Playing with Qubes Networking for Fun and Profit

17-21 minutes

Today, I would like to showcase some of the cool things that one can do with the Qubes networking infrastructure, specifically with all the new features that have been brought by the just released Qubes Beta 2. This will cover the use of multiple Net VMs for creating isolated networks, the use of a Proxy VM for creating a transparent Tor Proxy VM, as well as demonstration of how to use a Standalone VM with manually assigned devices, to create a “WiFi pen-testing” VM, which surely represents the “for fun” aspect of this post.

The virtual interfaces in client VMs are called ethX, and are provided by the xen_netfront kernel module, and the corresponding interfaces in the Net/Proxy VM are called vifX.Y and are created by the xen_netback module.

Each Net and Proxy VM implements NAT, specifically masquerading, for all the connected VMs. Additionally to this SNAT, each Net or Proxy VM provides also DNAT redirection for DNS resolutions, so that each VM behind a Proxy or Net VM thinks that it uses a DNS in the Net/Proxy VM, but in fact all the DNS request are DNAT-ed by all the Proxy and Net VMs down the original DNS that is provided to the final Net VM. This smart trick allows us to avoid running a DNS caching server in Proxy/Net VMs.

So, by default there is one Net VM, called 'netvm', that is automatically assigned all the networking devices in the system. There is also one Proxy VM, called 'firewallvm' that is directly connected to the default Net VM, and which provides networking to all other VMs in the system. This Proxy VM is used for firewall rules enforcement. Each such service VM consumes 200MB of RAM by default.

In some scenarios the machine might be connected to two or more physically separate networks (e.g. safe corporate intranet, reachable via ethernet cable on the user's desk, and the unsafe and evil Internet, reachable via WiFi card).

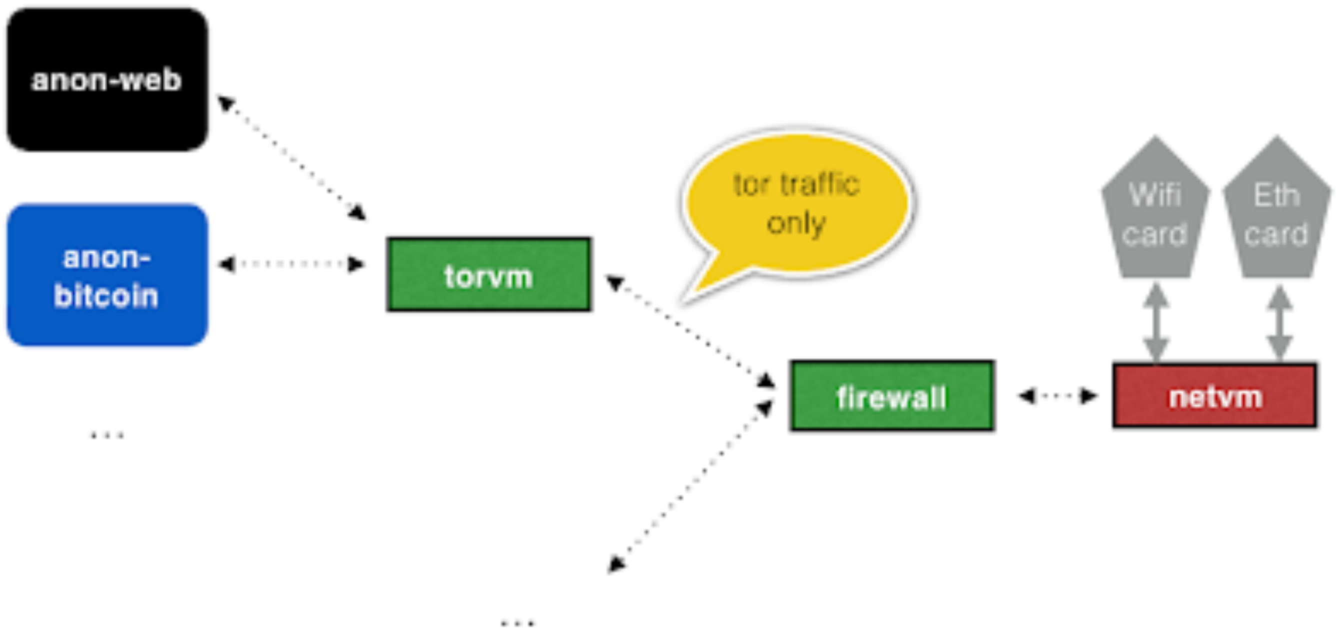
It is easy to use more than one Net VMs in Qubes, and assign different networking devices to different Net VMs, and also decide which VMs are connected to which Net VMs. The diagram below presents an exemplary such setup:

