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105 Comments

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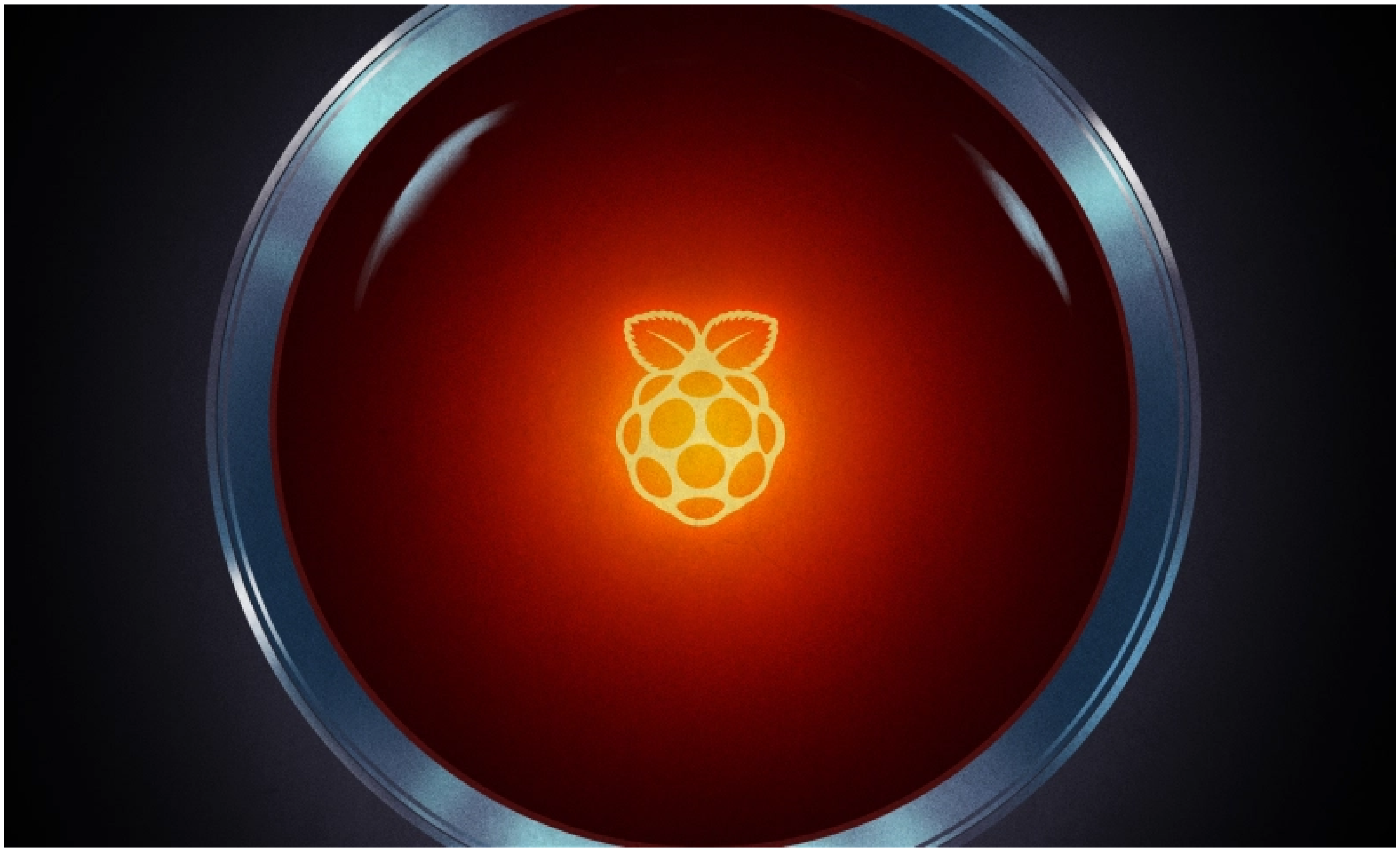


We've talked about PXE booting the Raspberry Pi 3B+, and then looked at the Raspberry Pi 4 as a desktop replacement. But there's more! The Pi 4 sports a very useful new feature, the flashable bootloader. Just recently a beta version of that bootloader was released that supports PXE — booting up over the network — which has become a must-have for those of us who have had consistently bad experiences with root filesystems on SD cards.

```
^C
pi@raspberrypi:~ $ mount
192.168.2.164:/nfs/raspi1 on / type nfs (rw,relatime,vers=3,r
devtmpfs on /dev type devtmpfs (rw,relatime,size=1867796k,nr_
sysfs on /sys type sysfs (rw,nosuid,nodev,noexec,relatime)
```

What are the downsides, I hear you ask? You might see slower speeds going across the network compared to a high quality SD card, particularly with the Pi 4 and its improved SD card slot. PXE does require an Ethernet cable; WiFi is not enough, so you have that restriction to contend with. And finally, this isn't a portable option — you are tethered to that network cable while running, and tethered to your network to boot at all.

