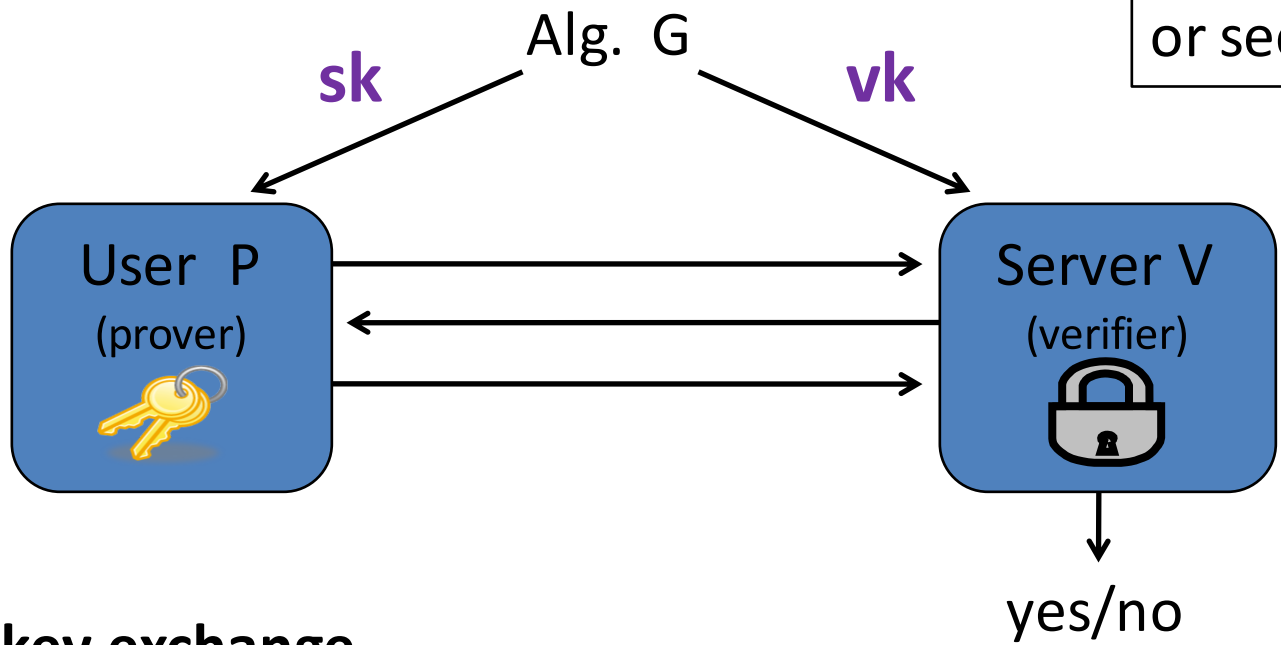
ID protocols

Overview

The Setup

vk either public
or secret



no key exchange

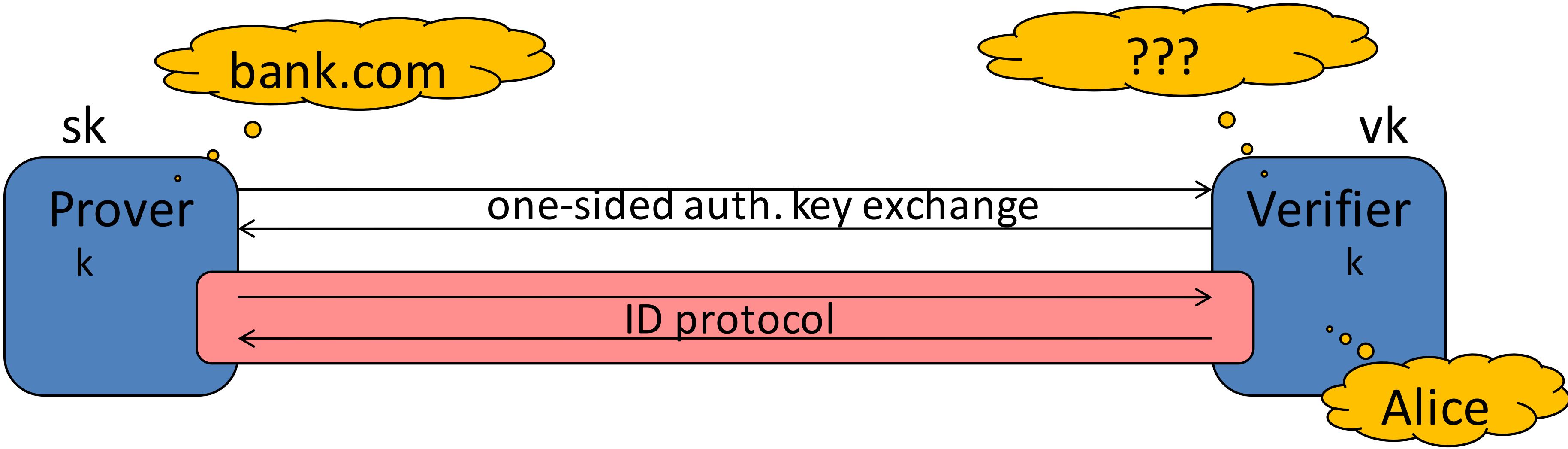
Applications: physical world

– Physical locks: (friend-or-foe)
  - Wireless car entry system
  - Opening an office door

– Login at a bank ATM or a desktop computer