And now, for any other VM, just set the appropriate Net VM (either firewallvm1 or firewallvm2, or 'none), to get it assigned to either of the isolated networks, e.g.:

...

This configuration provides very strong isolation between the VMs belonging to network #1, and the VMs belonging to network #2. Specifically, this becomes significant if we fear about potential remotely exploitable bugs in the client code of the core TCP/IP stack (in this case the Net VM could potentially compromise all the connected VMs -- but the same problem applies to even physically separated machines that use the same network).

Let's now play a bit with Proxy VMs and see how we can use it to create a simple Tor proxy VM. Such a VM would provide anonymized networking to all its clients, so would allow to easily create VMs for anonymous Internet access. The simple setup we would like to prepare is depicted on the figure below:



The 'torvm' Proxy VM provides anonymized networking to 'anon-web' and 'anon-bitcoin' VMs. All the traffic generated by the VMs behind 'torvm' is either fed into the Tor network, or discarded. Furthermore, any app running in those VMs is not able to read any global system identifiers, such as the external IP, external MAC address, etc.

Our Tor proxy would forward only the Tor traffic, so we don't have to fear about some Tor-not-aware applications, or even intentionally malicious ones to compromise the privacy of our connection. This is because such applications have no way to generate traffic to the outside world without going through our Tor proxy (unless they could exploit a hypothetical vulnerability in the Tor process running in the Tor VM). Also, the applications running in any VM behind the Tor proxy are not able to determine any globally identifiable IDs, such as the user's external IP address, the real MAC address used by real NICs, etc.

Interestingly just after writing the above paragraph, I discovered that one of our xenstore keys had wrong permissions and, as a result, any VM could read it and get to know the actual external IP (the key is used by a Net VM to communicate the external IP configuration to the connected Proxy VMs, so they could know when to update the firewall configuration). The fix for this problem is here, and the update (qubes-core-dom0-1.6.32) is now available for Dom0 (just do qvm-dom0-update to get it installed).

So, this represents a rather strong setup for use with Tor. Let's now have a look at how to practically create such a configuration, step by step.

First, let's create the VM that will become our Tor proxy:

```
[dom0]$ qvm-create torvm --proxy --label green
```

This will create a Proxy VM named 'torvm', based on the default template. We will need to now start the template VM and install the Tor client there:

```
[dom0]$ qvm-run -a fedora-14-x64 gnome-terminal
```

Alternatively, if we didn't trust the Tor client rpm package to be non-malicious, specifically for its installation scripts to be non malicious, we could have based this on a different template, e.g. one used for less trusted VMs, or we could installed the Tor client in /usr/local, that is backed by the VM's private storage, but this would require compiling Tor from sources.

Now, in the just started template VM, lets install the Tor client and (optionally) the Vidalia graphical frontend:

```
[fedora-14-x64]$ sudo yum install tor vidalia
```

And then power off the template VM. Now, every VM based on this template, started after the template shutdown, will also see the Tor binary in its filesystem.

Let's now configure our torvm to properly start Tor proxying at boot:

```
[dom0]$ qvm-run -a torvm gnome-terminal
```

Now, we will create the following script for starting up the Tor transparent proxy and setting up traffic redirection using iptables:

```
[torvm]$ vim /rw/config/start_tor_proxy.sh
```

