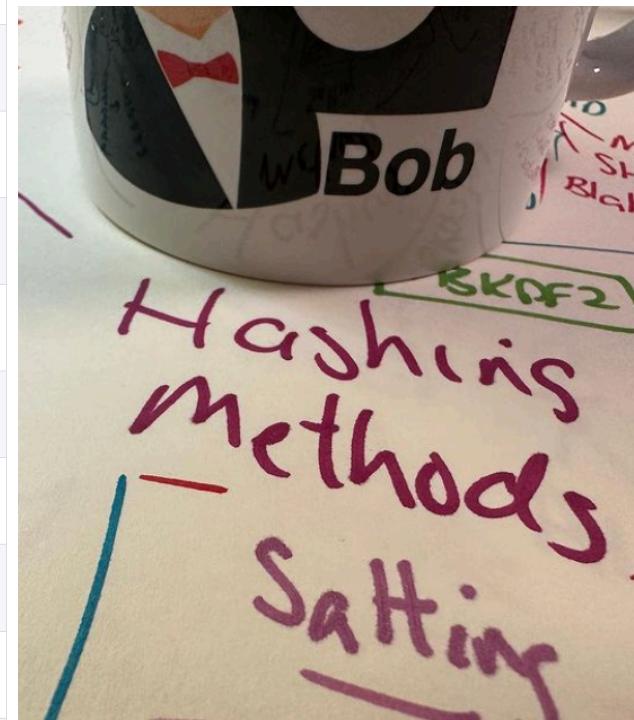
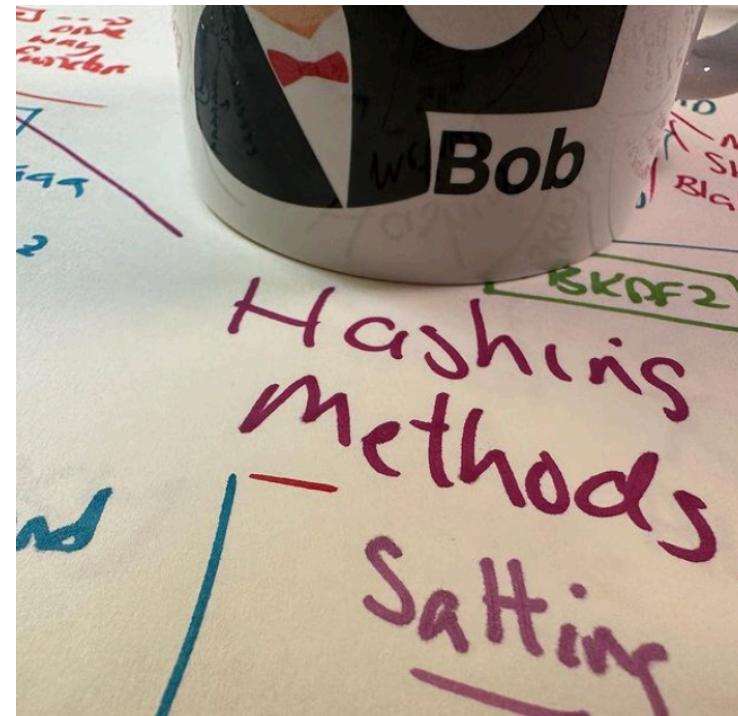


No	Date	Subject	Lab
2	27 Jan 2025	Ciphers and Fundamentals [Unit]	[Lab] [Demo]
3	3 Feb 2025	Symmetric Key [Unit]	[Lab] Vincent Rijmen
4	10 Feb 2025	Hashing and MAC [Unit]	[Lab] Ivan Damgård
5	17 Feb 2025	Asymmetric (Public) Key [Unit]	[Lab] Len Adleman
6	24 Feb 2025	Key Exchange [Unit]	[Lab] Whitfield Diffie
7	3 Mar 2025	Reading Week (Revision lecture)	Mini-project [Here] / Coursework
8	10 Mar 2025	Digital Signatures and Certificates [Unit]	[Lab]
9	17 Mar 2025	Test (Units 1-5) 40% of overall mark [Here]	
10	24 Mar 2025	Tunnelling [Unit]	[Lab] Marty Hellman
11	31 Mar 2025	Blockchain [Unit]	[Lab] Troy Hunt
12	7 Apr 2025	Future Cryptography [Unit]	[Lab]
13	28 Apr 2025	Host/Cloud Security [Unit]	[Lab]
14	5 May 2025	Coursework Hand-in - 60% of overall mark (Sunday, 11 May 2025) [Coursework]	Daniel J Bernstein Windows



Unit 3: Hashing

Hashing Types.
Hashing Methods.
Salting.
Collisions.
LM and NTLM Hashes (Windows).
Hash Benchmarks.
Message Authentication Codes (MACs).
Key Derivation Function (KDF)
OTP/HOTP.
Hashcat (for practical work)



Prof Bill Buchanan OBE
<https://asecuritysite.com/hash>

Unit 3: Hashing

';--have i been pwned?

Check if your email or phone is in a data breach

billgates@microsoft.com

pwned?

Oh no — pwned!

Pwned in 93 data breaches and found 9 pastes (subscribe to search sensitive breaches)

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<https://asecuritysite.com/hash>



Unit 3: Hashing

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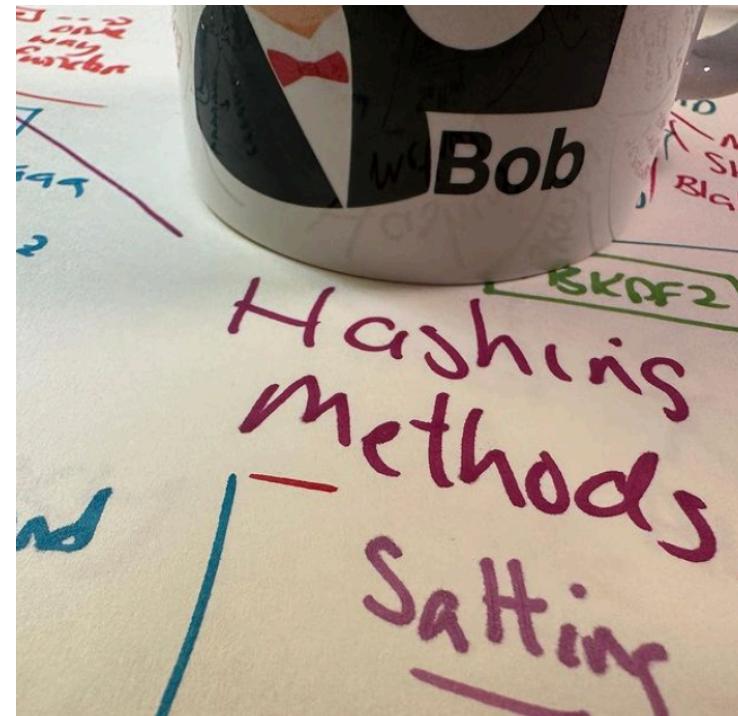
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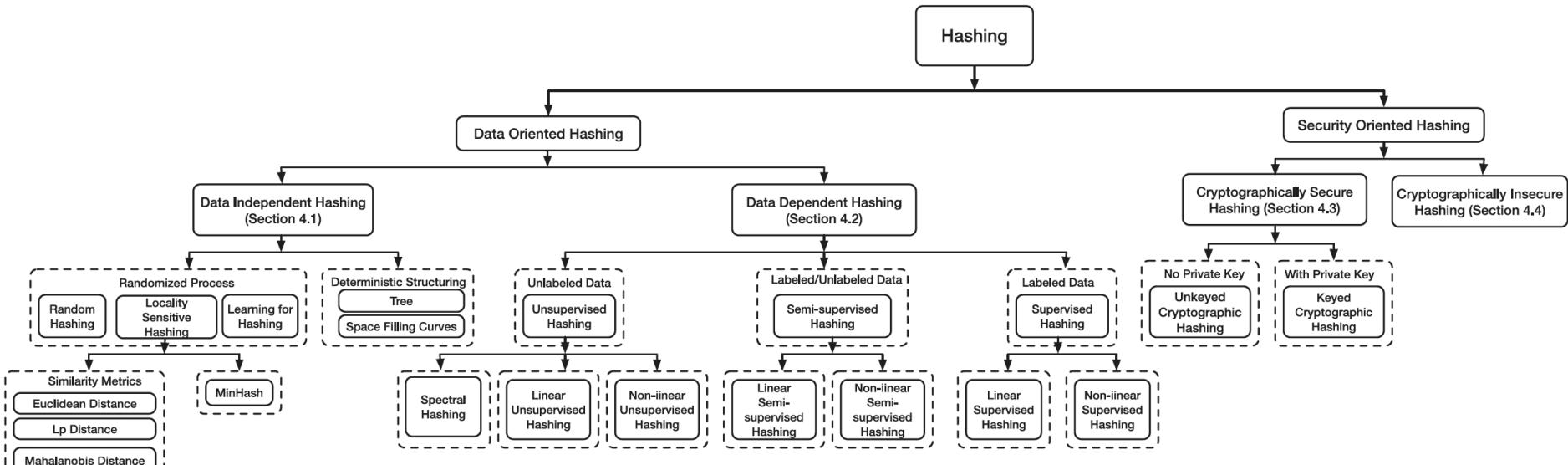
Hashcat (for practical work)



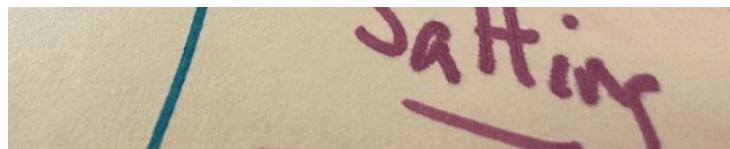
Prof Bill Buchanan OBE

<https://asecuritysite.com/hash>

Unit 3: Hashing



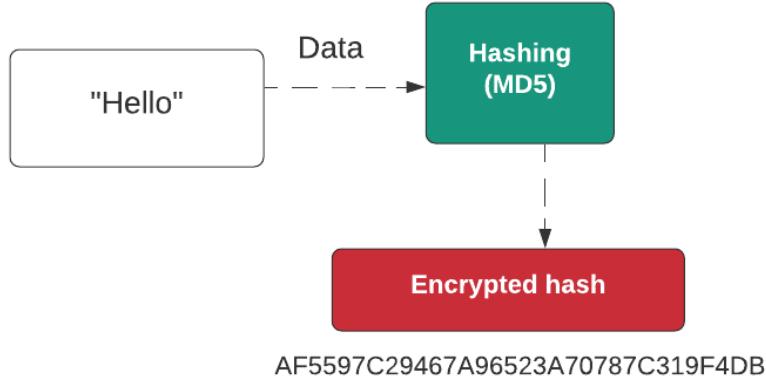
Hasncat (for practical work)



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<https://asecuritysite.com/hash>

Hashing



Hashed password

Bob: AF5597C29467A96523A70787C319F4DB

Hashed password with salt (hellozj8n)

Bob: zj8n:51A7C663A3BDCD06D6CE21E2BCB2AD5A

Cryptographic Hashes: MD5, SHA-1, SHA-256, SHA-3, RIPEMD, Blake2b

Windows hashes: NTLM

Non-cryptographic hashes: Spooky, Farm, FVN



Bob



MD5 Hash
(128-bit hash)

Hex

hello

5D41402ABC4B2A76B9719D911017C592

Hello

8B1A9953C4611296A827ABF8C47804D7

How are you?

04E35EB3E4FCB8B395191053C359CA0E

Napier

8F83571F9324AE4E23D773753055C7B6

Base64

hello

XUFAKrxLKna5cZ2REBfFkg==

Hello

ixqZU8RhEpa0J6v4xHgE1w==

How are you?

BONes+T8uLOVGRBTw1nKDg==

Napier

j4NXH5Mkrk4j13N1MFXHtg==



Bob



SHA-1 Hash
(160-bit hash)

	Hex
hello	AAF4C61DDCC5E8A2DABEDE0F3B482CD9AEA9434D
Hello	F7FF9E8B7BB2E09B70935A5D785E0CC5D9D0ABF0
How are you?	3031897E282167593FBB4DBE81DC48EBBE9A002D
Napier	BF81B135A5687766F4F464764EAC38CA8A4EBABA
	Base64
hello	qvTGHdzF6KLavt4PO0gs2a6pQ00=
Hello	9/+ei3uy4Jtwk1pdeF4MxdnQq/A=
How are you?	MDGJfighZ1k/u02+gdxI676aAC0=
Napier	v4GxNaVod2b09GR2Tqw4yopOuro=



Bob



MD5 Hash
(128-bit hash)

There are two kinds of cryptography in this world: cryptography that will stop your kid sister from reading your files, and cryptography that will **stop** major governments from reading your files. Cryptography is typically bypassed, not penetrated. Security is a process, not a product. Beware of Snake Oil Cryptography.

14375C20F07A9DF2EBDE78F063C5AD7C

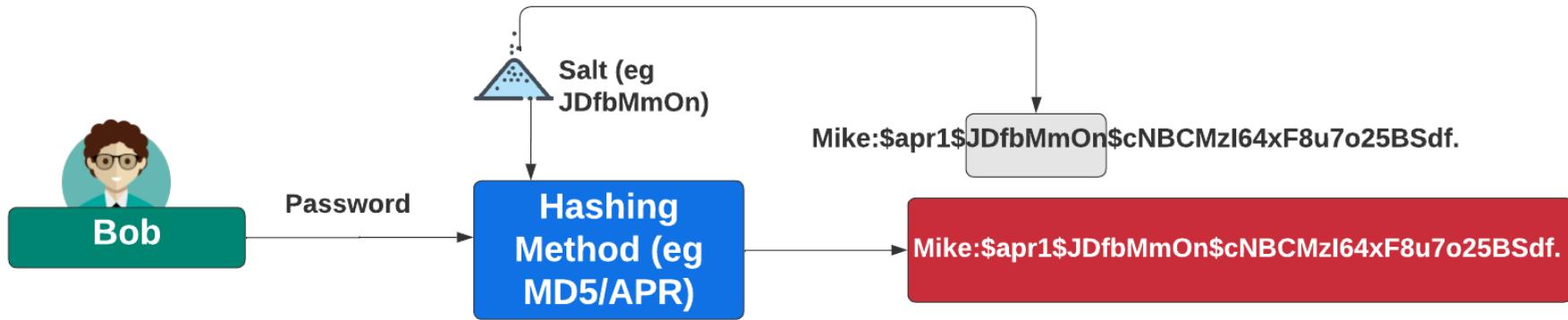
FDdclPB6nfLr3njwY8WtfA==

There are two kinds of cryptography in this world: cryptography that will stop your kid sister from reading your files, and cryptography that will **top** major governments from reading your files. Cryptography is typically bypassed, not penetrated. Security is a process, not a product. Beware of Snake Oil Cryptography.