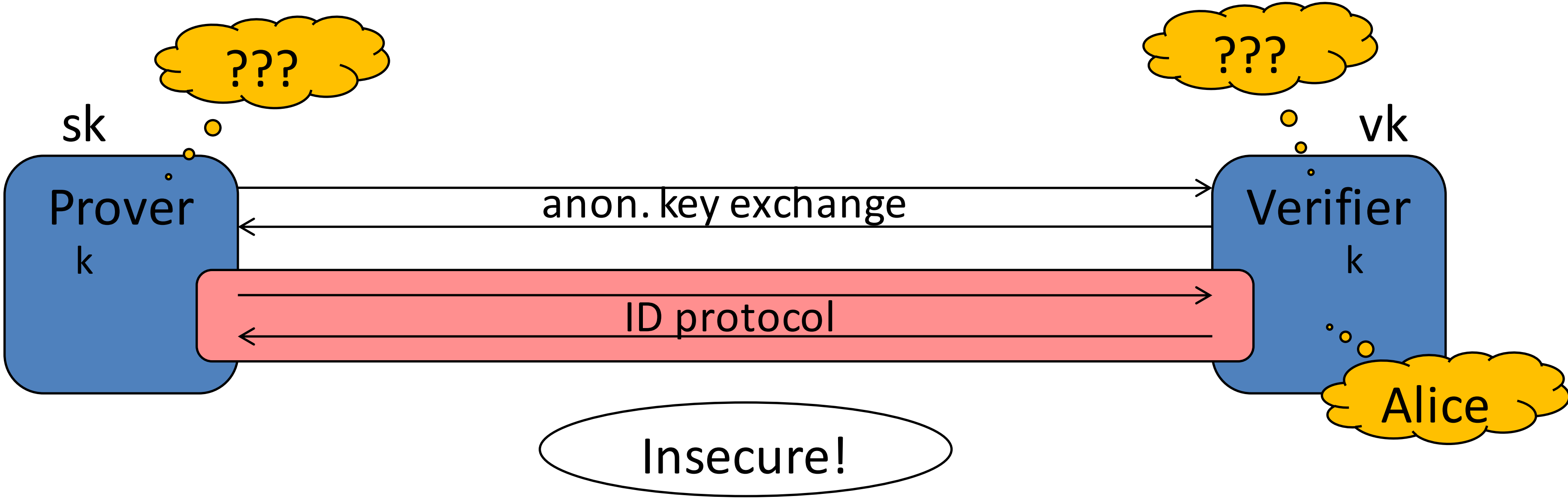
Applications: Internet

Login to a remote web site after a key-exchange with one-sided authentication (e.g. HTTPS)



ID Protocols: how not to use

- ID protocol do not establish a secure session between Alice and Bob !!
    - Not even when combined with anonymous key exch.
    - Vulnerable to man in to the middle attacks