...and now paste the following into this file:

```
#!/bin/sh

killall tor

QUBES_IP=$(xenstore-read qubes_ip)

TOR_TRANS_PORT=9040

if [ X$QUBES_IP == X ]; then

echo "Error getting QUBES IP!"

echo "Not starting Tor, but setting the traffic redirection anyway to prevent leaks."

QUBES_IP="127.0.0.1"

else

/usr/bin/tor \

--SocksPort 0 \

--TransListenAddress $QUBES_IP --TransPort $TOR_TRANS_PORT \

--DNSListenAddress $QUBES_IP --DNSPort 53 \

--RunAsDaemon 1 --ControlPort 9051 \

|| echo "Error starting Tor!"

fi

echo “0” > /proc/sys/net/ipv4/ip_forward

/sbin/iptables -t nat -F
```

```
/sbin/iptables -t nat -A PREROUTING -i vif+ -p udp --dport 53 -j DNAT --to-destination $QUBES_IP:53

/sbin/iptables -t nat -A PREROUTING -i vif+ -p tcp -j DNAT --to-destination $QUBES_IP:$TOR_TRANS_PORT

/sbin/iptables -I INPUT 1 -i vif+ -p udp --dport 53 -j ACCEPT

/sbin/iptables -I INPUT 2 -i vif+ -p tcp --dport 9040 -j ACCEPT

/sbin/iptables -F FORWARD



echo “1” > /proc/sys/net/ipv4/ip_forward
```

Except for the “QUBES_IP=$(xenstore-read qubes_ip)” line that reads the torvm's IP address, there is nothing Qubes-specific in the above listing. It's just a standard way of setting up transparent Tor proxy.

It is important that this file be located in the /rw directory, as this directory is backed by the VM's private storage and will survive VM reboots. The VM's root file-system is read-only and all the changes to it are lost on VM shutdown (VM gets an illusion of the root fs being writeable thanks to Copy-On-Write mechanism, but the actual COW backing device is cleared upon each VM shutdown).

We should also modify the /rw/config/rc.local script, to ensure that our Tor proxy is automatically started -- just paste the following into this script:

```
#!/bin/sh

# Uncomment this if you would like to use a custom torrc file:

#rm -f /rw/config/log

#ln -sf /rw/config/torrc /etc/tor/torrc

chkconfig qubes_netwatcher off

chkconfig qubes_firewall off

/rw/config/start_tor_proxy.sh
```

Finally we should also provide a script that would restart our proxy in case the user dynamically switched the NetVM, which would result in the completely different routing. This could be done by creating a script with predefined name qubes_ip_change_hook within /rw/config/ directory:

```
#!/bin/sh

/rw/config/start_tor_proxy.sh
```

Make sure that all the scripts are executable (chmod +x). And that's all. Now, shutdown the torvm:

```
[dom0]$ qvm-run --shutdown --wait torvm
```

From now on, every time you start the torvm (or when Qubes starts it in response to start of some other VM that uses torvm as its Net VM), the Tor transparent proxy should be automatically started.

Let's test this by creating a VM that would be using the just created Tor proxy:

```
[dom0]$ qvm-create anon-web --label black
```