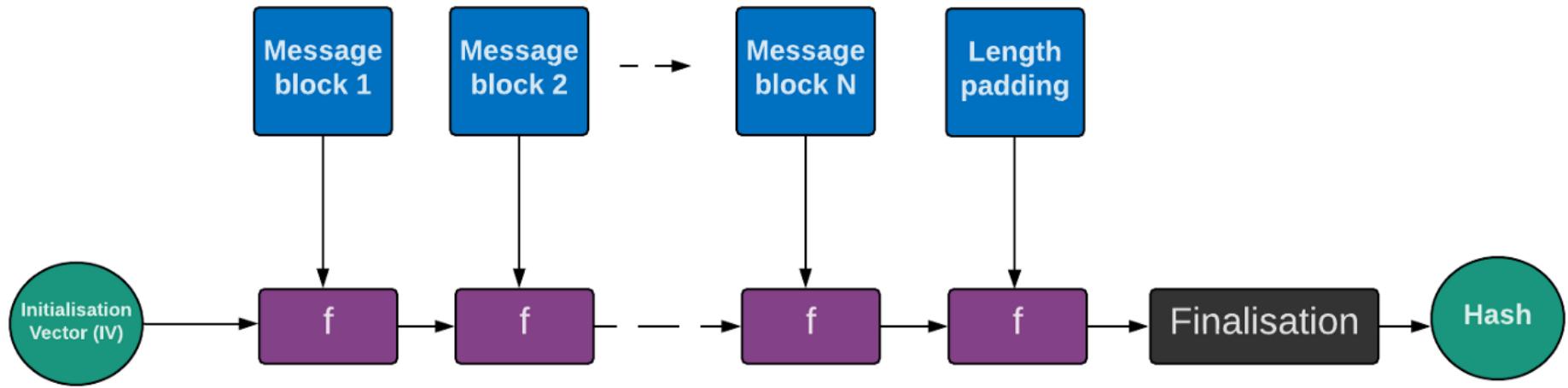
174F3AB19D8047DAE398CE620407B60B

F086sZ2AR9rjmM5iBAe2Cw==

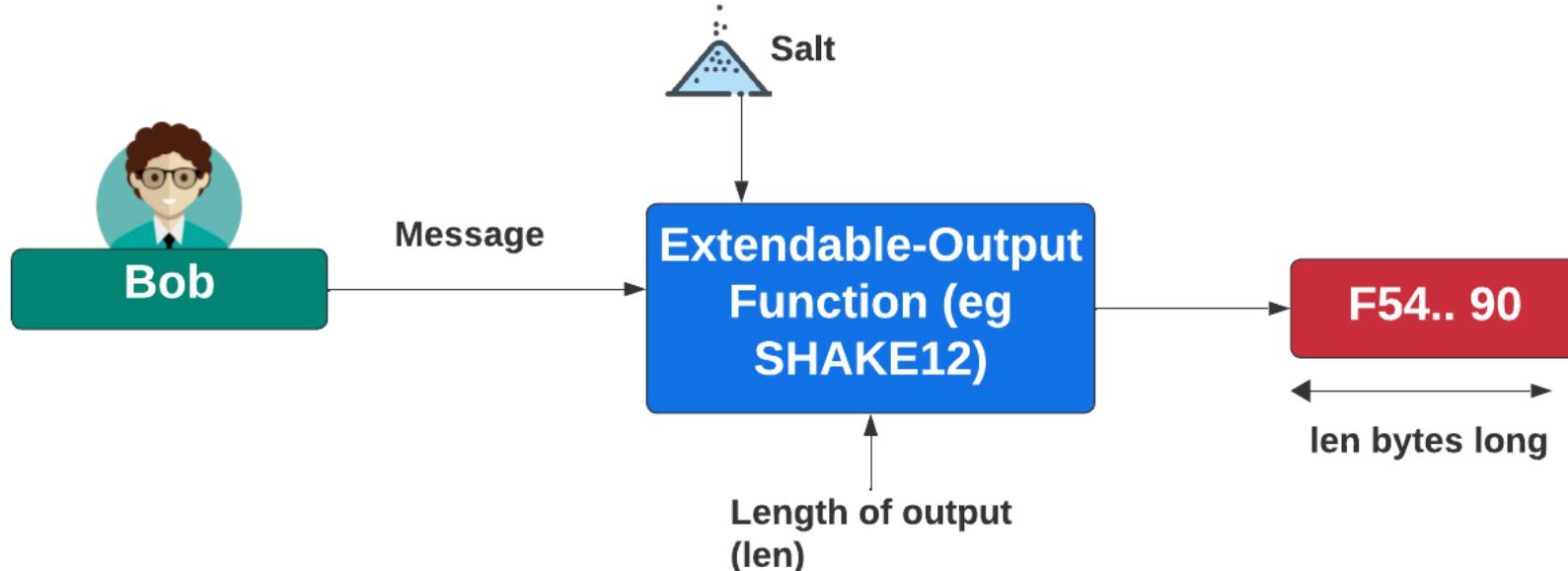
Adding Salt



Merkle-Damgård (MD) construction



XOF

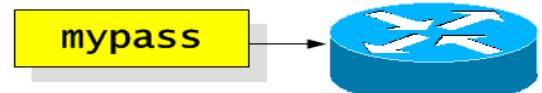


Windows login/ authentication



NT-password
hash for Windows
NT, XP and Vista

Cisco password storage (MD5)



MD5 encoded
password

```
# config t
(config)# enable secret test

Current configuration : 542 bytes
!
version 12.1
no service single-slot-reload-enable
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname Router
!
enable secret 5 $1$/Nwk$knSEQYXZvengjwogj/TGk0
```

One-way hash

- Hashes are used for digital fingerprints (see the next unit) and for secure password storage.
- Typical methods are NT hash, MD4, MD5, and SHA-1.

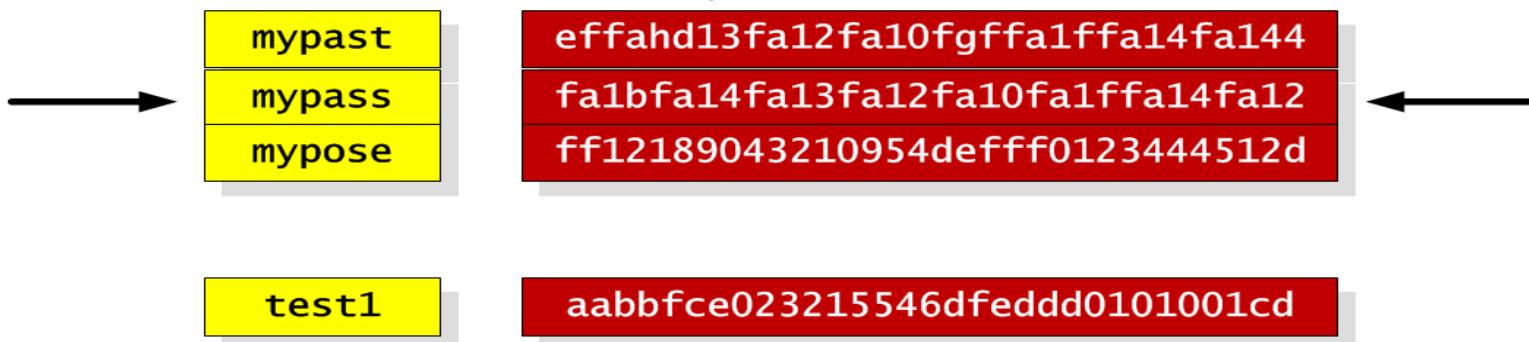
One-way hash

Windows login/ authentication



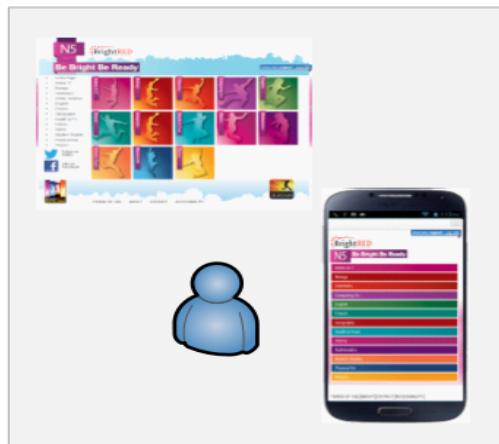
Hashing suffers from **dictionary attacks** where the signatures of well known words are stored in a table, and the intruders does a lookup on this

NT-password
hash for Windows
NT, XP and Vista





Risk 4: One Password Fits All



TJ-maxx
Marshalls.

47 million accounts



1 million accounts – in plain text. 77 million compromised

LinkedIn

6.5 million accounts
(June 2013)



150 million accounts compromised

#	Count	Ciphertext	Plaintext
1.	1911938	EQ7fIpT7i/Q=	123456
2.	446162	j9p+HwtWWT86aMjgZFLzYg==	123456789
3.	345834	L8qbAD3j13jioxG6CatHBw==	password
4.	211659	BB4e6x+b2xLioxG6CatHBw==	adobe123
5.	201580	j9p+HwtWWT/ioxG6CatHBw==	12345678
6.	130832	5djv7ZCI2ws=	qwerty
7.	124253	dQi0asWPYvQ=	1234567
8.	113884	7LqYZKVeq8I=	111111
9.	83411	PMDTbP0LZxu03SwrFUVYGA==	photoshop
10.	82694	e6MPXQ5G6a8=	123123



One account hack ... leads to others



Dropbox
compromised 2013

citigroup

200,000 client accounts

Brute Force - How many hash codes?

- 7 digit password with [a-z] ... how many?
 - Ans:
 - Time to crack - 100 billion per second:
- 7 digit with [a-zA-Z] ... how many?
 - Ans:
 - Time to crack – 100 billion per second:
- 7 digit with [a-zA-Z!@#\$%^&*()] ... how many?
 - Ans:
 - Time to crack – 100 billion per second:

Unit 3: Hashing

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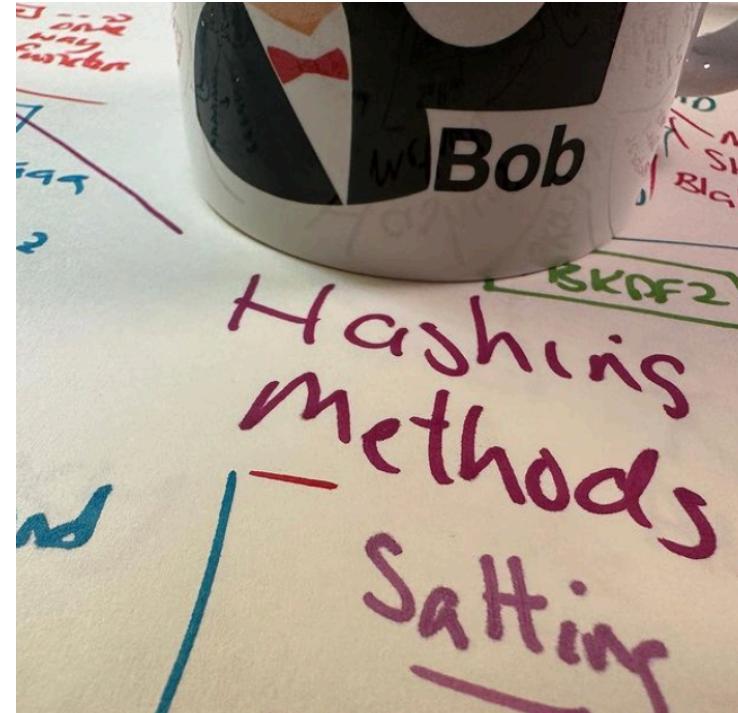
Key Derivation Function (KDF).

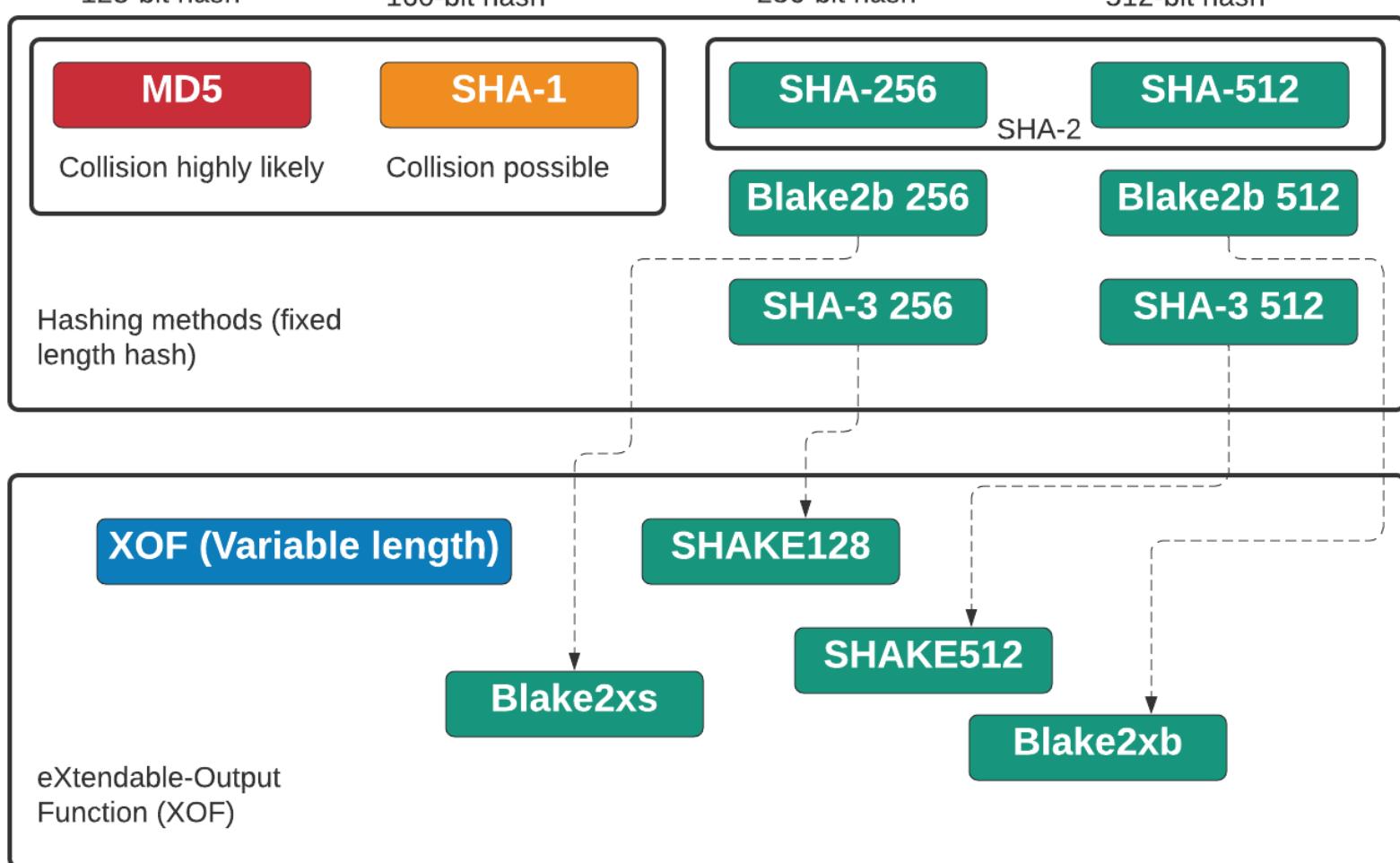
OTP/HOTP.

Hashcat

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<https://asecuritysite.com/hash>





OpenSSL

The screenshot shows a web application interface for selecting hashing methods. On the left, a sidebar lists various hashing algorithms: blake2b512 (selected), blake2s256, sha1, sha224, sha256, sha384, sha512, sha3-224, sha3-224, sha3-256, sha3-384, sha3-512, sha512-224, sha512-256, shake128, shake256, SM3, and blake2b512 again at the bottom. A 'Determine' button is at the bottom of the sidebar. The main content area shows the 'asecuritysite.com' logo and navigation menu (BLOGS, IP, IDS, MAGIC, NET, CISCO, CYBER, TEST, FUN, SUBJ, ABOUT). A section titled 'Popular Methods (MD5, SHA-1, SHA-256, SHA-512, SHA-3, Blake2b, and so on)' contains a yellow box with a note about supported hashing methods and examples for Linux and Windows commands. Below this is a terminal-like window showing the command 'echo -n "Hello" | openssl dgst -md5' resulting in the hash 'MD5d1a7fb5eab1c16cb4f7cf341cf188c3d'. The right side features a yellow sidebar with the text 'Open Crypt @asecuritysite' and a logo consisting of binary digits (0s and 1s) forming a stylized 'O'.

blake2b512
blake2s256
sha1
sha224
sha256
sha384
sha512
sha3-224
sha3-224
sha3-256
sha3-384
sha3-512
sha512-224
sha512-256
shake128
shake256
SM3
blake2b512

Determine

city site.com
s.com - Networksims

Welcome to Asec

BLOGS IP IDS MAGIC NET CISCO CYBER TEST FUN SUBJ ABOUT

g Methods (MD5, SHA-1, SHA-256, SHA-512, SHA-3, Blake2b, and so on)

Linux command: echo -n "Hello" | openssl dgst -md5
Windows command: echo | set /p = "Hello" | openssl dgst -md5