ID Protocols: how not to use

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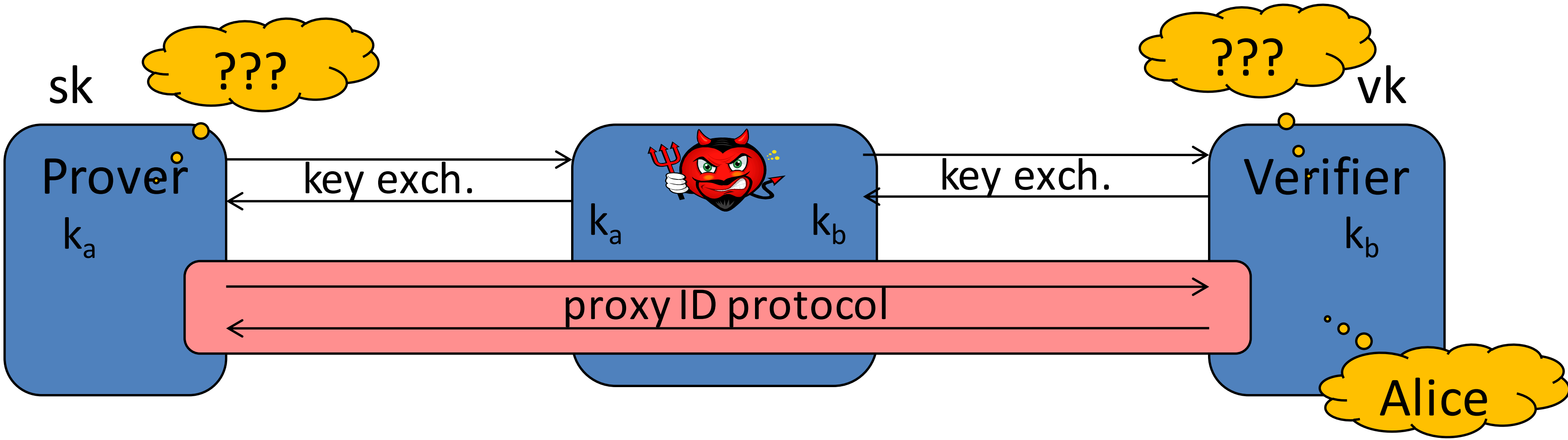
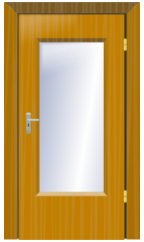


ID Protocols: Security Models

1. **Direct Attacker**: impersonates prover with no additional information (other than vk)
   – Door lock



2. **Eavesdropping attacker**: impersonates prover after eavesdropping on a few conversations between prover and verifier
   – Wireless car entry system

3. **Active attacker**: interrogates prover and then attempts to impersonate prover
   – Fake ATM in shopping mall

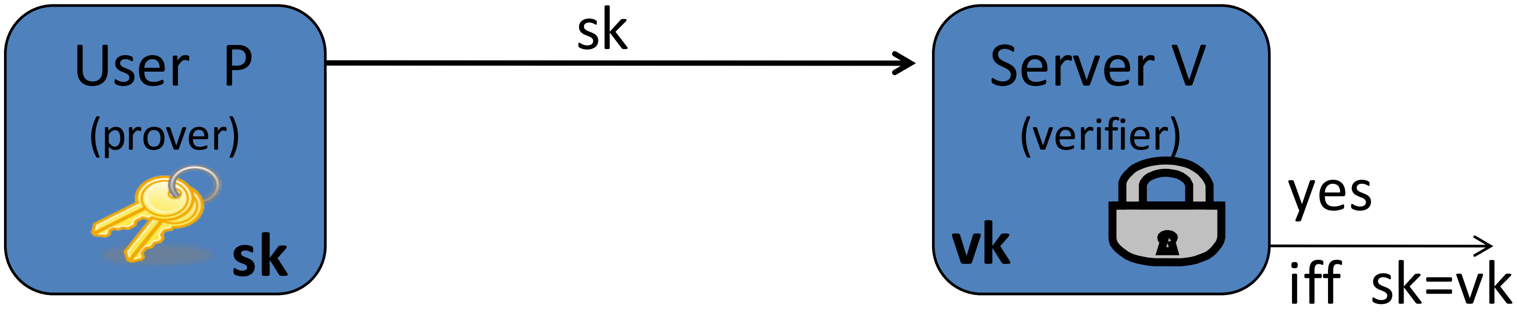
ID protocols

Direct attacks

Basic Password Protocol (incorrect version)

- **PWD**: finite set of passwords

- Algorithm G (KeyGen):
  - choose $pw \leftarrow PWD$. output $sk = vk = pw$.



