RSAConference2020
San Francisco | February 24 – 28 | Moscone Center

HUMAN ELEMENT

SESSION ID: HT-R07

Hunting Linux Malware for Fun and Flags

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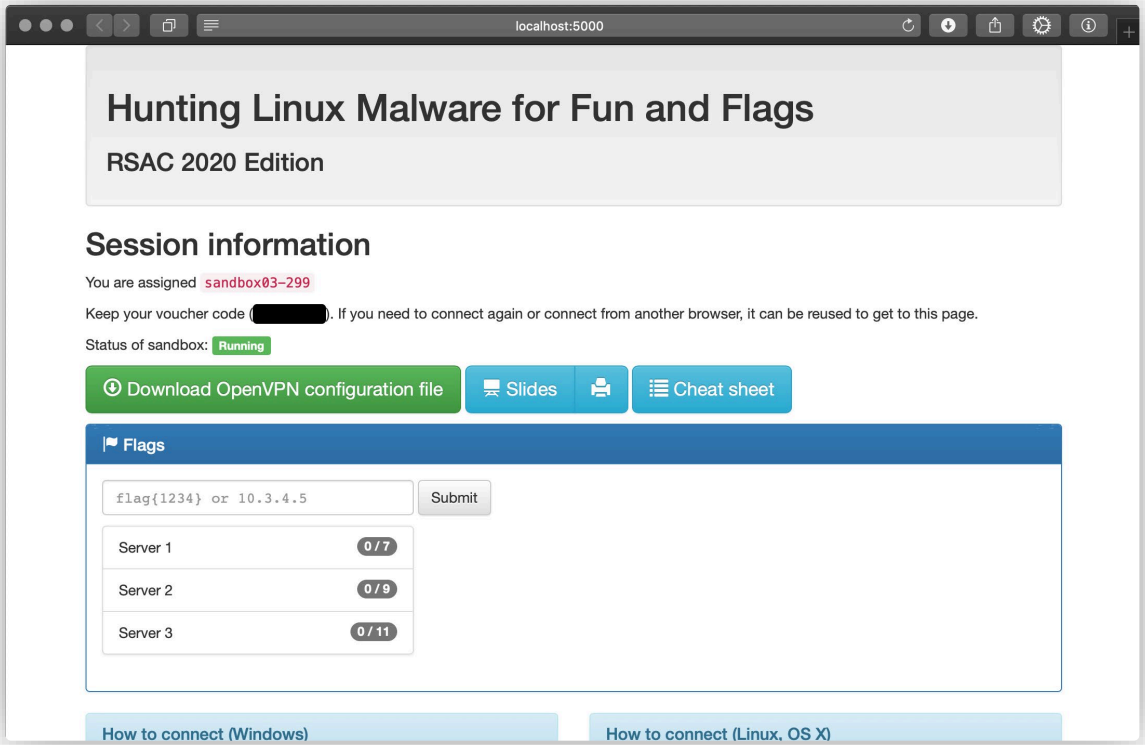
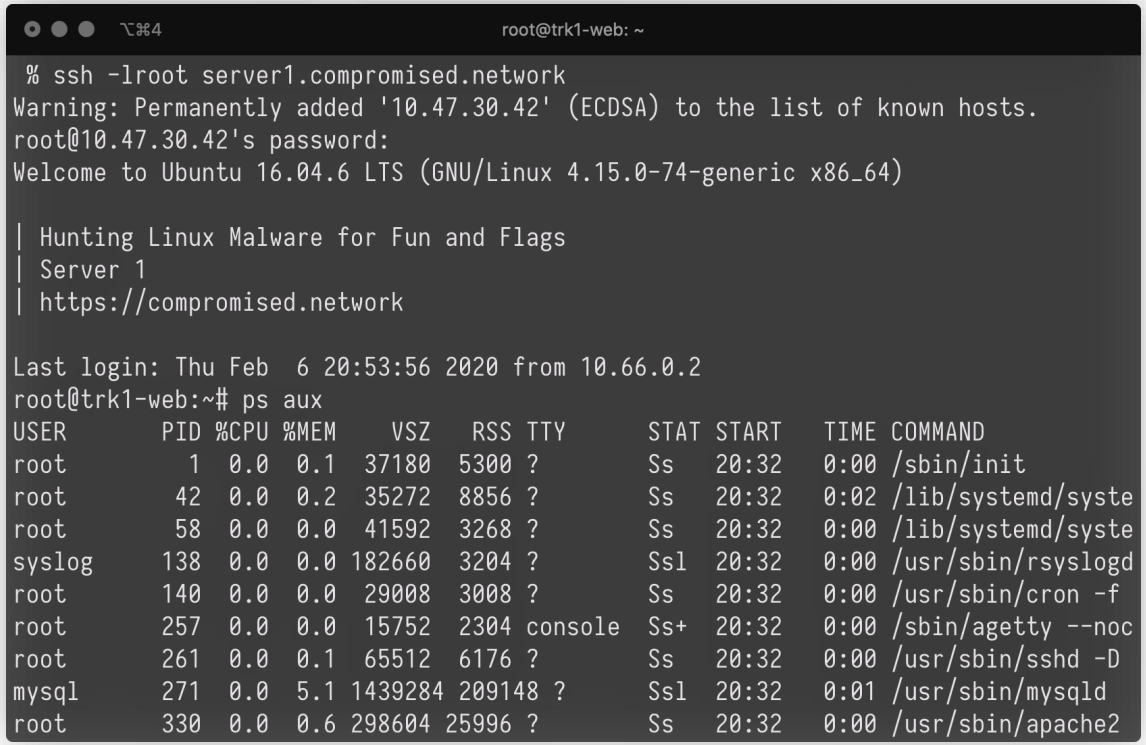
About this presentation