Message: Hello
Mode: md5
=====

MD5d1a7fb5eab1c16cb4f7cf341cf188c3d

Open Crypt
@asecuritysite

https://asecuritysite.com/openssl/openssl_full2

https://asecuritysite.com/webcrypto/crypt_hash

LM and NTLM

For example for LM Hash:

passphrase gives: 855c3697d9979e78ac404c4ba2c66533

hashme gives: FA-91-C4-FD-28-A2-D2-57-AA-D3-B4-35-B5-14-04-EE

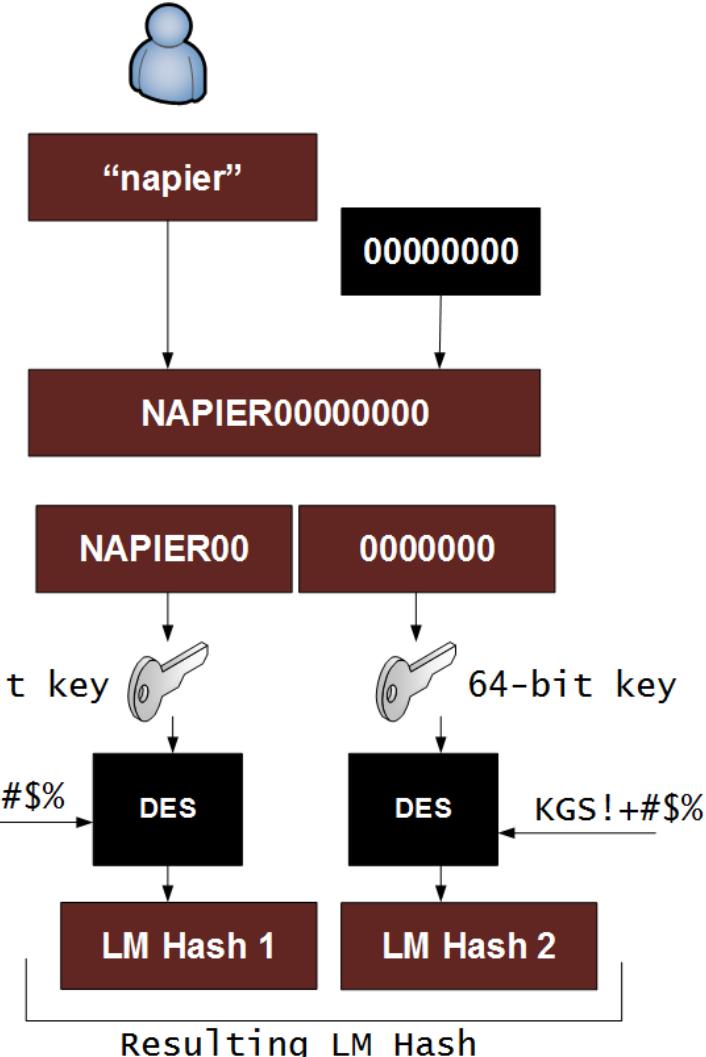
network gives: D7-5A-34-5D-5D-20-7A-00-AA-D3-B4-35-B5-14-04-EE

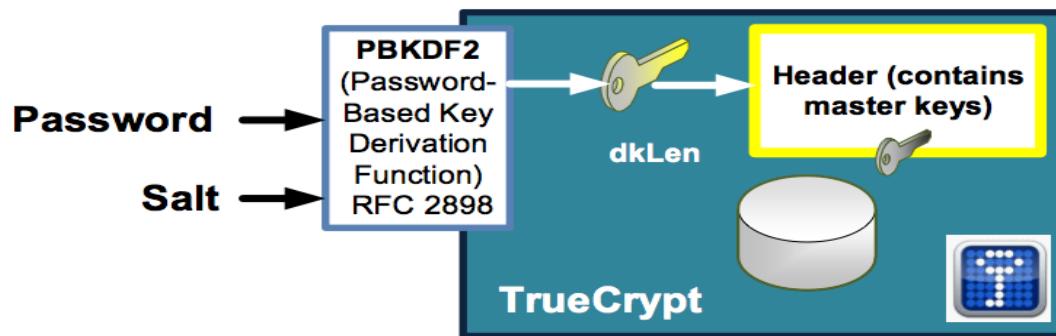
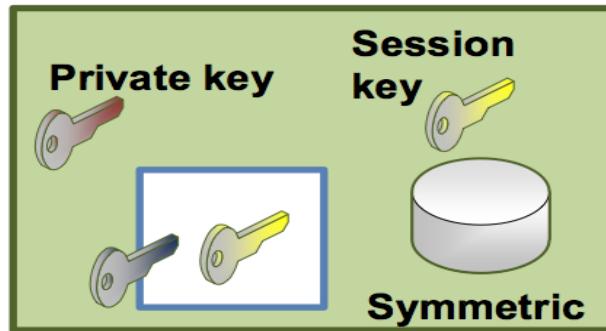
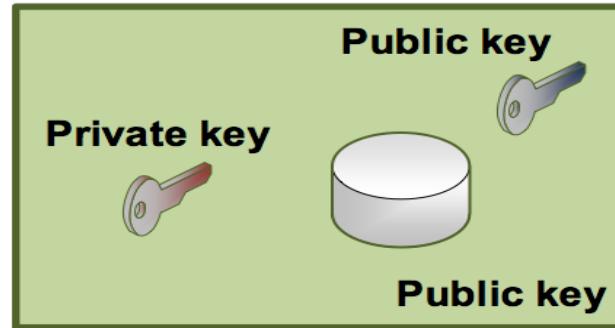
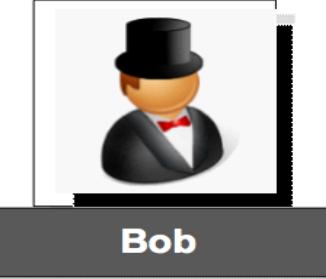
napier gives: 12-B9-C5-4F-6F-E0-EC-80-AA-D3-B4-35-B5-14-04-EE

Notice that the **right-most element of the hash** are always the same, if the password is less than eight characters. With more than eight characters we get:

networksims gives: D7-5A-34-5D-5D-20-7A-00-38-32-A0-DB-BA-51-68-07

napier123 gives: 67-82-2A-34-ED-C7-48-92-B7-5E-0C-8D-76-95-4A-50





AES
Twofish
3DES

RIPEMD-160
SHA-1
Whirlpool

DK = PBKDF2(PRF, Password, Salt, c, dkLen)
DK = PBKDF2(HMAC-SHA1, passphrase, ssid, 4096, 256)

Encrypting disks

Unit 3: Hashing

Hashing Types.

Hashing Methods.

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Key Derivation Function (KDF)

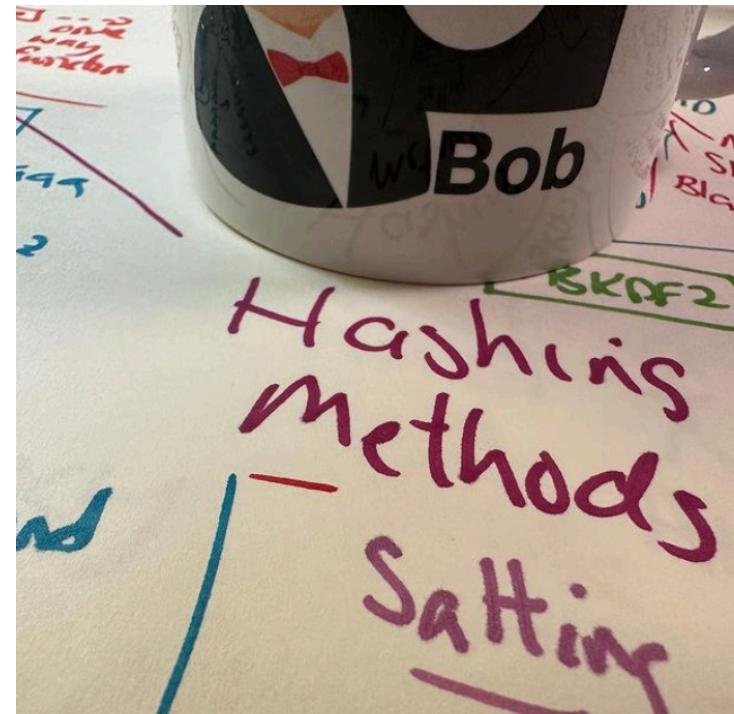
OTP/HOTP.

Secret Shares.

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<http://asecuritysite.com/crypto03>

<http://asecuritysite.com/encryption>



Adding salt

- Salt increases the range of the possible signatures



NT-password
hash for Windows
NT, XP and Vista

Salt increase the range of the signatures



password

\$1\$fred\$bATAk8UUH/IDAp9sd6IUv/

1

fred



bATAk8UUH/IDAp9sd6IUv/

password

bATAk8UUH/IDAp9sd6IUv/

fred

```
C:\openssl>openssl passwd -1 -salt fred password  
$1$fred$bATAk8UUH/IDAp9sd6IUv/
```



```
# cat /etc/shadow
root:$1$Etg2ExUZ$F9NTP7omafhK1lqaBMqng1:15651:0:99999:7:::
# openssl passwd -1 -salt Etg2ExUZ redhat
$1$Etg2ExUZ$F9NTP7omafhK1lqaBMqng1
```

```
$ openssl version
OpenSSL 1.0.1f 6 Jan 2014
```

```
$ openssl dgst -md5 file
MD5(file)= b1946ac92492d2347c6235b4d2611184
```

```
$ openssl genrsa -out mykey.pem 1024
Generating RSA private key, 1024 bit long modulus
.
.
.
e is 65537 (0x10001)
```

```
$ openssl rsa -in mykey.pem -pubout > mykey.pub
writing RSA key
```

```
$ cat mykey.pub
-----BEGIN PUBLIC KEY-----
MIIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQDXv9HSFkpM+ZoOQcpdHBZiuwX8
EzIKm0nsgjc5ZTYVaF9CMLtmKoTzep7aQX9o9nKepFt1kq73Ta9v0Pd6Cx61/cgY
xy2tShw0imrtFaVDFjX+7kLmc0uwbFFCoZMtJxIaXaa9SV2kARxOCTJ2u0jRTCCe
XU09IJGHnIhSNJeIJQIDAQAB
-----END PUBLIC KEY-----
```

```
$ cat /etc/shadow
root:$1$Etg2ExUZ$F9NTP7omafhK1lqaBMqng1:15651:0:99999:7:::
```

```
$ openssl passwd -1 -salt Etg2ExUZ redhat
$1$Etg2ExUZ$F9NTP7omafhK1lqaBMqng1
```

Unit 3: Hashing

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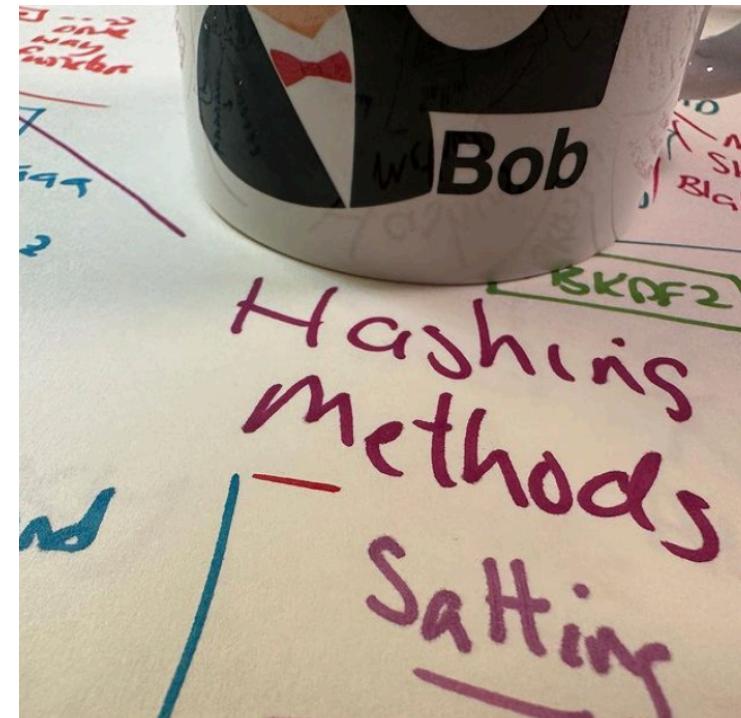
Key Derivation Function (KDF)

OTP/HOTP.

Hashcat.

Prof Bill Buchanan OBE

https://asecuritysite.com/hash



A major factor with hash signatures is:

- **Collision.** This is where another match is found, no matter the similarity of the original message. This can be defined as a **Collision attack**.
- **Similar context.** This is where part of the message has some significance to the original, and generates the same hash signature. This can be defined as a Pre-image attack.
- **Full context.** This is where an alternative message is created with the same hash signature, and has a direct relation to the original message. This is an extension to a Pre-image attack.

In 2006 it was shown that MD5 can produce collision within less than a minute.

A 50% probability of a collision is:

$$\sqrt{N(\text{signatures})} = \sqrt{2^n} = 2^{\frac{n}{2}}$$



where n is the number of bits in the signature. For example, for MD5 (128-bit) the number of operations that would be required for a better-than-50% chance of a collision is:

$$2^{64}$$

Note, in 2006, for SHA-1 the best time has been 18 hours

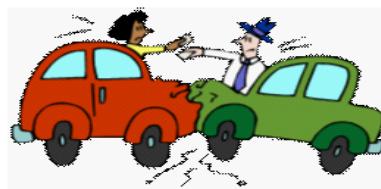
```
d131dd02c5e6eec4693d9a0698aff95c  
2fcab58712467eab4004583eb8fb7f89  
55ad340609f4b30283e488832571415a  
085125e8f7cdc99fd91dbdf280373c5b  
d8823e3156348f5bae6dacd436c919c6  
dd53e2b487da03fd02396306d248cda0  
e99f33420f577ee8ce54b67080a80d1e  
c69821bcb6a8839396f9652b6ff72a70
```

```
d131dd02c5e6eec4693d9a0698aff95c  
2fcab50712467eab4004583eb8fb7f89  
55ad340609f4b30283e4888325f1415a  
085125e8f7cdc99fd91dbd7280373c5b  
d8823e3156348f5bae6dacd436c919c6  
dd53e23487da03fd02396306d248cda0  
e99f33420f577ee8ce54b67080280d1e  
c69821bcb6a8839396f965ab6ff72a70
```

The MD5 signature
gives the same
result



79054025255FB1A26E4BC422AEF54EB4





Nat McHugh

- 10 hours of computing on the Amazon GPU Cloud.
- Cost: 60 cents
- Used: Hashcat (on CUDA)
- Birthday attack: A group size of only 70 people results in a 99.9% chance of two people sharing the same birthday.
- M-bit output there are 2^m messages, and the same hash value would only require $2^{(m/2)}$ random messages.
 $18,446,744,073,709,551,616$.

```
C:\openssl>openssl md5 hash01.jpg
```

```
MD5(hash01.jpg)= e06723d4961a0a3f950e7786f3766338
```

```
C:\openssl>openssl md5 hash02.jpg
```

```
MD5(hash02.jpg)= e06723d4961a0a3f950e7786f3766338
```

Chapter 3: Hashing

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LM and NTLM Hashes (Windows).

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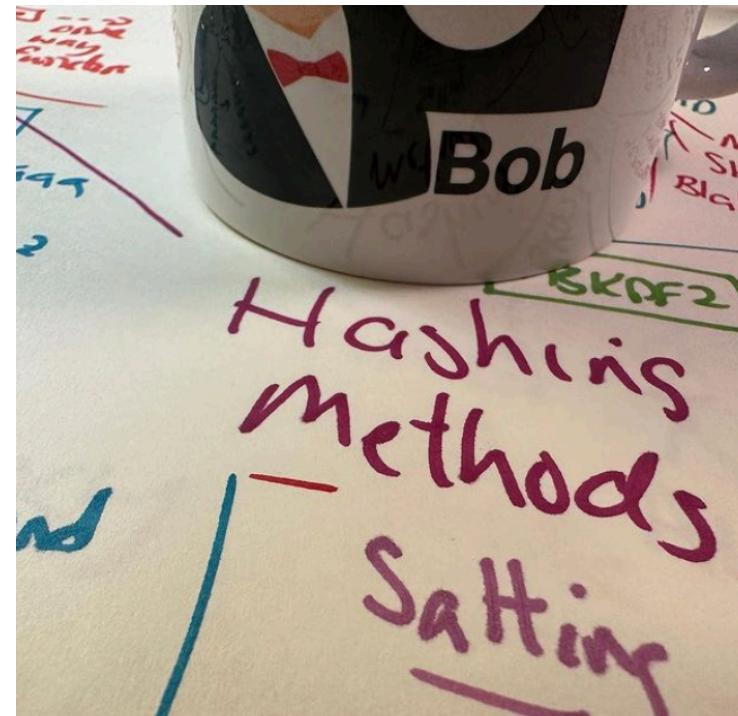
Key Derivation Function (KDF)

OTP/HOTP.

Hashcat.