Basic Password Protocol (incorrect version)

Problem: vk must be kept secret

- Compromise of server exposes all passwords
- Never store passwords in the clear!

password file on server

Alice	pw_{alice}
Bob	pw_{bob}
…	…

Basic Password Protocol: version 1

H: one-way hash function from PWD to X

- "Given H(x) it is difficult to find y such that H(y)=H(x)"

User P

(prover)

sk

$\xrightarrow{\text{sk}}$

Server V

(verifier)

vk = H(sk)

yes iff H(sk)=vk

password file on server

Alice	$H(pw_A)$
Bob	$H(pw_B)$
…	…

Problem: Weak Password Choice

Users frequently choose weak passwords: (adobe list, 2013)

Password:	123456	123456789	password	adobe123	12345678	qwerty	1234567
Fraction of users:	5%	1.1%	0.9%	0.5%	0.5%	0.5%	0.3%

Total: 8.8%

A common occurrence

- Example: the Rockyou password list, 2009 (6 most common pwds)

123456, 12345, Password, iloveyou, princess, abc123

Dictionary of 360,000,000 words covers about 25% of user passwords

Password:	123456	123456789	password	adobe123	12345678	qwerty	1234567
Fraction of users:	5%	1.1%	0.9%	0.5%	0.5%	0.5%	0.3%

Online dictionary attack: Suppose an attacker obtains a list of usernames. For each username the attacker tries to login using the password '123456'.

Success after 20 tries on average

Offline Dictionary Attacks

Suppose attacker obtains a **single** $vk = H(pw)$ from server

- **Offline** attack: hash all words in Dict until a word w is found such that $H(w) = vk$
- Time $O(|Dict|)$ per password

Off the shelf tools (e.g. John the ripper):

- Scan through **all** 7-letter passwords in a few minutes
- Scan through 360,000,000 guesses in few seconds

$\Rightarrow$ will recover 23% of passwords

Batch Offline Dictionary Attacks

Suppose attacker steals **entire** pwd file F

- Obtains hashed pwds for **all** users
- Example (2012): Linkedin (6M: SHA1(pwd))

Alice	$H(pw_A)$
Bob	$H(pw_B)$
…	…

Batch dict. attack:

- For each $w \in$ Dict: test if $H(w)$ appears in F (using fast look-up)

Total time: **O(|Dict| + |F|)** [Linkedin: 6 days, 90% of pwds. recovered]

Much better than attacking each password individually !

Preventing Batch Dictionary Attacks

Public salt:

- When setting password, pick a random n-bit salt S
- When verifying pw for A, test if $\mathbf{H(pw, S_A) = h_A}$

id	S	h
Alice	S_A	$H(pw_A, S_A)$
Bob	S_B	$H(pw_B, S_B)$
…	…	…

Recommended salt length, $n = 64$ bits

- Attacker must re-hash dictionary for each user

Batch attack time is now: $O(\ |\mathbf{Dict}| \times |\mathbf{F}|\ )$

How to hash a password?

<u>Linked-in</u>: **SHA1** hashed (**unsalted**) passwords

$\Rightarrow$ 6 days, 90% of passwords recovered by exhaustive search

The problem: SHA1 is too fast …
attacker can try all words in a large dictionary

To hash passwords:

- Use a **<u>keyed</u>** hash function (e.g., HMAC) where key stored in HSM
- In addition: use a **<u>slow</u>**, **<u>space-hard</u>** function

How to hash?

PBKDF2, **bcrypt**: slow hash functions

- Slowness by "iterating" a crypto hash function like SHA256

  Example: $H(pw) = SHA256(SHA256(\dots SHA256(pw, S_A) \dots))$
- Number of iterations: set for 1000 evals/sec
- Unnoticeable to user, but makes offline dictionary attack harder

Problem: custom hardware (ASIC) can evaluate hash function 50,000x faster than a commodity CPU

$\Rightarrow$ attacker can do dictionary attack much faster than 1000 evals/sec.

How to hash: a better approach

Scrypt: a slow hash function AND need lots of memory to evaluate

$\Rightarrow$ custom hardware not much faster than commodity CPU

Problem: memory access pattern depends on input password

$\Rightarrow$ local attacker can learn memory access pattern for a given password

$\Rightarrow$ eliminates need for memory in an offline dictionary attack

Is there a space-hard function where time is independent of pwd?