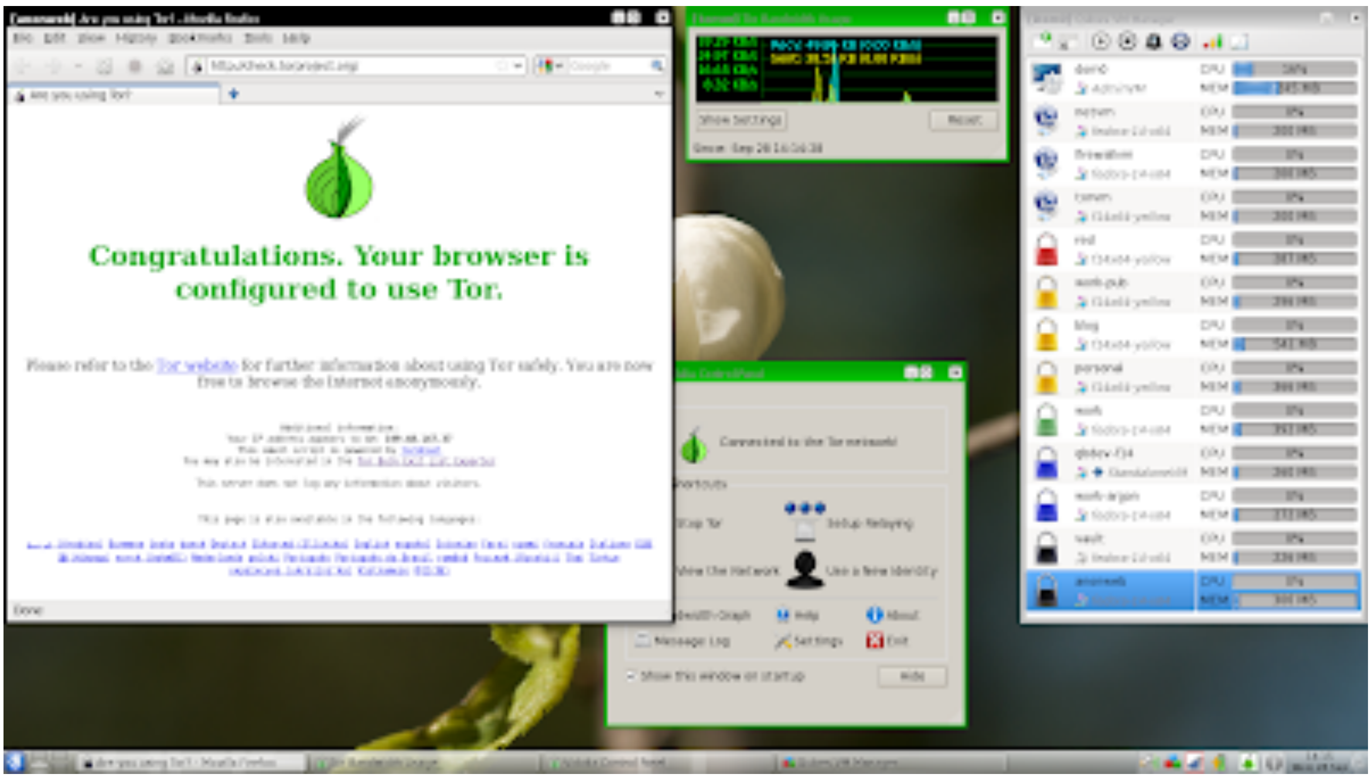
```
[dom0]$ qvm-prefs -s anon-web netvm torvm
```

Now, every time you start the anon-web VM (e.g. by clicking on the Web browser icon in the anon-web's start menu), Qubes will also ensure that torvm is up and running, and this in turn would configure all the Tor proxying for this VM.

Fo additional control one might want to use Vidalia, the graphical front end for Tor (this should be installed within the template VM that has been used for torvm). We could easily start Vidalia by just typing:

```
[dom0]$ qvm-run -a torvm vidalia
```

We should however make sure to disable "Start the Tor software when vidalia starts" option in Settings/General in Vidalia. Otherwise, Vidalia might kill your original Tor (that has transparent proxy open) and start own without transparent proxy enabled.



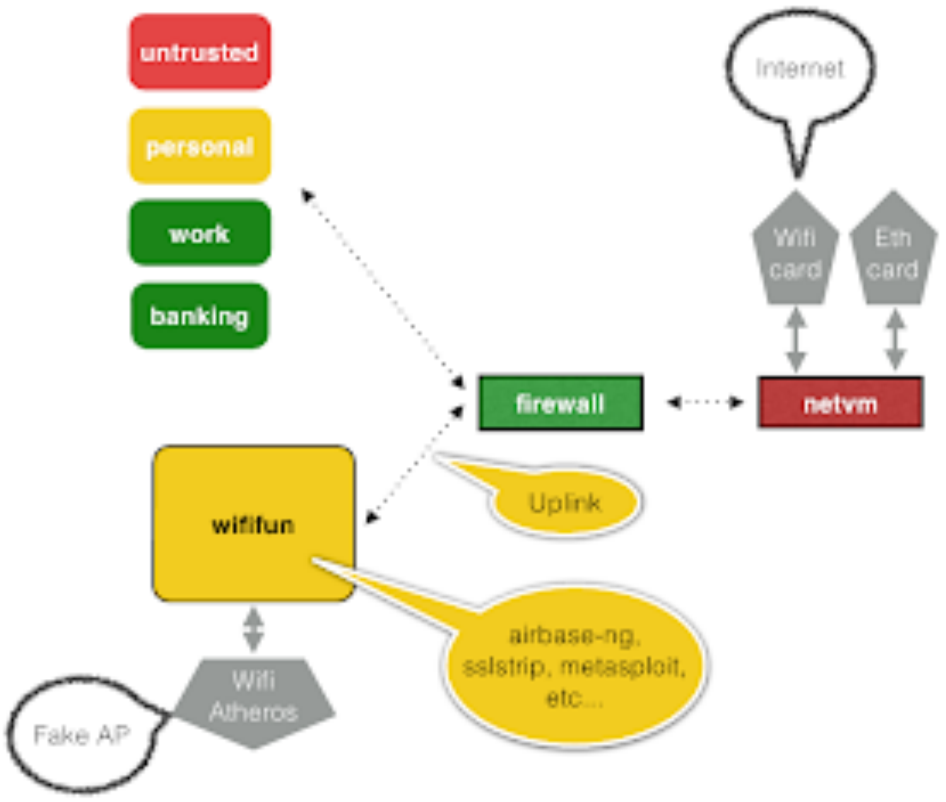
Congratulations. Your browser is configured to use Tor.

