

Chapter 3: Hashing

Hashing Types.

Hashing Methods.

Salting.

Collisions.

LM and NTLM Hashes (Windows).

Hash Benchmarks.

Message Authentication Codes (MACs).

OTP/HOTP.

Prof Bill Buchanan OBE

<http://asecuritysite.com/crypto03>

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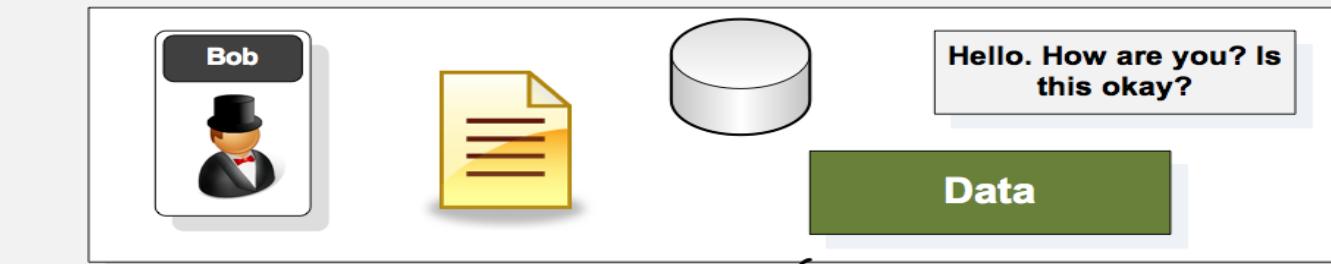
Secret Shares.

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How do we get a finger-print for data?



With a
fingerprint we
can hopefully tell
if Eve has
modified any of
the data

**Solved by Prof Ron Rivest
with the MD5 hash
signature.**



Author: Prof Bill Buchanan



**Hashing
Algorithm (MD5)
- 128 bit signature**



hello

XUFAKrxLKna5cz2REBffkg

Hello

ixqZU8RhEpaoJ6v4xHgE1w

Hello. How are you?

CysDE5j+zoubCYztTdsFiw

Napier

j4NXH5Mkrk4j13N1MFxHtg

Base-64

hello

5D41402ABC4B2A76B9719D911017C592

Hello

8B1A9953C4611296A827ABF8C47804D7

Hello. How are you?

CC708153987BF9AD833BEBF90239BF0F

Napier

8F83571F9324AE4E23D773753055C7B6

Hex



**Hashing
Algorithm (SHA-1)**
- 160 bit signature



hello

qvTGHdzF6KLavt4P00gs2a6pQ00=

Hello

9/+ei3uy4Jtwk1pdeF4MxdnQq/A=

Hello. How are you?

Puh2Am76bhjqE51btTwtsqbdFC8=

Napier

v4GxNavod2b09GR2Tqw4yopOuro=

Base-64

hello

AAF4C61DDCC5E8A2DABEDE0F3B482CD9AEA9434D

Hello

F7FF9E8B7BB2E09B70935A5D785E0CC5D9D0ABF0

Hello. How are you?

3EE876026EFA6E18EA13995B4D6B70B2A6DD142F

Napier

BF81B135A5687766F4F464764EAC38CA8A4EBABA

Hex



**Hashing
Algorithm (MD5)
- 128 bit signature**



Security and mobility are two of the most important issues on the Internet, as they will allow users to secure their data transmissions, and also break their link with physical connections.

F94FBED3DAE05D223E6B963B9076C4EC

+U++09rgXSI+a5Y7kHbE7A==

Base-64

Security and mobility are two of the most important issues on the Internet, as they will allow users to secure their data transmissions, and also break their link with physical connections.