On the other hand, if you're doing a permanent or semi-permanent install of a Pi, PXE is absolutely a winner. There are few things worse than dragging a ladder out to access a Pi that's cooked its SD card, not to mention the possibility that you firewalled yourself out of it. Need to start over with a fresh Raspbian image? Easy, just rebuild it on the PXE server and reboot the Pi remotely.

Convinced PXE is for you? Let's get started!

build the remote filesystem and set up the NFS and dnsmasq services. This article draws from a pair of official Pi network boot guides.

Bootloader Update

At the time of writing, the eeprom firmware that supports PXE boot is still in beta. We have to grab that firmware, change the boot order configuration, and then flash it to the onboard chip. Once the Pi 4 is booted off your Raspbian SD card, we can do the following to get the firmware updated:

```
sudo apt-get update
sudo apt-get upgrade
wget https://github.com/raspberrypi/rpi-eeprom/raw/master/firmware/beta/pieeprom-2019-10-16.bin
rpi-eeprom-config pieeprom-2019-10-16.bin > bootconf.txt
sed -i s/0x1/0x21/g bootconf.txt
rpi-eeprom-config --out pieeprom-2019-10-16-netboot.bin --config bootconf.txt pieeprom-2019-10-16.bin
sudo rpi-eeprom-update -d -f ./pieeprom-2019-10-16-netboot.bin
cat /proc/cpuinfo
```

That last command should output some information on the Pi itself. We're interested in the entry for the Pi's serial number. Take note of the last 8 characters of that code, as we'll use it later. In my case, it is "0c4c21e5". That's all the setup needed for the Pi itself.

Building the Filesystem

Last time we set up a PXE server, we used Centos and a dedicated network. This time, let's use Debian, and see if we can get PXE working on an existing home network. These instructions should apply for a Raspbian server as well.

The following simply builds the Pi's filesystem as an NFS share. The Raspbian image we're using does need two files manually updated, which is why we're deleting and re-downloading `start4.elf` and `fixup4.dat`

```
sudo apt-get install unzip kpartx dnsmasq nfs-kernel-server
sudo mkdir -p /nfs/raspi1
wget https://downloads.raspberrypi.org/raspbian_latest
unzip raspbian_latest
sudo kpartx -a -v 2019-09-26-raspbian-buster.img
mkdir rootmnt
mkdir bootmnt
sudo mount /dev/mapper/loop0p2 rootmnt/
sudo mount /dev/mapper/loop0p1 bootmnt/
sudo cp -a rootmnt/* /nfs/raspi1/
sudo cp -a bootmnt/* /nfs/raspi1/boot/
cd /nfs/raspi1/boot
sudo rm start4.elf
sudo rm fixup4.dat
sudo wget https://github.com/Hexxeh/rpi-firmware/raw/master/start4.elf
sudo wget https://github.com/Hexxeh/rpi-firmware/raw/master/fixup4.dat
```

Remember that serial number from earlier? Here's where it comes into play. The first place a Pi attempts to PXE boot from is a folder named the last 8 characters of that serial number. You'll want to replace each "0c4c21e5" below with the serial number you found earlier. We're also using a `bind` mount so the /boot folder is accessible as part of the tftp service, as well as being mounted as part of the NFS share. The advantage here is that the kernel and rest of the boot code can be updated using `apt`.

```
sudo mkdir -p /tftpboot/0c4c21e5
echo "/nfs/raspi1/boot /tftpboot/0c4c21e5 none defaults,bind 0 0" | sudo tee -a /etc/fstab
sudo mount /tftpboot/0c4c21e5
sudo chmod 777 /tftpboot
```

We'll create a file in the boot folder to enable SSH, modify the Pi's `fstab` so it won't look for filesystems on the SD card,

```
sudo touch /nfs/raspi1/boot/ssh
sudo sed -i /UUID/d /nfs/raspi1/etc/fstab
echo "console=serial0,115200 console=tty root=/dev/nfs nfsroot=192.168.2.209:/nfs/raspi1,vers=3 rw ip=dhcp r
```

Configuring Services

Setting up the NFS share is as easy as adding a line to `/etc/exports` and starting the services. Do note that we're not setting up a particularly secure NFS service. This isn't a problem on a home network where you trust all the computers, but don't run this setup exposed to the public internet.

```
echo "/nfs/raspi1 *(rw,sync,no_subtree_check,no_root_squash)" | sudo tee -a /etc/exports
sudo systemctl enable rpcbind
sudo systemctl enable nfs-kernel-server
sudo systemctl restart rpcbind
sudo systemctl restart nfs-kernel-server
```

