# Practical Password Cracking

"wannabes worry about clock speed –
real computer companies worry about cooling"

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# Password Cracking

Bad hashes and why they’re bad

Good hashes and why they’re good

Protecting your users from themselves

Cracking tools and techniques

# Problem

We want to store the user password in a reasonably safe way.

That means, we can check it’s correct but if an attacker breaches the system, they can’t just recover the password.

The solution is a one-way function, of which a hash is one example.

Obviously we want a one-way function with low number of collisions.

# Problem II

Supposedly a “one way” function should be hard to reverse.

We can make lots of guesses and see whether the answer is the same.
Quick function => quick guesses.

Example MD5 hash: “secret” -> 5ebe2294ecd0e0f08eab7690d2a6ee69

Collisions are so unlikely they’re not worth worrying about.

This is nothing to do with hash tables.

# Properties of Hash Functions

Maps arbitrary data to fixed length – eg any input produces 256-bit output.

Don’t want predictable collisions.

In many branches of Computer Science, faster is better (not here).

Small change in input produces large change in output.

Should be difficult to reverse.

# Examples – MD5

MD5 is a quick hash function mapping anything to a 128-bit value.

Unsalted hash, so feasible to build a lookup table.

```
$ for w in `cat /usr/share/dict/words` ; echo –n $j ;
echo –n $j | md5sum ; done > lookup.txt
```

MD5 is very quick – so guessing is quick.

# Examples – Salted MD5

We don't want people to build a lookup table, so we chuck a large random number (salt) into each hash.

```
Stored hash := salt ++ md5(salt ++ password)
```

Makes a lookup table unfeasibly large.  Slows hashcat to O(n).

Example is md5/shaXcrypt off UNIX – also does many "rounds"

```
root:$6$lZd0wvLZ$zb4lOouYxxx:::
```

# Examples – Salted MD5

```
$ for i in `seq 1 9` ; do openssl passwd -1
password ; done
TYPE / SALT / HASHED PASSWORD
$1$ybI6m63a$o4AqUQ5AqRzX4n2b6BvcR0
$1$e97Z4W.V$x9sbekkkDpZWluzw4FrFJ.
$1$7dyr5uqa$1Rz6NnnZD1Uszcsv5OQuu0
$1$QhqY.UV4$luSEu.3mIx5ZaqehnNkNv.
$1$9l.Ernhe$BZmHo1AaTf1MEVin.kcTO/
$1$KMfvTerj$REG7pa24ZndxoMHMhYMOn1
$1$em5.2cPE$Pb6ud.Uxjikg4w4n9KeLZ1
$1$q824kpm2$MTyqG5Q7Si6o5T7uVs69Z/
$1$tXVYUqFs$RoyzeFdFcffkgEXsf.6hb.
```

# Non-solutions #1

Random junk appended/prepended.

Web app using plain MD5 “7JjUe83k” + password + “He03Kje2UekEkmPa3MeRbKntw8T9Ons5”.

^k^3^8

Attack:

```
[List.Rules:SillyAppJTR]
Az"He03Kje2UekEkmPa3MeRbKntw8T9Ons5"A0"7JjUe83k"
```

(for each candidate,
append "He03Kje2UekEkmPa3MeRbKntw8T9Ons5",
prepend "7JjUe83k“, then test)

# Non-solutions #1

```
$./john jamietest --wordlist=testdict.txt --format=raw-sha1 --rules=SillyAppJTR
7JjUe83kFOOBARHe03Kje2UekEkmPa3MeRbKntw8T9Ons5 (jamie)
```

Recovers the original. A bit slower but not really very useful in terms of protection.

**DO NOT ROLL YOUR OWN CRYPTO**

HMAC-MD5 is there if you need to introduce a secret.

# Non-solutions #2

Any of:

```
md5(sha1(password))
md5(md5(salt) + md5(password))
sha1(sha1(password))
sha1(str_rot13(password + salt))
```

(No computationally harder)

# Non-solutions #3

NTLM is based off MD4, unsalted -> so hashcat doesn't slow down as number of hashes increase. Same for all unsalted.

LM is even worse – upper case, chop into 2 x 7 char bits

There's no reason to prevent long passwords / special characters in web sites.