8A8BDC3FF80A01917D0432800201CFBF

iovcP/gKAZF9BDKAAgHPVW==

Hex

OpenSSL

```
root@kali:~# echo -n "hello" | openssl md5  
(stdin)= 5d41402abc4b2a76b9719d911017c592
```

```
root@kali:~# echo -n "hello" | md5sum  
5d41402abc4b2a76b9719d911017c592 -
```

```
root@kali:~# openssl md5 pw  
MD5(pw)= 859b6a9be3b45262c4414bd1696ba91b
```

```
root@kali:~# md5sum pw  
859b6a9be3b45262c4414bd1696ba91b pw
```

Hash methods supported:

```
md2          md4          md5          rmd160        sha  
sha1
```



Authentication

Message Hash

[Path] / filename

[C:\windows\System32\
12520437.cpx
12520850.cpx
8point1.wav
aaclient.dll
AC3ACM.acm
Ac3audio.ax
ac3filter.cpl
accessibilitycpl.dll
ACCTRES.dll
acledit.dll
.
.
ZSHP1020.CHM
ZSHP1020.EXE
ZSHP1020.HLP
ZSPOOL.DLL
ZTAG.DLL
ZTAG32.DLL

MD 5 sum

0a0feb9eb28bde8cd835716343 b03b14
d 69ae057cd82d04ee7d311809 abefb2a
beab 165fa58ec5253185 f32e124685d5
ad 45dedfdcf69a28cbaf6a2ca84b5f1e
59683d1e4cd0b1ad6ae32e1d627ae25f
4b87d889edf278e5fa223734 a9bbe79a
10b27174d46094984 e7a05f3c36acd2a
ac 4cecc86eeb8e1cc2e9fe022cff3ac1
58f57f2f2133a2a77607 c8ccc9a30f73
0bcee3f36752213d1b09d18e69383898

c 671ed [Path] / filename

96e45a
[C:\windows\system32\
12520437.cpx
12520850.cpx
8point1.wav
aaclient.dll
AC3ACM.acm
Ac3audio.ax