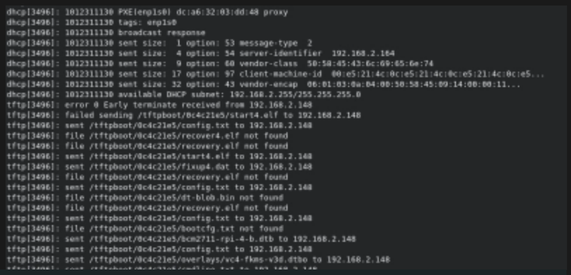
We need to add our settings to the `dnsmasq` config file, which is where most of the magic happens. Let's talk about that "proxy" setting. What we're asking `dnsmasq` to do is watch for DHCP requests, and rather than respond to those requests directly, wait for the primary DHCP server to assign an IP address. If `dnsmasq` sees a request for PXE information, it will send additional information to inform the PXE-capable device of the PXE server information. The upside is that this approach lets us support PXE booting without modifying the primary DHCP server.

You will need to adjust the dhcp-range setting to match your network. Usually it can be set to the broadcast address of your network, which can be identified using `ip addr`, looking at the `brd` entry.

```
echo 'dhcp-range=192.168.2.255,proxy' | sudo tee -a /etc/dnsmasq.conf
echo 'log-dhcp' | sudo tee -a /etc/dnsmasq.conf
echo 'enable-tftp' | sudo tee -a /etc/dnsmasq.conf
echo 'tftp-root=/tftpboot' | sudo tee -a /etc/dnsmasq.conf
echo 'pxe-service=0,"Raspberry Pi Boot"' | sudo tee -a /etc/dnsmasq.conf
```

Success!

The final step is to start `dnsmasq` and watch the log for connections.



```
dhcp[3496]: 1012311130 PXE(enp1s0) dc:a6:32:03:dd:48 proxy
dhcp[3496]: 1012311130 tags: enp1s0
dhcp[3496]: 1012311130 broadcast response
dhcp[3496]: 1012311130 sent size:  1 option: 53 message-type  2
dhcp[3496]: 1012311130 sent size:  4 option: 54 server-identifier  192.168.2.164
dhcp[3496]: 1012311130 sent size:  9 option: 60 vendor-class  50:58:45:43:6c:69:65:6e:74
dhcp[3496]: 1012311130 sent size: 17 option: 97 client-machine-id  00:e5:21:4c:0c:e5:21:4c:0c:e5:21:4c:0c:e5...
dhcp[3496]: 1012311130 sent size: 32 option: 43 vendor-encap  06:01:03:0a:04:00:50:58:45:09:14:00:00:11...
dhcp[3496]: 1012311130 available DHCP subnet: 192.168.2.255/255.255.255.0
tftp[3496]: error 0 Early terminate received from 192.168.2.148
tftp[3496]: failed sending /tftpboot/0c4c21e5/start4.elf to 192.168.2.148
tftp[3496]: sent /tftpboot/0c4c21e5/config.txt to 192.168.2.148
tftp[3496]: file /tftpboot/0c4c21e5/recover4.elf not found
tftp[3496]: file /tftpboot/0c4c21e5/recovery.elf not found
tftp[3496]: sent /tftpboot/0c4c21e5/start4.elf to 192.168.2.148
tftp[3496]: sent /tftpboot/0c4c21e5/fixup4.dat to 192.168.2.148
tftp[3496]: file /tftpboot/0c4c21e5/recovery.elf not found
tftp[3496]: sent /tftpboot/0c4c21e5/config.txt to 192.168.2.148
tftp[3496]: file /tftpboot/0c4c21e5/dt-blob.bin not found
tftp[3496]: file /tftpboot/0c4c21e5/recovery.elf not found
tftp[3496]: sent /tftpboot/0c4c21e5/config.txt to 192.168.2.148
tftp[3496]: file /tftpboot/0c4c21e5/bootcfg.txt not found
tftp[3496]: sent /tftpboot/0c4c21e5/bcm2711-rpi-4-b.dtb to 192.168.2.148
tftp[3496]: sent /tftpboot/0c4c21e5/config.txt to 192.168.2.148
tftp[3496]: sent /tftpboot/0c4c21e5/overlays/vc4-fkms-v3d.dtbo to 192.168.2.148
```

```
sudo systemctl enable dnsmasq
sudo systemctl restart dnsmasq
sudo tail -f /var/log/daemon.log
```

At this point, you can take the Pi 4 we configured, remove the SD card, and attempt booting it over PXE. You should be able to see the `tftp` requests for boot files in the log, and finally an NFS mount request. Congratulations, we've made it work!

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