- This presentation is an introduction to Linux malware analysis and incident response
  - Using commonly available tools
- There is a whole sandbox available where you can test your skills
  - This is where the fun and flags are!
  - Real-world scenarios
    - Trainees are granted root access
    - Use real (defused) malware
    - Real network interactions

Workshop overview





You only need a web browser, an OpenVPN client and an SSH client to start hunting

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Why this presentation and workshop?


Dissecting Linux/Moose
The Analysis of a Linux Router-based Worm Hungry for Social Networks
Olivier Bilodeau & Thomas Dupuy
May 2015
ESET ENJOY SAFER TECHNOLOGY
OPERATION WINDIGO
The vivisection of a large Linux server-side credential stealing malware campaign
ESET ENJOY SAFER TECHNOLOGY
Unboxing Linux/Mumblehard
Muttering spam from your servers
Marc-Etienne M.Léveillé
April 2015
ESET Research White papers // December 2018
Romain Dumont, Marc-Etienne M.Léveillé, Hugo Porcher
THE DARK SIDE OF THE FORSSHE
A landscape of OpenSSH backdoors

Why malware on Linux servers?

- Servers have a lot of bandwidth
- Servers have a high uptime
- As a result, they make good targets for
  - Sending spam
  - Reverse proxy
  - Open proxy
  - Traffic redirection
  - Hosting services (e.g. DNS) and web pages (e.g. phishing)

Why care?

- Bad IP reputation
  - Prevents sending legitimate email messages
- Slows down legitimate software and services
- Servers often host the most critical data in the enterprise[1]
- Risk of data exfiltration
  - Passwords
  - E-mail addresses
  - Credit card numbers
  - Etc.

[1] Jon Amato, Mario de Boer, *Gartner Technical Professional Advice – Solution Criteria for Endpoint Protection Platforms*, 2020-01-09

Why understand them?

- If you don’t find out how you were compromised, it might come back by the same door
- If you don’t clean everything, it might come back using another backdoor
- Understand what is at risk
- Explain the behavior of very sneaky malware

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Incident response artifacts

Artifacts

- Filesystem
  - Logs
  - Malware persistence (if any)
- Memory
  - Process memory and state
  - Kernel memory
- Network
  - Configuration
  - Packet capture (in-band and out-of-band)

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Filesystem

Common file metadata

- Name
- Size
- Type
  - Regular file
  - Directory
  - Symbolic link
  - Special (device)
- Owner
  - User
  - Group
- Access rights
  - Read, write and execute
  - Owner, group and others
- Timestamps
  - Access
  - Last modification
  - Last metadata modification
  - *Creation date*