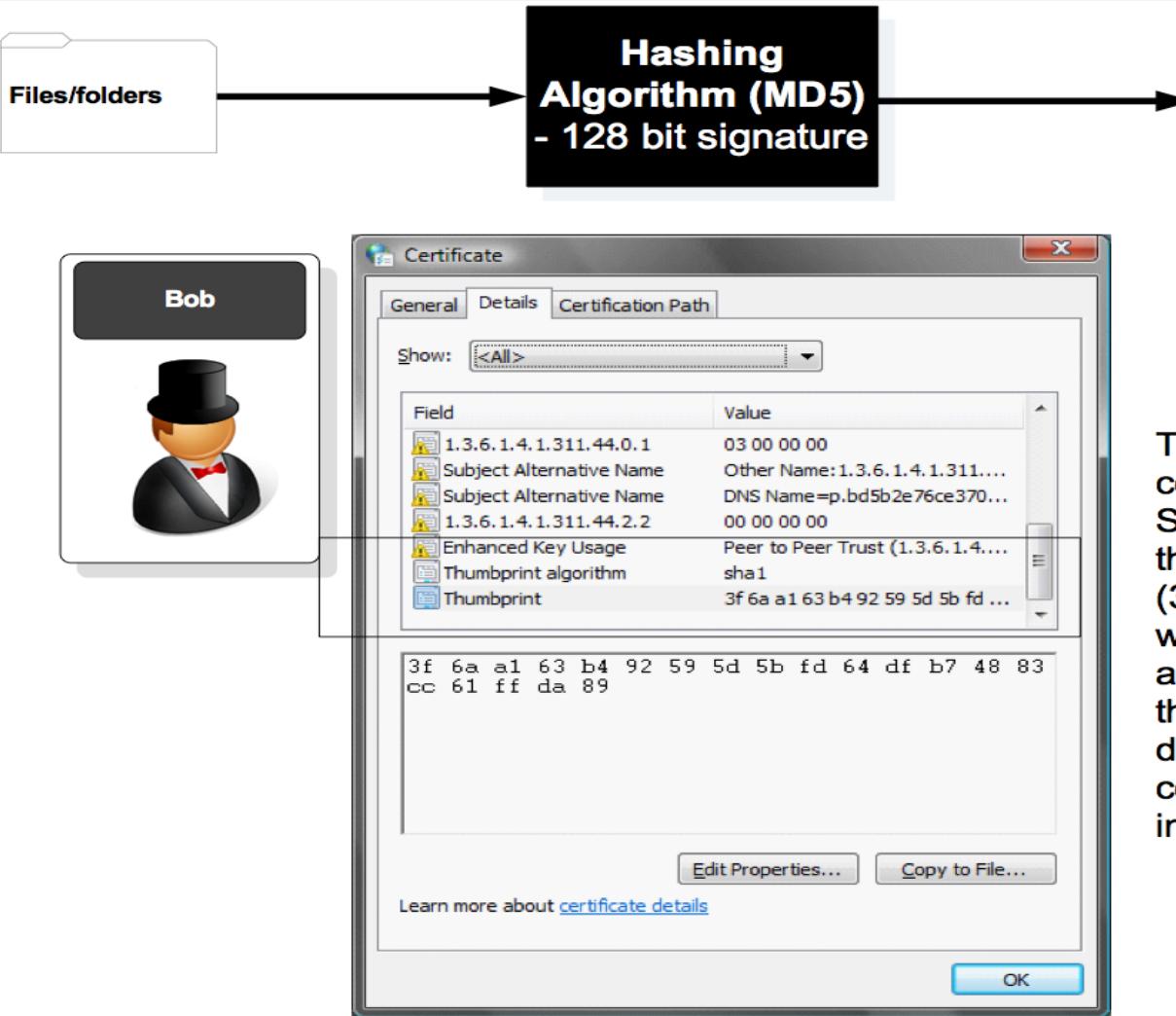
MD 5 sum

Cg /rnrKL3ozYNXFjQ7A7FA==
1prgV82C0E7n0xGAmr77Kg==
vqswX 6w0xSUxhfMuEkaF 1Q==
rUXe 39z2mijLr2osqEtFhg==
wg 9HkzQsa1q4y4dYnriXw==
S 4fYie3ye0X6Ijc0qbvnmg==

Hashing
Algorithm (MD5)
- 128 bit signature

Hash signature

- Hash signatures are used to gain a signature for files, so that they can be checked if they have been changed.

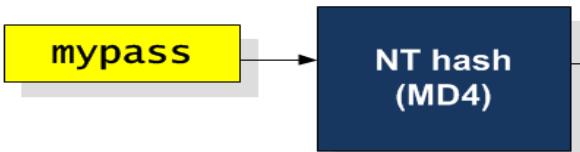


Hash signature

- Hash signatures are used to identify that a file/certificate has not been changed.

The digital certificate has an SHA-1 hash thumbprint (3f6a...89) which will be checked, and if the thumbprint is different, the certificate will be invalid.

Windows login/ authentication

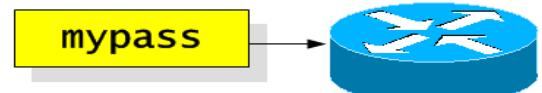


One-way hash

- 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.

NT-password
hash for Windows
NT, XP and Vista

Cisco password storage (MD5)