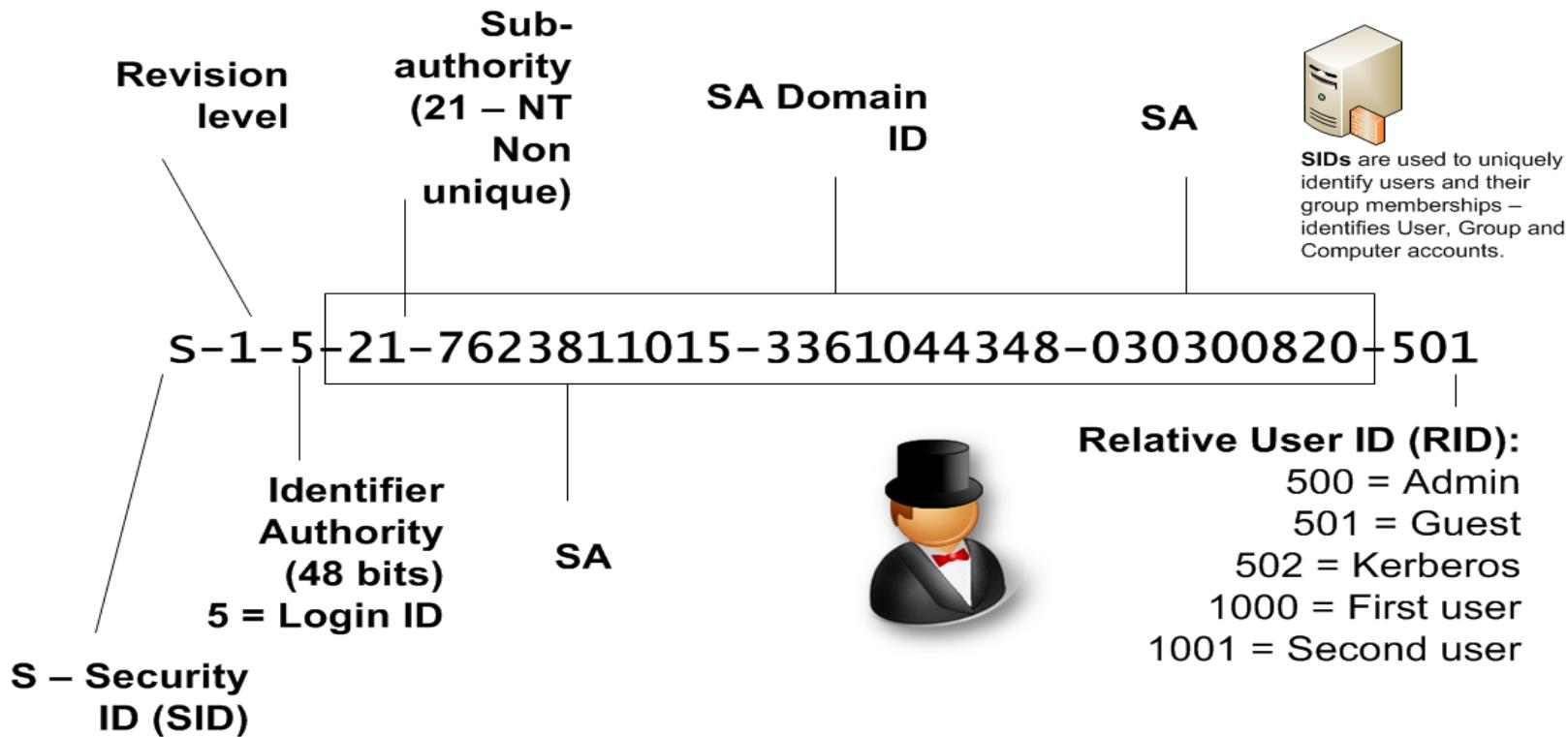
Prof Bill Buchanan OBE

<https://asecuritysite.com/hash>



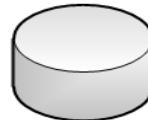
```
C:> user2sid \pluto guest  
S-1-5-21-7623811015-3361044348-030300820-501  
C:> sid2user 5 21 7623811015 3361044348 030300820 500  
Name is Fred  
Domain is PLUTO
```

Windows
CEH

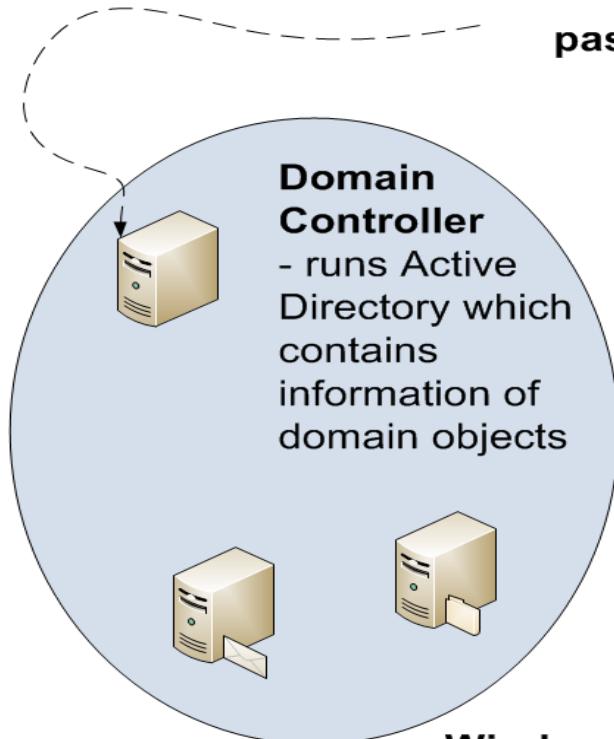
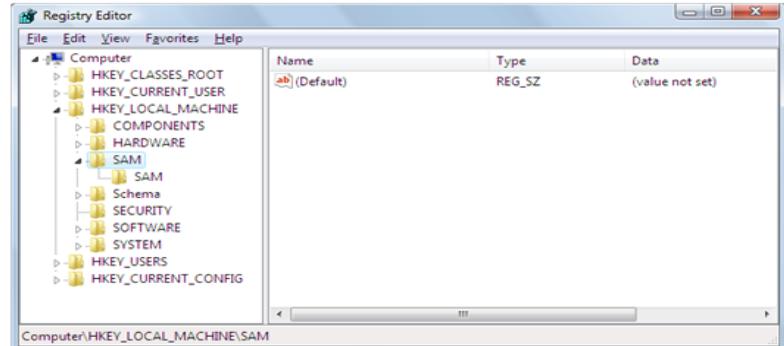




HKLM\SAM



SAM Database
(stores
usernames
and
passwords)



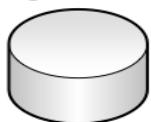
Subsystem (Lsass) – Windows Security mechanism – Attached by Sasser Worm which exploited a buffer overflow



Local Authority

- Responsible for local security policy**
- Controls access.
 - Managing password policies.
 - User authentication.
 - Audit messages.

SAM



Registry: HKEY_LOCAL_MACHINE\SAM



- LM Hash (Windows XP, 2003)
- NTLMv2 (Windows 7, 8, etc) – connect to Active Directory
- NTLM (Windows 7, 8, etc) – No salt

```
C:\Windows\System32\config>dir  
Volume in drive C has no label.  
Volume Serial Number is A2B3-7C7A
```

```
Directory of C:\Windows\System32\config  
05-Oct-14 05:52 PM      262,144 SAM  
05-Oct-14 05:56 PM      262,144 SECURITY  
05-Oct-14 08:39 PM    149,946,368 SOFTWARE  
05-Oct-14 08:40 PM    15,728,640 SYSTEM
```

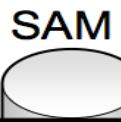
- bkhive - dumps the syskey bootkey from a Windows system hive.
- samdump2 - dumps Windows 2k/NT/XP/Vista password hashes.

hashme gives: FA-91-C4-FD-28-A2-D2-57-AA-D3-B4-35-B5-14-04-EE
FF2A43841C84518A18795AB6E3C8A62E (NTLM)

napier gives: 12-B9-C5-4F-6F-E0-EC-80-AA-D3-B4-35-B5-14-04-EE
307E40814E7D4E103F6A69B04EA78F3D (NTLM)

<user>:<id>:<LM hash>:<NTLM hash>:<comment>:<homedir>:

```
Root@kali:~# cat pw  
myuser:500:12B9C54F6FE0EC80AAD3B435B51404EE:307E40814E7D4E103F6A69B04EA78F3D:::  
Root@kali:~# john pw  
Loaded 1 password hash (LM DES [128/128 BS SSE2])  
NAPIER  
          (napier)  
guesses: 1  time: 0:00:00:00 100% (1)  c/s: 4850  trying: NAPIER - N4PI3R  
Use the "--show" option to display all of the cracked passwords reliably
```



Registry: HKEY_LOCAL_MACHINE\SAM

```
Root@kali:~# cat pw
myuser:500:12B9C54F6FE0EC80AAD3B435B51404EE:307E40814E7D4E103F6A69B04EA78F3D:::
Root@kali:~# john pw
Loaded 1 password hash (LM DES [128/128 BS SSE2])
NAPIER          (napier)
guesses: 1  time: 0:00:00:00 100% (1)  c/s: 4850  trying: NAPIER - N4PI3R
Use the "--show" option to display all of the cracked passwords reliably

<user>:<id>:<LM hash>:<NTLM hash>:<comment>:<homedir>:
password:500:E52CAC67419A9A224A3B108F3FA6CB6D:8846F7EAEE8
FB117AD06BDD830B7586C:$
myuser:500:12B9C54F6FE0EC80AAD3B435B51404FF·307E40814F7d4
E103F6A69B04EA78F3D:::
```

The ophcrack interface shows the following data:

User	LM Hash	NT Hash	LM Pwd 1	LM Pwd 2	NT Pwd
password	E52CAC67...	8846F7EA...	PASSWOR	D	password
myuser	12B9C54F6...	307E40814...	NAPIER	empty	napier

Progress: 34% in RAM

Preload: done Brute force: done Pwd found: 2/2 Time elapsed: 0h 0m 17s



Hash Crackers/Bit Coin Miners



25 GPU Hash Cracker

- An eight character NTLM password cracked in 5.5 hours. 14 character LM hash cracked in six minutes. 350 billion hashes per second.

Fast Hash One

- 1.536TH/s – Cost 3-5,000 dollars.



Estimated Password Recovery Times — 1x Terahash Brutalis, 44x Terahash Inmanis (448x Nvidia RTX 2080)

Full US keyboard mask attack with Terahash Hashstack

	Speed	Length 4	Length 5	Length 6	Length 7	Length 8	Length 9	Length 10	Length 11	Length 12	Length 13
NTLM	31.82 TH/s	Instant	Instant	Instant	Instant	3 mins 29 secs	5 hrs 30 mins	3 wks 0 day	5 yrs 7 mos	538 yrs 1 mo	51.2 mil
MD5	17.77 TH/s	Instant	Instant	Instant	Instant	6 mins 14 secs	9 hrs 50 mins	1 mo 1 wk	10 yrs 1 mo	963 yrs 4 mos	91.6 mil
NetNTLMv1 / NetNTLMv1+ESS	16.82 TH/s	Instant	Instant	Instant	Instant	6 mins 35 secs	10 hrs 24 mins	1 mo 1 wk	10 yrs 8 mos	1 mil	96.8 mil
LM	15.81 TH/s	Instant	Instant	Instant	Instant						
SHA1	5.89 TH/s	Instant	Instant	Instant	Instant	18 mins 47 secs	1 day 5 hrs	3 mos 3 wks	30 yrs 7 mos	2.9 mil	276.3 mil
SHA2-256	2.42 TH/s	Instant	Instant	Instant	Instant	45 mins 39 secs	3 days 0 hr	9 mos 1 wk	74 yrs 4 mos	7.1 mil	671.9 mil
NetNTLMv2	1.22 TH/s	Instant	Instant	Instant	Instant	1 hr 30 mins	5 days 23 hrs	1 yr 6 mos	147 yrs 10 mos	14.1 mil	1335.5 mil
SHA2-512	801.9 GH/s	Instant	Instant	Instant	1 min 28 secs	2 hrs 17 mins	1 wk 2 days	2 yrs 4 mos	224 yrs 9 mos	21.4 mil	2029.7 mil
decrypt, DES (Unix), Traditional DES	647.59 GH/s	Instant	Instant	Instant	1 min 48 secs	2 hrs 50 mins	1 wk 4 days	2 yrs 11 mos	278 yrs 3 mos	26.5 mil	2513.3 mil
Kerberos 5, etype 23, TGS-REP	206.97 GH/s	Instant	Instant	Instant	5 mins 38 secs	8 hrs 54 mins	1 mo 0 wk	9 yrs 2 mos	870 yrs 10 mos	82.8 mil	7864 mil
Kerberos 5, etype 23, AS-REQ Pre-Auth	206.78 GH/s	Instant	Instant	Instant	5 mins 38 secs	8 hrs 54 mins	1 mo 0 wk	9 yrs 2 mos	871 yrs 8 mos	82.9 mil	7871.2 mil
md5crypt, MD5 (Unix), Cisco-IOS \$1\$ (MD5)	7.61 GH/s	Instant	Instant	1 min 37 secs	2 hrs 33 mins	1 wk 3 days	2 yrs 7 mos	249 yrs 5 mos	23.7 mil	2252.6 mil	213995.1 mil
LastPass + LastPass sniffed	1.78 GH/s	Instant	Instant	6 mins 52 secs	10 hrs 52 mins	1 mo 1 wk	11 yrs 2 mos	1.1 mil	101.1 mil	9600.8 mil	912079.6 mil
macOS v10.8+ (PBKDF2-SHA512)	335.09 MH/s	Instant	Instant	36 mins 34 secs	2 days 9 hrs	7 mos 2 wks	59 yrs 7 mos	5.7 mil	538.2 mil	51127.7 mil	4857134 mil
WPA-EAPOL-PBKDF2	277.23 MH/s					9 mos 0 wk	72 yrs 0 mo	6.8 mil	650.5 mil	61799.3 mil	5870931.8 mil
TrueCrypt RIPEMD160 + XTS 512 bit	211.78 MH/s	Instant	Instant	57 mins 52 secs	3 days 19 hrs	11 mos 3 wks	94 yrs 3 mos	9 mil	851.6 mil	80899.5 mil	7685455.6 mil
7-Zip	181.51 MH/s	Instant	Instant	1 hr 7 mins	4 days 10 hrs	1 yr 1 mo	110 yrs 0 mo	10.5 mil	993.6 mil	94389.2 mil	8966975.1 mil
sha512crypt \$6\$, SHA512 (Unix)	119.46 MH/s	Instant	1 min 5 secs	1 hr 42 mins	6 days 18 hrs	1 yr 9 mos	167 yrs 2 mos	15.9 mil	1509.7 mil	143419.6 mil	13624861.4 mil
DPAPI masterkey file v1	47.23 MH/s	Instant	2 mins 44 secs	4 hrs 19 mins	2 wks 3 days	4 yrs 5 mos	422 yrs 10 mos	40.2 mil	3818.1 mil	362723.1 mil	34458696.1 mil
RAR5	28.15 MH/s	Instant	4 mins 35 secs	7 hrs 15 mins	4 wks 0 day	7 yrs 5 mos	709 yrs 7 mos	67.4 mil	6407.6 mil	608720.6 mil	57828453.9 mil
DPAPI masterkey file v2	27.82 MH/s	Instant	4 mins 39 secs	7 hrs 20 mins	4 wks 1 day	7 yrs 6 mos	717 yrs 10 mos	68.2 mil	6482.1 mil	615797.6 mil	58500769.5 mil
RAR3-hp	20.84 MH/s	Instant	6 mins 12 secs	9 hrs 47 mins	1 mo 1 wk	10 yrs 1 mo	958 yrs 2 mos	91.1 mil	8652.3 mil	821972.3 mil	78087367.8 mil
KeePass 1 (AES/Twofish) and KeePass 2 (AES)	17.8 MH/s	Instant	7 mins 15 secs	11 hrs 28 mins	1 mo 2 wks	11 yrs 9 mos	1.1 mil	106.7 mil	10131.9 mil	962529.5 mil	91440305.8 mil
bcrypt \$2*\$, Blowfish (Unix)	11.37 MH/s	Instant	11 mins 21 secs	17 hrs 57 mins	2 mos 1 wk	18 yrs 5 mos	1.8 mil	167 mil	15860.3 mil	1506727.9 mil	143139150.9 mil
Bitcoin/Litecoin wallet.dat	3.55 MH/s	Instant	36 mins 18 secs	2 days 9 hrs	7 mos 2 wks	59 yrs 1 mo	5.6 mil	534.1 mil	50743.7 mil	4820655.6 mil	457962282.7 mil

Unit 3: Hashing

Hashing Types.