Basic filesystem

- Finding new files
- `ls -alt | head`
  - List files that were recently modified in the current directory

```
# ls -lat | head
total 44
-rw------- 1 root root 4322 Oct 29 11:21 .bash_history
drwx------ 1 root root   22 Oct 28 23:52 .aptitude
-rw------- 1 root root   81 Oct 28 22:44 .lesshst
drwx------ 1 root root  240 Oct 28 21:59 .
-rw------- 1 root root 5726 Oct 28 21:59 .viminfo
```

Basic filesystem

- `stat $FILE`
  - Full file details


```
# stat .viminfo
  File: '.viminfo'
  Size: 5726            Blocks: 16         IO Block: 4096
regular file
Device: 11h/17d Inode: 63052       Links: 1
Access: (0600/-rw-------)  Uid: (0/root)   Gid: (0/root)
Access: 2015-10-28 21:59:36.283368614 -0400
Modify: 2015-10-28 21:59:36.283368614 -0400
Change: 2015-10-28 21:59:36.283368614 -0400
 Birth: -
```

Basic filesystem

- `find / -newermt 2019-10-28`
  - Find files that were modified after October 28th
  - Based on the same metadata that can be tampered with

```
# find /home/james -newermt 2020-02-01
/home/james
/home/james/wwwroot/index.php
/home/james/wwwroot/static/css/plugins/isimg/css.php
/home/james/.lesshst
/home/james/.bash_history
```

Basic filesystem

- `file $FILE`
  - Identify file type

```
# file .viminfo
ELF 64-bit LSB executable, x86-64, version 1 (SYSV),
dynamically linked, interpreter /lib64/ld-linux-x86-
64.so.2, for GNU/Linux 2.6.32, stripped
```

Package integrity

- `debsums`
  - Dpkg-based distributions (Debian, Ubuntu)
- `rpm -Va`
  - RPM-based distributions (RHEL, CentOS, Fedora)

Malicious or not?

```
# rpm --verify keyutils-libs
(no error)
# rpm -qi keyutils-libs
Name        : keyutils-libs                Relocations: (not relocatable)
Version     : 1.4                               Vendor: CentOS
Release     : 4.el6                      Build Date: Fri 22 Jun 2012 02:20:38
Install Date: Mon 27 Jan 2014 06:08:43 Build Host: c6b10.bsys.dev.centos.org
Group       : System Environment/Base  Source RPM: keyutils-1.4-
4.el6.src.rpm
Size        : 59320                           License: GPLv2+ and LGPLv2+
Signature   : RSA/SHA1, Sun 24 Jun 2012 06:18:51, Key ID 21efc4bf71fbfe7b
URL         : http://people.redhat.com/~dhowells/keyutils/
Summary     : Key utilities library
Description :
This package provides a wrapper library for the key management facility
system
calls.
```

Logs

- `/var/log`
  - `auth.log`
  - HTTP logs
  - `messages`, `syslog`, etc.
- systemd's `journalctl`
- auditd log

Using auditd

- *The Linux audit framework provides an auditing system that reliably collects information about any security-relevant (or non-security-relevant) event on a system.*
- Part of the kernel
  - Must be enabled during kernel compilation or have a loadable kernel module
  - Enabled on most distributions
- Logs system calls and other types of events
- Logs can be sent over the network

Using auditd

- `auditctl`: Define what you want to log
- `ausearch`: Search in log files
  - Logs are text files, so `grep` and other tools works fine too for this task

```
# auditctl -a exit,always -S execve
[...]
# ausearch -m EXECVE
type=EXECVE msg=audit(1373838239.340:4474200): argc=4
a0="rm" a1="-f" a2="-f" a3="/tmp/q"
type=EXECVE msg=audit(1373838239.341:4474201): argc=4
a0="touch" a1="-r" a2="/etc/ssh/sshd_config"
a3="/etc/ssh/ssh_config"
```

Offline filesystem

- If you don't have access to the live system but have an image of the partition.