MD5 encoded
password

One-way hash

Types

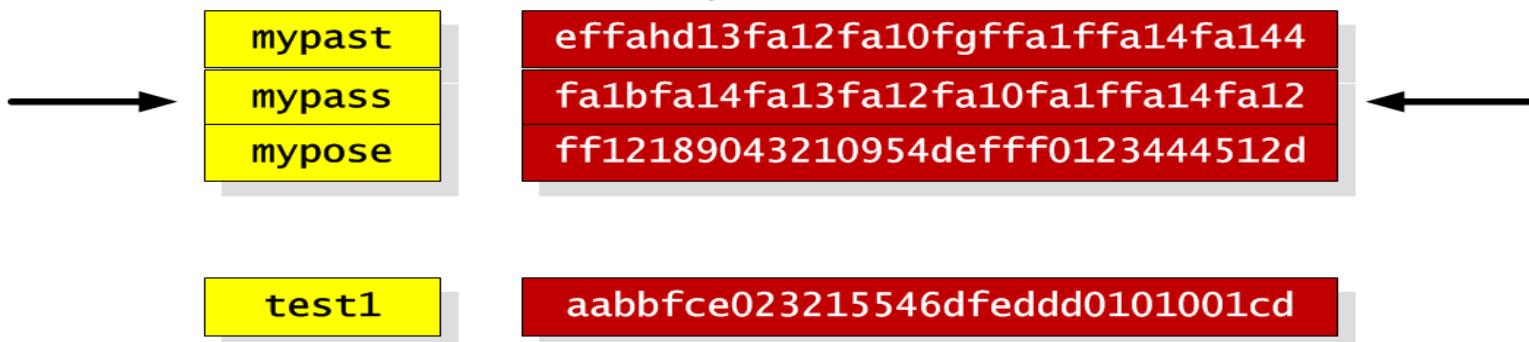
One-way hash

Windows login/ authentication



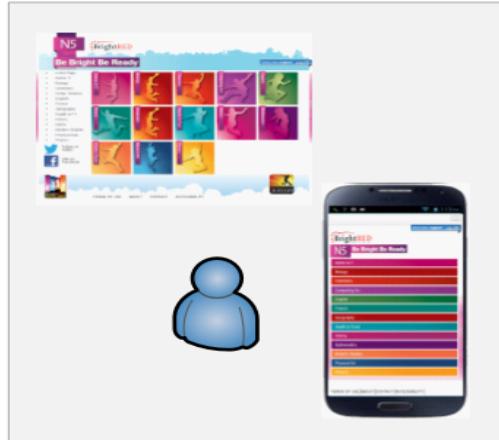
Hashing suffers from **dictionary attacks** where the signatures of well known words are stored in a table, and the intruders does a lookup on this

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:

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LM Hash

LM Hash. LM Hash is used in many versions of Windows to store user passwords that are fewer than 15 characters long.

SHA-3

SHA-3. SHA-3 was known as Keccak and is a hash function designed by Guido Bertoni, Joan Daemen, Michaël Peeters, and Gilles Van Assche. MD5 and SHA-0 have been shown to be susceptible to attacks, along with theoretical attacks on SHA-1. NIST thus defined there was a need for a new hashing method which did not use the existing methods for hashing, and setup a competition for competing algorithms. In October 2012, Keccak won the NIST hash function competition, and is proposed as the SHA-3 standard.

Tiger

Bcrypt

Bcrypt. This creates a hash value which has salt.

RIPEMD

RIPEMD (RACE Integrity Primitives Evaluation Message Digest) and GOST. RIPEMD160. RIPEMD is a 128-bit, 160-bit, 256-bit or 320-bit cryptographic hash function, and was created by Hans Dobbertin, Antoon Bosselaers and Bart Preneel. It is used on TrueCrypt, and is open source. The 160-bit version is seen as an alternative to SHA-1, and is part of ISO/IEC 10118