Hashing Methods.

Salting.

Collisions.

LM and NTLM Hashes (Windows).

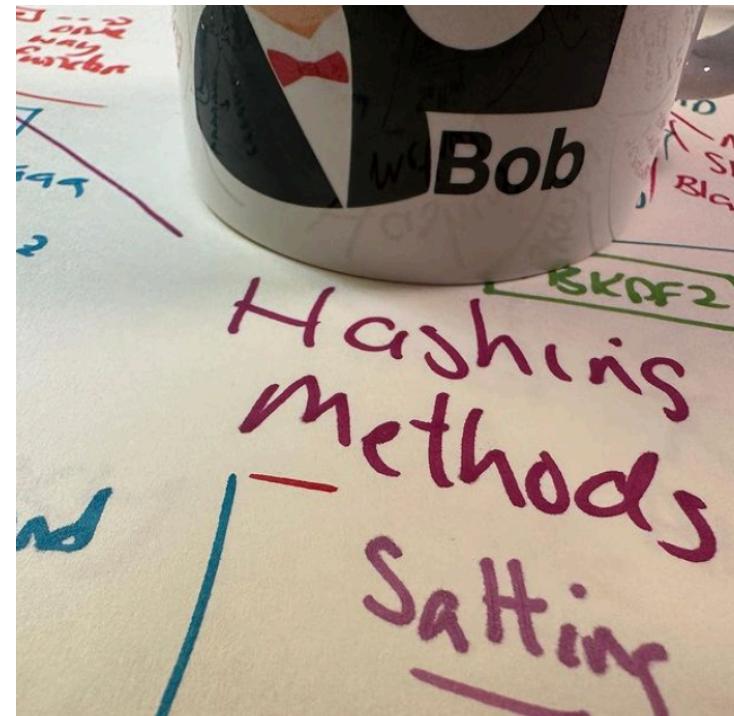
Hash Benchmarks.

Message Authentication Codes (MACs).

Key Derivation Function (KDF)

OTP/HOTP.

Hashcat.



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<https://asecuritysite.com/hash>

Benchmark

Ultra fast:	
Murmur:	545,716 hashes per second
Fast:	
SHA-1:	134,412
SHA-256:	126,323
MD5:	125,741
SHA-512:	76,005
SHA-3 (224-bit):	72,089
Medium speed:	
LDAP (SHA1):	13,718
MS DCC:	9,582
NT Hash:	7,782
MySQL:	7,724
Postgres (MD5):	7,284
Slow:	
PBKDF2 (SHA-256):	5,026
Cisco PIX:	4,402
MS SQL 2000:	4,225
LDAP (MD5):	4,180
Cisco Type 7:	3,775
PBKDF2 (SHA1):	2,348
Ultra-slow:	
LM Hash:	733
APR1:	234
Bcrypt:	103
DES:	88
Oracle 10:	48

Hashes "The quick brown fox jumps over the lazy dog:

SHA-1:	2fd4e1c67a2d28fcfd849ee1bb76e7391b93eb12
SHA-256:	d7a8fbb307d7809469ca9abcb0082e4f8d5651e46d3cdb762d02d0bf37c9e592
SHA-512:	07e547d9586f6a73f73fbac0435ed76951218fb7d0c8d788a309d7 85436bbb642e93a252a954f23912547d1e8a3b5ed6e1bfd7097821233fa0538f3db854fee6
MD-5:	9e107d9d372bb6826bd81d3542a419d6
DES:	ZDeS94Lcq/6zg
Bcrypt:	\$2a\$05\$2czCv5GYgkx3aobmEyewB.ejV2hePMdbvTdCyNaSzWtIGPPjB2xx6
APR1:	\$apr1\$ZDzPE45C\$3PvRanPycmNc6c2G9wT9b/
PBKDF2 (SHA1):	\$pbkdf2\$5\$Wkr6UEU0NUM\$0RB2bimWrMY.EPYibpaBT2q3HFg
PBKDF2 (SHA-256):	\$pbkdf2-sha256\$5\$Wkr6UEU0NUM\$yrJz2oJix7uBJZwZ/50vWUgdE l/i0ffqeU4obqC0pk4
LM Hash:	a7b07f9948d8cc7f97c4b0b30cae500f
NT Hash:	4e6a076ae1b04a815fa6332f69e2e231
MS DCC:	efa9778bbc94a7360f664eb7d7144725
LDAP (MD5):	{MD5}9e107d9d372bb6826bd81d3542a419d6
LDAP (SHA1):	{SHA}2fd4e1c67a2d28fcfd849ee1bb76e7391b93eb12
MS SQL 2000:	0x0100BF77CE595DCD1FC87A37B3DEBC27A8C97355CB96B8BAB 63E602662BA5D5D33B913E422499BE72FF3D9BB65DE
MySQL:	*A4E4D26FD0C6455E23E2187C3AABE844332AA1B3
Oracle 10:	4CDA2299FCAD0499
Postgres (MD5):	md5d44c15daa11770f25c5350f7e5408dd1
Cisco PIX:	kGyKN5CqdFQ1qJUs
Cisco Type 7:	15260309443B3E2D2B3875200108010D41505640135E1B0E080 519574156401540035E460B594D1D53020B5C

Benchmark

BLAKE 3

Hash function	MiB/sec	cycl./hash	cycl./map	Quality problems
<hr/>				
blake3_c	1285.91	340.01	552.63	no 32bit portability
blake2b-256_64	356.97	1222.76	1435.0	
blake2b-224	356.59	1228.5	1425.87	
blake2b-160	356.08	1236.84	1458.15	
blake2b-256	355.97	1232.22	1443.31	Sparse high 32-bit
md5-128	353.76	638.29	803.39	
md5_32a	353.64	629.85	799.56	Sparse high 32-bit
sha1_32a	353.03	1385.8	1759.9	Cyclic low32, 36.6% distrib
rmd128	334.36	659.03	838.32	Bad seeds
blake2s-128	295.3	698.09	1059.2	
pearsonhash64	287.95	174.11	196.50	Avalanche, Seed, SSSE3 only. broken MSVC
pearsonhash128	287.95	171.72	194.61	Avalanche, Seed, SSSE3 only. broken MSVC
pearsonhash256	264.51	184.87	218.79	Avalanche, Seed, SSSE3 only. broken MSVC
blake2s-256	215.28	1014.88	1230.38	
blake2s-160	215.01	1026.74	1239.54	
blake2s-256_64	211.52	1044.22	1228.43	
blake2s-224	207.06	1063.86	1236.50	
rmd160	202.16	1045.79	1287.74	Bad seeds, Cyclic hi32
sha2-256_64	148.01	1376.34	1624.71	Bad seeds, Moment Chi2 7
sha2-256	147.8	1374.9	1606.06	Bad seeds, Moment Chi2 4
sha2-224_64	147.6	1360.1	1620.93	Bad seeds, Cyclic low32
sha2-224	147.13	1354.81	1589.92	Bad seeds, Comb low32
asconhashv12	144.98	885.02	1324.23	
sha3-256	100.58	3877.18	4159.79	PerlinNoise
sha3-256_64	100.57	3909	4174.63	PerlinNoise
asconhashv12_64	86.73	684.02	606.93	
floppsyhash	35.72	1868.92	1411.07	
tifuhash_64	35.6	1679.52	1212.75	Cyclic low32

BLAKE3

one function, fast everywhere

Jack O'Connor (@oconnor663)
Jean-Philippe Aumasson (@veorq)
Samuel Neves (@sevenps)
Zooko Wilcox-O'Hearn (@zooko)

<https://blake3.io>

We present BLAKE3, an evolution of the BLAKE2 cryptographic hash that is both faster and also more consistently fast across different platforms and input sizes. BLAKE3 supports an unbounded degree of parallelism, using a tree structure that scales up to any number of SIMD lanes and CPU cores. On Intel Cascade Lake-SP, peak single-threaded throughput is 4× that of BLAKE2b, 8× that of SHA-512, and 12× that of SHA-256, and it can scale further using multiple threads. BLAKE3 is also efficient on smaller architectures: throughput on a 32-bit ARM1176 core is 1.3× that of SHA-256 and 3× that of BLAKE2b and SHA-512. Unlike BLAKE2 and SHA-2, with different variants better suited for different platforms, BLAKE3 is a single algorithm with no variants. It provides a simplified API supporting all the use cases of BLAKE2, including keying and extendable output. The tree structure also supports new use cases, such as verified streaming and incremental updates.

View

Slowing a hash

Ulta fast:

Murmur: 545,716 hashes per second

Fast:

SHA-1:	134,412
SHA-256:	126,323
MD5:	125,741
SHA-512:	76,005
SHA-3 (224-bit):	72,089

Medium speed:

LDAP (SHA1):	13,718
MS DCC:	9,582
NT Hash:	7,782
MySQL:	7,724
Postgres (MD5):	7,284

Slow:

PBKDF2 (SHA-256):	5,026
Cisco PIX:	4,402
MS SQL 2000:	4,225
LDAP (MD5):	4,180
Cisco Type 7:	3,775
PBKDF2 (SHA1):	2,348

Ultra-slow:

LM Hash:	733
APR1:	234
Bcrypt:	103
DES:	88
Oracle 10:	48

To slow the hash, we can use rounds, where we continually hash for a number of rounds. In the following we use 5,000 rounds:

====Splunk hashed password=====

User: Fred

Password: qwerty123

Salt: Uk8SVGLsBuSmD75R

=====Hashed password Fred:

\$6\$Uk8SVGLsBuSmD75R\$Lhp5yjwRUAM.LbH5IlthZ1u0bAUdJwBvvccBshAvpFPiRn62EYeiKOaP8xh97aV4UaNfV
yKRZhUy/3ZOzd1oc.

root@kali:~# hashcat -b -m 1800

Initializing hashcat v0.49 with 1 threads and 32mb segment-size...

Device.....: Intel(R) Core(TM) i7-8850H CPU 2.60GHz

Instruction set..: x86_64

Number of threads: 1

Hash type: sha512crypt, SHA512(Unix)

Speed/sec: **454 words**

root@kali:~# hashcat -b -m 0

Initializing hashcat v0.49 with 1 threads and 32mb segment-size...

Device: Intel(R) Core(TM) i7-8850H CPU 2.60GHz

Instruction set..: x86_64

Number of threads: 1

Hash type: MD5

Speed/sec: **17.33M words**

SHA512-crypt

Non-cryptographic hashing

Hash function	MiB/sec	cycl./hash	cycl./map	Quality problems
o1hash	12439661.09	16.77	166.13	insecure, no seed, zeros, fails all tests
crc32_hw1	23208.73	46.74	179.70	insecure, 100% bias, collisions, distrib, BIC, machine-specific (x86 SSE4.2)
t1ha0_aes_noavx	22785.26	38.71	180.61	LongNeighbors, machine-specific (x86 AES-NI)
t1ha0_aes_avx1	22714.85	48.12	226.52	LongNeighbors, machine-specific (x64 AVX.txt)
t1ha0_aes_avx2	22345.33	44.38	556.47	LongNeighbors, machine-specific (x64 AVX2)
falkhash	20202.42	173.63	321.52	Sparse, LongNeighbors, machine-specific (x64 AES-NI)
MeowHash64low	17378.06	85.48	237.60	Sparse, invertible, machine-specific (x64 AES-NI)
MeowHash32low	17374.64	85.48	258.53	Sparse, invertible, machine-specific (x64 AES-NI)
MeowHash	17371.91	85.48	247.96	Sparse, invertible, machine-specific (x64 AES-NI)
FarmHash32	17112.05	47.7	214.71	machine-specific (x64 SSE4/AVX)
xxh3	16538.52	32.81	184.86	DiffDist bit 7 w. 36 bits, BIC
xxh3low	16462.36	32.77	199.79	
farmhash32_c	16299.81	47.79	219.19	machine-specific (x64 SSE4/AVX)
xxh128low	15174.85	33.79	187.05	
xxh128	15174.14	40.46	195.65	
farsh32	14053.09	74.29	245.33	insecure: AppendedZeroes, collisions+bias, MomentChi2, LongNeighbors
metrohash64crc_2	14034.84	48.94	162.54	UB, Cyclic 8/8 byte, DiffDist, BIC, machine-specific (SSE4.2/NEON)
metrohash64crc_1	14000.5	49.08	150.54	UB, Cyclic 8/8 byte, DiffDist, BIC, MomentChi2, machine-specific (SSE4.2/NEON)
metrohash128crc_1	13948.67	65.2	168.08	UB, machine-specific (SSE4.2/NEON)
metrohash128crc_2	13920.19	65.12	176.70	UB, machine-specific (SSE4.2/NEON)
halftime_hash128	13478.23	97.79	252.14	
wyhash32low	12911.09	29.59	205.43	2 bad seeds
wyhash	12879	30.35	196.77	2^33 bad seeds
CityCrc128	12343.43	74.5	209.75	
fletcher2	12011.15	25.29	298.60	bad seed 0, UB, fails all tests
fletcher4	11928.55	25.27	293.49	bad seed 0, UB, fails all tests
halftime_hash256	11620.28	98.44	252.60	
fibonacci	11339.87	26.33	705.64	UB, zeros, fails all tests
ahash64	9862.62	27.32	181.68	rust
Spooky128	9751.14	63.84	192.47	UB
Spooky64	9747.47	62.2	191.71	UB

Used for hash tables. Google recommend the following for 64-bit hashes without quality problems:

- xxh3low
- wyhash
- ahash64
- t1ha2_atonce
- FarmHash
- halftime_hash128
- Spooky32
- pengyhash
- nmhash32
- mx3
- MUM/mir
- fasthash32

Unit 3: Hashing

Hashing Types.

Hashing Methods.

Salting.

Collisions.

LM and NTLM Hashes (Windows).

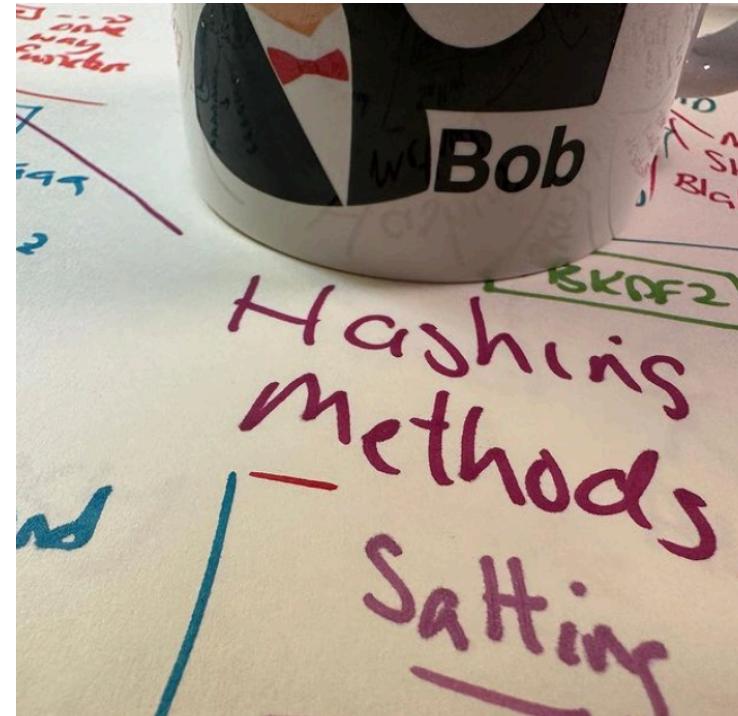
Hash Benchmarks.

Message Authentication Codes (MACs).

Key Derivation Function (KDF)

OTP/HOTP.

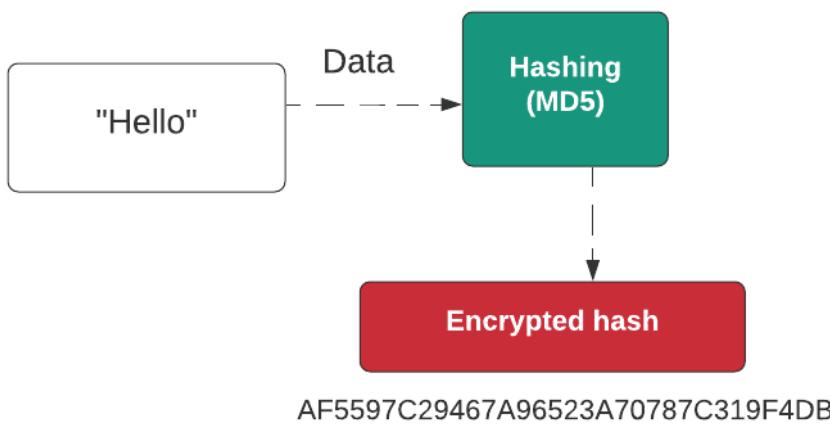
Hashcat.