The web browser runs in the 'anon-web' VM that uses 'torvm' for networking access, and thus all the traffic generated by 'anon-web' is routed through the Tor network, or discarded if it's a different traffic than TCP or DNS.

Of course one case easily create more VMs that would be using torvm as their Net VM, as so would have anonymized network access. The beauty of this solution is that in case one of my anonymized VM gets compromised, others do not. Plus, the already mentioned benefit, that no matter whether apps in those VMs are buggy, or even intentionally malicious, they would not be able to leak out the user's external IP address.

Creating a WiFi pen-testing VM

Finally let's have some fun and create a WiFi pen-testing VM. The desired config is depicted below:



Because we would like to use all sorts of

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pen-testing security software in this VM, it would make sense to create it as a *Standalone VM*, which means that it would get its own copy of the whole file-system (as opposed to just the home directory, /rw and /usr/local, as it is the case with regular Qubes VMs). This would ease the installation of all the extra software we would need there, and also ensure that even if the install/build scripts were malicious, the damages would be contained only to this very VM and nothing else. Also, for some reason the standard Linux WiFi stack and drivers still don't support injection on (all?) most of the WiFi cards out of the box, so we would need to patch the actual kernel drivers -- yet another reason to use a Standalone VM in this case.

So, let's create the VM first, and assign a WiFi card to it:

[dom0]$ qvm-create wififun --standalone --label yellow

[dom0]$ qvm-prefs -s wififun memory 800 # ensure at least this mem at startup

[dom0]$ qvm-prefs -s wififun kernel none # use own copy of kernel and modules

[dom0]$ qvm-pci -a wififun

You can easily find the BDF address of any device using the lspci command in Dom0 -- this would be something like e.g. “02:00.0”. You should make sure that this WiFi card is not used by any other VM, specifically by your default Net VM (called 'netvm' in a standard Qubes installation). Ideally you could just use a dedicated Express Card-based WiFi card, leaving the built in WiFi assigned to your default Net VM.

Because it's a Standalone VM, Qubes will make a copy of the whole root filesystem, and thus it would eat about 5GB of your disk (normal VMs would take only as much space as their private fs takes up).

Let's now start the VM...

```
[dom0]$ qvm-run -a wififun gnome-terminal
```

... and then install the prerequisite software there, starting with downloading the reasonably new compat-wireless sources, together with the required injection patches, and then building and installing the new kernel modules. All actions below are now executed within the VM. This stuff here is really nothing Qubes- or Xen-specific -- one would do more or less the same on any Linux in order to get injection working (so, treat this as a free bonus WiFi hacking tutorial on Linux).

```
[wififun]$ wget http://linuxwireless.org/download/compat-wireless-2.6/compat-wireless-2011-07-14.tar.bz2

[wififun]$ wget http://patches.aircrack-ng.org/channel-negative-one-maxim.patch

[wififun]$ wget http://patches.aircrack-ng.org/mac80211-2.6.29-fix-tx-ctl-no-ack-retry-count.patch

[wififun]$ wget http://patches.aircrack-ng.org/mac80211.compat08082009.wl_frag+ack_v1.patch

[wififun]$ sudo yum install kernel-devel patch gcc

[wififun]$ tar xjf compat-wireless-2011-07-14.tar.bz2

[wififun]$ cd compat-wireless-2011-07-14

[wififun]$ patch -p1 < ../channel-negative-one-maxim.patch

[wififun]$ patch -p1 < ../mac80211-2.6.29-fix-tx-ctl-no-ack-retry-count.patch

[wififun]$ patch -p1 < ../mac80211.compat08082009.wl_frag+ack_v1.patch

[wififun]$ make

[wififun]$ sudo make unload

[wififun]$ sudo make install
```