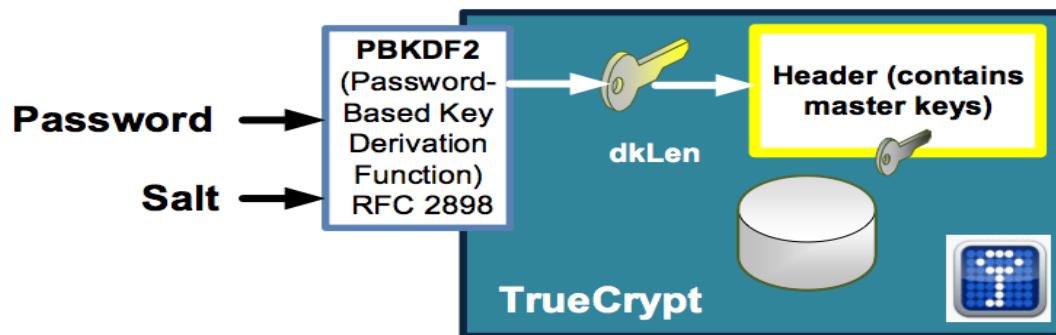
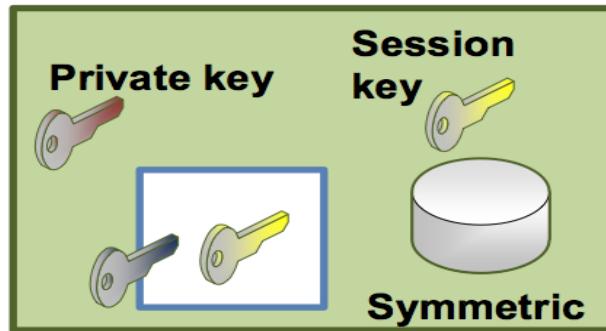
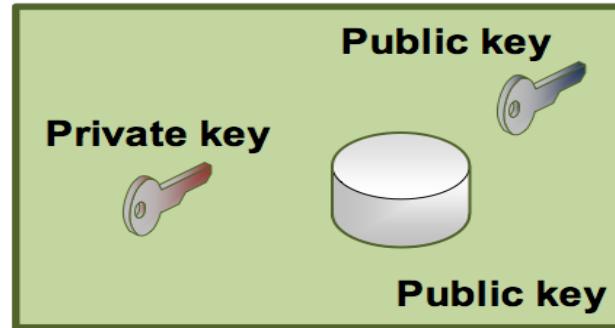
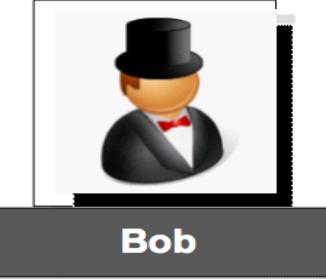
Tiger. Tiger is a 192-bit hash function, and was designed by Ross Anderson and Eli Biham in 1995. It is often used by clients within Gnutella file sharing networks, and does not suffer from known attacks on MD5 and SHA-0/SHA-1. Tiger2 is an addition, in which the message is padded with a byte of 0x80 (in a similar way to MD4, MD5 and SHA), whereas in Tiger it is 0x01. Otherwise the two methods are the same in their operation.

Murmur

While hashing methods such as MD5 and SHA-1 use crypto methods, the Murmur and FNV hashes uses a non-cryptographic hash function. The Murmur hash, designed by Austin Appleby, uses a non-cryptographic hash function. This can be used for general hash-based lookups. It has a good performance compared with other hashing methods, and generally provide a good balance between performance and CPU utilization. Also it performs well in terms of hash collisions.

FNV

FNV (Fowler–Noll–Vo) is a 64-bit non-cryptographic hash function developed by Glenn Fowler, Landon Curt Noll, and Phong Vo. There are two main versions, of which 1a is the most up-to-date version.



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

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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
```

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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

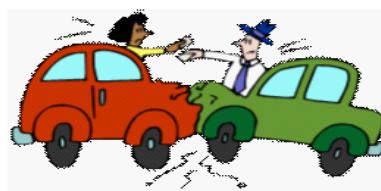
```
d131dd02c5e6eec4693d9a0698aff95c  
2fcab58712467eab4004583eb8fb7f89  
55ad340609f4b30283e488832571415a  
085125e8f7cdc99fd91dbdf280373c5b  
d8823e3156348f5bae6dacd436c919c6  
dd53e2b487da03fd02396306d248cda0  
e99f33420f577ee8ce54b67080a80d1e  
c69821bcb6a8839396f9652b6ff72a70
```