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<https://asecuritysite.com/hash>

Hashing



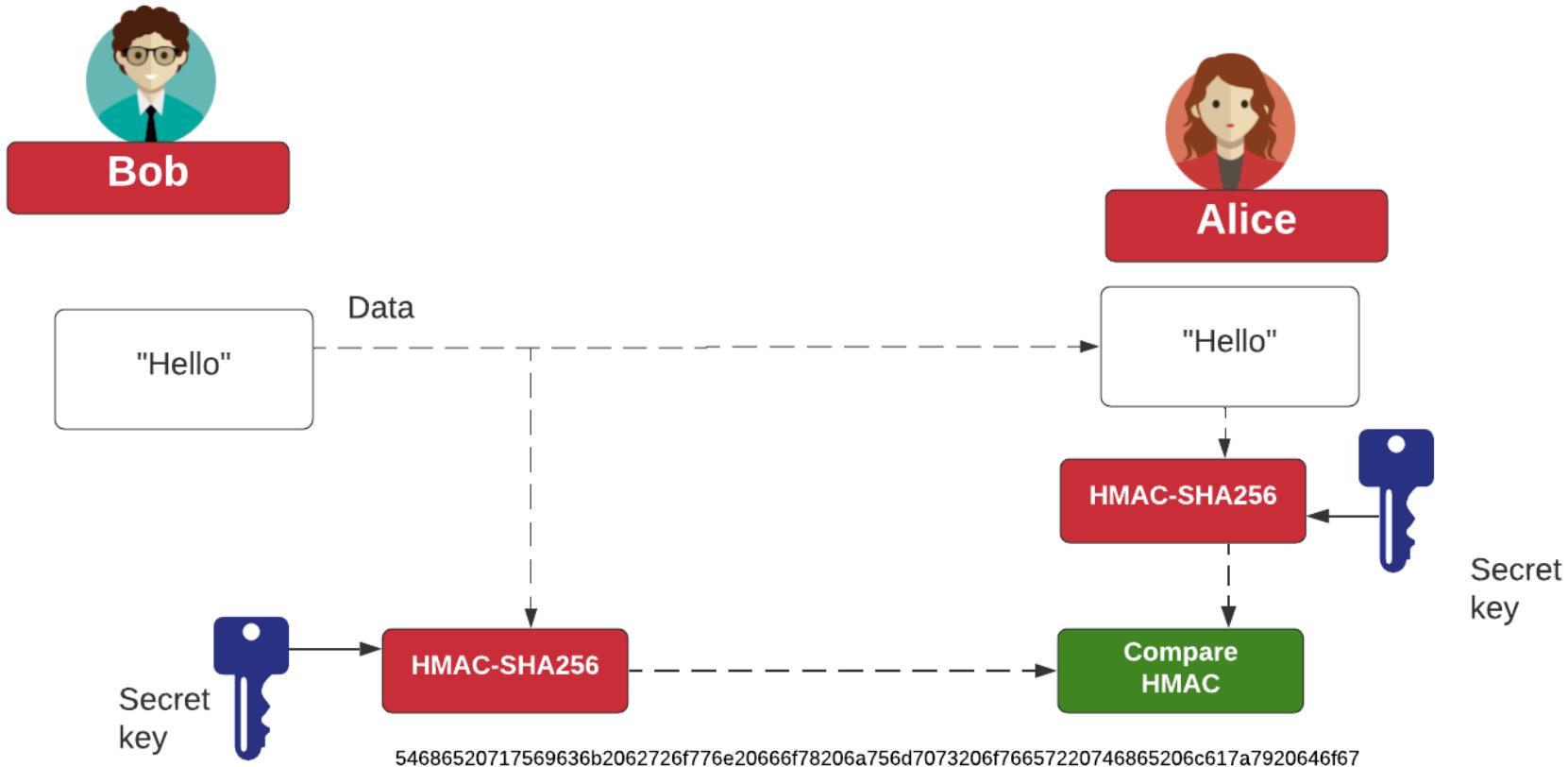
Hashed password

Bob: AF5597C29467A96523A70787C319F4DB

Hashed password with salt (hellozj8n)

Bob: zj8n:51A7C663A3BDCD06D6CE21E2BCB2AD5A

HMAC



Unit 3: Hashing

Hashing Types.

Hashing Methods.

Salting.

Collisions.

LM and NTLM Hashes (Windows).

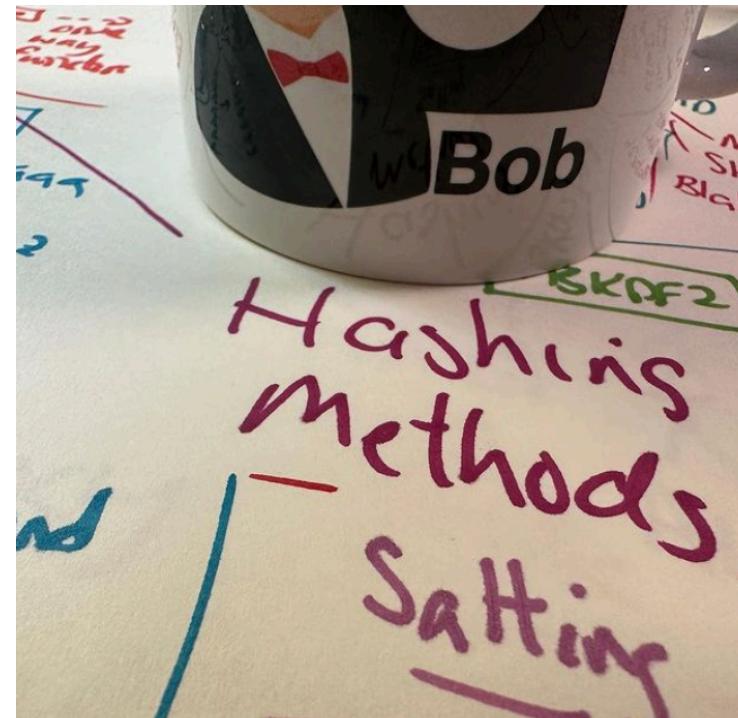
Hash Benchmarks.

Message Authentication Codes (MACs).

Key Derivation Functions (KDF)

OTP/HOTP.

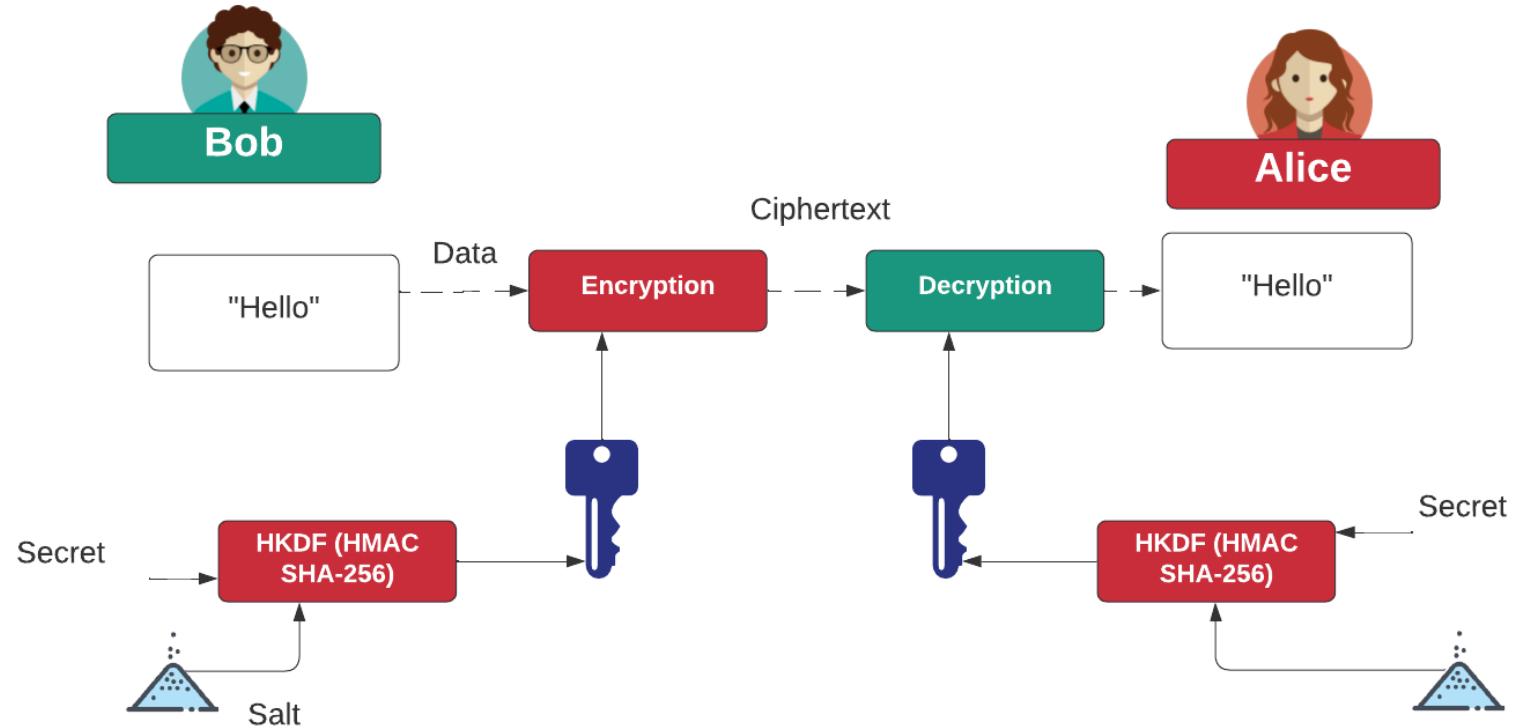
Hashcat.



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HKDF



```
Hashing type: SHA-256
Message: hello
  Hex: 68656c6c6f
Salt: 8e94ef805b93e683ff18
Info:  
=====
```

PRK: 1e133888e9fed8f9ceb210f88af26fa8f62f4190dd230f6317bf9f61ee07a690

OKM: 13485067e21af17c0900f70d885f0259

Key (Hex): 13485067e21af17c0900f70d885f0259

Key (Base-64): E0hQZ+Ia8XwJAPcNiF8CWQ==

HKDF

Unit 3: Hashing

Hashing Types.

Hashing Methods.

Salting.

Collisions.

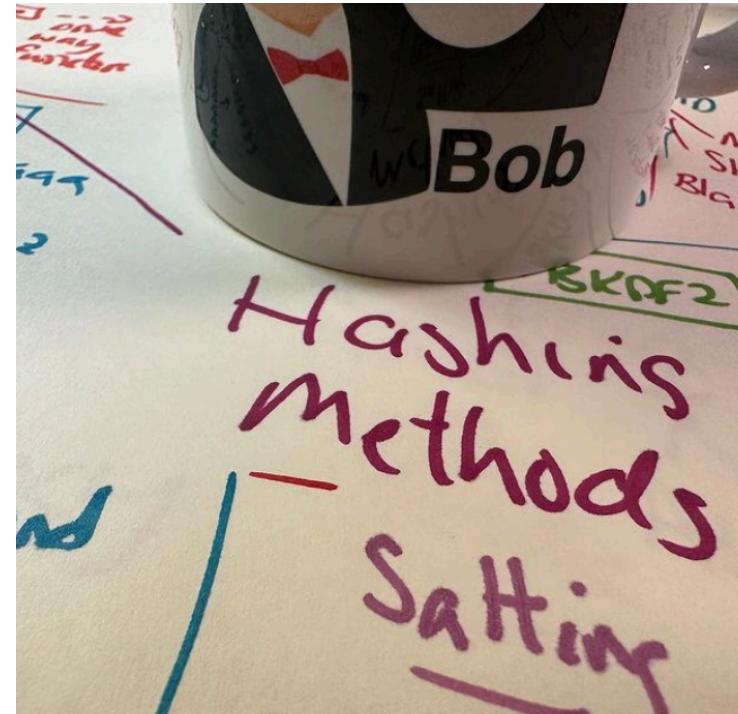
LM and NTLM Hashes (Windows).

Hash Benchmarks.

Message Authentication Codes (MACs).

OTP/HOTP.

Hashcat.



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<https://asecuritysite.com/hash>



One-time password

$f(m)$

$f(f(m))$

$f(f(f(m)))$



System logon

One-time password (timed)

$H(t_1)$

$H(t_2)$

$H(t_3)$



System logon

One-time password (counter)

$H(c_1)$

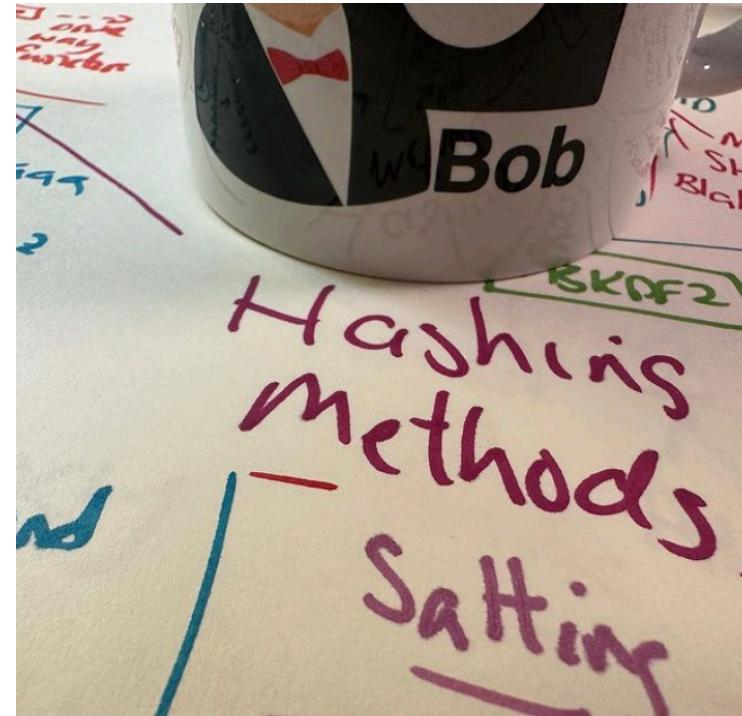
$H(c_2)$



System logon

Unit 3: Hashing

Hashing Types.
Hashing Methods.
Salting.
Collisions.
LM and NTLM Hashes (Windows).
Hash Benchmarks.
Message Authentication Codes (MACs).
Key Derivation Function (KDF)
OTP/HOTP.
Hashcat



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<https://asecuritysite.com/hash>

Hashing

Hashcat

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<https://asecuritysite.com/hash>



Hashcat

- **Rule-based Attacks.** Define a rule of the password.
- **Dictionary Attacks.** Search through a dictionary of common passwords.
- **Brute-Force Attacks.** Search through

Attack modes: Brute-force, Combinator, Dictionary, Mask, Rule-based, Toggle-case and Hybrid.