- Password hashing competition (2015): **Argon2i** (also Balloon)

ID protocols

Security against eavesdropping attacks

(one-time password systems)

Eavesdropping Security Model

Adversary is given:

- Server's vk, and
- the transcript of several interactions between honest prover and verifier. (example: remote car unlock)

adv. goal is to impersonate prover to verifier

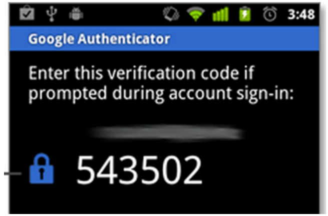
A protocol is "secure against eavesdropping" if no efficient adversary can win this game

The password protocol is clearly insecure !

One-time passwords (secret vk, stateful)

Setup (algorithm G):

- Choose random key **k**
- Output **sk = (k,0)** ; **vk = (k,0)**



Identification:

prover

sk = (k,0)

↓

sk = (k,1)

⋮

$r_0 \leftarrow F(k,0)$ →

$r_1 \leftarrow F(k,1)$ →

6 digits

server

vk = (k,0)

↓

vk = (k,1)

⋮

Yes iff $r = F(k,0)$

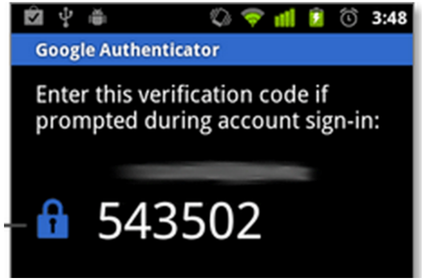
often, time-based updates: $r \leftarrow F(k, \text{time})$ [stateless]

The SecurID system (secret vk, stateful)

"Thm": if F is a secure PRF then protocol is secure against eavesdropping

RSA SecurID uses AES-128:

128 bit key → F
32 bit ctr → F
F → 6 digit output



Advancing state: sk ← (k, i+1)

- Time based: every 60 seconds
- User action: every button press

Both systems allow for skew in the counter value

Google authenticator

- 6-digit timed one-time passwords (TOTP) based on [RFC 6238]
- Wide web-site adoption:
  - Evernote, Dropbox, WordPress, outlook.com, …

To enable TOTP for a user: web site presents QR code with embedded data:

otpauth://totp/Example:**alice@dropbox.com**?
secret=**JBSWY3DPEHPK3PXP** & issuer=Example

(Subsequent user logins require user to present TOTP)

Danger: password reset upon user lockout

Server compromise exposes secrets

March 2011:

- RSA announced servers attacked, secret keys stolen

  $\Rightarrow$ enabled SecurID user impersonation

Is there an ID protocol where server key vk is public?

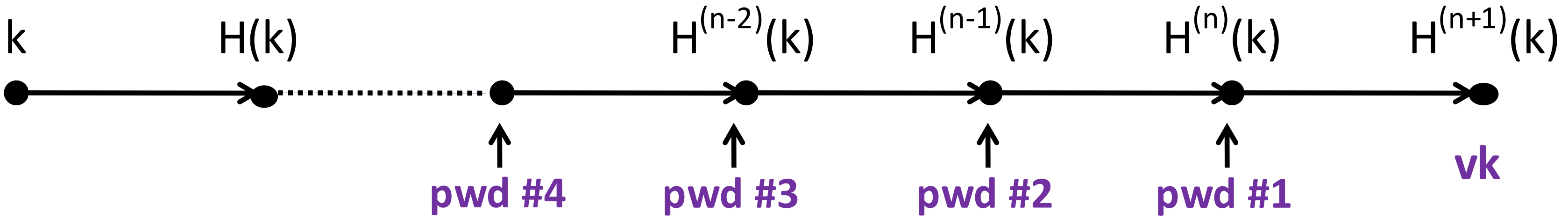
The S/Key system (public vk, stateful)

Notation: $H^{(n)}(x) = \underbrace{H(H(\ldots H(x)\ldots))}_{\text{n times}}$

<u>Algorithm G:</u> (setup)

- Choose random key $k \leftarrow K$
- Output **sk = (k,n)** ; $\mathbf{vk = H^{(n+1)}(k)}$