```
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
```

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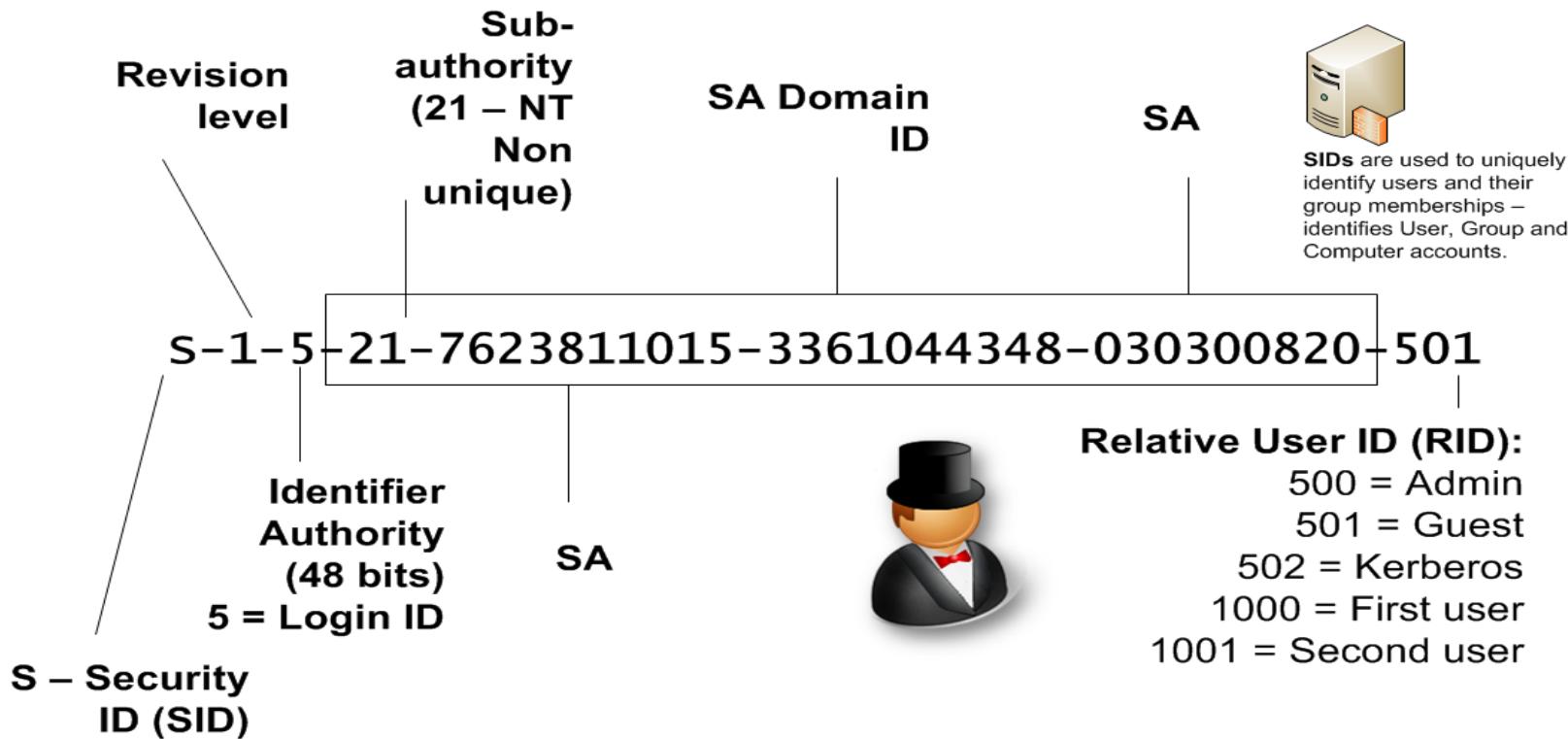
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<http://asecuritysite.com/encryption>