Now, lets reboot the VM to ensure that all the patched drivers will get properly loaded on each VM boot:

```
[dom0]$ qvm-run --shutdown --wait wififun

[dom0]$ qvm-run -a wififun gnome-terminal
```

Let's first see if the WiFi driver got properly loaded and if the interface has been created (look for wlanX interface):

```
[wififun]$ ifconfig -a
```

If yes, then proceed with the steps below (if not, then have a look into dmesg and see what was the problem):

```
[wififun]$ sudo bash

[wififun]# yum install aircrack-ng dnsmasq

[wififun]# airmon-ng start wlan0

[wififun]# iptables -F INPUT

[wififun]# iptables -F FORWARD
```

```
[wififun]# echo “1” > /proc/sys/net/ipv4/ip_forward
```

Note that you don't need to add any explicit masquerading rules, as they are applied by default on Qubes VMs (you can take a look at the *nat* table in the VM if you want to see by yourself).

Edit the /etc/dnsmasq.conf, so that it contains at least the following:

```
interface=at0

dhcp-range=192.168.0.50,192.168.0.150,12h
```

and then start the dnsmasq daemon -- we will use it for providing DHCP to our fake AP (the at0 interface will be created by airbase-ng and emulates the “uplink” of a traditional AP):

```
[wififun]# /etc/init.d/dnsmasq start
```

And finally the fake AP:

```
[wififun]# airbase-ng -e free_wifi mon0
```

and on another console (before any client connects, but after airbase-ng got started), configure the at0 interface (make sure it matches what you wrote into dnsmasq.conf):

```
[wififun]# ifconfig at0 192.168.0.1 up
```

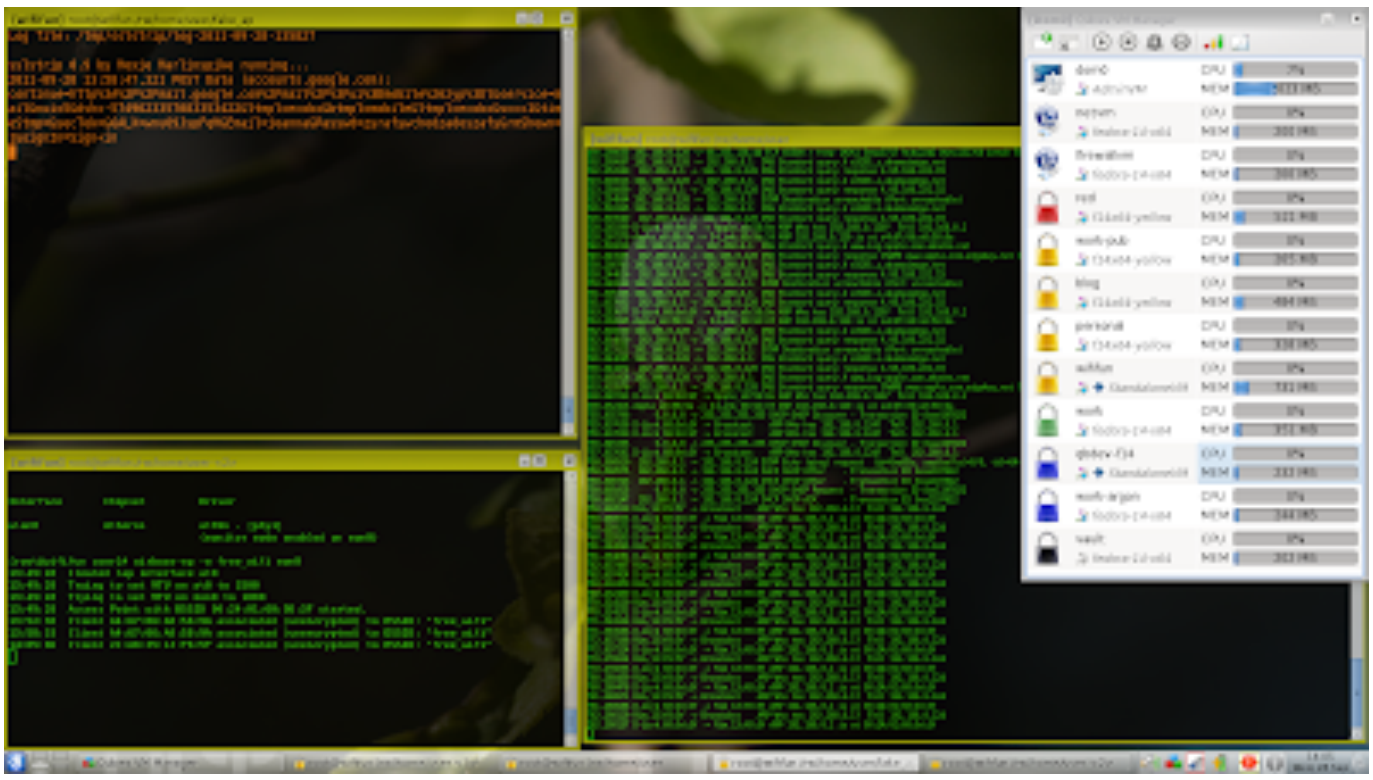
(you can also add an udev rule to that automatically).