Hashcat

- hashcat [options] hashfile [mask] wordfiles | directories
- hashcat -m 0 myhash myfile.txt -o output.txt

* **General:**
-m, --hash-type=NUM Hash-type, see references below
-a, --attack-mode=NUM Attack-mode, see references below

* **Benchmark:**
-b, --benchmark Run benchmark

* **Files:**
-o, --outfile=FILE Define outfile for recovered hash
--outfile-format=NUM Define outfile-format for recovered hash, see references below

--show Show cracked passwords only (see --username)

* **Resources:**
-c, --segment-size=NUM Size in MB to cache from the wordfile
-n, --threads=NUM Number of threads

* **Rules:**
-r, --rules-file=FILE Rules-file use: -r 1.rule
-g, --generate-rules=NUM Generate NUM random rules
--generate-rules-func-min=NUM Force NUM functions per random rule min
--generate-rules-func-max=NUM Force NUM functions per random rule max

* **Toggle-Case attack-mode specific:**
--toggle-min=NUM Number of alphas in dictionary minimum
--toggle-max=NUM Number of alphas in dictionary maximum

* **Mask-attack attack-mode specific:**
--pw-min=NUM Password-length minimum
--pw-max=NUM Password-length maximum

* **Permutation attack-mode specific:**
--perm-min=NUM Filter words shorter than NUM
--perm-max=NUM Filter words larger than NUM

* **Table-Lookup attack-mode specific:**
-t, --table-file=FILE Table file
--table-min=NUM Number of chars in dictionary minimum
--table-max=NUM Number of chars in dictionary maximum

Hashcat

- hashcat
[options]
hashfile [mask]
wordfiles |
directories]
- hashcat -m 0
myhash
myfile.txt -o
output.txt

-a, --attack-mode=NUM

Attack Modes:

0 = Straight

1 = Combination

2 = Toggle-Case

3 = Brute-force

4 = Permutation

5 = Table-Lookup

6 = Prince

Hashcat

- hashcat [options] hashfile [mask] wordfiles | directories
- hashcat -m 0 myhash myfile.txt -o output.txt

```
-a, --attack-mode=NUM  
-m hash-type  
* Hash types:  
  
0 = MD5  
10 = md5($pass.$salt)  
20 = md5($salt.$pass)  
30 = md5(unicode($pass).$salt)  
40 = md5($salt.unicode($pass))  
50 = HMAC-MD5 (key = $pass)  
60 = HMAC-MD5 (key = $salt)  
100 = SHA1  
110 = sha1($pass.$salt)  
120 = sha1($salt.$pass)  
130 = sha1(unicode($pass).$salt)  
140 = sha1($salt.unicode($pass))  
150 = HMAC-SHA1 (key = $pass)  
160 = HMAC-SHA1 (key = $salt)  
200 = MySQL323  
300 = MySQL4.1/MySQL5  
400 = phpass, MD5(Wordpress), MD5/phpBB3), MD5(Joomla)  
500 = md5crypt, MD5(Unix), FreeBSD MD5, Cisco-IOS MD5  
900 = MD4  
1000 = NTLM  
1400 = SHA256  
1410 = sha256($pass.$salt)  
5500 = NetNTLMv1-VANILLA / NetNTLMv1-ESS  
5600 = NetNTLMv2  
5700 = Cisco-IOS SHA256  
8900 = scrypt  
9200 = Cisco $8$  
10000 = Django (PBKDF2-SHA256)
```

Hashcat - Outputs

- hashcat [options] hashfile [mask| wordfiles|directories]
- hashcat -m 0 myhash myfile.txt -o output.txt

Output format

- 1 = hash[:salt]
- 2 = plain
- 3 = hash[:salt]:plain
- 4 = hex_plain
- 5 = hash[:salt]:hex_plain
- 6 = plain:hex_plain
- 7 = hash[:salt]:plain:hex_plain
- 8 = crackpos
- 9 = hash[:salt]:crackpos
- 10 = plain:crackpos
- 11 = hash[:salt]:plain:crackpos
- 12 = hex_plain:crackpos
- 13 = hash[:salt]:hex_plain:crackpos
- 14 = plain:hex_plain:crackpos
- 15 = hash[:salt]:plain:hex_plain:crackpos

Hashcat

```
root@kali: ~
File Edit View Search Terminal Help
Stopped: Thu Oct 1 18:24:42 2015
root@kali:~# hashcat -m 1400 mytext.txt words.txt
Initializing hashcat v0.49 with 1 threads and 32mb segment-size...
Added hashes from file mytext.txt: 1 (1 salts)
Activating quick-digest mode for single-hash

NOTE: press enter for status-screen

106a5842fc5fce6f663176285ed1516dbb1e3d15c05abab12fdca46d60b539b7:help

All hashes have been recovered

Input.Mode: Dict (words.txt)
Index.....: 1/1 (segment), 1 (words), 5 (bytes)
Recovered.: 1/1 hashes, 1/1 salts
Speed/sec.: - plains, - words
Progress...: 1/1 (100.00%)
Running...: --:--:--:-
Estimated.: --:--:--:-

Started: Thu Oct 1 18:25:28 2015
Stopped: Thu Oct 1 18:25:28 2015
root@kali:~# '/root/Desktop/malware' [ ]
```

```
hashcat -m 1400 mytext.txt words.txt
```

Hashcat

```
File Edit View Search Terminal Help
root@kali:~# nano mytextlm.txt
root@kali:~# hashcat -m 1000 mytextlm.txt words.txt
Initializing hashcat v0.49 with 1 threads and 32mb segment-size...
Added hashes from file mytextlm.txt: 1 (1 salts)
Activating quick-digest mode for single-hash

NOTE: press enter for status-screen

0333c27eb4b9401d91fef02a9f74840e:help

All hashes have been recovered

Input.Mode: Dict (words.txt)
Index.....: 1/1 (segment), 1 (words), 5 (bytes)
Recovered.: 1/1 hashes, 1/1 salts
Speed/sec.: - plains, - words
Progress...: 1/1 (100.00%)
Running....: --:--:--:--
Estimated.: --:--:--:--

Started: Thu Oct 1 18:31:48 2015
Stopped: Thu Oct 1 18:31:48 2015
root@kali:~#
```

```
hashcat -m 1000 mytextnt.txt words.txt
```

Combinational Attack (-a 1)

```
Hashcat -m 0 -a 1 hash.txt dict1.txt dict2.txt
```

dict1.txt

```
jam  
jar  
jimmy  
jamie
```

```
jamcar  
jarcar  
Jimmymcar  
Jamiecar  
jamcat  
jarcat  
jimmymcat  
jamiecat
```

dict2.txt

```
car  
cat  
call
```

Hashing

Brute Force (-a 3)

Prof Bill Buchanan OBE

<https://asecuritysite.com/hash>



Hashcat – Brute Force

- hashcat [options]
hashfile [mask]
wordfiles | directories]
- hashcat -m 0 myhash
myfile.txt -o output.txt

Custom charsets:

-1, --custom charset1=CS	User-defined charsets
-2, --custom charset2=CS	Example:
-3, --custom charset3=CS	--custom charset1=?abcdef : sets
charset ?1 to 0123456789abcdef	charset ?2 mycharset.hcchr : sets charset ?2
-4, --custom charset4=CS	to chars contained in file

Character sets

?l = abcdefghijklmnopqrstuvwxyz
?u = ABCDEFGHIJKLMNOPQRSTUVWXYZ
?d = 0123456789
?s = !"#\$%&'()*+,./;:<=>?@[\]^_`{|}|~
?a = ?l?u?d?s
?b = 0x00 - 0xff

Hashcat – Brute Force

?l = abcdefghijklmnopqrstuvwxyz

?u = ABCDEFGHIJKLMNOPQRSTUVWXYZ

?d = 0123456789

?s = !"#\$%&'()*+,.-./:;<=>?@[\]^_`{|}~

?a = ?l?u?d?s

?b = 0x00 - 0xff

aaaaaaaa

aaaaaaaab

...

zzzzzzzz

- -1 abcdefghijklmnopqrstuvwxyz0123456789
- -1 abcdefghijklmnopqrstuvwxyz?d
- -1 ?l0123456789-1 ?l?d

Hashcat – Brute Force

```
hashcat -a 3 -m 1000  
mytextlm.txt ?!?!?I?  
I?I?I?I?I
```

[keyspace: aaaaaaaaaa
– zzzzzzzz]

Input.Mode: Mask (?!) [1]

Index.....: 0/1 (segment), 26 (words), 0 (bytes)
Recovered.: 0/1 hashes, 0/1 salts
Speed/sec.: - plains, - words
Progress...: 26/26 (100.00%)

Running...: --:--:--:--

Estimated.: --:--:--:--

Input.Mode: Mask (?!?) [2]

Index.....: 0/1 (segment), 676 (words), 0 (bytes)
Recovered.: 0/1 hashes, 0/1 salts
Speed/sec.: - plains, - words
Progress...: 676/676 (100.00%)

Running...: --:--:--:--

Estimated.: --:--:--:--

Input.Mode: Mask (?!?!?) [3]

Index.....: 0/1 (segment), 17576 (words), 0 (bytes)
Recovered.: 0/1 hashes, 0/1 salts
Speed/sec.: - plains, - words
Progress...: 17576/17576 (100.00%)

Running...: --:--:--:--

Estimated.: --:--:--:--

0333c27eb4b9401d91fef02a9f74840e:help

All hashes have been recovered

Input.Mode: Mask (?!?!?) [4]

Index.....: 0/1 (segment), 456976 (words), 0 (bytes)
Recovered.: 1/1 hashes, 1/1 salts
Speed/sec.: - plains, - words
Progress...: 271188/456976 (59.34%)

Running...: --:--:--:--

Estimated.: --:--:--:--

Hashcat – Brute Force

- **hashcat -a 3 -m 1000
mytextlm.txt hel?I
[keyspace: hela - help]**

Input.Mode: Mask (h) [1]

Index.....: 0/1 (segment), 1 (words), 0 (bytes)

Recovered.: 0/1 hashes, 0/1 salts

Speed/sec.: - plains, - words

Progress...: 1/1 (100.00%)

Running...: --:--:--:--

Estimated.: --:--:--:--

Input.Mode: Mask (he) [2]

Index.....: 0/1 (segment), 1 (words), 0 (bytes)

Recovered.: 0/1 hashes, 0/1 salts

Speed/sec.: - plains, - words

Progress...: 1/1 (100.00%)

Running...: --:--:--:--

Estimated.: --:--:--:--

Input.Mode: Mask (hel) [3]

Index.....: 0/1 (segment), 1 (words), 0 (bytes)

Recovered.: 0/1 hashes, 0/1 salts

Speed/sec.: - plains, - words

Progress...: 1/1 (100.00%)

Running...: --:--:--:--

Estimated.: --:--:--:--

0333c27eb4b9401d91fef02a9f74840e:help

All hashes have been recovered

Input.Mode: Mask (hel?l) [4]

Index.....: 0/1 (segment), 26 (words), 0 (bytes)

Recovered.: 1/1 hashes, 1/1 salts

Speed/sec.: - plains, - words

Progress...: 16/26 (61.54%)

Running...: --:--:--:--

Estimated.: --:--:--:--

Hashcat – Brute Force

```
...  
  
b1b735762130797915df96acf5bf09b8:hel9  
  
All hashes have been recovered  
  
Input.Mode: Mask (hel?d) [4]  
Index.....: 0/1 (segment), 10 (words), 0 (bytes)  
Recovered..: 1/1 hashes, 1/1 salts  
Speed/sec.: - plains, - words  
Progress...: 10/10 (100.00%)  
Running....: --:--:--:  
Estimated.: --:--:--:
```

hashcat -a 3 -m 1000 mytextlm.txt hel?d
[keyspace: hela - help]

Unit 3: Hashing

Rules and Lists

Prof Bill Buchanan OBE

<http://asecuritysite.com/crypto02>

<http://asecuritysite.com/encryption>



Hashcat – Password List

```
root@kali:~# wc -l /usr/share/wordlists/rockyou.txt  
14344392 /usr/share/wordlists/rockyou.txt
```

123456	abc123
12345	nicole
123456789	daniel
password	babygirl
iloveyou	monkey
princess	lovely
1234567	jessica
rockyou	anthony
12345678	friends
	butterfly

```
root@kali:~# hashcat -m 0 mytextmd.txt /usr/share/wordlists/rockyou.txt
```

```
Initializing hashcat v0.49 with 1 threads and 32mb segment-size...
```

```
Added hashes from file mytextmd.txt: 1 (1 salts)
```

```
Activating quick-digest mode for single-hash
```

```
NOTE: press enter for status-screen
```

```
25f9e794323b453885f5181f1b624d0b:123456789
```

```
All hashes have been recovered
```

```
Input.Mode: Dict (/usr/share/wordlists/rockyou.txt)
```

```
Index.....: 1/5 (segment), 3627099 (words), 33550339 (bytes)
```

```
Recovered.: 1/1 hashes, 1/1 salts
```

```
Speed/sec.: - plains, - words
```

```
Progress...: 4/3627099 (0.00%)
```

Hashcat – Rules

Name	Function	Description	Example Rule	Input Word	Output Word
Nothing	:	Do nothing	:	p@ssW0rd	p@ssW0rd
Lowercase	l	Lowercase	- - - - - -	p@ssW0rd	p@ssw0rd
Uppercase	u	Uppercase	u	p@ssW0rd	P@SSWORD
Capitalize	c	Capitalize 1st, lower rest	- - - c - - -	p@ssW0rd	P@ssw0rd
Append	\$X	Append character X to end	\$1	p@ssW0rd	p@ssW0rd1
Prepend	^X	Prepend character X to front	^1 - - - - - -	p@ssW0rd	1p@ssW0rd
Replace	sXY	Replace all instances of X with Y	ss\$	p@ssW0rd	p@\$sW0rd

```
root@kali:~# ls /usr/share/hashcat/rules
best64.rule
combinator.rule
d3ad0ne.rule
dive.rule
generated.rule
Incisive-leetspeak.rule
InsidePro-HashManager.rule
InsidePro-PasswordsPro.rule
leetspeak.rule
Ninja-leetspeak.rule
oscommerce.rule
rockyou-30000.rule
specific.rule
T0x1c-insert_00-99_1950-2050_toprules_0_F.rule
T0x1c-insert_space_and_special_0_F.rule
T0x1c-insert_top_100_passwords_1_G.rule
T0x1c.rule
T0x1cv1.rule
toggles1.rule
toggles2.rule
toggles3.rule
toggles4.rule
toggles5.rule
```

Name	Function	Description	Example Rule	Input Word	Output Word
Nothing	:	Do nothing	:	p@ssW0rd	p@ssW0rd
Lowercase	l	Lowercase	l	p@ssW0rd	p@ssw0rd
Uppercase	u	Uppercase	u	p@ssW0rd	P@SSWORD
Capitalize	c	Capitalize 1st, lower rest	c	p@ssW0rd	P@ssw0rd
Append	\$X	Append character X to end	\$1	p@ssW0rd	p@ssW0rd1
Prepend	^X	Prepend character X to front	^1	p@ssW0rd	1p@ssW0rd
Replace	sXY	Replace all instances of X with Y	ss\$	p@ssW0rd	p@\$SW0rd

edinburgh

Ed1nburgh123

Capitalise the first character.

Add a 1, 2 .. 0 at the end.

Add “123” at the end.