```
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
```

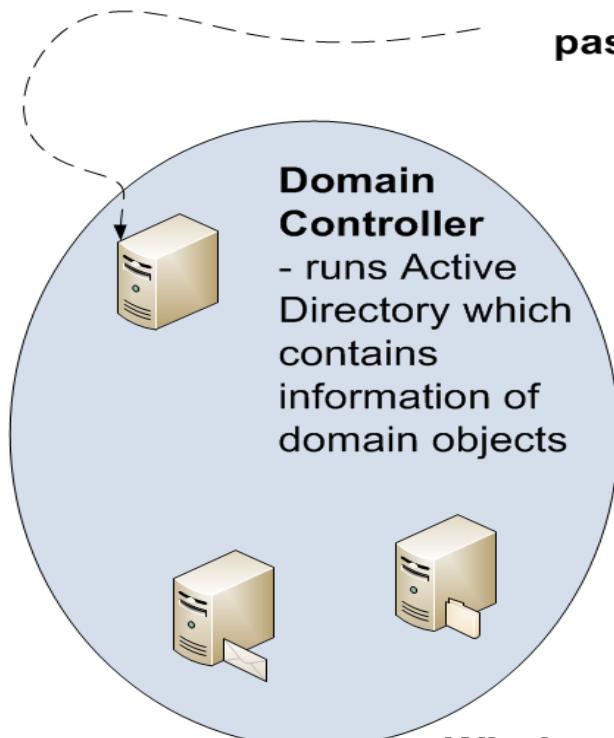
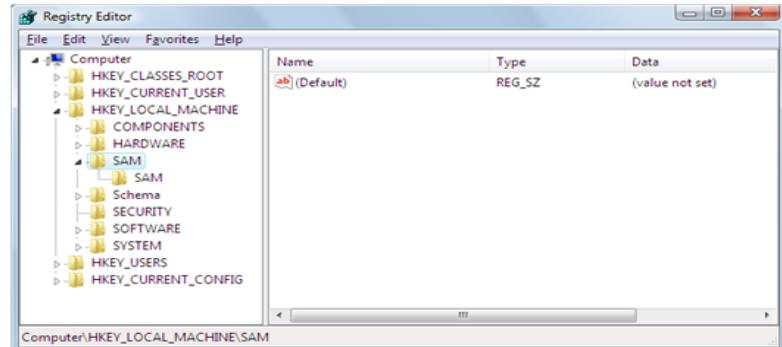
Windows
CEH





HKLM\SAM

SAM Database
(stores usernames and passwords)



Windows domain

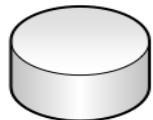
Subsystem (Lsass) – Windows Security mechanism – Attached by Sasser Worm which exploited a buffer overflow



Local Authority

- 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
```

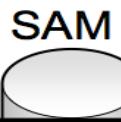
- bkhive - dumps the syskey bootkey from a Windows system hive.
- samdump2 - dumps Windows 2k/NT/XP/Vista password hashes.

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



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

Chapter 3: Hashing

Hashing Types.

Hashing Methods.

Salting.

Collisions.

LM and NTLM Hashes (Windows).

Hash Benchmarks.

Message Authentication Codes (MACs).

OTP/HOTP.

Prof Bill Buchanan OBE

<http://asecuritysite.com/crypto03>

<http://asecuritysite.com/encryption>

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

Slowing a hash

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:

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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.LbH5IlthZ1u0bAUdJwBvvccBshAvpFPiRn62EYeiKOaP8xh97aV4
UaNfVykRZhUy/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**

Chapter 3: Hashing

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Hash Benchmarks.