and just to verify it really is working:

```
[wififun]# tcpdump -i at0
```

... and now, just wait for a client to connect to your AP. What you do next is only limited by your imagination... But hey, this article is about Qubes networking and not about 0wning client systems ;)

Here's an innocent example using Moxie's sslstrip (amazing this attack still works so well at the end of 2011...):



My 'wififun' VM in action using a simple sslstrip attack, that surprisingly still works pretty nice...

Please note that as your wififun VM is a regular Qubes VM, it is automatically connected to the default Net VM, which in turn provides networking to it. That's why it is so easy to create a fully functioning fake AP.

When using custom driver domains, there are currently some catches you should be aware:

Catch #1: When you start a driver domain *late* after system boot, so after some days of uptime and extensive use of VMs, Xen might not be able to allocate enough continues (in terms of MFNs) memory for a driver domain. And PV driver domains, unlike normal domains or HVM driver domains, do require MFN-continuous memory for their DMA buffers (HVM domains do not need that, because IOMMU can create an illusion of this; even though IOMMU is also used for PV driver domains, for protection, it doesn't actively translate bus addresses into GMFNs).

This is usually not a big problem in practice, because in most cases all the driver domains are started early at system boot, when there is still plenty of non-fragmented memory available. However it might become a problem when one wishes to start e.g. the WiFi pen-testing at some later time. The work around is to close as many VMs as possible before starting such driver domain, and then also reducing, for a moment, the amount of memory assigned to Dom0:

```
[dom0]$ xm mem-set 0 1600m
```

and then starting the driver domain should be fine. Now we can start all other domains, and that should no longer be problematic for the already running driver domain.

Catch #2: Some network cards, notably Express Cards, might not work well with the 3.0.4 pvops kernel that we use in all VMs by default. In that case you might want to try to use the 2.6.38.3 xenlinux kernel in your WiFi fun VM -- to do that, follow these steps:

```
[dom0]$ sudo qvm-dom0-update kernel-qubes-vm-2.6.38.3-10.xenlinux.qubes
```

```
[dom0]$ cp /var/lib/qubes/vm-kernels/2.6.38.3/* /var/lib/qubes/appvms/wififun/kernels/
```

```
[dom0]$ qvm-prefs wififun -s kernelopts "swiotlb=force"
```