- Capture: `dd if=/dev/sda3 of=$IMAGE_FILE`
  - Works over SSH too!
- Browse: `mount -o loop,ro $IMAGE_FILE /mnt`

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System memory

Analyzing a live process

- Identify running processes
  - `ps auxw`
  - `top`, `htop`

```
# ps auxw
root       7673  0.0  0.0  55164  5292 ?   Ss  Oct19  0:01 /usr/sbin/sshd -D
root       7718  0.0  0.3 200676 127160 ?  Ss  Oct21  2:29 /lib/systemd/systemd
root       7948  0.0  0.0 248844 25032 ?   Ss  Oct20  0:18 /usr/sbin/apache2 -k
webuser    7953  0.0  0.0 141732  4188 ?   S   Oct20  0:06 /usr/sbin/apache2 -k
webuser    5023  6.2  0.0  39764  8936 ?   Ss  Oct28 66:08 /tmp/.ICE-A5BF7
[...]
```

Analyzing a live process

- List open files and network streams
  - `lsof -p $PID`

```
sshd    3642    sshd  cwd       DIR                0,17       166         256 /
sshd    3642    sshd  rtd       DIR                0,17       166         256 /
sshd    3642    sshd  txt       REG                0,17    787080        2231 /usr/sbi…
sshd    3642    sshd  mem       REG                0,16                 36265 /lib/x86…
sshd    3642    sshd  mem       REG                0,16                 36267 /lib/x86…
[...]
sshd    3642    sshd    2u      CHR                 1,3       0t0        1028 /dev/null
sshd    3642    sshd    3u     IPv4           146293912       0t0         TCP
                                158.69.117.51:ssh->182.100.67.59:41000 (ESTABLISHED)
sshd    3642    sshd    4u     unix 0xffff88072c5cbc00       0t0  146289562 socket
```

procfs

- *procfs* provides a lot of useful details
- Mounted at `/proc`
- Contains one directory per process at `/proc/$PID`

```
$ ls /proc/3537
attr             cwd       map_files   oom_adj        schedstat     syscall
autogroup        environ   maps        oom_score      sessionid     task
auxv             exe       mem         oom_score_adj  setgroups     timers
cgroup           fd        mountinfo   pagemap        smaps         timerslack_ns
clear_refs       fdinfo    mounts      patch_state    smaps_rollup  uid_map
cmdline          gid_map   mountstats  personality    stack         wchan
comm             io        net         projid_map     stat
coredump_filter  limits    ns          root           statm
cpuset           loginuid  numa_maps   sched          status
```

procfs exe magic link

- Find the path of the executed file
  - `ls -l /proc/$PID/exe`
- Retrieve the executable file **even if it was deleted**
  - `cp /proc/$PID/exe malware.elf`

```
# ps aux | grep 25465
web   25465   6.6 0.0   39764   936 ? Ss Oct29 157:52 crond
# ls -l /proc/25465/exe
lrwxrwxrwx 1 web www-data 0 Oct 29 04:09
/proc/25465/exe -> /tmp/.ICE-684c
```

procfs environ

- `/proc/$PID/environ` contains the environment variables of a process separated by null bytes

```
# tr '\0' '\n' < /proc/1179/environ
MAIL_CONFIG=/etc/postfix
MAIL_LOGTAG=postfix
LANG=C
SSH_CONNECTION=10.0.2.2 58505 10.0.2.15 22
GENERATION=1654316
```

Process stalling

- Stop a process without destroying its resources.
  - `kill -SIGSTOP $PID`

- Resume a process previously stopped with `SIGSTOP`
  - `kill -SIGCONT $PID`

Process memory dump

- Acquisition
  - `gcore $PID` **and** `cp /proc/$PID/exe malware.elf`
- Alternative acquisition tool
  - `memfetch` from `http://lcamtuf.coredump.cx`
- Analysis (simple)
  - `strings`
- Analysis (in-depth)
  - `gdb malware.elf $PID.core`

Kernel memory

- Acquisition
  - VM snapshot
  - LiME (Linux Memory Extractor)
- Analysis
  - Volatility Framework
- Only helpful if kernel is compromised via malicious kernel module (rootkit)