# NTLM Dump – DC

C:\>ntdsutil

ntdsutil: activate instance ntds

ntdsutil: ifm

ifm: create full c:\temp\ifm

ifm: quit

ntdsutil: quit

python impacket/examples/secretsdump.py -system SYSTEM -ntds ntds.dit LOCAL

# NTLM Dump – non-DC

reg save HKLM\system system.reg

reg save HKLM\security security.reg

reg save HKLM\sam sam.reg

python impacket/examples/secretsdump.py -system system.reg  -security security.reg -sam sam.reg LOCAL

# Other “Webby” Examples

https://hashcat.net/wiki/doku.php?id=example_hashes

mysql4.1/5: fcf7c1b8749cf99d88e5f34271d636178fb5d130

phpass, WordPress (MD5), Joomla (MD5):
$P$984478476IagS59wHZvyQMArzfx58u.

phpass, phpBB3 (MD5):
$H$984478476IagS59wHZvyQMArzfx58u.

JWT: eyJhbGciOiJIUzI1NiJ9.e..HRnrkiKmio2t3JqwL32guY

Django SHA-1: sha1$fe76b$02d5916…f044887f4b1abf9b013

Apache MD5: $apr1$71850310$gh9m4xcAn3MGxogwX/ztb.

# Getting hold of hashes – contrived ex.

$ python sqlmap.py -u "http://192.168.31.130/owaspbricks/content-2/index.php?user=harry" --dump

[14:15:50] [INFO] the back-end DBMS is MySQL

web server operating system: Linux Ubuntu 10.04 (Lucid Lynx)

web application technology: PHP 5.3.2, Apache 2.2.14

back-end DBMS: MySQL >= 5.0

**harry@getmantra.com | 5f4dcc3b5aa765d61d8327deb882cf99**

hashcat64.exe -m 0 5f4dcc3b5aa765d61d8327deb882cf99 dict\breachcompilation.txt -r ./rules/InsidePro-PasswordsPro.rule -O

**5f4dcc3b5aa765d61d8327deb882cf99:password**

# Actual Solutions – Better Hashing

PBKDF2 (RFC2898) – takes a number of “rounds” or iterations to make it costly. e.g. System.Cryptography.Rfc2898DeriveBytes

WPA2: PBKDF2(HMAC−SHA1, passphrase, ssid, 4096, 256)

Bcrypt, Scrypt, Argon (not many implementations yet)

# Actual Solutions – Better Hashing

Or http://php.net/manual/en/function.password-hash.php which is based on blowfish.

```
echo password_hash("rasmuslerdorf",
PASSWORD_DEFAULT);
```

```
$2y$10$.vGA1O9wmRjrwAVXD98HNOgsNpDczlqm3Jq
7KnEd1rVAGv3Fykk1a
```

# Requirements

Salt should be from CSPRNG (java SecureRandom, etc)

Salt should be long enough to make lookup table infeasible.

Hashing should be done server-side.

Hash should be computationally expensive (not one round of MD5)

# “Pepper”

Using an application secret as well as the salt – this is not stored with the hash. Might help, might not.

Doesn’t make it computationally harder, but you have to find the “pepper” first.

Most apps don’t do this; salted hashes should be OK without extra bits.

# Actual Solutions – Better Hashing

bcrypt and SHA512crypt take a similar approach so that making guesses is costly.

```
$ ./hashcat64.bin -m 1800 sha512.txt -a 3
?l?l?l?l --username
Hash.Type.....: sha512crypt, SHA512(Unix)
Speed.GPU.#1...:    38749 H/s

$6$9sirPrQg$keedQFIOyFrljxxxxiA2l7eksg1:toor
```