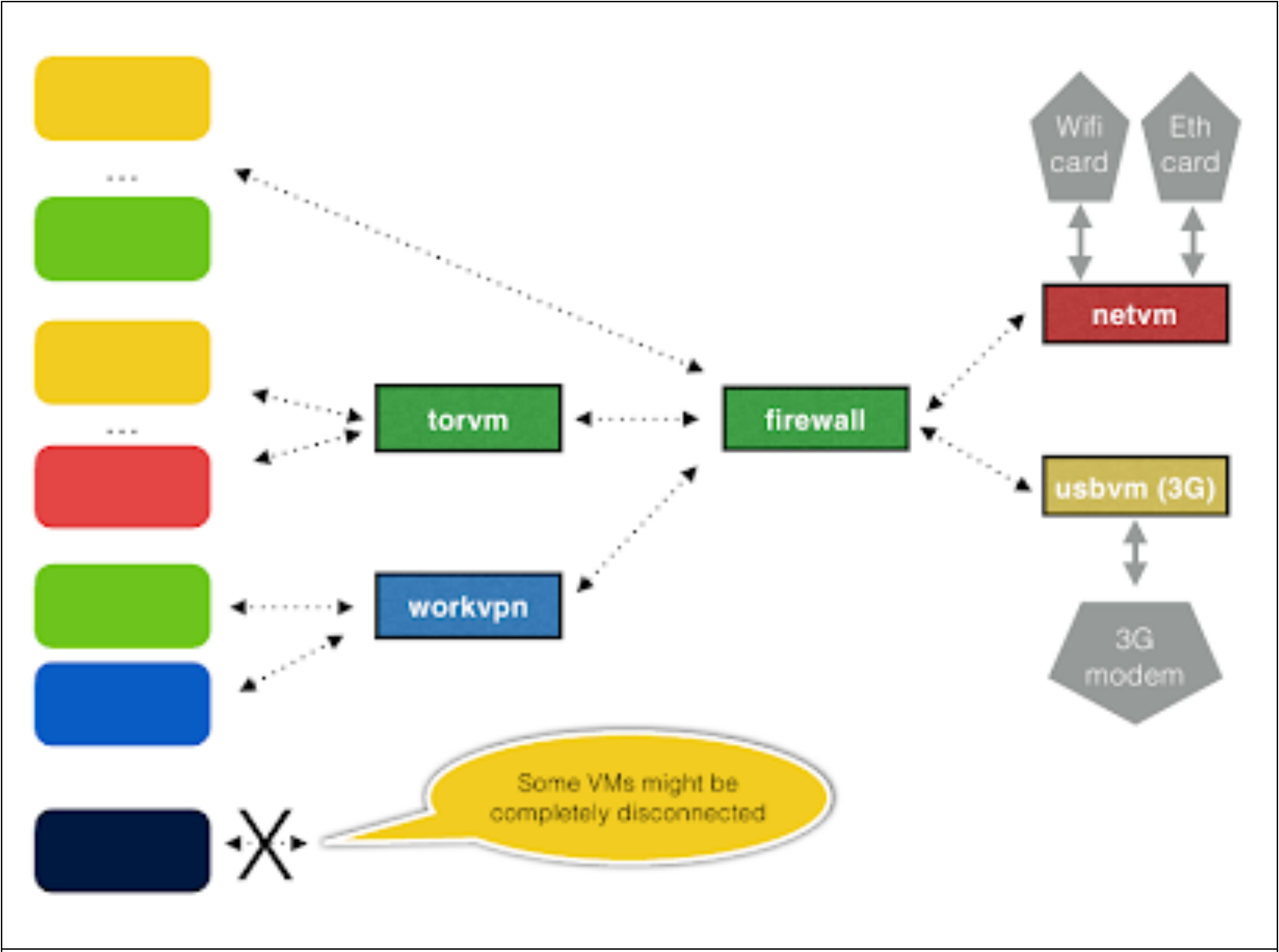
And then, in the VM:

```
[wififun]$ sudo yum install kernel-devel-2.6.38.3-10.xenlinux.qubes
```

And rebuild the compat-wireless, unload, install modules, and then load drivers again.

Summary

As you can see, Qubes Beta 2 now offers a very advanced networking infrastructure that allows more advanced users to create very sophisticated configurations, allowing for pretty good isolation between various domains and networks. Qubes leaves it up to the user (or admin) to figure out what would be the best configuration -- most users would be happy with the default simple setup with just one Net VM and one Firewall VM, while others would go for much more advanced setups.



A bit more advanced networking setup. The usbvm has a 3G modem assigned, and it is possible to dynamically switch between the Net VMs without restarting any other VMs.