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Network

Network configuration

- Dump iptables rules
  - `iptables-save`
  - `ip6tables-save`

```
# iptables-save
[...]
-A POSTROUTING -s 0.0.0.0/0 --dport 8080 -o eth0 -j
SNAT --to-source 89.4.205.9
-A PREROUTING -i eth0 -p tcp -m tcp --dport 8080 -j
DNAT --to-destination 58.48.66.108:80
```

Network capture

- Acquisition
  - `tcpdump -i eth0 -s 0 -w capture.pcap`
- Analysis
  - `tshark -r capture.pcap`
  - Wireshark
  - `bro -r capture.pcap`

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Malware analysis

Two approaches

- Script-based malware
  - PHP
  - Perl
  - Python
- Compiled malware
  - ELF executables

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Script-based malware

Script-based malware

- Can be obfuscated
  - Removed whitespace
  - Variables renamed

```
<?php function
PXN1YnN0ci($a,$b){$c=array(139,164,40,72);if($b==62)
{$d=substr($a,$c[0]+$c[1],$c[2]);}elseif($b==12){$d=sub
str($a,$c[0],$c[1]);
}elseif($b=92){$d=trim(substr($a,$c[0]+$c[1]+$c[2]));}r
eturn$d;} ?>
```

Reversing script-based malware

- Most programming languages have a tool to *tidy* code
  - Perl -> `perltidy`
  - Python -> PythonTidy
  - PHP -> `php-cs-fixer`
  - Etc.
- Rename variables with search and replace

Script-based malware

- Strings and literals can be packed
  - `43 ^ 0x20 + 30`
  - `\x42\x56`

```
$stg="ba"."\x73\x65"."64_d".strrev("edo\x63e");eval($st
g("JHNlcnZlcl91c2VyX2FnZW
JWRVJbJ0hUVFBfVVNFUl9BR0VOVCddOw0KJHNlcnZlcl9yZWZlcmVyI
CAgICAgID0gQCRfU0VSVkVSWy
[...]
dIVFRQX1JFRkVSRVInXTsNCiRzZXJ2ZXJfZm9yd2FyZGVkX2ZvciA9I
EAkX1N")
```

Reversing script-based malware

- **Always work in an isolated environment**
- Use interactive prompts to evaluate parts of the code
  - Perl -> `perl -de1`
  - Python -> `ipython`
  - PHP -> `php -a`
  - Etc.
- Replace `eval` with `print`

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Compiled malware

Compiled malware

- ELF executable in the native architecture of the system
- More challenging to understand
- Can also be packed

Reverse engineering compiled malware

- Statically
  - `strings`
  - radare2
  - IDA Pro ($)

Reverse engineering compiled malware

- Dynamically
  - `strace`
  - `ltrace` for dynamically linked binaries
  - `gdb`, or any other debugger you like
  - `gcore`
- **Always work in an isolated environment when playing with malware**