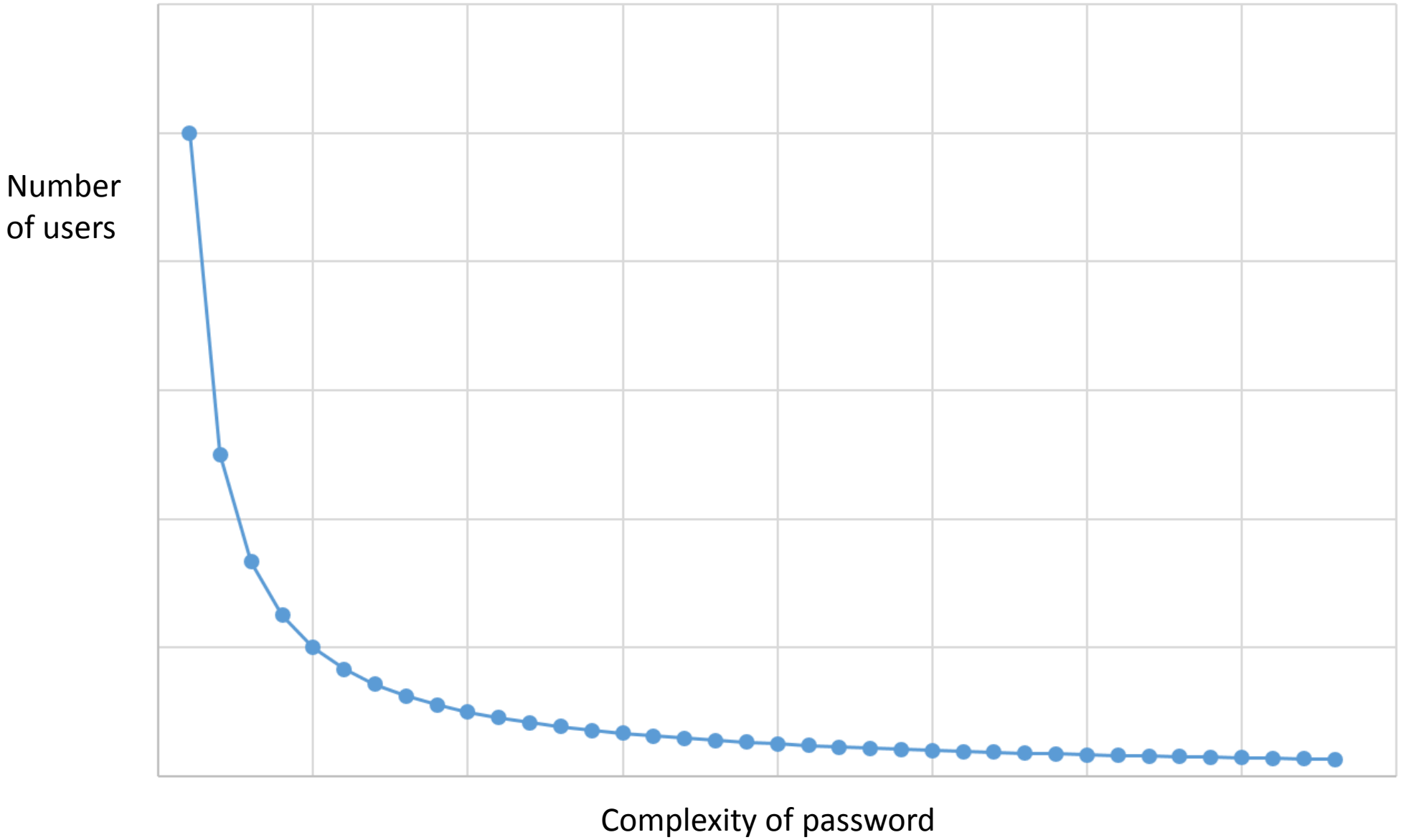
# Actual Solutions – Better Hashing

bcrypt and other algorithms use number of rounds or cost factor so you can make a hash computation take longer.

```
<?php
$options = [
    'cost' => 12,
];
echo password_hash("rasmuslerdorf", PASSWORD_BCRYPT, $opti
ons);
?>
```

```
$2y$12$QjSH496pcT5CEbzjD/vtVeH03tfHKFy36d4J0Ltp3lRtee9HDxY
3Ks
```

# Helping Your Users



# Helping Your Users

Try to enforce length/complexity.

But be aware, “Password123!” meets most length/complexity guidelines.

Check for dictionary words ?

Check for password stuffing (someone replaying passwords found in another breach) – e.g. rate limit, CAPTCHAs, account lockout etc.