<u>Identification:</u>



The S/Key system (public vk, stateful)

Identification (in detail):

- Prover (**sk=(k,i)**): send $t \leftarrow H^{(i)}(k)$; set $sk \leftarrow (k,i-1)$
- Verifier($vk=H^{(i+1)}(k)$): if $H(t)=vk$ then $vk \leftarrow t$, output "yes"

Notes: vk can be made public;
but need to generate new sk after n logins ($n \approx 10^6$)

"Thm": S/Key_n is secure against eavesdropping (public vk)
provided H is one-way on n-iterates

SecurID vs. S/Key

S/Key:

- **public** vk, **limited** number of authentications
- Long authenticator t (e.g., 80 bits)

SecurID:

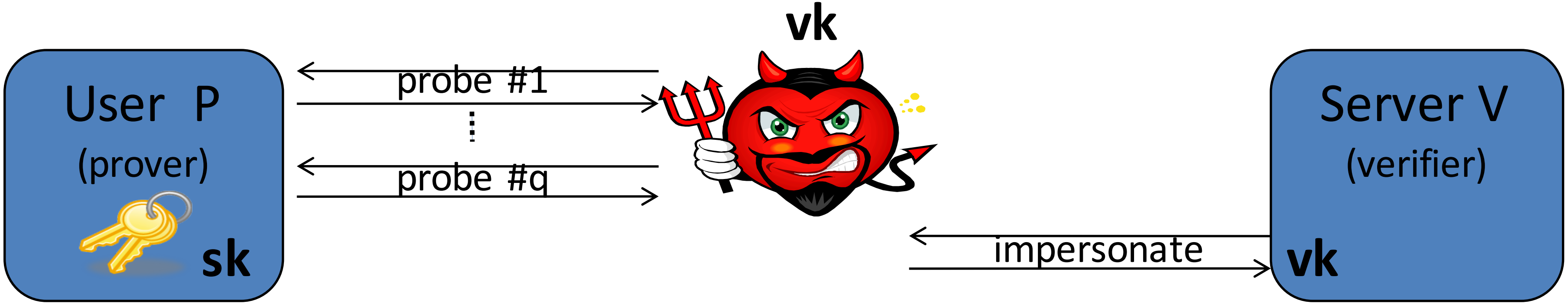
- **secret** vk, **unlimited** number of authentications
- Short authenticator (6 digits)

ID protocols

Security against active attacks

(challenge-response protocols)