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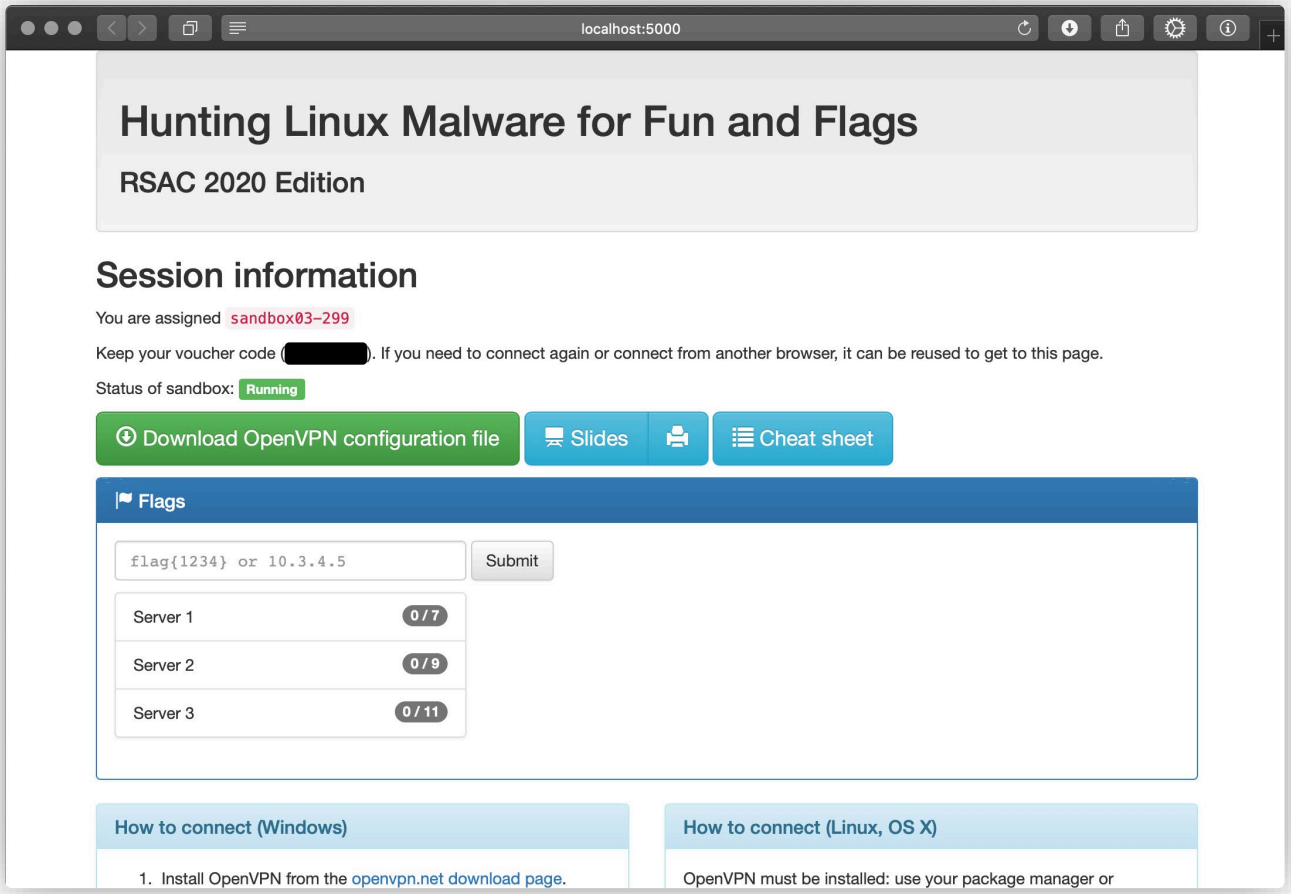
Apply what we've learned

This week you should

- Get hands-on experience using the Hunting Linux Malware for Fun and Flags workshop

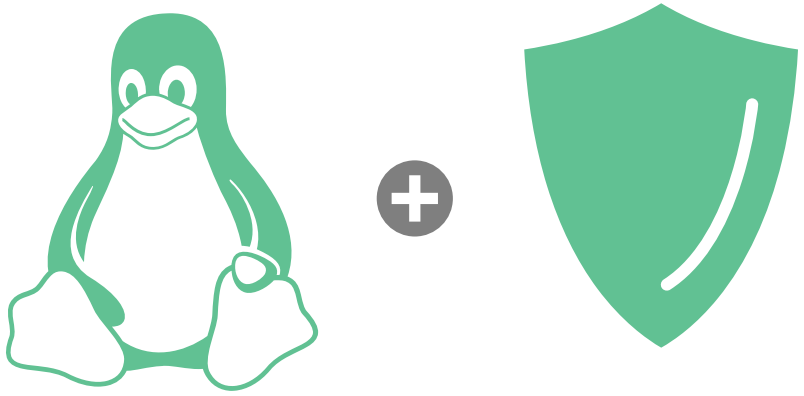


Within three months you should

- Identify your Linux assets
  - Both on-premise and rented
  - Who has access to them?
  - From where are they reachable?
- Read articles and papers about Linux malware

Next you should

- Enable 2FA on all Linux servers
- Consider deploying security product (EPP and/or EDR) on your Linux servers[1]
  - *Malware and attacks impact systems, whether they are workstations, servers, mobile devices or assets in the cloud*



[1] Jon Amato, Mario de Boer, *Gartner Technical Professional Advice – Solution Criteria for Endpoint Protection Platforms*, 2020-01-09

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