Crack your own passwords and expire the compromised ones.

Check for breached passwords at set time – see below:

# Checking for Breached Passwords

```
$ curl
"https://haveibeenpwned.com/api/v2/pwnedpassword/"`echo
-n password | sha1sum | cut -f 1 -d' '` -D
HTTP/2 200    [ found in a breach ]
```

```
$ curl
"https://haveibeenpwned.com/api/v2/pwnedpassword/"`echo
-n psdfasdfasdgasdfgasdgasdgassword | sha1sum | cut -f
1 -d' '` -D -
HTTP/2 404    [ not found in breach ]
```

# Tools - Hashcat

Very good GPU cracker, but also does CPU / FPGA.

Get the binaries from the net, install the latest NVIDIA drivers and it should be ready.

On Linux, needs an X server running to overlock.

On Windows, use MSI Afterburner.

# Tools - Hashcat

Basic usage – mode –a0 is assumed if not specified – dict+rules

hashcat64.exe –m <hash type> hashlist.txt dictionary.txt rules.rule

Incremental:

Hashcat64.exe –m <hash type> -a3 hashlist.txt [ <mask> ]

Where ?l lower case ?u upper case ?d digit ?s special

Hashcat64.exe –m <hashtype> -a3 hashlist.txt ?u?l?l?l?l?l?d?s

# Tools - Hashcat

xorg.conf:

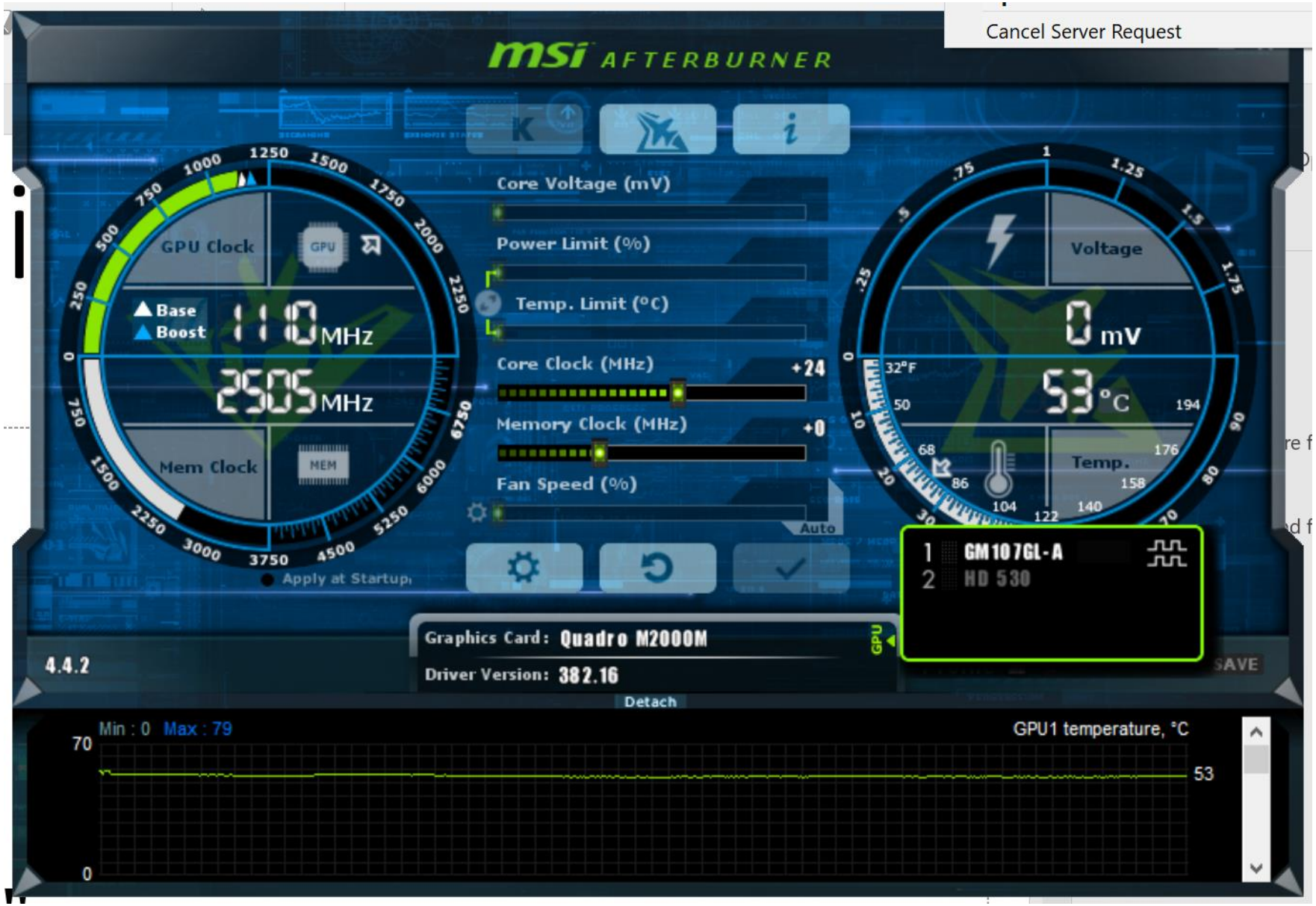
```
Section "Device"
    Identifier     "Device0"
    Driver         "nvidia"
    VendorName     "NVIDIA Corporation"
    BoardName      "GeForce GTX 1080 Ti"
    Option         "Coolbits" "13"
    Option         "RegistryDwords" "PowereMizerEnable=0x1; PowerMizerLevelAC=0x3; PerfLevelSrc=0x2222"
    Option "AllowEmptyInitialConfiguration" "true"
EndSection
```