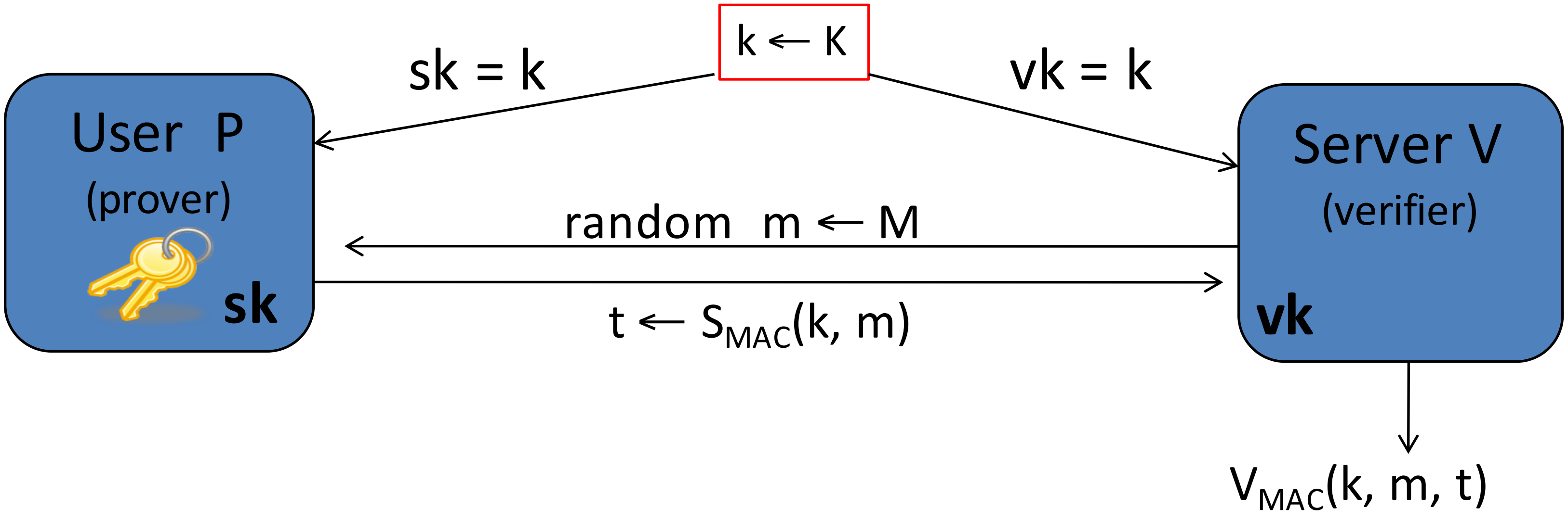
Active Attacks



- Offline fake ATM: interacts with user; later tries to impersonate user to real ATM
- Offline phishing: phishing site interacts with user; later authenticates to real site

All protocols so far are vulnerable

MAC-based Challenge Response (secret vk)



"Thm": protocol is secure against active attacks (secret vk), provided (S_{MAC}, V_{MAC}) is a secure MAC

MAC-based Challenge Response

Problems:

- vk must be kept secret on server
- dictionary attack when k is a human pwd:

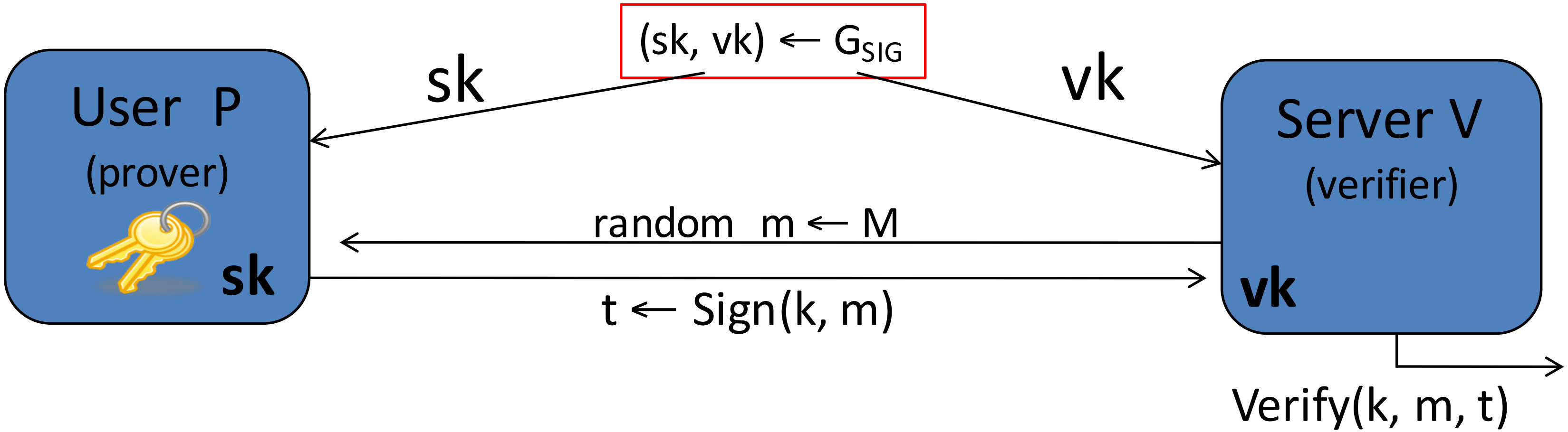
  Given [m , S_{MAC}(pw, m)] eavesdropper can try all pw $\in$ Dict to recover pw

Main benefit:

- Both m and t can be short
- CryptoCard: 8 chars each

Sig-based Challenge Response (public vk)

Replace MAC with a digital signature:



"Thm": Protocol is secure against active attacks **(public vk),** provided (G_{SIG} ,Sign,Verify) is a secure digital sig.

but t is long (≥20 bytes)

Summary

ID protocols: useful in settings where adversary cannot interact with prover during impersonation attempt

Three security models:

- **Direct**: passwords (properly salted and hashed)
- **Eavesdropping attacks**: One time passwords
  - SecurID: secret vk, unbounded logins
  - S/Key: public vk, bounded logins
- **Active attacks**: challenge-response

THE END