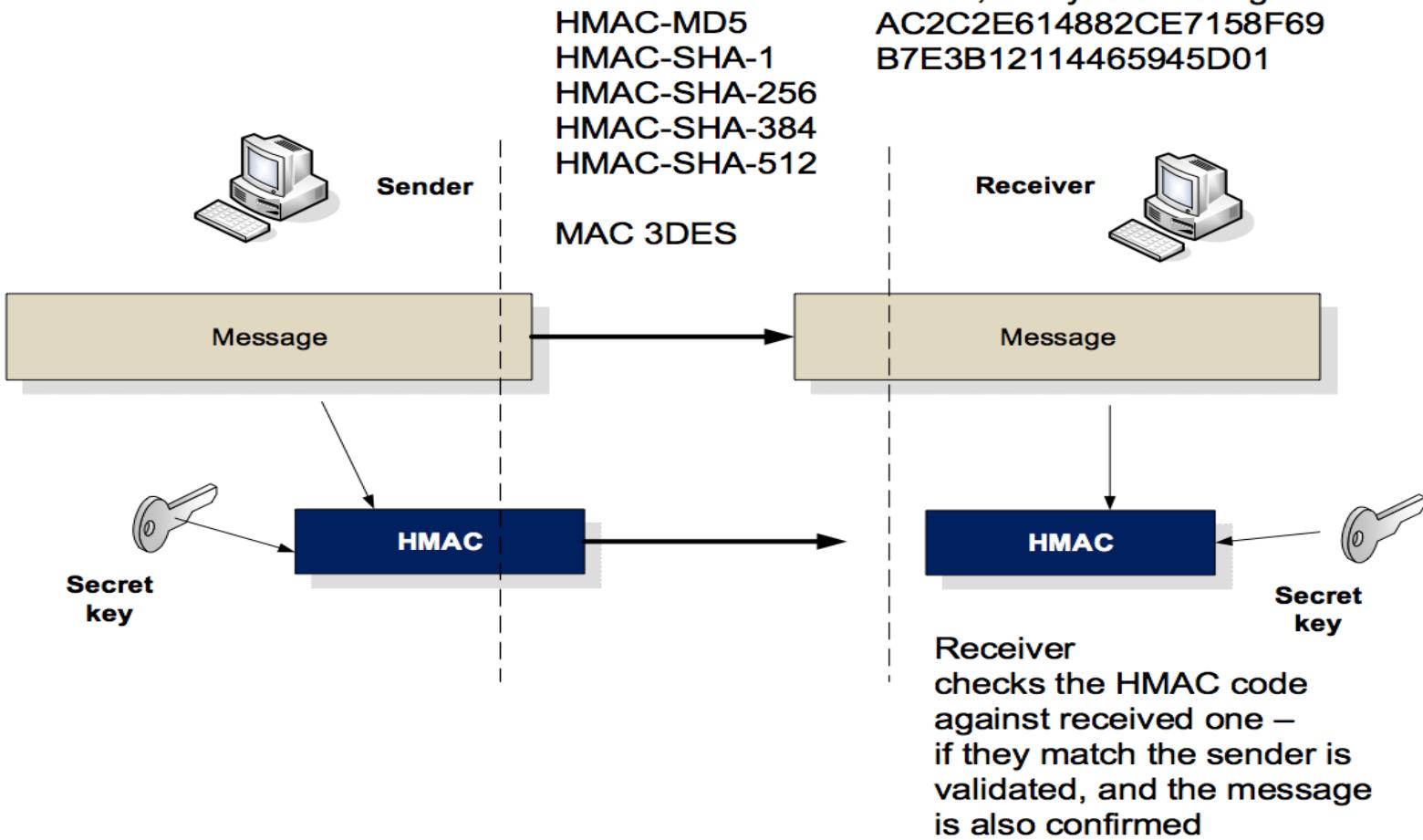
Message Authentication Codes (MACs).

OTP/HOTP.

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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

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Hashing

Hashcat

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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
```

jamcar
jarcar
Jimmycar
Jamiecar
jamcat
jarcat
jimmycat
jamiecat

dict1.txt

jam
jar
jimmy
jamie

dict2.txt

car
cat
call

Hashing

Brute Force (-a 3)

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<http://asecuritysite.com/encryption>



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
-4, --custom charset4=CS	-2 mycharset.hcchr : sets charset
?2 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?I?I
```

```
[keyspace: aaaaaaaaaa  
- zzzzzzzz]
```

Input.Mode: Mask (?I) [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 (?I?I) [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 (?I?I?I) [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 (?I?I?I?I) [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?l
[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]

Chapter 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	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

```
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
T0xlc-insert_00-99_1950-2050_toprules_0_F.rule
T0xlc-insert_space_and_special_0_F.rule
T0xlc-insert_top_100_passwords_1_G.rule
T0xlc.rule
T0xlcv1.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'
sa@ se3 sl1
```

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
```