# Tools – Hashcat overclocking

```
#!/bin/bash
export MEMCLOCK=200   # don’t blame me if this breaks your card
export GFXCLOCK=100   # and this. Works for Me™
export POWER=180      # power limit if you want one
export FAN=80         # trade off between temp and fan noise

XAUTHORITY=/run/user/131/gdm/Xauthority nvidia-settings \
-a [gpu:0]/GpuPowerMizerMode=1 \
-a [gpu:0]/GPUMemoryTransferRateOffset[3]=$MEMCLOCK \
-a [gpu:0]/GPUFanControlState=1 -a [fan:0]/GPUTargetFanSpeed=$FAN \
-a [gpu:0]/GPUGraphicsClockOffset[3]=$GFXCLOCK
nvidia-smi -pl $POWER
```

# Tools – Hashcat overclocking



# Tools – John the Ripper

JTR with all the bits and bobs, including UTF-8 support and GPUs.

```
$ git clone
https://github.com/magnumripper/JohnTheRipper.git
$ cd JohnTheRipper/src
$ ./configure
```

# on mine – vi Makefile and delete –DJOHN_AVX – for some reason

```
$  make install
```

Ex: john hashlist.txt --wordlist=/usr/share/dict/rules --rules=Extra

# Careful with non 7-bit ASCII

```
$ echo -n "möt" | md5sum
43191e523ba88fba40a6744b67b8f546
```

user:43191e523ba88fba40a6744b67b8f546

Crack this with cudaHashcat:  ?b?b?b?b

43191e523ba88fba40a6744b67b8f546:$HEX[6d**c3b6**74]

(depends on hashing scheme and pre-processing of input data)

| | | | |
|---|---|---|---|
| U+00F6 | ö | c3 b6 | LATIN SMALL LETTER O WITH DIAERESIS |

# Brief digression into UTF-8

Lower 7 bit ASCI chars stored as 1-byte – themselves

Top-bit set chars are stored as follows:

| Bits of code point | First code point | Last code point | Bytes in sequence | Byte 1 | Byte 2 |
|---|---|---|---|---|---|
| 7 | U+0000 | U+007F | 1 | 0xxxxxxx | |
| 11 | U+0080 | U+07FF | 2 | 110xxxxx | 10xxxxxx |

So 246 is 11110110 – stored as 1100 0011 10 110110 – which is C3 B6

# Careful with non 7-bit ASCII

passwd is “mötorhead”