Substitute ‘a’ for ‘@’

Substitute ‘l’ for a ‘1’

Substitute ‘5’ for an ‘s’

Substitute ‘3’ for an ‘e’

Substitute ‘0’ for an ‘o’

```
:
#Lowercase
l
#Uppercase
u
#Capitalise first character
c
#Add '1' to the end
$1
#Add '2' to the end
$2
#Add '3' to the end
$3
#Add '123' to the end
$1 $2 $3
#Substitute 'a' for '@'
sa@
#Substitute 'a' for '4'
sa4
#substitute 'l' for '1'
sl1
#Substitute 'a' for '@', 'e' for '3', 'l' for '1'
```

Hashcat – With Battlefield Hash

```
root@kali:~/hashes# hashcat -m 0 bfield.hash /usr/share/wordlists/rockyou.txt  
Initializing hashcat v0.49 with 1 threads and 32mb segment-size...
```

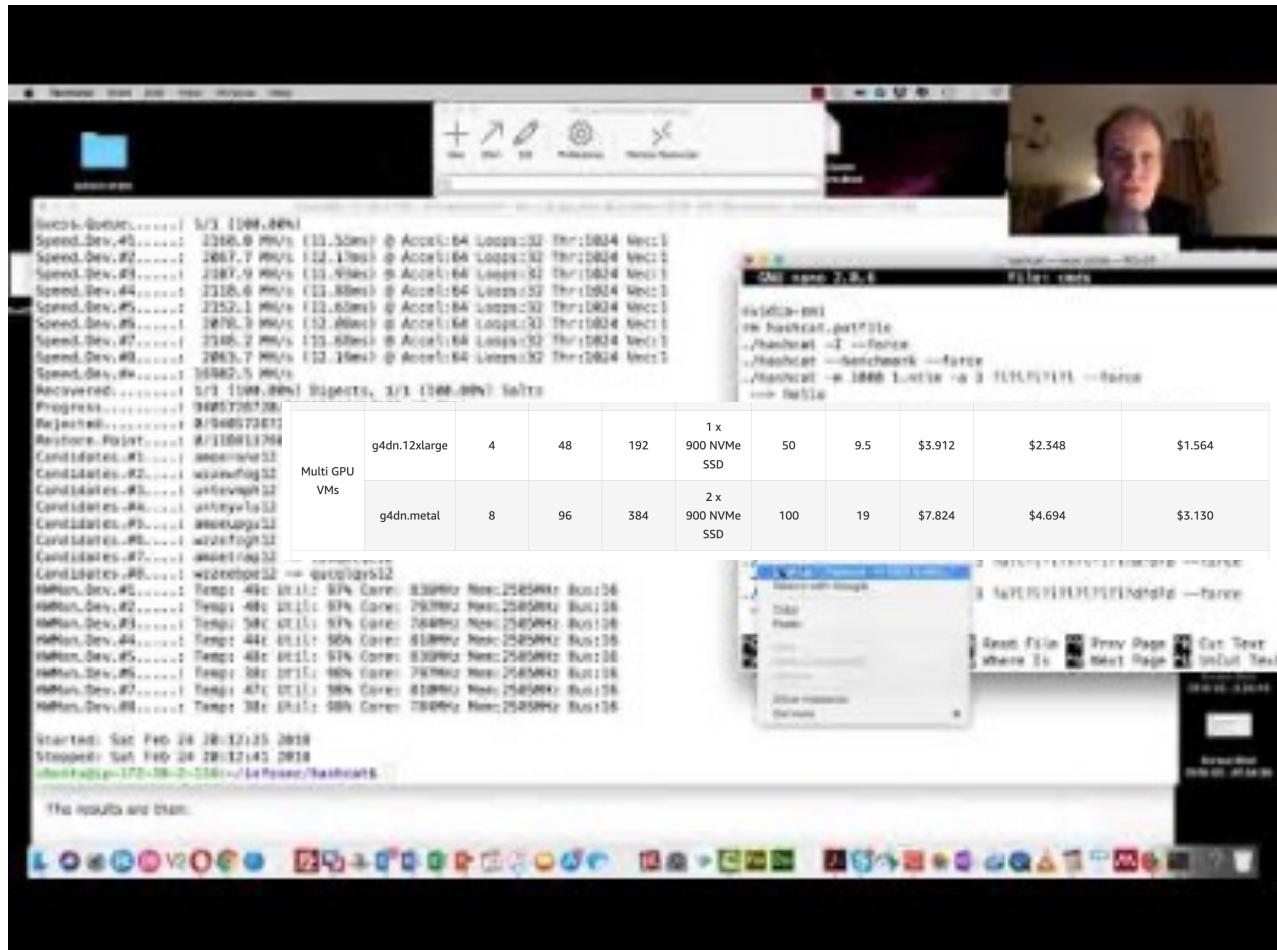
Added hashes from file bfield.hash: 548686 (1 salts)

NOTE: press enter for status-screen

```
e10adc3949ba59abbe56e057f20f883e:123456  
25f9e794323b453885f5181f1b624d0b:123456789  
5f4dcc3b5aa765d61d8327deb882cf99:password  
f25a2fc72690b780b2a14e140ef6a9e0:iloveyou  
8afa847f50a716e64932d995c8e7435a:princess  
fce920f7412b5da7be0cf42b8c93759:1234567  
25d55ad283aa400af464c76d713c07ad:12345678
```

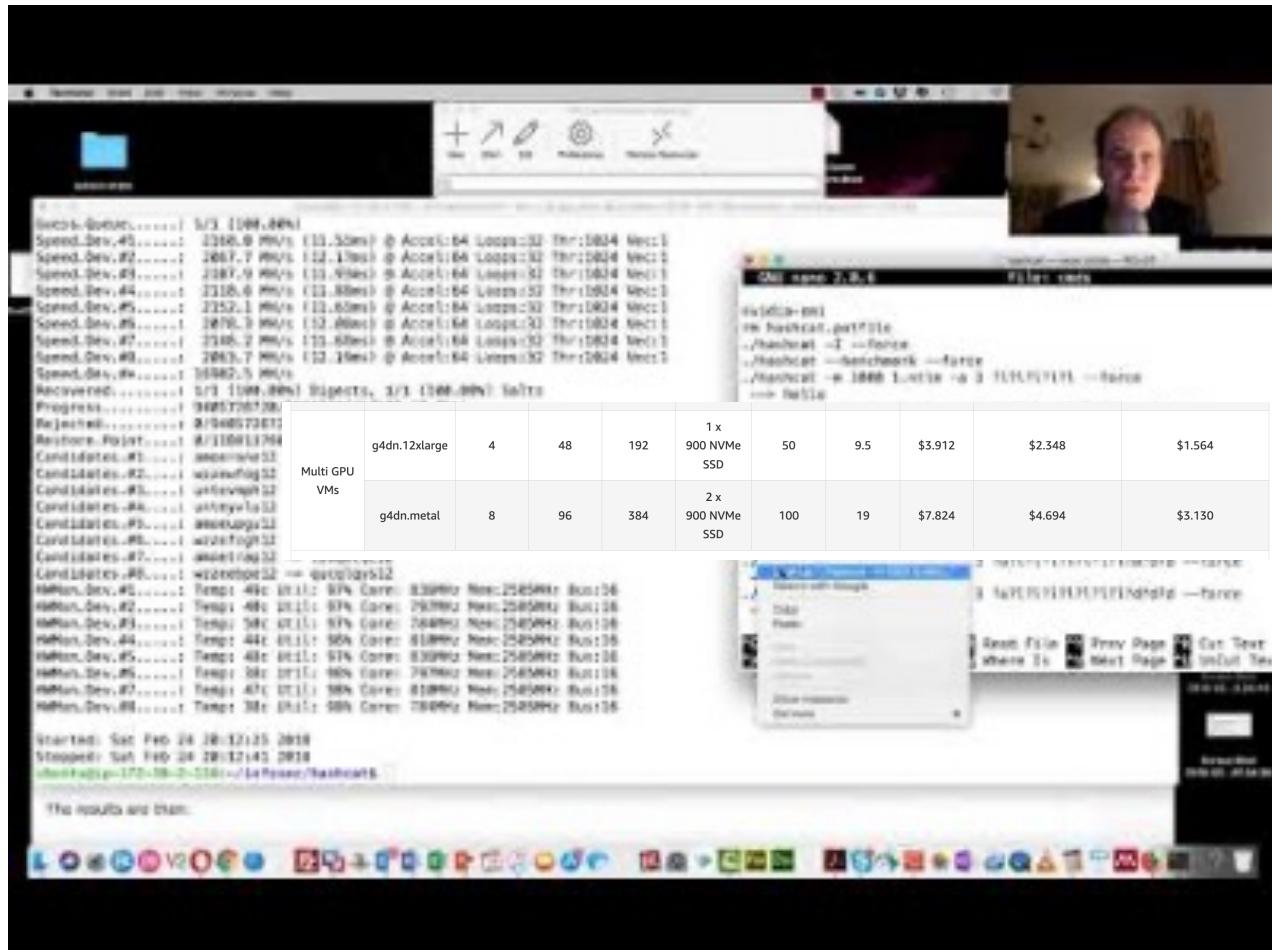
Hashcat – With 8xGPU

Name	GPUs	vCPU	Memory (GiB)	GPU Memory (GiB)	Price/hr* (Linux)	Price/hr* (Windows)	1-yr Reserved Instance Effective Hourly* (Linux)	3-yr Reserved Instance Effective Hourly* (Linux)
g5s.xlarge	1	4	30.5	8	\$0.75	\$0.93	\$0.525	\$0.405
g3.4xlarge	1	16	122	8	\$1.14	\$1.876	\$0.741	\$0.538
g3.8xlarge	2	32	244	16	\$2.28	\$3.752	\$1.482	\$1.076
g3.16xlarge	4	64	488	32	\$4.56	\$7.504	\$2.964	\$2.152



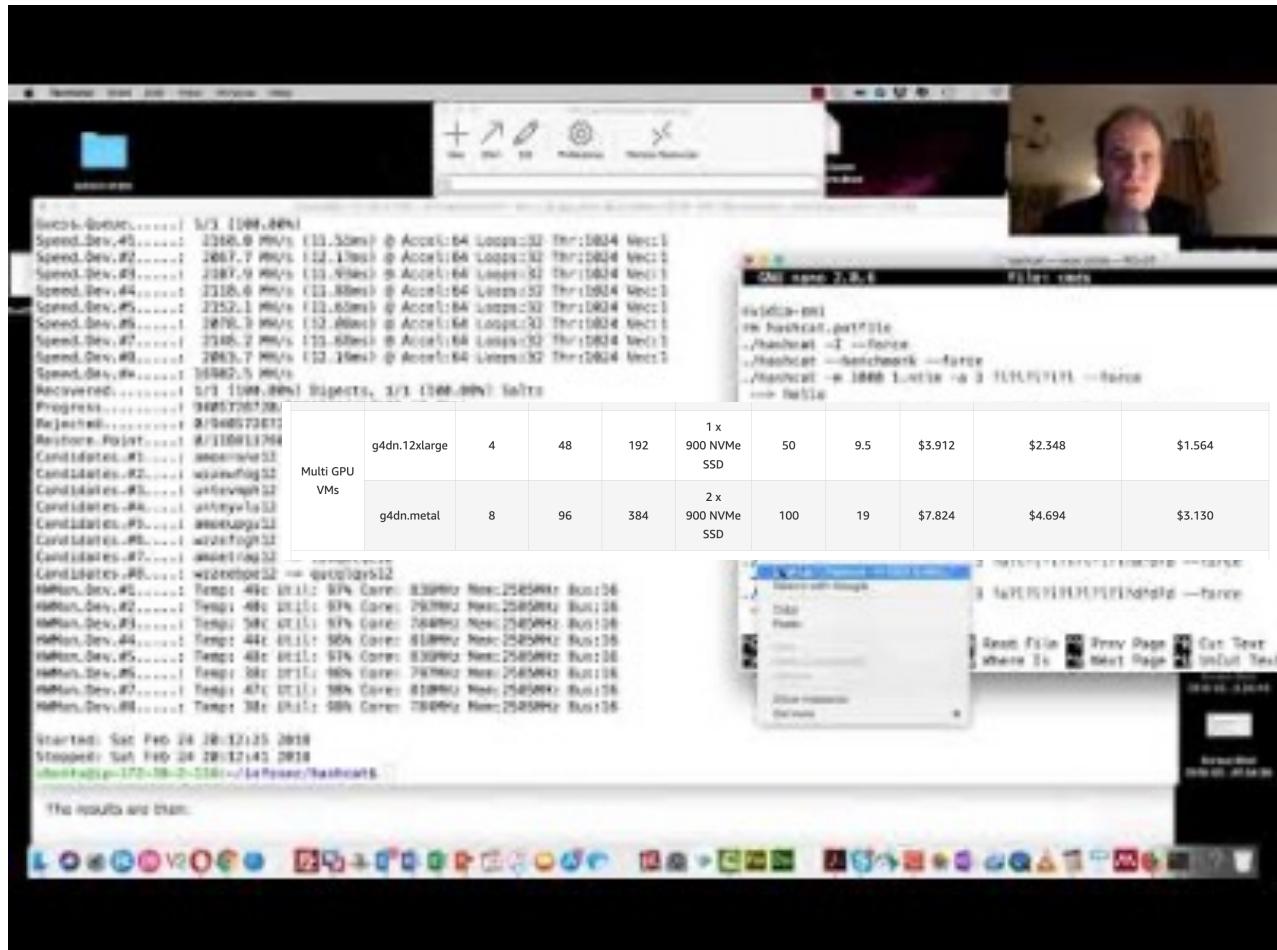
Hashcat – With 8xGPU

Name	GPUs	vCPU	Memory (GiB)	GPU Memory (GiB)	Price/hr* (Linux)	Price/hr* (Windows)	1-yr Reserved Instance Effective Hourly* (Linux)	3-yr Reserved Instance Effective Hourly* (Linux)
g5s.xlarge	1	4	30.5	8	\$0.75	\$0.93	\$0.525	\$0.405
g3.4xlarge	1	16	122	8	\$1.14	\$1.876	\$0.741	\$0.538
g3.8xlarge	2	32	244	16	\$2.28	\$3.752	\$1.482	\$1.076
g3.16xlarge	4	64	488	32	\$4.56	\$7.504	\$2.964	\$2.152



Hashcat – With 8xGPU

Name	GPUs	vCPU	Memory (GiB)	GPU Memory (GiB)	Price/hr* (Linux)	Price/hr* (Windows)	1-yr Reserved Instance Effective Hourly* (Linux)	3-yr Reserved Instance Effective Hourly* (Linux)
g5s.xlarge	1	4	30.5	8	\$0.75	\$0.93	\$0.525	\$0.405
g3.4xlarge	1	16	122	8	\$1.14	\$1.876	\$0.741	\$0.538
g3.8xlarge	2	32	244	16	\$2.28	\$3.752	\$1.482	\$1.076
g3.16xlarge	4	64	488	32	\$4.56	\$7.504	\$2.964	\$2.152



GPUs in the Cloud

G5: NVIDIA A10G Tensor Core GPUs. Up to 192 vCPUs. 31.2 teraFLOPS, 24GB RAM.

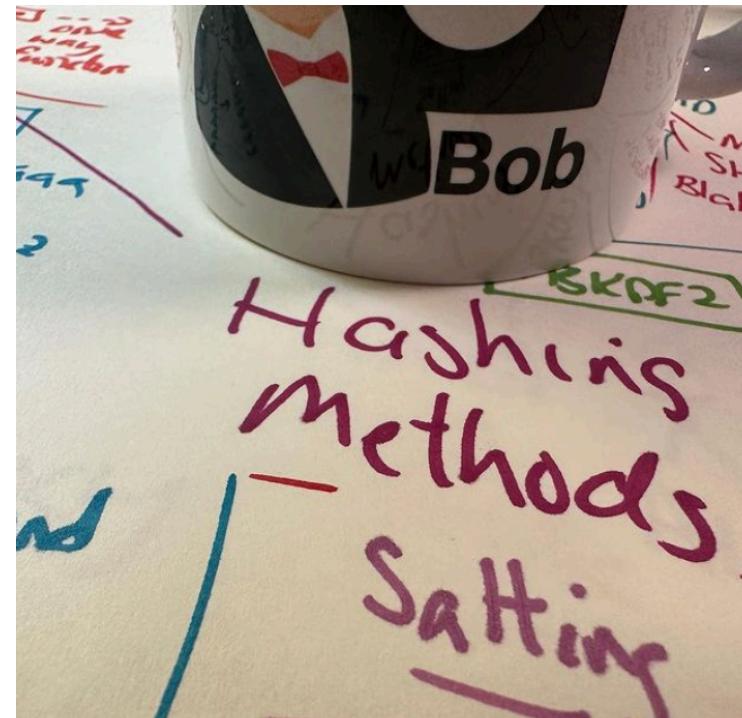
Name	GPUs	vCPU	Memory (GiB)	GPU Memory (GiB)	Price/hr* (Linux)	Price/hr* (Windows)	1-yr Reserved Instance Effective Hourly* (Linux)	3-yr Reserved Instance Effective Hourly* (Linux)
g3s.xlarge	1	4	30.5	8	\$0.75	\$0.93	\$0.525	\$0.405
g3.4xlarge	1	16	122	8	\$1.14	\$1.876	\$0.741	\$0.538
g3.8xlarge	2	32	244	16	\$2.28	\$3.752	\$1.482	\$1.076
g3.16xlarge	4	64	488	32	\$4.56	\$7.504	\$2.964	\$2.152

Multi GPU VMs	g4dn.12xlarge	4	48	192	1 x 900 NVMe SSD	50	9.5	\$3.912	\$2.348	\$1.564
	g4dn.metal	8	96	384	2 x 900 NVMe SSD	100	19	\$7.824	\$4.694	\$3.130

Multi GPU VMs	g5.12xlarge	4	96	48	192	1x3800	40	16	\$5.672	\$3.403	\$2.269
	g5.24xlarge	4	96	96	384	1x3800	50	19	\$8.144	\$4.886	\$3.258
	g5.48xlarge	8	192	192	768	2x3800	100	19	\$16.288	\$9.773	\$6.515

Unit 3: Hashing

Hashing Types.
Hashing Methods.
Salting.
Collisions.
LM and NTLM Hashes (Windows).
Hash Benchmarks.
Message Authentication Codes (MACs).
OTP/HOTP.
Hashcat (for practical work)



Prof Bill Buchanan OBE
<https://asecuritysite.com/hash>