`root:$6$lZd0wvLZ$zb4lOouYxxx:::`

**hashcat64 -m 1800 sha512.txt motordict.txt --username**

$6$lZd0wvLZ$zb4lOouYxxx0pgJ90:$HEX[6d**c3b6**746f7268656164]

motordict.txt : 6d **c3 b6** 74 6f 72 68 65 61 64

# Careful with non 7-bit ASCII

C:\> net user /add mot möt

Crack this with cudaHashcat:  ?b?b?b?b

9e8ad77244a880f7f1f10d0b46693fce:$HEX[6d**f6**74]

It seems ö is coded as \xf6 and not the two-byte UTF-8 encoding. (NTLM)

# Careful with non 7-bit ASCII

Compare LM/NTLM for the same account:

LM 759c0a91bxxx8728d99f4:xxxxxxx$HEX[4542505**09c**]

NTLM 7b0ee41fxxx6376a6aee3c:xxxxxxx$HEX[65627070**a3**]

xxxxxxxebpp£

Coded in two different ways – depending on LM/NTLM.

# NTLM: > Oxff with hashcat

Password is “Dŵr”. We need to use raw MD4.

# ./hashcat64.bin -m 900 dwr.txt -a3 -2 44 -1 00 --hex-charset ?2?1?b?b?b?1

5441d13...3fdb2e87:**$HEX[4400 7501 7200]**

0x0044 0x0175 0x0072

D ŵ r

# Custom char maps with hashcat

We want some non-ASCII chars, but not all possible byte values.

**$ perl -e '$i=32; while ($i<127) { print chr($i); $i++ }; $i=192; while ($i<255) { print chr($i); $i++ };' > win-ext.hcchr**

**hashcat64.exe -m 1000 bot.txt -a 3 -1 win-ext.hcchr ?1?1?1?1?1?1?1?1 --username --increment**

9883fd245e9aee55ad39d31752eb4a4d:$HEX[62f674]

# Oracle

Connect as a DBA to Oracle 11g with sqlplus

```
set heading off
set feedback off
set pagesize 1000
set linesize 100

SELECT name || ':' || SUBSTR(spare4,3) FROM sys.user$ WHERE spare4 IS NOT NULL ORDER BY name;
```

DBSNMP:A092440872DEAA491B0F8C16F4A2C9304928238617DA4741CBF3683A469C

# Oracle

```
DBSNMP:A092440872DEAA491B0F8C16F4A2C930492823 8617DA4741CBF3683A469C
```

For hashcat, first 40 / last 20 hex chars and separate:

```
A092440872DEAA491B0F8C16F4A2C93049282386:17DA4741CBF3683A469C
```

```
hashcat64.exe -m 112 oracle.txt -a 3
```

```
a092440872deaa491b0f8c16f4a2c93049282386:17da4741cbf3683a469c:dbsnmp
```

# Postgresql

```
select passwd, usename from pg_shadow
```

then remove "md5" from the front of passwd, and use passwd:username

Run with -m 12

# Targetted Attacks - hashcat

# swap char - leetify ( word -> w0rd )
so0
# append ‘!’
$!
# Toggle case of first letter
T0
# Enclose in quotes
^”$”
#prepend 123
^3^2^1

https://hashcat.net/wiki/doku.php?id=rule_based_attack

# Targetted Attacks - wordlists

Troy Hunt's list – unpublished ?

Breach compilation list https://gist.github.com/scottlinux/9a3b11257ac575e4f71de811322ce6b3

Crackstation https://crackstation.net/

Probabilistic password lists https://github.com/berzerk0/Probable-Wordlists

SecLists Passwords https://github.com/danielmiessler/SecLists/tree/master/Passwords

Your found passwords / --loopback option

Reference here: http://www.blacktraffic.co.uk/pw-dict-public/

# Targetted Attacks - hashcat

## Hybrid attack – dictionary and rules

```
hashcat64.exe -m 0 -a 6 642395xxxx4863eca rock.txt
-r rules/InsidePro-PasswordsPro.rule

642395cef47664a970441d3c94863eca:powerslave1984
```

## Hybrid attack – two word lists (cross-product)

```
hashcat64.exe -m 0 -a 1 642395xxxx4863eca rock.txt
found.txt
```

# Troy Hunt's List

https://www.troyhunt.com/introducing-306-million-freely-downloadable-pwned-passwords/

SHA1, so it's very quick. These, and 275 million others, were recovered on a Dell Precision 7510 / Quadro M2000M

tres metros sobre el cielo [ tr: three meters above the sky ]

john_a_ujo_firman@yahoo.co.id1 [ data issues? ]

S0metimearoundmidnight [leetified phrase]

qwertyuiopasdfghjklzxcvbnm12332 [ keyboard pattern ]

danthemanfrombristolland

ironwhoironfuckingmaiden [ personal favourite ]

# Greyarea – 1 x 1080 Ti

MD5..... : 32.8 GH/s (29.15ms)
SHA1... : 11.2 GH/s (83.96ms)
LM..... : 22.2 GH/s (84.00ms)
NTLM.. : 53.2 GH/s (17.69ms)

£1000 – basically bog standard components plus NVIDIA

# Troy Hunt's List - Density

```
#./hashcat-4.0.1/hashcat64.bin -O -m 100 ../uncracked-sha1.txt -a3 --increment-min=12 -i

* Device #1: pthread-AMD A6-9500 RADEON R5, 8 COMPUTE CORES 2C+6G, skipped.
* Device #2: GeForce GTX 1080 Ti, 2792/11170 MB allocatable, 28MCU

Hash.Type........: SHA1
Hash.Target......: ../uncracked-sha1.txt
Guess.Mask.......: ?1?2?2?2?2?2?3?3?3?3?d [12]
Guess.Charset....: -1 ?l?d?u, -2 ?l?d, -3 ?l?d*!$@_, -4 Undefined
Speed.Dev.#2.....:  9675.8 MH/s (11.57ms)  [ ~ 10 bn/s ]

07bbb269b7f9b7bf2a649dc5d2472ad9058f5889:hpkhhp999999
```

# Targetted Attacks - hashcat

Search a specific set of characters [a-z]{4-6}

```
hashcat64.exe -m 1800 -a 3 --increment-min=4 --
increment-max=6 --increment $6$mZVuffPMxxxFF0
?l?l?l?l?l?l
```

Hybrid attack – dictionary and mask

```
hashcat64.exe -m 0 -a 6 642395xxxx4863eca rock.txt
?d?d?d?d

642395cef47664a970441d3c94863eca:powerslave1984
```

# Targetted Attacks - hashcat

Hcmask files are series of ?d?l type clauses

```
hashcat64.exe -m 1800 -a 3
password.hcmask $6$mZVuffPMxxxFF0
```

Pp,@a4,s5$,o0,?1?2?3?3w?4rd?d?d?d?s

Tries [Pp][@a4][s5$][s5$][oO]rd?d?d?d?s
e.g. P455w0rd123!

# Hcmask files

Pp,@a4,s5$,o0,?1?2?3?3w?4rd?a?a

Pp,@a4,s5$,o0,?1?2?3?3W?4rd?a?a?a

Pp,@a4,s5$,o0,?1?2?3?3w?4rd?a?a?a

Pp,@a4,s5$,o0,?1?2?3?3W?4rd?a?a?a?a

Pp,@a4,s5$,o0,?1?2?3?3w?4rd?a?a?a?a

Pp,@a4,s5$,o0,?a?1?2?3?3W?4rd?a

…

$ hashcat-4.0.1\hashcat64.exe -m 1000 users.ntlm -a3 password.hccmask

# Tools

Hate_crack ( trusted sec ) https://github.com/trustedsec/hate_crack

(couldn't get this one to go on Windows – can't map NVIDIA cards through to Vmware workstation?)

Autohashcat https://gitlab.com/pentest/autohashcat

(saves some keystrokes by running common / sensible params, and tries to identify hash type for you)

Ramdisks can be your friend when preprocessing

# Too Long; Didn’t Read

Use PBKDF2, bcrypt, scrypt or Argon, hash server-side.

Try to stop users picking dumb passwords.

Try to stop brute-force attacks against the site. (e.g. present CAPTCHA after 3 failed logins per username)

If email is login, then worry about password stuffing. (e.g. present CAPTCHA after 3 failed logins per source IP)

# Questions